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Report No. 105

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REGIONAL ICE SCOUR DATA BASE UPDATE STUDIES

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Last, but certainly not least, the study participants wish to acknowledge the patience of Mr. G.J. Hodgson, General Manager, Geonautics Limited who tolerated numerous ammendments to the scope of the original work and allowed the authors additional time above and beyond the terms of the contract thereby ensuring the success of the project.

SUMMARY

The Regional Ice Scour Data Base Update Studies were carried out by Geonautics Limited with funding provided through the Environmental Studies Research Funds (ESRF). The purpose of the study was to update and refine a regional, computerized data base of ice scour distribution and characteristics for the eastern Canadian continental shelf which was established by researchers at the Atlantic Geoscience Centre in an effort to provide a better understanding of the iceberg scour process and its relationship with the seabed and environment.

The East Coast Ice Scour Data Base incorporates regional survey lines of sidescan sonar and sub-bottom profiler data from the Grand Banks, Labrador Shelf, Baffin Island Shelf and Lancaster Sound regions, resulting in the inclusion of approximately 10,500 line kms of data. In addition, ice scour information from a series of site-specific wellsite surveys from the Grand Banks region is available as a unique data base, providing an additional 12,106 line kms of data. Site-specific information has not been included for study regions other than the Grand Banks, although, an inventory of all available wellsite surveys has been prepared, which identifies the location and size of each wellsite survey, water depths at the site, number of scours identified in the wellsite report and other pertinent information.

A preliminary analysis of the data base holdings for each of the four geographic regions was undertaken in the form of detailed studies of defined areas in each region, with the exception of Lancaster Sound. The purpose of the detailed studies was to illustrate the level of information which can be extracted from the data base.

Two iceberg scour populations were distinguished on the northeastern Grand Banks. In water depths greater than 110 m there exists a dense population of partially buried scours, the majority of which are believed to have formed prior to and during the low sea

level stand. A seemingly younger scour population occurs in water depths of less than 110 m, though it is also superimposed on the relict population below 110 m, appearing much "fresher" on sidescan sonograms. This population includes only modern (post Wisconsinon) scours in water depths of less than approximately 110 m. A detailed study was undertaken in the vicinity of the Avalon Channel, as this area has one of the greatest concentrations of well preserved iceberg scours in the Grand Bank region. Results indicate that scour parameters are often highly dependent on water depth and geologic conditions.

Scour data from the Labrador Shelf region show weak trends in distribution on a regional scale, with scour densities generally greatest on Saglek Bank, decreasing southward along the shelf. Scours generally trend south-southeast, reflecting the influence of the Labrador Current. A detailed study undertaken in the area of the Karlsefni Trough, Saglek Bank utilized mosaiced data and revealed large local variations in iceberg scour parameters, likely reflecting small scale changes in bathymetry, geology and perhaps oceanography and their effect on individual scour morphology and distribution.

In the Baffin Island-Davis Strait region it is difficult to draw any regional conclusions, as a result of sporadic data coverage. Density of scouring is generally high in all areas shallower than 200 m. Orientations are predominantly contour parallel, trending south-southeast, which is suggestive of a strong current influence. Detailed studies conducted in the region suggest that localized bathymetry has affected scour morphology and distribution. These studies produced ambivalent results concerning the effects of surficial geology on iceberg scour parameters.

As a result of a paucity of sidescan sonar and sub-bottom profiler coverage in the Lancaster Sound region, relatively little is known about ice scour distribution and variability. Available data does indicate that short scours and craters are common in shallow, nearshore waters (<50 m), suggestive of scouring by drifting sea ice,either in the form of ridges or small icebergs. In waters deeper than 50 m there is evidence of extensive scouring by drifting icebergs.

To provide potential users of the data base with an indication of the degree of confidence with which measurements may be viewed, a validity study was undertaken which involved re-analysis of randomly selected sample areas from each of the regions examined, excluding Lancaster Sound. The study analyzed anticipated sources of error and degrees of potential variability. The greatest factor affecting reliability of scour parameter measurements within the data base was found to be interpreter variability, with differing amounts dependent on the parameter in question and the complexity of local seabed conditions. Values commonly ranged from 10 to 30 percent between the mean values of an original interpreter and those of a remeasuring interpreter. A smaller scale validity study was conducted during the course of the detailed study in the Karlsefni Trough, Saglek Bank area which examined the reproducibility of results gathered from different methods and surveys. Some degree of bias was found to exist between any matched pair of observations in the same area.

RÉSUMÉ

La mise à jour de la base de données régionale des affouillements glaciaires a été realisee par la société Geonautics Limited et financée par Environmental Studies Research Funds (ESRF). Cette étude a pour but de mettre à jour et d'adjuster la base de données régionale informatisée sur la distribution et les caractéristiques des affouillements glaciaires de la partie est du Plateau continental canadien. Cette base de données avait été établie par des chercheurs de l'Atlantic Geoscience Centre pour fournir une meilleur explication du processus d'affouillement des icebergs et de ses effets sur le fond marin et sur l'environnement.

Cette base de données contient les levés régionaux obtenus par sonar à balayage latéral ainsi que les profiles de sismique - réflection des Grands bancs, du Plateau continental du Labrador et de la Terre de Baffin ainsi que les profiles du détroit de Lancaster, soit l'inclusion de quelque 10,500 km de tracés. De plus, less données sur les affouillements glacaires, tirées à partir d'une série de levés réalists sur des emplacements spécifiques de la région des Grands bancs, constituent une base de données unique et disponible séparément, contenant 12,106 km de tracés supplémentaires. On n'a pas inclu les données sur les emplacements spécifiques des régions autres que celle des Grands bancs, mais on a dressé un inventaire de tous les levés d'emplacements disponibles, contenant la situation et l'etendue des levés pour chaque emplacement, les profondeurs de l'eau à l'emplacement, le nombre d'affouillements relevés dans le rapport d'emplacement ainsi que tout autre renseignement pertinent.

Une analyse préliminaire du contenu de la base de données pour chacune des quatre régions géographiques a été entamee en réalisant des études détaillées d'espaces bien délimités de chaque région géographique, a l'exception du détroit de Lancaster.

On a sélectionné deux populations d'affouillements du nord-est des Grands bancs. A des profondeurs de plus de 110 m, on retrouve une population dense d'affouillements partiellement enfouis, dont la majorité auraient été formés avant ainsi qu'au cours de la période de bas niveaux des mers. On retrouve,dans les eaux de moins de 110 m de profondeur, une population apparemment plus récente d'affouillements, mais superposée à la population relique et d'apparence plus "fraîche" sur les sonogrammes. Il est probable qu'elle comprenne des affouillements modernes. On a entrepris une étude détaillée dans les environs du détroit d'Avalon, car cette région présente une concentration d'affouillements bien préservés d'icebergs, des plus denses de la région des Grands bancs. Les résultats indiquent que les mesures des affouillements sont souvent reliées de trés prés à la profondeur de l'eau et aux conditions géologiques.

Les données sur les affouillements de la région du plateau du Labrador ne semblent pas réveler de fortes tendances du point de vue de la distribution à l'échelle régionale: la densité des affouillements est en général plus élevée sur le banc de Saglek et diminue vers le sud, en suivant le plateau. Les affouillements suivent généralement une direction sud-sud est et reflétent l'influence du Courant du Labrador. Une étude détaillée, entreprise dans la région du fossé de Karlsefni et du banc de Saglek et incluant des données en mosaique, a révélé d'importantes variations locales dans les mesures des affouillements d'iceberg, reflétant probablement des changements de petite échelle dans la bathymétrie, la géologie et peut-être l'océanographie et leurs effets sur la morphologie et la distribution d'affouillements individuels.

Dans la région de la Terre de Baffin et du détroit Davis, il est difficile de tirer la moindre conclusion sur la région, car les données sont sporadiques. La densité des affouillements est généralement élevée dans toutes les régions de moins de 200 m de profondeur d'eau. On retrouve surtout des orientations parallèles aux isoplèthes, de direction sud-sud est, ce qui sugg re l'influence marquante du courant. Des études détaillées entreprises dans la région semblent indiquer que la bathymétrie locale ait affecté la morphologie et la distribution des affouillements. Ces études ont donné des résultats ambivalents quant aux effets de la géologie des surfaces sur les paramètres des affouillements d'iceberg.

Suite à un manque de sonogrammes et de profiles pour la région du détroit de Lancaster, on dispose de peu de renseignements sur la distribution et la variabilité des affouillements glaciaires de cette région. Les données disponibles révèlent que de courts affouillements et des cratères se retrouvent fréquemment dans les eaux côtières peu profondes (50 m), signalement d'affouillements dûs à la dérive des glaces, sous forme de crêtes ou de petits icebergs. Dans les eaux d'une profondeur de plus de 50 m, on retrouve des indications d'un grand nombre d'affouillements causes par des icebergs en dérive.

Afin de fournir aux usagers intéressés de la base do données une indication du niveau de confiance que l'on peut accorder aux mesures obtenues, on a entrepris une étude de validité avec reprise de l'analyse des aires échantillonnées à partir de trois des régions examinées, mais en omettant le détroit de Lancaster. L'étude a fait l'analyse des sources anticipées d'erreur et des degrés de variabilité possibles. Le principal facteur affectant la fiabilité des mesures des paramètres d'affouillement dans la base de données s'est avéré être la variabilité de l'interprétation, avec des résultats différents suivant le paramètre étudié. Les valeurs variaient de 10 à 30% entre les valeurs moyennes obtenues lorsr de l'interprétation originale et celles obtenues lors d'une interprétation de reprise des mesures. Une étude de validité de moindre échelle a été entreprise sur l'étude détaillée de la région du banc de Saglek et du fossé de Karlsefni pour examiner la reproductibilité des résultats obtenus à partir de méthodes et de levés différents. Elle révèle un certain degré de déviation entre toute paire assortie d'observations prélevées dans la même région.

1.0 REGIONAL ICE SCOUR DATA BASE

1.1 INTRODUCTION

A computerized data base of ice scour characteristics and regional distribution for the eastern Canadian continental margin presently exists at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. This data base, initially established by researchers at the Atlantic Geoscience Centre (AGC),[1] Geological Survey of Canada (d'Apollonia and Lewis 1981; d'Apollonia 1983; Todd 1984), has been extensively updated and amended in this study.

This east coast ice scour data base provides an appreciation for ice scour variability by facilitating statistical summaries of scour dimensions and distribution. It also contains information that will permit investigation of the interrelationship of scours, environment and geology. Combined with oceanographic data (currents) and knowledge of modern iceberg flux and draft distributions, the data base should provide a useful perspective to assist in differentiating modern and ancient scour regimes and in evaluating the character and intensity of present-day ice scouring over localized areas of the seabed.

As a result of better understanding of the surficial geology and geologic history of the eastern Canadian continental shelf, a number of additions and improvements have been implemented in this update of the east coast ice scour data base. These changes do not involve significant alterations to the original analysis technique, but do provide more information towards a better understanding of the iceberg scouring process and its relationship with the seabed and environment.

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1. Supported by the Federal Government's Panel on Energy Research and Development (PERD), Offshore Geotechnics Program.

Quantitative information on iceberg scour dimensions, orientation, geological and environmental setting has been compiled for small representative sample areas from a network of regional survey lines of sidescan sonar and high resolution seismic profiler data. These were collected over the past decade by the Atlantic Geoscience Centre (AGC) of the Geological Survey of Canada (GSC) operating from the Bedford Institute of Oceanography. Areas covered include the Grand Banks, Labrador Shelf, Baffin Island Shelf and Lancaster Sound, for a total of 10,550 line kms of data (Figure 1). Table 1 lists the current data base holdings, indicating the sample areas analysed previously by AGC scientists and those analysed for this ESRF study by Geonautics personnel.

In addition to the regional data, Mobil Oil Canada, Ltd. provided its "Catalogue of Iceberg Scours and Ice Related Features" (NORDCO Limited 1982). The catalogue was jointly funded by the various Hibernia participants, consisting of Mobil Oil Canada, Ltd., Columbia Gas Development of Canada Ltd., Chevron Canada Resources Limited, Gulf Canada Resources, Inc. and Petro-Canada Inc. This data set was drawn from 12,106 line kms of data, consisting of 25 wellsite seabed surveys and two regional data sets (4000 and 8000 series lines). This information has been incorporated separately as "site-specific data" in an effort to maintain information unique to the Mobil data base and also as a result of some degree of incompatibility between the regional and site-specific data sets. It is recognized that in areas where regional lines overlap wellsite surveys the possibility exists that scours common to both data sets may be entered as separate features. This is further addressed in Section 2.7.

For purposes of analysis, each regional survey line was divided into 2 km long sample areas. The parameters recorded for each sample area include: an estimate of the total number of visible scours and the relative area of ice-disturbed seabed; measurements of length, orientation, width, and, where possible, depth and berm height for all ice scours (or a representative selection where the number of scours

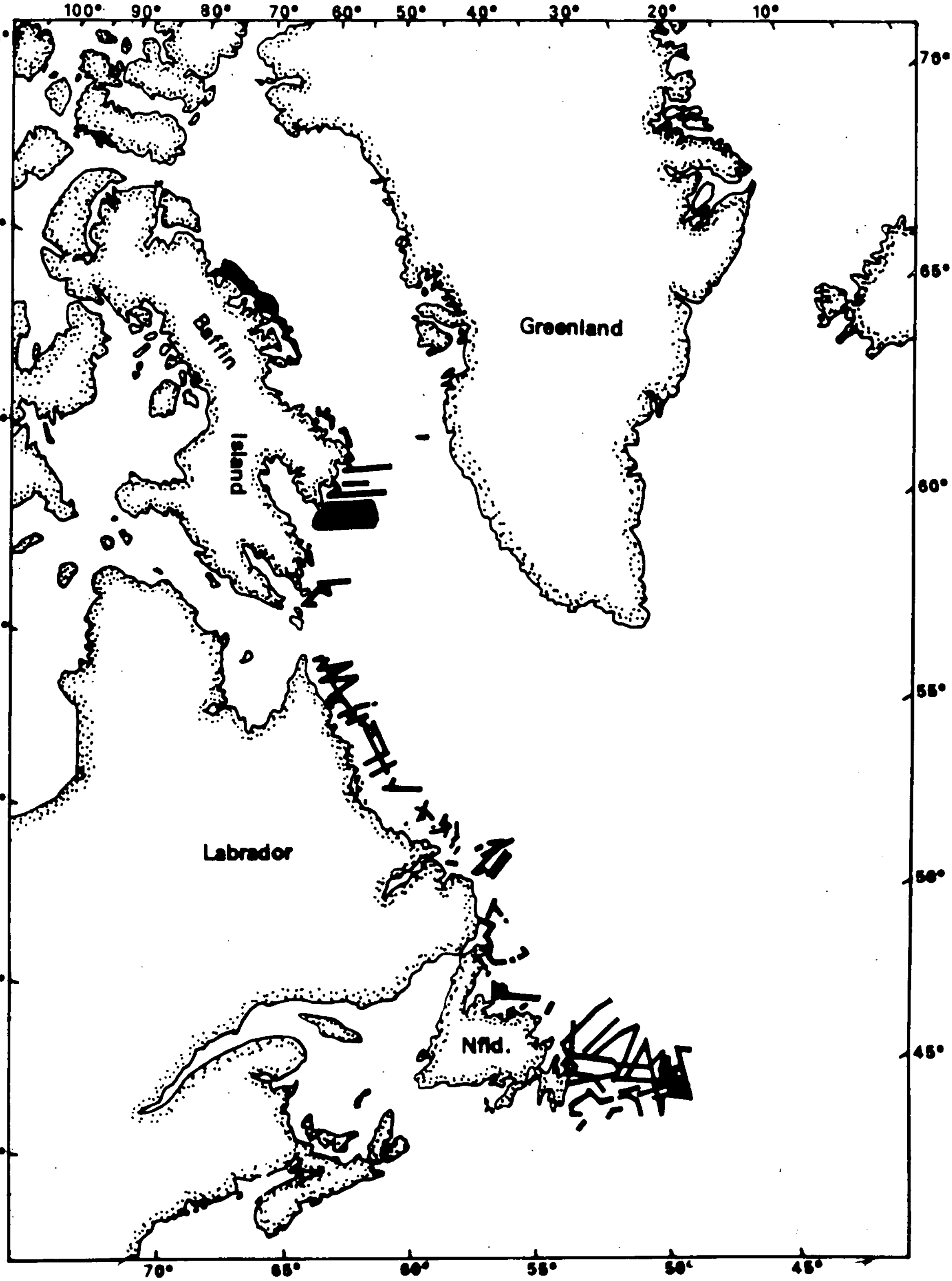

Figure 1 Regional Ice Scour Data Base holdings. Dots and lines (closely spaced dots) indicate sample areas examined. Width of survey lines not to scale.

Table 1

Ice Scour Data Base Holdings

(a) Regional Survey Data

Cruise	Number of Sample Areas		Number of Line km	
	Previous	ESRF	Previous	ESRF
73-027	--	210	--	420
76-023	11	--	30	--
76-025	37	--	100	--
77-011	--	144	--	288
78-023	85	127	153	271
78-029	202	--	484	--
79-018	--	43	--	86
79-019	215	58	630	116
8000 Series	--	136	--	272
80-010	809	207	1454	415
80-028	287	105	818	210
80-035	--	390	--	780
81-045	40	324	80	648
81-012	--	32	--	64
82-039	--	19	--	38
82-054	351	146	705	292
83-030	--	137	--	274
83-033	--	16	--	32
84-024	--	141	--	282
84-035	--	566	--	1132
C-CORE/Cormorant 1984	--	238	--	476
TOTAL HOLDINGS	2,037	3,039	4,454	6,096
	4,869 areas		10,550 km	

Table 1 (Continued)

(b) Site-Specific Survey Data

Site-Specific Data	Line Km	Year of Survey
Ben Nevis	277	1979
Cumberland	282	1980
Dana North	214	1980
Dana South	339	1980
Hebron	449	1980
Hibernia (Chevron)	130	1979
Hibernia North	290	1979
Hibernia South	168	1979
Hibernia West	170	1980
Ragnar	282	1980
Rankin	818	1980
Nautilus	268	1980
Tempest North	403	1979
Trave/White Rose	600	1979
Mercury	422	1980
West Flying Foam	434	1980
White Rose Flank	888	1980
Linnet	587	1982
Mara	630	1983
Dominion	188	1983
Titus	210	1983
Voyager	221	1983
Saronac	640	1982
Archer Flank	1,086	1982
Bonanza	345	1982
4000 Series Reg. Lines	645	1980
8000 Series Reg. Lines	1,120	1980
TOTAL	12,106 LINE KMS.	

exceeded 15); the plan shape and profile character of each measured scour; the type and distribution of seabed sediments; the geologic sequence, with particular attention to the character and thickness of the surficial geologic unit; and the presence of other seabed features such as bedforms, trawl marks, pockmarks, etc.

This report documents the update procedure and presents the results of preliminary analysis of the data base holdings for four separate regions (Grand Banks Region: 42° - 51°N; Labrador Region: 51°-61°N; Baffin Island-Davis Strait Region: 61°-72°N; Lancaster Sound Region: 72°-77°N). Also included are maps, figures, tables, illustrations and statistical analyses of scour features. Two 1:1,000,000 scale charts have been created for each of the study regions. The first displays the existing data coverage, both regional and site-specific (available wellsite surveys), while the second displays iceberg scour data as generated from the regional data base holdings. Included is information on the degree of disturbance of the seabed by icebergs, maximum depth of iceberg scours, scour orientations and bathymetry. Lancaster Sound does not have an existing data coverage chart, due to the extremely limited amount of suitable data. The charts are presented in pockets at the rear of the report. In addition, detailed studies have been carried out in each region, excluding Lancaster Sound, to illustrate the potential usefulness of the data base given sufficient data coverage, as well as to reveal scour characteristics peculiar to each region.

Copies of the data base in diskette form may be obtained from the Atlantic Geoscience Centre in Dartmouth, Nova Scotia, as an Open File Report of the Geological Survey of Canada.

1.2 SURVEY INSTRUMENTS AND DATA QUALITY

All measurements of iceberg scour marks for the east coast ice scour data base were made from sidescan sonograms and/or high resolution seismic profiler records. A brief discussion of the systems commonly used, their merits and limitations, and some of the problems inherent in the records they produce will aid the assessment of the accuracy and reliability of the measurements of ice scour parameters.

Most of the sidescan records collected by AGC and examined for this data base were produced with a medium range, 70 kHz sidescan sonar (Jollymore 1974). This relatively low frequency, medium resolution system is usually operated to record seabed features over a swath of 1.5 km width (750 m per channel). Records of this scale are ideal for recognition and identification of iceberg scour marks.

Recently, more use has been made of a Klein 100 kHz sidescan system, usually operated at a range of 200 m per channel. This system provides higher resolution sonograms because of the higher sonar frequency and more rapid firing rate.

Data collected using the SeaMARC sidescan sonar system on BIO cruise 84-035 were also examined and entered into the data base. This system utilizes 27 and 30 kHz side-looking sonars, producing lower resolution records than 70 or 100 kHz systems, and is towed at a significant height above the seabed resulting in a swath width of up to 5 km. It was generally used in deeper waters beyond the operational water depths of the BIO and Klein sidescan sonar systems.

A small amount of Klein 500 kHz data were also examined but they are not as relevant to the study because, while capable of recording details well, the shorter range capability makes identification of complete scours more difficult.

Because each system is usually operated at different ranges with different degrees of resolution, it is important for users of the data base to be aware of the type of data collection system from which the measurement analysis was performed. For this reason, the types of equipment used have been coded into the data base.

Sidescan data quality is dependent on a number of operating parameters; one of the most important being sea state (Todd 1984). Rough seas produce a high level of ambient noise which can effectively reduce the dynamic tonal range (brightness or darkness) of the sonogram, making feature identification more difficult. In addition, pitch and yaw of the towfish result in a general reduction of spatial resolution and often creates a saw-toothed aspect to otherwise linear features. Users may refer to available weather and sea state records as the date and time of collection for each sample area is coded into the data base.

Loss of data quality can also be caused by a stratification of temperature, salinity or suspended matter in the water column which can alter the profile of sonic velocity and cause refraction of the sonar signal, effectively reducing the range of coverage. Data which were greatly affected by such phenomenon were generally excluded from the data base.

The height of the towfish above the seabed also affects the clarity of the sidescan sonogram. If not operated at optimum height, fresh scours can appear degraded and smaller scours may not be visible at all. This is particularly critical when making inferences about scour age based on scour clarity.

Finally, there are scale distortions inherent in all the sidescan sonograms examined. Differences between the across-track and along-track scales (the aspect ratio) can be as high as 5 to 1. This distortion causes round features to appear oblong and linear features to appear more perpendicular to the survey track. The aspect ratio is corrected in a computer subroutine for all measurements from sidescan sonograms (d'Apollonia 1983). Both corrected and uncorrected values are stored in the data base. Slant range distortion is not corrected in the data base.

An additional consideration when mapping seabed features from sidescan records is the effect of their orientation relative to the survey line. The acoustic pulse of the sidescan sonar experiences much greater reflection, producing a much better defined image, from an angled surface which is parallel to the heading of the towfish than from one which is perpendicular. This limitation is inherent in sidescan sonar surveying and can be expected to lead to a bias in the mapping of features which are parallel or sub-parallel to the ship's track.

The sidescan records enable observation and measurement of such parameters as number of scour occurrences, percent seabed disturbance by icebergs, scour shapes in plan view, scour lengths, widths, orientations, clarity, degree of post scour reworking, degree of berm development, crosscutting relationships, presence and size of ice related craters, and differentiation of major sediment types on the immediate seabed.

In addition to these parameters, seismic reflection profiler data provide information on scour profile morphology and information on the type of geologic unit which is scoured, the depth of scour in that unit, the thickness of the unit and the nature of the unit or units below that which was scoured. These are important relationships for understanding the various types of interactions of icebergs with the seabed in different areas and the effect icebergs have on different sediments.

Most of the AGC seismic reflection profiler data are Huntec DeepTowed Seismic (DTS) profiles (Hutchins et al. 1976). These data provide high resolution, heave-compensated profiles of the seabed, and resolve differences in depth to 0.5 m and occasionally 0.2 m. This is essential for recognition of iceberg scours and accurate measurement of their morphology (depth, profile shape, and berm height).

As the profiler insonifies a relatively large area of the seabed (because of its cone shaped beam pattern), the return signal constitutes an averaged depth to seabed. This also results in hyperbola-shaped, off-axis reflections, or side echoes, on prominent reflectors such as scour berms. These side echoes become more prominent with increasing towfish height. In areas with numerous prominent reflectors (such as heavily scoured areas), side echoes overlap, often masking deeper parts of the scour and making measurement of scour depth and berm height difficult. However, a basal trench reflection is often visible, usually with side echoes of its own and this assists greatly in estimating actual scour depth. Figure 2 shows a particularly well-developed iceberg scour in stratified sediment, the effect of side echo reflections on the apparent profile, and the probable true base of the depression.

Also utilized on some of the regional cruises in place of the Huntec DTS profiler was the Nova Scotia Research Foundation (NSRF) Deep Towed Sub-Bottom profiling system (generally referred to as the NSRF V-Fin). This system has operating parameters close to those of the Huntec DTS in terms of theoretical depth of sediment penetration and resolution, although it is not fully heave compensated. This can, under certain sea conditions, produce a profiler record with an undulatory seabed, making differentation of iceberg scours difficult. As well, on some BIO cruises, a 3.5 kHz sub-bottom profiler was the only system utilized. The 3.5 kHz profiler has limited acoustic penetration, especially in sandy and gravelly sediments, and is not heave compensated.

In addition to information on surficial geologic units and thickness of scoured units, many of the Huntec profiles quantify the acoustic reflectivity (Parrott et al. 1980) of the seabed. This parameter provides the interpreter with information on the nature of sediment at the seabed surface and assists in relating seismic profile data with sidescan sonograms. Acoustic reflectivity measurements were routinely recorded where available and input to the data base.

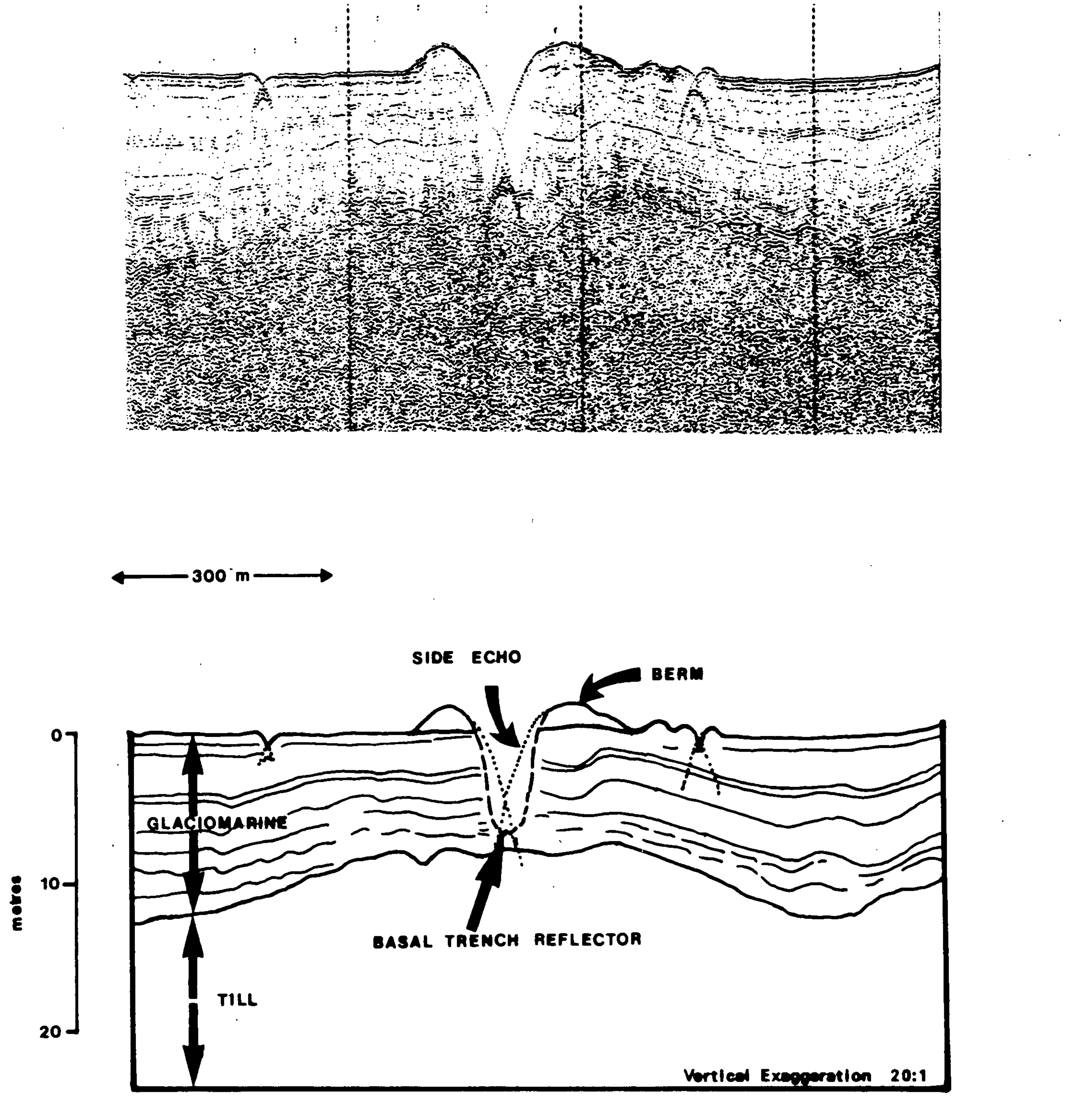

Figure 2 Huntec DTS profile across a well developed iceberg scour in stratified glaciomarine sediment from the Labrador Shelf. The two berms are well developed and their base is marked by the original, pre-scour seabed, illustrating that this material was displaced. The side echoes are artifacts produced by off-axis reflections from the wide angle boomer sound source as it approached and passed over the scour. The truncated internal reflections within the glaciomarine sediment better mark the true flanks of the scour as shown in the interpretation below. The base of the scour is marked by a reflection also exhibiting side echoes. The vertical exaggeration of the profile is 20x.

1.3 ICE SCOUR PARAMETER DESCRIPTION

The east coast ece scour data base updated in this study consists of independent entries of ice scour and related parameters for individual sample areas of the seafloor as defined by start and end fix positions along a regional survey line. In each sample area observations and measurements were made on numerous scours in an attempt to obtain data for a representative scour population. The actual number of measured scours depends on a number of factors including the variability of the measured parameters of the population, degree of clarity and population size. In areas of low to moderate scour density all scours (up to 15) were measured. In densely scoured sample areas, 10 to 15 randomly selected features in each sample area were measured and assumed to constitute a representative sample of the scour population in that area. Parameters which were routinely measured for each sample area are described in this section in detail. In all cases, uncorrected values for scour length, width and orientation were input to the data base. These were corrected for aspect ratio by computer processing and both corrected and uncorrected values are stored in the data base (d'Apollonia 1983). A sample of the worksheet compiled for each regional sample area is given in Figure 3. Each of the following parameter descriptions includes the line number on the worksheet where the information is entered. The worksheet format for site-specific data differs somewhat from that in Figure 3. Specific differences are noted in the descriptions below.

LINE 1

ANALYST:

Person responsible for analysis and compilation of a sample area. This information was not available for the site-specific data.

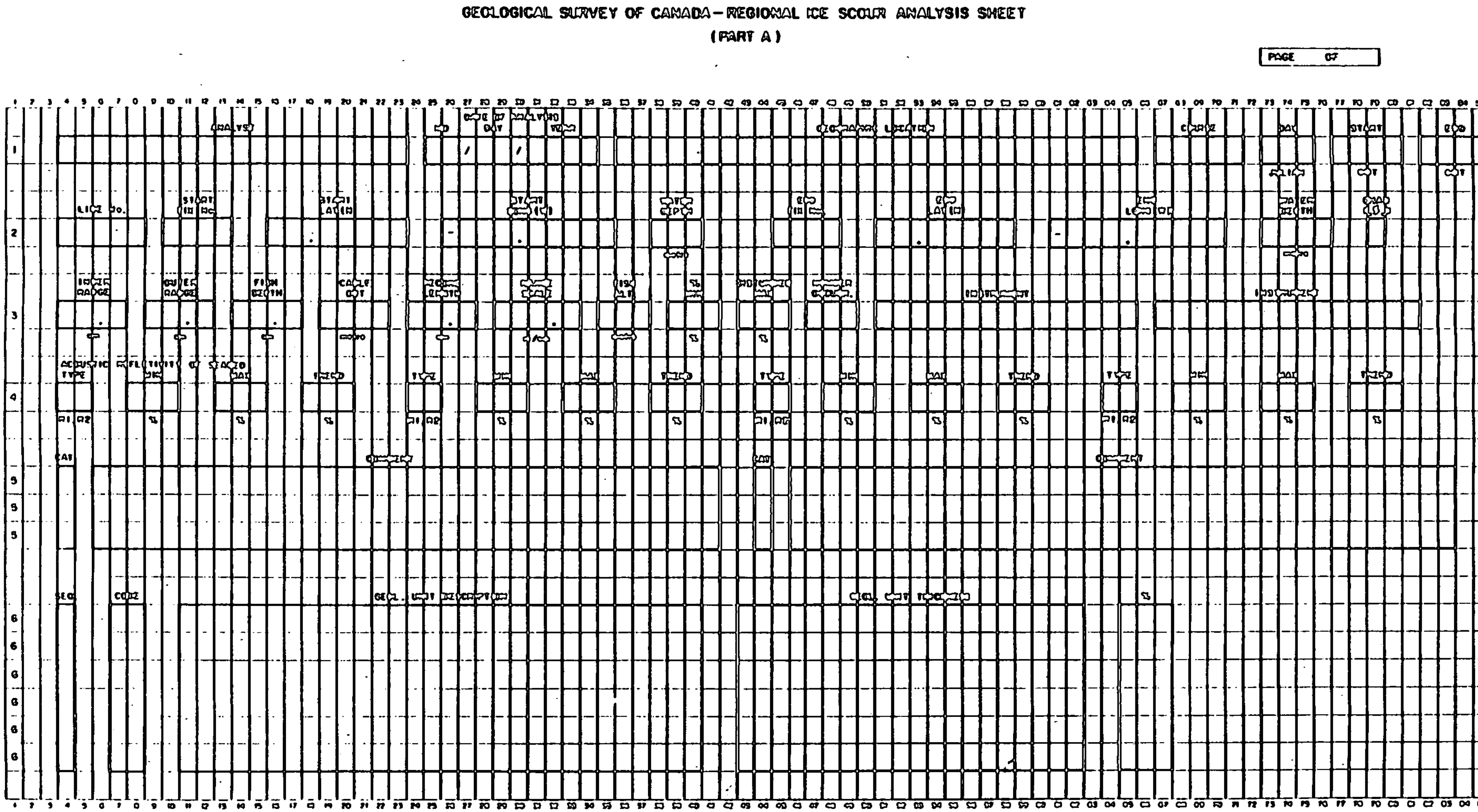

Figure 3 Most recent Ice Scour Database worksheet; Part A. Database entries described in text are keyed to the line numbers in the left column (1).

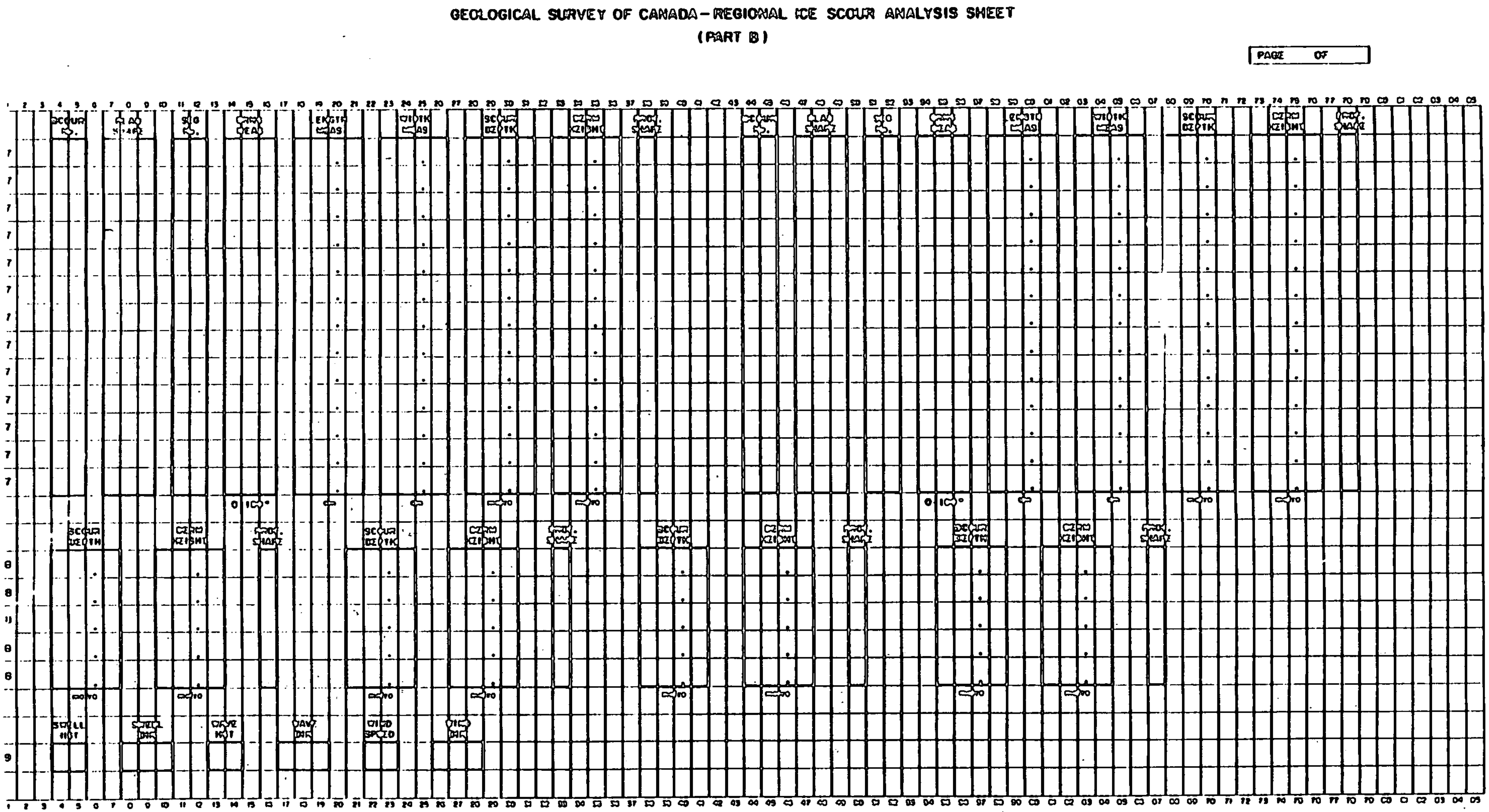

Figure 3 (cont'd). Most recent Ice Scour Database worksheet; Part B

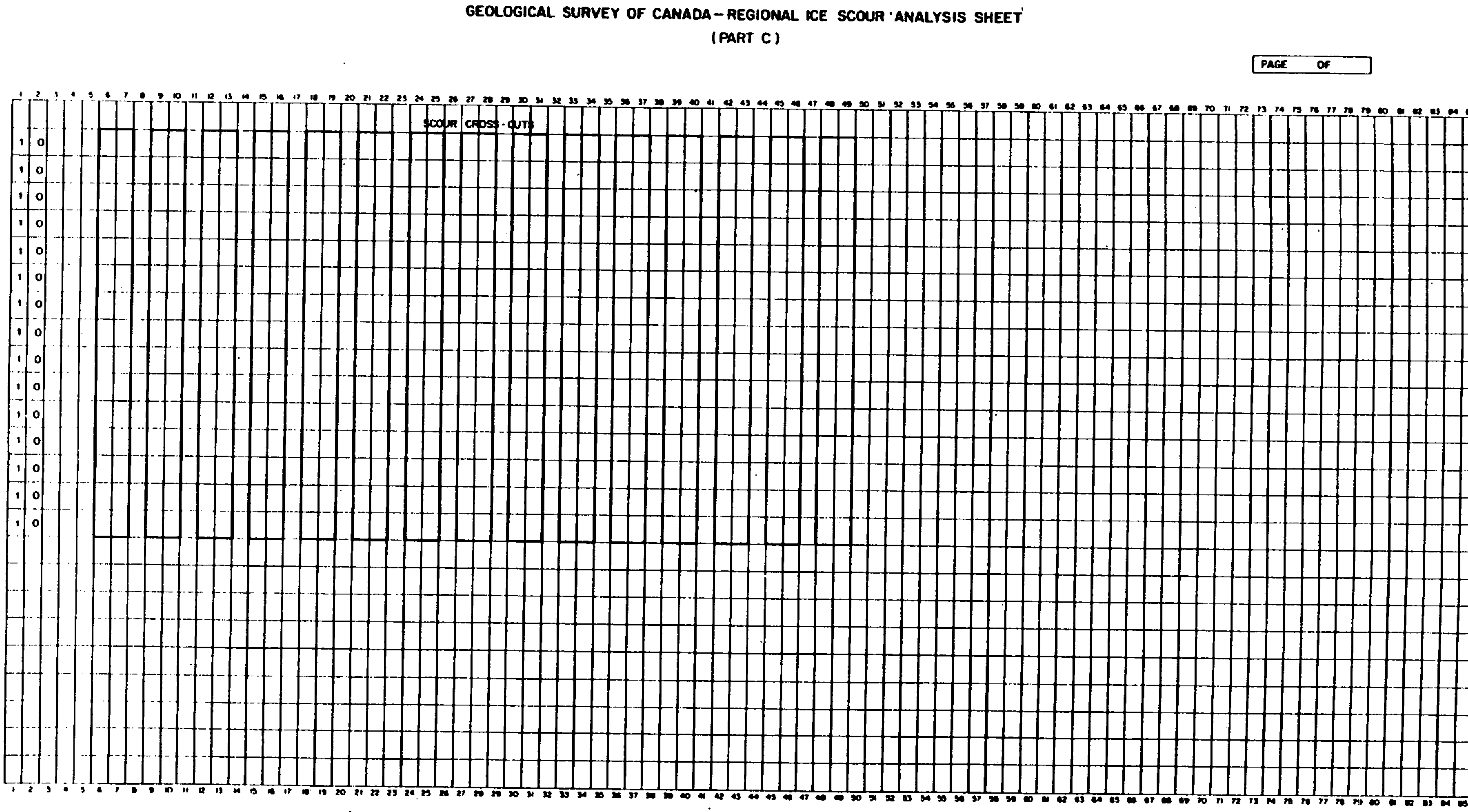

Figure 3 (cont'd). Most recent Ice Scour Database worksheet; Part C

DATE OF ANALYSIS:

(Not available (N/A) for the site-specific data).

Format: xx/yy/zzzz where xx = month
yy = day
zzzz = year

GEOGRAPHIC LOCATION:

Geographic name describing location of the sample area.

CRUISE:

Generally, the regional cruise number is entered here. Industry surveys are designated as INDUS., while all other site-specific, non-BIO surveys are entered by their site name abbreviations.

DAY:

The Julian day of the survey at the start point of a regional sample area.

START TIME/END TIME:

The GMT survey times at the start and end points of a regional sample area. These times are picked such that the along track length of all sample areas will be 2 km, regardless of ship speed. Users have found that a sample area length of two kilometres along the ship's track provides a manageable area of coverage for data analysis. This sample length is adhered to regardless of the across track range of the sidescan sonogram (which usually ranges from 500 m to 1500 m).

LINE 2

LINE NUMBER, START FIX NUMBER, END FIX NUMBER:

Only used where regional survey lines are annotated using line no./ fix no. versus GMT times, as traditionally used for BIO cruises.

START DEPTH/END DEPTH:

Water depth at beginning and end of a sample area. For BIO cruises, this data is generally available from computer files and therefore was not, as a rule, manually compiled. The estimated accuracy is ± 2 m, uncorrected for tidal variation.

START LATITUDE, LONGITUDE/END LATITUDE, LONGITUDE:

This information is available in computer files (BIO-NAV) for BIO cruises and, therefore was generally not input manually. For the site-specific data up to six sets of corner coordinates are given defining the site boundaries.

CHANNEL:

Refers to sidescan channel analyzed: S = Starboard; P = Port; B = both.

LINE 3

RANGE, INNER/OUTER:

Average sidescan slant range of a sample area respectively closest and farthest from the towfish transducer, scaled in centimeters from the sidescan record (N/A to site-specific data).

FISH DEPTH:

Tow depth of sidescan fish below sea surface, scaled in centimetres. This parameter can only be measured when sea-surface reflection from sidescan fish is visible on the record (N/A to site-specific data).

CABLE OUT:

Refers to the length of the sidescan tow cable. This is drawn from computer files (BIO-NAV) for BIO cruises when available and therefore was generally not input manually (N/A to site-specific data).

RECORD LENGTH:

The sidescan record length between the start and end point of a sample area, scaled in centimetres. This information is used in the subroutine which removes distortion from sidescan measurements and also in the calculation of section length (N/A to site-specific data).

RANGE SCALE:

The sidescan slant range scale. Used in the subroutine to correct for distortion (across track/along track scale differences) of features measured on sidescan record. Calculated by dividing the slant range (in metres) by the sidescan record width (measured in centimetres) from the shot point (representing towfish transducer location) to the outer edge of the record (i.e., OUTER RANGE). A velocity of sound in water of 1,500 m/s is assumed for all range calculations for sidescan sonogram analysis (N/A to site-specific data).

FISH ALTITUDE:

An average measurement in centimetres from the centre of a sidescan record to the initial seabed return. This measurement can be used to help calculate slant range distortion (N/A to site-specific data).

PERCENT DISTURBED (MIN, MAX):

Visual estimate of the percentage of a sample area disturbed by scouring. The disturbed area includes all discernable scours, craters and their embankments. This is a qualitative measure and, therefore, is generally quoted as a range (e.g., 50-60 percent), except in the early stages of the data base compilation when only a single value was given. Caution must always be exercised in interpreting this parameter, since relict heavily scoured areas may have been partly or completely buried by later sedimentation (e.g., see detailed study for Avalon Channel). A convention adopted here classifies such areas as heavily disturbed (i.e. 80-90 percent, 90-100 percent).

NUMBER OCCURRENCES:

A visual estimate of the number of independent scour marks in a sample area from sidescan record. In all cases, an attempt was made to place a specific quantity in the OCCURRENCES category. For heavily scoured areas, the number of occurrences is always considered a minimum value as scours may have been obscured due to reworking of the seabed by scouring and sedimentary degradation.

INSTRUMENT:

Instruments used to obtain records analyzed in each sample area. Most commonly Huntec DeepTow Seismic System and BIO sidescan system (70 kHz). A complete discussion of these instruments, their capabilities and limitations is given in Section 1.2. NSRF V-Fin and 3.5 kHz sub-bottom profilers and Klein 100 kHz, 500 kHz and SeaMARC II 27/30 kHz sidescan records were used less commonly.

LINE 4

ACOUSTIC REFLECTIVITY OF SEABED:

The Huntec DeepTow System is capable of measuring and displaying the strength of the acoustic pulse reflected from the seabed in two separate time windows (R1 and R2). These measurements give information about the type of material at and just below the seabed (Parrott et al. 1980). Wherever available, the minimum, maximum and average values of R1 and R2 over a sample area are recorded in the data base. Over heavily scoured areas reflectivity measurements as indicators of sediment type are not reliable, due to focusing and defocusing of the reflected signal by topographic irregularities.

LINE 5

COMMENTS:

There are a total of six comment categories: [Category] 1: Large or Unusual Scours - Any unusually long, wide or deep scours within an area have been commented upon here. Also included are documented occurrences of scours made by multiple keel icebergs and scours with distinctive shapes.

Category 2: Other Comments - In this section, comments on particular aspects not discussed elsewhere, or expansions upon prior observations are noted.

Category 3: Sidescan Image Quality - An estimate of the quality of the sidescan record for a given area, on a scale of 1 through 5 (1 = very poor; 5 = very good). Occasionally, descriptive terms are substituted.

Category 4: Scour Clarity - This is a qualitative estimate of the distinctness of scour features on a scale of 1 to 5 (1 = very poor; 5 = very good). Occasionally, descriptive terms were used. Scour clarity is influenced by the type and thickness of material being scoured, hydraulic reworking and post-scour infill, as well as the quality of the sidescan record.. The observation of post-scour reworking may be an indicator of the age of scouring when viewed in context of the geologic history. In some instances two separate scour populations may be recognized on the basis of differences in clarity, among other things. In these cases two values for scour clarity are recorded. Scour clarity and sidescan image quality are new parameters not previously entered into the data base. It should be noted that there is a tendency to measure the clearer, well developed scours in any given sample area. This may introduce a bias into the general attempt to obtain a representative sample for each area.

Category 5: Berm Development - A visual estimate of the size,continuity and sharpness of scour berms as seen on the sidescan record (0 = no berms; 1 = poorly preserved or developed berms; 2 = well preserved or developed berms). As with scour clarity, berm development is influenced by hydraulic reworking and sidescan record quality, as well as the type of material being scoured. This parameter was not included in previous data base compilations.

Category 6: Other Seabed Features - Features other than scours which are visible on either sidescan or Huntec records may be entered here. These include ripple marks or other bedforms, trawl marks, shell patches, pock-marks, bedrock outcrops, etc.

LINE 6

GEOLOGY:

i) SEQUENCE:

A numerical code for each recognized geologic unit (but not specific to that unit) referring to the relative sequential (vertical) position of each unit within a sample area. Units are numbered beginning with 00 at the seabed, 01 for the unit below, and so on. In each case, the unit designated 00 is the scoured unit unless codes for deeper units are marked with a percent symbol (%). Codes are consistent within study regions as established by ESRF and adopted for this study (see Section 1.1).

ii) CODE:

An alpha-numeric code for each recognized surficial (Quaternary) sediment or bedrock geologic unit. The code is specific to the geologic unit and numbered from oldest to youngest. Names (if available) and descriptions of the units and their corresponding codes are tabulated for each of the study regions (see list of tables). Note that codes are not necessarily the same for geologic units of similar description in the different study regions. This parameter was rarely, if ever, input in previous analyses, but consistently included, where possible, in this update.

iii) GEOLOGIC UNIT DESCRIPTION:

A brief characterization of the surficial and subsurface geology based on the sidescan and sub-bottom profiler data for sample area. For the site-specific data, only the geology in the immediate vicinity of individual features was available and this has been incorporated with the pertinent scour information.

iv) GEOLOGIC UNIT THICKNESS:

The thickness of each geologic unit, measured in metres from sub-bottom profiler. An assumed seismic velocity of 1500 m/s was used in calculation of these values. Geologic unit thickness was not routinely measured in previous data base updates. Particular attention is paid to the upper, scoured unit.

Also, any additional comments concerning the geology of a sample area have been listed in the excess spaces to the right of the THICKNESS value.

v) PERCENTAGE:

Intended use was to describe the percentage of seabed coverage of each surficial unit. (ie. those units with a sequence code of "00"), although entry problems did not permit inclusion in the final database.

LINE 7

SCOUR PARAMETERS:

i) SCOUR NUMBER:

Each individual ice scour feature measured in a sample area is assigned a number beginning with 01 and continuing in ascending numerical order.

ii) PLAN SHAPE:

Based on sidescan sonograph records individual scours are classified in plan shape as being straight (ST), arcuate (ARC), sinuous (SIN) or crater-like (C). Scours in the last category are commonly referred to as pits or impact craters (See Figure 4).

iii) SEGMENT NUMBER:

Arcuate or sinuous scours were approximated by a series of straight-line segments in order to characterize them accurately.

iv) BEARING MEASURED:

The apparent azimuth of a scour segment measured clockwise from the ships heading (see Figure 5). For sinuous and arcuate scours, measurements proceed systematically from one end of the scour to the other. Measured orientations are converted to true bearings by computer subroutine. For site-specific data this measurement represents the true scour orientation.

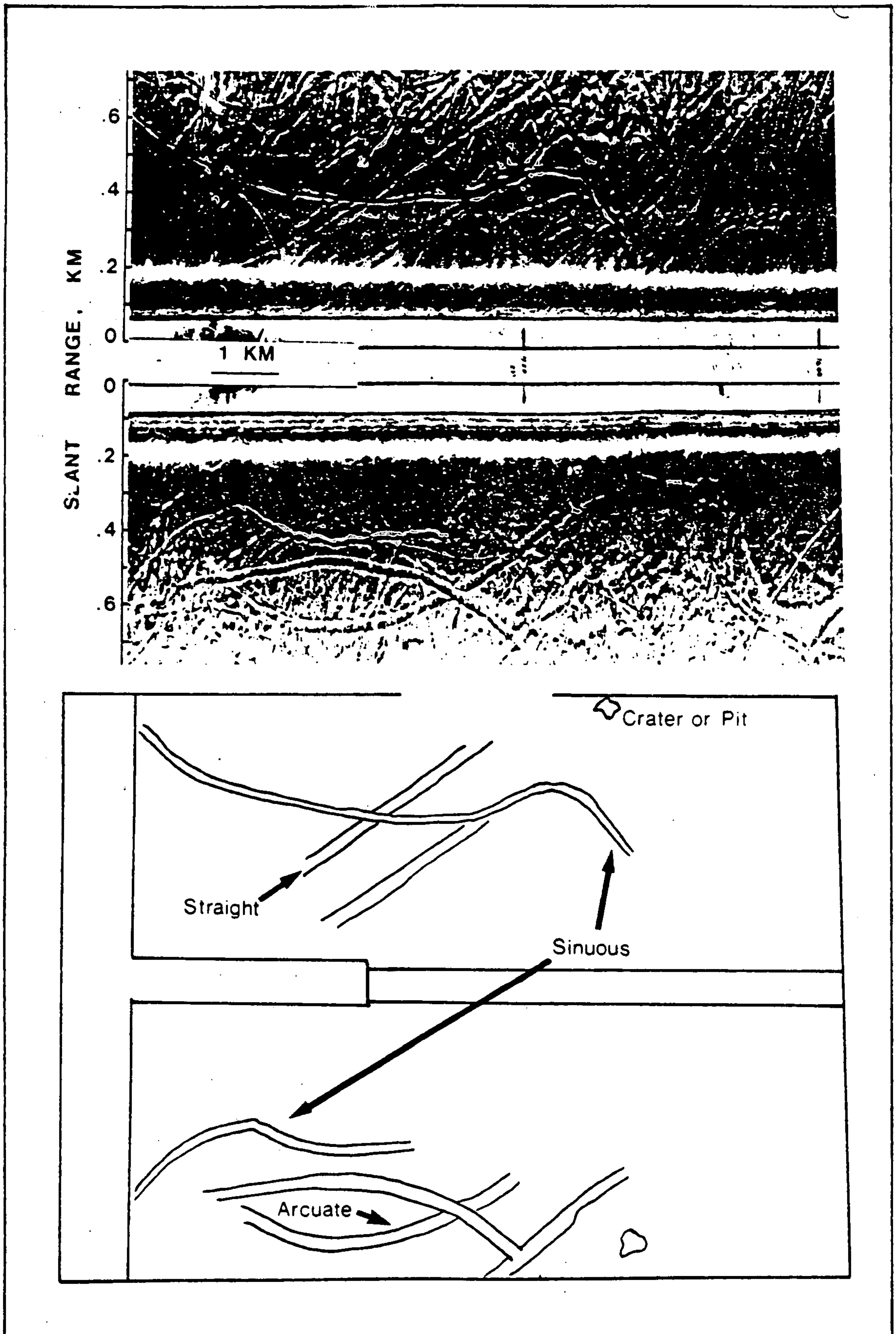

Figure 4 Sidescan sonogram examples of straight, accurate and sinuous scours and an iceberg pit. (from Todd 1984)

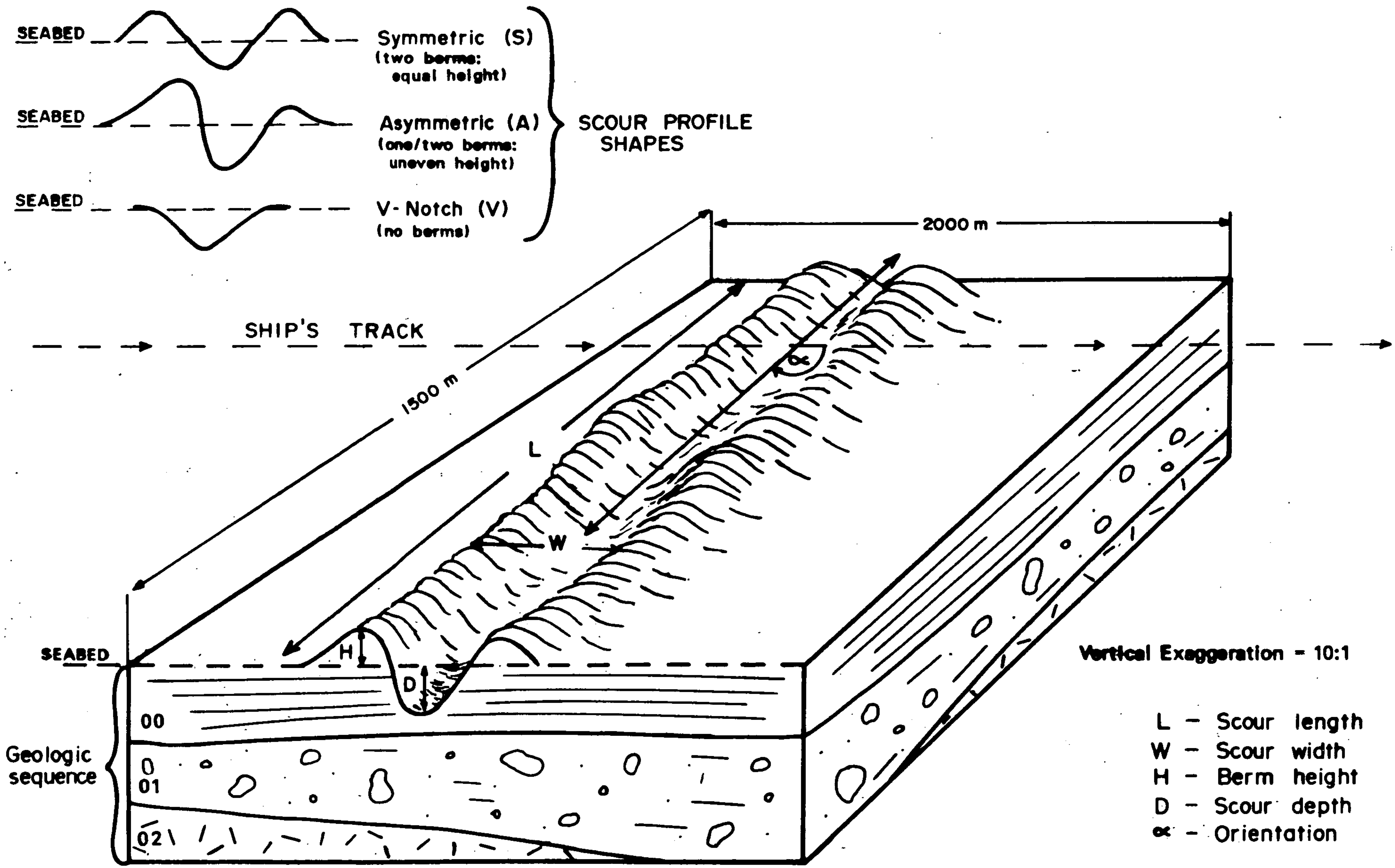

Figure 5. Representation of a typical sample area showing (1) horizontal dimension, (2) ship's track (3) angle of scour orientation (relative to ship's track), (4) scour length, width, depth and berm height, (5) classification of scour shapes in profile view, and (6) differentiation of geologic units.

v) LENGTH MEASURED:

The measured length of a scour or scour segment scaled in centimetres and later converted to metres by subroutine. Since individual sample areas have finite boundaries, this measured length is not to be taken as an absolute scour length. In rare instances where unusually long scours are observed to extend into adjoining areas, a note is made in the comments section under LARGE OR UNUSUAL SCOURS. No distinction is made between scours whose absolute lengths are recorded and those truncated at the sample area boundaries.

In the case of site-specific data, the length is given in metres as measured from 1:10,000 scale site charts and generally has a numeric qualifier as follows: 1) The entire scour is evident on data but only the point where it crosses a survey line is documented. 2) The scour goes beyond the limits of the sidescan sonar range, the length indicated is as much as can be seen on the sidescan. 3) The scour extends beyond the boundaries of the wellsite survey. 4) Only used in the case of the 4000 and 8000 series data and indicates that both ends of the scour are not clearly visible.

iv) WIDTH MEASURED:

The width of each scour or scour segment measured normal to its longest dimension from crest to crest of each berm (Figure 4), scaled in centimetres (measured from sidescan records only). The crest to crest measurement is easily and consistently measured from sidescan sonograms by measuring the distance between the acoustic shadows generated by each berm. The extent of seabed disturbance by scouring outside the berms is difficult to interpret from the records since one of the scour flanks is often in an acoustic shadow zone and therefore not defined. Prior to the ESRF data base update studies, only the widest scour in a sample area was measured and recorded. For the site-specific data the width given is the true width with the following qualifiers: Blank - nothing documented. 1) indicates the data were not reinterpreted, ie. width taken directly from an existing report.

vii) SCOUR DEPTH:

Scour depths are measured as illustrated in Figures 2 and 5 from high-resolution sub-bottom profiler (i.e. Huntec DTS) data only. A sound velocity of 1500 m/s is assumed for all scour depth estimates.

As illustrated, measurements are made from an inferred datum line which reflects the trend of the seabed surface in the immediate vicinity of the scour. Ideally this line is meant to reflect the shape of the seabed prior to scouring. In heavily scoured areas this datum becomes rather arbitrary.

In occasional areas where the high resolution reflection data indicate that scours contain a significant amount of infill, depth measurements are made to the interpreted original base of the scour and a separate measure of infill thickness is recorded in the COMMENTS section.

Because the Huntec and sidescan towfish are towed independently and are not positioned with respect to each other, scours visible on the Huntec record generally cannot be reliably correlated with those on the corresponding sidescan record and are therefore commonly entered as separate observations on Line 8. Note that these depth observations were not assigned a scour number. Prior to the ESRF update studies only the deepest scour in a sample area was input into the data base. Knowledge of the scale of the Huntec records allows accurate measurement of depths in metres. Limitations of system resolution preclude accurate measurement of scours with depths less than approximately 0.2 metres. The error in depth measurements is also estimated to be on the order of +/-0.2 m (Hutchins et al. 1976). The following qualifiers have been used for the site-specific data: 1) Used occasionally for 1.0 m, 0.5 m and 0.3 m depth to indicate that scour or pit depths are too small to measure accurately, but are discernable on the sub-bottom profiler data 2) Indicates depth was obtained from an existing report. 3) No data. 4) Indicates that nothing was visible on the profiler data although the scour crossed the survey line. In some cases these scours have been given an arbitrary depth of 0.5m.

viii) BERM HEIGHT:

For each scour depth measured from a Huntec record, a corresponding berm height was also measured as illustrated in Figures 2 and 4. For asymmetric scours, the highest berm was measured. The combination of both scour depth and berm height measurements should give a more complete characterization of total seabed relief than scour depth measurements alone. This parameter has been measured for the scour update data only.

ix) PROFILE SHAPE:

In cross-section, scours are classified as being symmetric (S), asymmetric (A) or V-notched (V). See Figure 4. This measurement was obtained from the profiler data, and where possible, is correlated to individual scours from the sidescan data. When this was not possible it was entered independently as a measurement from DTS only.

LINE 9

SWELL HEIGHTS AND DIRECTION, WAVE HEIGHT AND DIRECTION, WIND SPEED AND DIRECTION:

This information is often available from the BIO cruise data but not routinely included in the data base.

LINE 10

SCOUR CROSSCUTS:

This information was obtained from the sidescan sonar records. The scour number is entered in the first column with the scours that it appears to crosscut entered in the succeeding columns. In the early stages of the data base only the existence or nonexistence of crosscutting was indicated.

INFORMATION UNIQUE TO SITE-SPECIFIC DATA BASE:

a) Water depth at the extreme ends of each scour as defined by the data.

b) Sediment type in the immediate area of each scour as follows:

Gravel GG
Sand and Gravel SG
Sand with Gravel Patches SX
Glacial Marine Sediments GM
Glacial Till GT
Bedrock BR
Shell Facies SF

c) Sediment thickness in metres qualified as follows

0 = not confident of value

1 = confident of value

2 = measurement obtained from existing report

d) Presence of bedforms in area of scour, yes (Y), no (N)

e) Geographic coordinates for start and end of each scour.

1.4 QUALITY CONTROL

Two levels of quality control were exercised during creation of the data base. First, during the data entry phase tabulated summaries of entered data were checked for any anomalous outliers, mis-spelling or other obvious errors. Second, a comprehensive edit of the data base holdings was undertaken in 1988 by Canadian Seabed Research Limited. The goal of this work was to add information which had not been included within the data base at the time of data entry and to verify the correctness of certain extreme values for measured parameters. As well, miscellaneous data quality checks were conducted and recommendations were made concerning possible further editing procedures. The majority of these concerned editing of spelling and grammar, which, to date, has not been carried out.

As part of the Canadian Seabed Research edit, Bathymetric and navigational information for the regional cruises were gathered from available AGC navigation tapes and incorporated into the data base. One exception included bathymetric data from a number of sample areas on regional BIO cruise 83-030 which were unavailable. Navigational information for a total of 24 sample areas also could not be verified and were assigned a special editing flag, for exclusion from the data base.

Extreme values for the parameters of scour depth, width and berm height were also checked, remeasured and verified by Canadian Seabed Research. Values checked were those greater than 5 m for scour depth and berm height and greater than 275 m for scour width. Two examples were found to be incorrect and were changed.

The remaining editing involved parameters such as acoustic reflectivity, area location identifiers, missing start ranges and chart lengths. These were checked and corrected where missing, or in some cases, inconsistently recorded. Also checked were a number of cases of incompatible combination, such as a percent disturbed value listed as zero but with a value greater than zero having been assigned to the number of occurrences. Most of these were corrected. Once the editing procedure was completed, all sample areas, with the exception of 25 suspect cases, were classified as suitable for inclusion in the data base.

1.5 VALIDITY STUDY

1.5.1 General Discussion

To provide a potential user of the regional ice scour data base with some indication of the reliability of information which may be drawn from it, a validity study was conducted by Geonautics Limited. The goal of this study was to identify and, where possible, quantify potential sources of variation within the data base, with special emphasis on the issue of interpreter variability. The site-specific data were not included in this analysis.

Three potential sources of error and variation are postulated. The first involves scalar mistakes in measurement, analyst entry errors and data (keypunch) entry errors. The second is a function of interpreter variability (tied to a number of factors), while the third stems from natural variability in the seabed features being measured. An attempt was made to analyze these factors individually. However, as a result of the multitude of factors involved in any given measurement (data quality, natural variability, selection and measurement procedures, etc...) it was not possible to completely separate and quantify each.

1.5.2 Methodology

The approach taken for the validity study is as follows. A number of sample areas from the entire regional data base were randomly selected for remeasurement of record and scour parameters, using the latest format adopted in the data base update. Before a sample area was deemed suitable for re-analysis, certain selection criteria were met as follows: (i) water depth over the interval of the sample area of less than 250 m; (ii) both sidescan sonar and sub-bottom profiler data available for the area; (iii) record quality of the sidescan and profiler data classified in the data base as "average" or better ($\geq$ 3 on a scale of 5); (iv) editing criteria established by Canadian Seabed Research Limited (1988) having been satisfied. These criteria allowed for focusing of the validity study resources on that part of the data base which would most likely be used in an assessment of the risks of modern iceberg scouring and to ensure that the samples selected are representative (random selection) and therefore applicable to the whole data set.

Four separate data listings, each consisting of 50 randomly chosen sample areas were then produced. These came from 255 suitable segments from the Baffin-Davis region, 298 from the Labrador Shelf between 50^{o} and 60^{o}30'N, 58 sample areas on the Grand Banks which display scouring and 162 on the Grand Banks which had been listed in the data base as containing no ice related features. These four sets were generated late in 1988 utilizing a random number generation program on the CDC CYBER computer at BIO.

Of the selected sample areas, 25 were reanalyzed for each of the Labrador Shelf and Baffin-Davis regions, with approximately 40 reanalyzed for the Grand Banks region where scouring had been noted.

In addition, a number of randomly selected sample areas for the Grand Banks region which had previously been classified as unscoured were reviewed. All measurements were made by an experienced interpreter with no prior involvement in the data base compilation and recorded in a format corresponding with that used for the most recent update (Figure 3). As has been pointed out by d'Apollonia Association (1987) the method of analysis and organization of the data base have been modified over a number of years as the data base was developed. This is considered problematic for the determination of an overall error and variability rate for the data base.

All visible scours and craters (also termed "pits") were remeasured in light to moderately scoured sample areas. Where scouring was more intense all scours were traced onto a sheet of mylar film and numbered. A random number generator was then used to select a total of 15 scours from each sample area for remeasurement. The resulting data were entered twice into a VAX minicomputer at Geonautics Limited facility in St. John's. A direct comparison of the duplicated files then allowed assessment and for correction of any keypunch errors in the remeasured part of the validity study.

A printout of the existing data for the sample areas selected for re-measurement, along with the original data sheets for most of the areas was provided by AGC/BIO to Geonautics. This information was required in order to determine the degree of keypunch entry errors which occurred in the formulation of the data base. The original data sheets were entered twice into the Geonautics VAX minicomputer in the same format as the remeasured sample areas. This return to the format of the data sheets was necessary due to changes in the format of the data base during its compilation which created difficulties in direct data comparisons for statistical purposes.

The first step in the validity analysis was the determination of anticipated keypunch error rates for the data base. This required a manual comparison of variables as they were recorded on the original data sheets and as they are presently found in the data base. Important to this analysis was the assurance that no editing of the parameter values had taken place since their entry into the data base file. This limited the process for determining this error rate to certain variables which had not been edited during the quality control work discussed in the previous section. These were; inner and outer ranges, chart length, scour orientation and scour length. A tally was made of the total number of keypunch errors over a given number of entries to determine a percentile figure of this source of error. As a result of the random selection process it is assumed that examples of data entered over the entire time period of the study were checked, therefore providing a reasonable value for the complete data base. The results are presented in the following section.

Scaling (measurement) variability and scaling/analyst entry errors were addressed next, utilizing the parameters of inner and outer range and chart length. Scaling variability is considered to have resulted from measurement of what can be poorly defined points on the sidescan records, as well as variable precision on the part of different interpreters and differences between channels. Errors in scaling were defined as any recorded value which lay outside a maximum allowable range of values for a given measurement, as defined during remeasurement.

The approach taken was to have a team of two interpreters remeasure inner and outer ranges, along with chart (record) length, for 45 sample areas randomly selected from the validity study sample set. A maximum and minimum possible value for each of the ranges was agreed upon, taking into account all possible sources of variation. As well as the uncertain nature of the boundaries and interpreter precision, allowances were made for changing values along the interval of the sample area and across channels. A number of sample areas (15) had to be excluded, as they were from an early phase of data collection where the interpreter was not necessarily measuring the maximum values of range. For chart length, consideration was given to imprecise measuring techniques and occasional rounding of values to the nearest centimetre in determining an acceptable variation from the remeasured values.

Presentation of the "allowable" range in values for each of the inner and outer ranges and chart length is of very limited use to a potential user. This is the case because these values are constant, irrespective of the measured length and cannot therefore be expressed as a percentage. They are also uncorrected values and do not represent true scale measurements. More relevant is the determination of an error rate for these scaling measurements. This was done by considering any values outside the acceptable ranges to be either scaling or transcription (analyst entry) errors. The original data sheets were checked previously to remove keypunch entry as an error source. This rate can then be used as an indication of the expected error rate for measurements taken of actual ice related features. However, the varying relative magnitude of scour measurements (ie: width versus length) likely have differing potentials for error.

Interpreter variability was examined once the existing (original) and remeasured data sets had been entered as two compatible computer files. A statistical comparison of equivalent measurements between original and re-interpreted data is presented in the results section. Directly compared are the parameters of estimated percent disturbed, number of occurrences, record length and maximum scour depth. For scour parameters it was necessary to average the values of length, width, depth and berm height and tabulate orientations for each sample area before comparison. This required a computer sub-routine to convert multi-segmented scours to equivalent straight line features. The validity study remeasurements and update studies measurements both presented a range in values for estimated percent disturbance. The midpoint of these ranges was used as a single value for comparison.

A file was created for each of the five original interpreters whose sample areas were remeasured, which included both their original and the remeasured values. For each of the parameters, with the exception of scour orientations, the remeasured value was then subtracted from the original, providing the difference between the two. The mean value of all the differences and the standard deviation were then calculated, providing an indication of the variability between each of the original interpreters and the remeasuring interpreter. The mean difference was then compared to the average original value to create a percentile value of variability. Scour orientations were not averaged and dealt with in this manner for each parameter, but were plotted as histograms for comparison between interpreters. These histograms are presented in Appendix 1. Where a large variability was noted between interpreters an attempt was made to determine the reason for the difference.

Finally, the natural variability inherent in ice-related seabed features was analyzed. Approximately 45 scours from each of the Labrador and Baffin-Davis regions and 40 scours from the Grand Banks were remeasured to record minimum and maximum widths over their observed interval. Preferentially chosen for this task were linear features, minimizing width changes due to variable distortion at different angles on the record. It should be noted that limited measurement precision is considered to result in a clustering of values about certain percentages. As well, no consideration was given to the effects of changing surficial geology and water depth over the interval of a given scour. These considerations are addressed in Section 3.6.

The natural variability in scour depths over the length of a scour is not as easily analyzed as width, since only one measurement can be taken from sub-bottom profiler records. This variability is addressed to some extent in Section 3.6.8. Overall, with regards to natural variability, it is considered likely that for a given interval, the range of existing depths and widths would be adequately represented by the scours selected for measurement. This may not, however, be the case in areas of very light scouring.

1.5.3 Results

The validity study produced the following results.

Keypunch entry errors; A total of 4 keypunch entry errors were located within 1654 entries, providing an error rate of 0.24% in the data base. Both the pre-ESRF and ESRF update studies data contain this type of error.

Scaling/Analyst Entry Errors and Allowable Range in Values; Inner ranges were given a maximum acceptable range (about the remeasured values) of ±8 mm. Of the 45 areas remeasured, 15 displayed large differences as a result of changing definition of the inner and outer range over the period of the study and were therefore excluded.

Outer ranges were given a maximum acceptable range of ±1.2 cm. The same 15 sample areas were excluded.

Chart length was assigned an acceptable range of ±4 mm. A total of three measurements were located which exceeded the maximum permitted range about the remeasured value. This was within 105 measurements which were checked, giving a combined scaling/analyst entry error rate of 2.86%.

Interpreter Variability; The mean values of the differences between the original interpreters and the remeasured values for each parameter are presented in Table 2, which is broken down on the basis of the 8 parameters examined. Each parameter is sub-divided for the five original interpreters. Scour orientations for each sample area are presented in Appendix 1 as a side by side comparison of histograms, sub-divided by interpreter.

Table 2

STATISTICAL COMPARISON OF THE DIFFERENCES BETWEEN SCOUR PARAMETER MEASUREMENTS OF ORIGINAL VERSUS REMEASURING INTERPRETER

DIFFERENCES CALCULATED BY SUBTRACTING REMEASURED VALUES FROM ORIGINAL

NEGATIVE VALUE INDICATES REMEASURED VALUES HIGHER THAN ORIGINAL

Parameter	Original Interpreter	Average Original Value	Sum of Difference	Mean Value of Difference	Standard Deviation	Number of Comparisons	Percent Variability
Percent Disturbed	A	35	-264	-9.1	$1.901 \times 10^{+1}$	29	26.0
	B	37	-198	-7.9	$1.827 \times 10^{+1}$	25	21.3
	C	17	-249	-22.6	$3.274 \times 10^{+1}$	11	132.9
	D	28	+45	+4.5	$1.081 \times 10^{+1}$	10	16.1
	E	63	-45	-7.5	$1.782 \times 10^{+1}$	6	11.9
Number of Occurrences	A	14	-62	-2.2	6.646	29	15.7
	B	11	-294	-12.8	$1.297 \times 10^{+1}$	25	116.4
	C	8	-25	-2.3	5.533	11	28.8
	D	8	-3	-0.3	2.751	10	3.8
	E	26	-4	-0.8	$1.028 \times 10^{+1}$	5	3.1
Scour Length (cm - uncorrected)	A	7.3	-2.00	-0.07	3.288	27	0.01
	B	14.1	+82.88	+4.87	6.549	17	34.5
	C	10.6	+14.28	+2.38	2.534	6	22.5
	D	15.0	+32.29	+4.61	4.495	7	30.7
	E	11.1	+19.66	+3.93	3.659	5	35.4
Scour Width (cm - uncorrected)	A	0.5	-2.99	-0.37	3.925×10^{-1}	8	74.0
	B	0.7	+4.84	+0.27	2.305×10^{-1}	18	38.6
	C	1.0	-1.08	-0.11	3.886×10^{-1}	10	11.0
	D	0.8	-1.08	-0.11	3.233×10^{-1}	10	13.8
	E	0.5	+0.46	+0.08	7.763×10^{-2}	6	16.0
Scour Depth (m)	A	0.5	-0.16	-0.04	2.470×10^{-1}	4	8
	B	1.2	+5.51	+0.61	4.310×10^{-1}	9	50.8
	C	1.3	-3.53	-0.50	7.790×10^{-1}	7	38.5
	D	1.1	+0.26	-0.04	4.528×10^{-1}	6	3.6
	E	0.9	-0.20	-0.04	3.451×10^{-1}	5	4.4
Maximum Scour Depth (m)	A	2.2	-0.90	-0.04	5.221×10^{-1}	21	1.8
	B	1.5	-3.10	-0.34	8.918×10^{-1}	9	22.7
	C	1.8	-11.20	-1.60	1.828	7	88.9
	D	1.6	-2.10	-0.35	3.146×10^{-1}	6	21.9
	E	2.3	-3.30	-0.66	5.683×10^{-1}	5	28.7
Berm Height (m)	A	NOT MEASURED BY THIS INTERPRETER		—	—	0	—
	B	0.6	+2.18	+0.24	2.432×10^{-1}	9	40.0
	C	0.7	-1.25	-0.21	4.483×10^{-1}	6	30.0
	D	0.2	-1.07	-0.18	2.083×10^{-1}	6	90.0
	E	0.5	-1.62	-0.32	3.968×10^{-1}	5	64.0

When viewing the values presented in Table 2 it is important to note that the number of comparisons used to derive the interpreter variability is not equal for all five interpreters, nor was the number consistent for each parameter. In some cases, the number of comparisons is unfortunately low. More comparisons may have acted to smooth out the effects of any unusual differences between interpretations. This is the case because of the differing degrees of involvement of the interpreters and inconsistent recording of values. Where no value had been entered, no comparison was made. Entered values of zero were compared. Very noteworthy are a number of samples (9 out of 27) analyzed by interpreter B which were originally interpreted as unscoured but which were re-interpreted to contain scours. Most of the 9 cases (out of 27 compared for this interpreter) were within one area, where seabed features had previously been interpreted as bedrock outcrops. It is a matter of interpretation as to which is correct. This situation tended to increase the variability between interpreter B and the remeasured values. The analyses of interpreter A were carried out prior to the ESRF update studies and generally only involved measurements of maximum scour width and depth. Berm height was not recorded before the ESRF update studies.

Percent disturbed: Interpreter variability ranged from 11 to 26 percent of the original value, with the exception of 132% for interpreter C. In this case, 4 of the 11 areas compared, all from consecutive intervals, far exceeded the variability range of the other interpreters, while the remaining 7 were within that range. Relatively low data quality over the intervals in question is considered to have been the cause of the extreme variation.

Number of Occurrences: With the exception of interpreter B, interpreter variabilities ranged from 3 to 29 percent. The exception, at 116%, is abnormally high, resulting from the situation where 9 of the 27 areas compared were considered unscoured by interpreter B, but were subsequently reinterpreted as scoured.

Scour Length: The interpreter variability ranged from 0 to 35 percent for scour length. Much of the variability is thought to be the result of the remeasuring interpreter's reluctance to measure scours into the inner ranges of the sidescan sonar records, since the variabilities for interpreters B to E all fall within a range of 23 to 35 percent greater length. The pre-ESRF update studies analyses conducted by interpreter A purposely did not measure scours within the inner ranges.

Scour Width: Interpreter variability ranges from between 11 and 16 percent for interpreters C, D and E, to 39% for B and 74% for A. The large discrepancy with interpreter A is a result of a low number of comparisons, all within an area of a single cruise, where scour clarity was low and the width interpretations were consistently different. The mean values of the difference between the remeasured values and interpreters C, D and E are less than or equal to the measuring precision.

Average Scour Depth: Interpreter variabilities of less than 10% were noted for A, D and E, with 39% and 51% for B and C respectively. Remeasured values averaged 51 percent lower than those of interpreter B, while averaging 39 percent greater than interpreter C.

Maximum Scour Depth: Variabilities range from 1 to 89%, with interpreters B, D and E averaging approximately 25%. The abnormally high value for interpreter C appears to have resulted from differing interpretation of depth within a particularly heavily scoured region, combined with a low number of comparisons.

Berm Height: Interpreter variability ranges from 30 to 90 percent for this parameter. It was not measured in pre-ESRF update studies work by interpreter A, and entered into relatively few of the analyses of interpreters B, C, D and E. The mean value of the differences for all interpreters approximates the measurement precision of 0.2 m.

Scour Orientations: Although it was not possible to average the scour orientations, histograms of existing and remeasured values are presented for each sample area in Appendix 1. These illustrate that in most cases the two sets are reasonably close in scour orientation values. It should be noted that in many cases, especially heavily scoured areas, the remeasured group consisted of a higher number of scours than was measured by the original interpreter.

It is considered that the remeasured values were determined by an able and competent interpreter and that they represent realistic interpretations. That differences exist, therefore, can be taken by a potential user as an indication of the levels of interpreter variability that likely exist throughout the data base. Although Table 2 does indicate that the remeasuring interpreter commonly had values higher than those of the original interpreters, the remeasured values generally lie within the range of values measured by the original interpreters.

The values of interpreter variability are different for each of the parameters examined for this study. It is difficult, therefore, to produce a single overall percentile value for interpreter variability. However, the range of values commonly lay between 0 and 30 percent when a number of extreme cases were excluded. These extremes, when examined individually, are generally due to differences in interpretation over a very limited regions of complex seabed conditions, such as was the case between the new interpreter and original interpreter B (number of occurrences). For a potential user of the data base involved in regional studies as opposed to very small scale work, such widely different possible interpretations are unlikely to affect data extracted from the data base.

It is therefore suggested that the potential for interpreter variability in the overall data base lies between 10 and 30 percent. While this provides a useful guide, it should be remembered that in areas of complex seabed geology (eg. where bedrock outcrops at the seabed) and over intervals of low data quality, high levels of interpreter variability have been noted. Interpreter variability is at least one order of magnitude greater than either of the previously discussed keypunch or scaling/analyst entry errors. Since the data compared to derive the values for interpreter variability did not have these errors corrected, the range of 10 to 30 percent variation can be considered to include all three sources of variability.

Natural Variability

A total of 127 scours were remeasured to record a maximum and minimum width over their observed lengths. Of these scours, 27 (21.3%) displayed no measurable variation. Of the remaining 100 scours, 91 displayed a variability of less than 35%. The maximum value was 50%, while the mean lies between 20 and 25 percent. No consideration was given to the effects of surficial geology, changing water depths and variable distortion from the sidescan records. Generally, linear iceberg scours were selected to minimize this last effect.

1.5.4 Implications

It is recommended that a user of the data base allow for a possible variability of up to 30% in data extracted, while bearing in mind that in isolated cases the variability may be greater. For parameters dealt with specifically in this study, Table 2 and the accompanying discussion may provide better indications of anticipated variability. The imprecision of the value presented for variability is largely a function of both the wide interplay of variables concerned with a given measurement and the methodology of the data collection.

Factors contributing to uncertainty in the measurement of a parameter include data quality, geologic conditions, scour age and degradation, instrument type, and accompanying seabed features, along with the interpreter and methodology in use at a given time. Also, except for the parameters of scour width, observed length, orientation, depth and berm height, many of the data gathered during the study can be viewed as qualitative. This is especially true for the parameters of percent seabed disturbance and number of scour occurrences and is likely true for scour depth and berm height in areas of high scour density. Those concerned with the formation of similar data bases in the future may be advised to limit these parameters to broad categories (eg. 0-30%, 30-60%, 60-90%).

One part of the interpreter variability recognized in this study is likely the result of the long history of the data base and changing update procedures. As an example, one could consider the parameters of inner and outer range which, in early stages of the data base were selected such that only the optimum portion of the sidescan record wwould be included in the analysis. In later updates, including this work, the entire sidescan record was used. Quality control, whereby rigid methodologies were established and remeasurements were systematically made during the data collection by different interpreters would have minimized such potential problems and provided a better indication of true interpreter variability.

As it stands, inconsistencies do exist in the data base in the way in which parameters were incorporated. An example is the earliest (pre-update studies) method of measuring only the maximum scour depths and widths. This evolved in later stages to the procedure of making up to 15 representative measurements of each. The maximum value of scour depth would likely have been included (due to its being the most pronounced feature on the sub-bottom profiler record) although this may not have been the case for scour width (see Section 4.6.2).

With regards to the natural variability of iceberg scours, dealt with briefly by this validity study, it is recommended that a user bear in mind that measurements of parameters incorporated in the data base are, in general, average or representative values, and that any given feature may display changes along its length. The values presented, however, should serve to provide an overview of trends of iceberg scours in a given region since the existing measures constitute a statistical sample of the scour population.

2.0 GRAND BANKS REGIONS

2.1 REGIONAL SETTING

The Grand Banks of Newfoundland cover an area of over 100,000 km^2 above the 100 m isobath and are flat-topped with only a slight seaward dip. The main physiographic features are relatively isolated basins and broad channels (see Figure 6). Whale and Downing Basins are both less than 200 m deep with an undulating topography. Avalon Channel, the largest channel, extends along the eastern edge of the Avalon Peninsula swinging west around the south coast of the Peninsula and then into Haddock Channel (Figure 7). It reaches depths of 200 m in isolated basins.

Trends of the main oceanographic currents around the Grand Banks are shown in Figure 7, while approximate iceberg drift patterns are shown in Figure 6. Although iceberg flux across the Grand Banks varies widely on an annual basis, an average of 400 icebergs drift into the Grand Banks area annually (Murray 1969; Dinsmore 1972; Lewis and Benedict 1981b). While the greatest component of these are transported around the eastern boundary of Grand Bank at approximately the 200 m isobath and below by the main branch of the Labrador Current, a small component of the icebergs reach into and follow the Avalon Channel (see Figure 6). A comparatively smaller number of icebergs are pushed onto Grand Bank itself by rotary currents, semidiurnal tides or storms (Blenkarn and Knapp 1969; Newfoundland Petroleum Directorate 1983).

The bedrock geology of the Grand Banks can be divided into three units (King et al. 1986) as shown in Table 3. Metamorphosed Precambrian rocks constitute acoustic basement and are exposed along the margin of the Avalon Peninsula and at the Virgin Rocks and Eastern Shoals. In the Avalon Channel and much of the inner Grand Banks to Downing Basin and the Virgin Rocks, the bedrock comprises a nearly

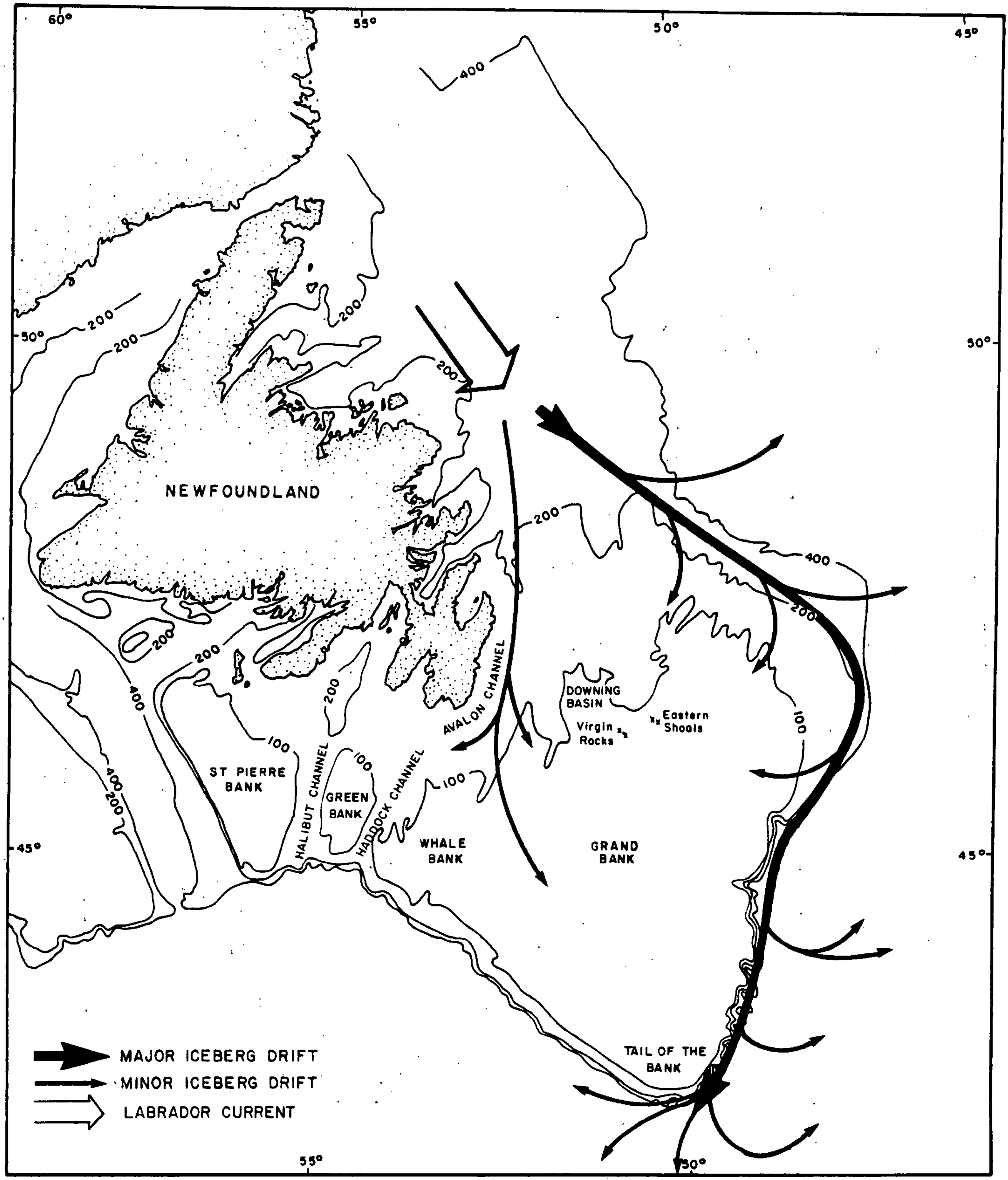

Figure 6. The main physiographic features of the Grand Banks of Newfoundland with approximate iceberg drift patterns. (from Dinsmore 1982)

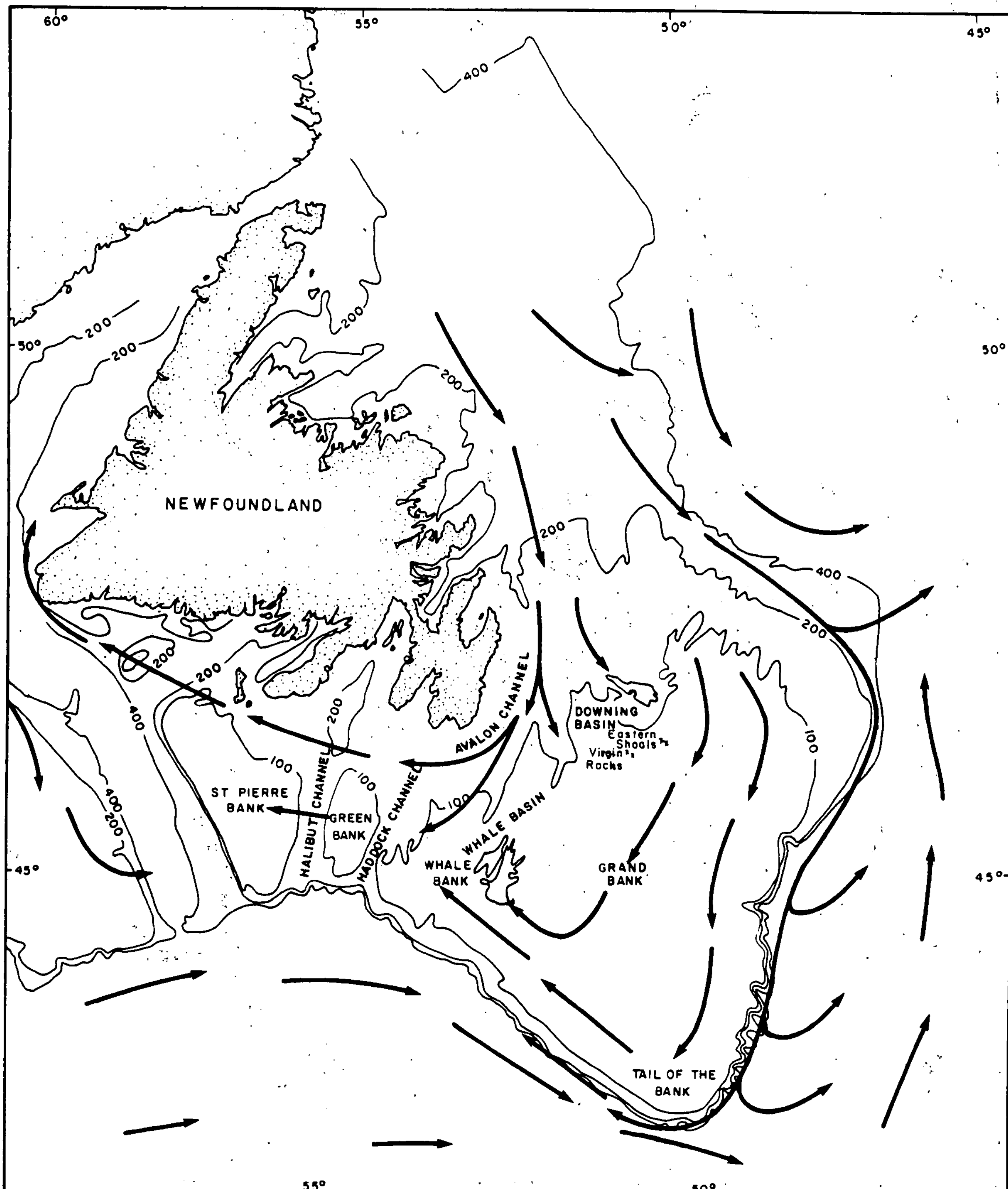

Figure 7. Major surface currents within the Grand Banks area. (compiled by R. Reinigar and C.R. Mann,. BIO. Dartmouth, NS)

Table 3

Geologic Sequence, Grand Banks Region

UNIT OR CODE #	DESCRIPTION OF GEOLOGIC UNIT
6	Post-Glacial sediments: A) weakly stratified ponded clays and some silts (usually below former sea level stand) B) primarily well sorted sands and gravels; usually thin deposits on unconformable surface of coastal plain sediments (Further differentiated in Hibernia area by Barrie et al. 1984).
5	Glaciomarine sediments; subglacial and proglacial, typically well stratified, pebbly silts and clays usually restricted to basins.
4	Glacial till. Typically acoustically homogeneous and relatively transparent; nonstratified. Occurs as thin cover over much of inner shelf.
3	Mesozoic/Cenozoic coastal plain sediments. Located in mid to outer shelf regions. Gently easterly dipping stratification. Comprised mainly of semi-consolidated clastic sediments.
2	Cambro-Devonian Sequence. Black shales, grey shales and redbeds. Occur between Avalon Peninsula and Virgin Rocks.
1	Acoustic Basement. Precambrian metasediments and volcanics mainly restricted to nearshore areas. Outcrops at Virgin Rocks, Eastern Shoals and along Newfoundland coast.

conformable sequence of well indurated shales and red sandstones of Cambrian to Devonian age. To the east these rocks are unconformably overlain by a gently dipping, seaward younging sequence of semiconsolidated clastic sediments. They are of Cretaceous to Tertiary age and extend to the edge of the continental shelf where sediments of Pliocene or possibly younger age occur. The top of this bedrock sequence is defined by a well developed angular unconformity which on the outer shelf is very smooth and gently dipping but over much of the inner shelf is greatly undulating, probably as a result of fluvial and glacial carving.

The surficial geologic units consist of glacial till, stratified glaciomarine silts and clays and reworked sand and gravel. The till and glaciomarine sediment were deposited when the Avalon ice cap extended across the Avalon Channel and probably across most of northeastern Grand Banks (Slatt 1977; Fader and King 1981). A thin (0-5 m) blanket of till covers much of the inner bank areas, over the Cambro-Devonian rocks.

Fader and King (1981) suggest that during the low sea level stand, relative water depth across the northeastern and northwestern part of Grand Bank was between 110 and 120 metres below the present sea level. The sand and gravel deposits which are prevalent in water depths less than this are remnants of reworked bedrock and glacial sediments which were transgressed during the sea level rise. Sediment thicknesses across most of the outer bank are often less than 1 m except where bedforms (often sand ridges) have built up thicknesses of up to 5 m and in isolated deeper basins where till and glaciomarine sediment can reach 10's of metres in thickness.

In the Hibernia area the surficial sediment facies have been subdivided to include five units based on sediment texture, thickness and presence of bedforms (Barrie et al. 1984).

2.2 DATA COVERAGE

A complete listing and map of the cruise data analysed during this and previous studies on the Grand Banks is given in Appendix 2 and this coverage is illustrated in map form on Chart 1. Cruise information for the northeastern portion of Grand Bank is presented separately, at a larger scale, as Chart 2.

Grand Banks analysis included data from ten BIO cruises:

1) BIO 75-009 data comprise Huntec DTS data only. Most of the survey lines are long, regional, east/west oriented tracks ranging from Avalon Channel to Flemish Pass. The profiles could not be analysed for iceberg scour occurrences because excessive towfish heave masks the data.

2) BIO 77-011 data were collected in the Avalon Channel/Downing Basin area. Both Huntec DTS and sidescan (BIO 70 kHz) were present. Analysis of the data began in 1981 and was completed in 1984 as part of the present update study.

3) BIO 78-023 data are from the northeast Newfoundland Shelf and northern part of the Avalon Channel. Both sidescan (BIO 70 kHz) and Huntec DTS data are present. Part of this cruise has been included with the Labrador Shelf inventory.

4) BIO 80-010 data include both sidescan (BIO 70 kHz) and Huntec DTS data over most of the cruise. The data traverse northern Grand Bank, the Hibernia area, the shelf edge near Flemish Pass and include several survey lines across the southern part of the bank. Some of these data were previously entered into the data base by AGC researchers. No sidescan data exists for much of the northeast part of the shelf and slope in water depths greater than 100 m. The Huntec DTS data in these areas were entered into the data base.

5) BIO 81-012 data are concentrated around the Hibernia area and to the north and east. The majority of sidescan data are Klein 100 kHz. The only profiler data are 3.5 kHz records with no heave compensation. The data indicate very little penetration in sandy and gravelly areas rendering them of little use for this study.

6) BIO 81-045 cruise is concentrated in the Hibernia region. The 70 kHz sidescan data are of variable quality, with much acute water column interference. Few Huntec DTS records accompany the sidescan and those that exist are of limited use due to excessive heave motion.

7) BIO 82-039 data cover much of the area southwest of the Virgin Rocks and include both Huntec DTS and Klein 100 kHz sidescan records. These data suffer somewhat due to rough sea conditions. Scours in this area are of very low relief making them difficult to recognize on the sidescan records.

8) BIO 83-033 cruise covers much of the Hibernia area and northward. Both 100 kHz Klein sidescan and Huntec DTS profiles were examined.

9) BIO 84-024 data were collected in the Avalon Channel region. Both BIO 70 kHz and Klein 100 kHz sidescan records were utilized in the analysis, along with Huntec DTS profiles. These data were entered in 1985 as part of the update study.

10) BIO 84-035 data were collected in the Flemish Pass region and northeast Newfoundland Shelf, utilizing the SeaMARC sidescan sonar system. No profiler data were available. All data were entered in 1985 as part of the update study.

2.3 OTHER DATA SOURCES

A cruise conducted by the Centre for Cold Ocean Resources Engineering (C-CORE) in 1984 utilizing the H.M.C.S. Cormorant provided data which were incorporated directly into the regional data base as part of this update. These data are referred to as C-CORE/CORMORANT in the data base. This survey covered areas of the Grand Banks, including the Hibernia region, where scouring rates are very low. A Klein 100 kHz sidescan system was utilized. No profiler data are available. Other iceberg scour information presently available for the Grand Banks region includes industry data from site-specific wellsite surveys, one regional data set collected for Mobil Oil Canada, Ltd. by Geomarine Associates in 1980 (4000 series) and one regional set collected by BIO/C-CORE personnel, also in 1980 (8000 series).

An inventory listing of all available and released well site survey reports and an overview of their relevant contents has been conducted by Geonautics Limited as part of the present study and is presented in Appendix 6, valid to March, 1988. A number of proprietary reports were incorporated into the inventory with the permission of Petro-Canada Inc., BP Resources Canada Limited, Canterra Energy Ltd., Husky Oil Operations Ltd., Mobil Oil Canada, Ltd. and Texaco Canada Enterprises Ltd. Reports were viewed at both the Canada Newfoundland Offshore Petroleum Board (CNOPB) office in St. John's and in the offices of Geonautics Limited. The only site-specific scour data presently available in the east coast ice scour data base is that information incorporated from the compilation discussed in the following section.

2.3.1 Site-Specific Data Base Compilation

In 1982 and 1983 Geonautics Limited submitted two reports to Mobil Oil Canada, Ltd. and its partners. The first, in 1982, was entitled "A Catalogue of Iceberg Scours and Ice Related Features on the Grand Banks of Newfoundland". It documented the occurrence of scours and pits from Mobil's own data, released reports and some BIO regional data. Utilized were 17 wellsite surveys, a set of regional lines between the Hibernia and Trave/White Rose wellsites (4000 series), data from the BIO/C-CORE cruise (8000 series), and data from BIO cruise (Hudson) 80-010.

In 1983 an update to this report was conducted for Mobil Oil Canada, Ltd. This involved the addition of data from eight wellsite surveys and any available BIO regional cruises. Statistical analyses were performed on the various scour parameters to define any interrelationships which might be inferred.

With the permission of Mobil Oil Canada, Ltd. and its partners the iceberg scour data contained within the Mobil data base was originally intended to be incorporated directly with the ESRF data base. In an effort to maintain information unique to the Mobil data base, which resulted in some degree of incompatibility with regional data, it was eventually decided to enter all available site-specific data as a separate file in the ESRF data base. Due to the fairly tight line spacing of the 4000 and 8000 series regional cruises it was decided to include these as part of the site-specific data set. It should be noted that a small portion of the 8000 series cruise is also included in the regional data base. The data entry format was altered slightly in the production of this site-specific data file to better represent the differences between the site-specific and regional data sets.

2.4 DATA COMPILATION - METHODOLOGY AND LIMITATIONS

Because of the relative scarcity of iceberg scours in water depths of less than 100 m (in comparison to the more northern ESRF study areas), the analysis of all Grand Banks data for this update study usually involved measurement of all recognized scours within any given sample area. Exceptions to this were made where scour density was high, i.e. along the bank perimeters and parts of the Avalon Channel. Scours on the bank top (approximately 90 m water depth) rarely exhibit any depth on seismic profiler records and it was not worthwhile analysing areas without sidescan coverage. However, where average scour depths are greater than about 1 m, measurements of scour depth and shape were recorded even when there was no accompanying sidescan data. This could only be done in areas where the analyst was reasonably certain that the features were, in fact, iceberg scours. In many cases, without the confirmation of lateral continuity and sub-parallel edges (scour berms) as gained from sidescan records, scours can be difficult to differentiate from other types of features such as fluvial channels, megaflutes or small-scale topographic undulations.

2.5 SCOUR SUMMARY

Two populations of ice scours have been distinguished on northeastern Grand Bank by Fader and King (1981) and Lewis and Barrie (1981) and their findings are confirmed in this study. In water depths greater than approximately 110 m , a dense pattern of partially buried iceberg furrows extends across the entire northeast portion of the bank. In deeper water the furrows are more sharply defined, in part because they are deeper and not as fully buried. Most of this iceberg furrow population is probably relict, formed prior to and during the low sea level stand between 16,000 and 12,000 years B.P. when the shoreline was approximately along the present 110 m bathymetric contour (Fader and King 1981).

The modern, post-glacial (Holocene) scour population, in contrast, is much more sparse, with only isolated scour occurrences. However, many of the scours have a fresher appearance on sidescan sonograms, not having been buried or reworked as much as the relict population. These younger scours occur in water depths less than 110 m but are not restricted to this zone. The fresher looking, presumably younger scours are also superimposed on the partially buried population below 110 m water depth. Chart 3 shows scour zones which can be related in part to some parameters of the two scour populations and in part to bathymetry.

The following discussion of regional iceberg scour distribution and character focuses mainly on the eastern part of the bank, as that area west of 51°W longitude (west of Virgin Rocks) is considered in greater detail with accompanying maps in the following section on the Avalon Channel Detailed Study (Section 2.6).

2.5.1 Scour Occurrences Above Pleistocene Low Sea Level Stand

The area of lowest scour density is restricted primarily to water depths less than approximately 110 m; the area transgressed during the Holocene sea level rise.

These bank-top scours range in appearance on sidescan sonograms from fresh-looking with well-developed berms to highly degraded and barely discernable. Because their depths are generally less than 0.5 m and berms are small or absent, they are usually only discernable on the sonograms by virtue of a textural difference on the seabed caused either by the scouring process or by post scouring processes. This occurs for example when (a) scours in a lag deposit expose and churn up underlying sand, or are subsequently partially infilled by sand, or (b) scours penetrate a sand layer and expose underlying gravel. The bank-top scours are often discontinuous, though some as long as 8 km have been observed (Fader and King 1981). They also are most commonly sinuous in plan form, probably reflecting the influence of sporadic and variable driving forces (currents).

2.5.2 Scour Dimensions

Lewis and Barris (1981), reported on scour dimensions on northeastern Grand Bank from measurements in the earlier version of the ice scour data base, noting among other aspects, the dependency of these parameters on water depth. In the water depth range examined (80 m to 160 m) they observed general increases in scour density, average scour width and average maximum scour depth with increasing water depth. Additional data compiled in this update study conform to their findings in most cases.

Average percentage seabed disturbance by scours is between 0.2 and 1.5 percent in areas above the 110 m isobath for the northeastern bank. These low values are also predominant in more western areas of the bank (see Chart 3) where scour density is usually less than 1.5 occurrences per square km above the 110 m isobath. Average maximum scour widths (per 2 km sample area) are relatively narrow at less than 30 m and maximum scour depths are very rarely greater than 1.0 m in this depth range.

Iceberg scour orientations in water depths less than 110 m on eastern Grand Bank are shown on Chart 3. Those scours south of 47°N latitude show a nearly random orientation pattern with only a slight preferred NE-SW orientation. This pattern probably reflects the highly variable nature of the driving forces in the area.

2.5.3 Scour Occurrences Below Pleistocene Sea Level Stand

The deeper water population of primarily relict and partially buried scours noted earlier shows on the chart of percent seabed disturbance as a zone of high variability, with some locations showing little or no evidence of scours and some with up to 100 percent seabed disturbance. This area corresponds to Zone 1 as mapped by Fader and King (1981). The variability of scour density mapped in this zone is due in part to initial variations in scour density but is also due to a varying degree of sediment infill over the scoured surface. An undulating surface is often visible below the surficial blanket of sand on Huntec DTS profiles and may represent a relict scoured surface (Barrie et al. 1984). The area north of the Avalon Channel and in deep water (>250 m) along the northern edge of Grand Bank is characterized by high seabed disturbance and deep scours. The BIO 80-010 survey line running NE out of Trinity Bay into water depths between 300 and 320 m shows seabed disturbance in places as high as 95 percent over a 2 km sample area. Scours are visible to water depths of 400 m on the flanks of northeastern Grand Bank and appear less degraded than scours in shallower water.

Scour depth measurements are also variable in the deeper water zone. For example, one line east of the Hibernia region shows an average maximum scour depth of 1.8 m between 140 and 200 m water depth while a nearby line shows only a few shallow scours. Presumably the discrepancy is due to variations both in the initial scour depth distribution and in the rate of sediment infill.

Scour depth measurements also show a general increase in average maximum depths with increasing water depth. Additions to the ice scour data base in this update study serve to extend observations to greater water depths, both on the eastern and northern edges of the bank. The relationship of increasing scour depth with greater water depth continues down to at least 250 m immediately north of the Avalon Channel where maximum scour depth reaches 7.0 m (average is 3.5 m). On the northern and eastern bank edges, maximum depth is typically 2.0 to 3.0 m, although on the northeastern edge exceptions occur in water depths greater than 300 m where depths reach 6.0 to 7.0 m. The exact nature of these deep scours is not clear because sidescan data are not available in this water depth to supplement the Huntec profiler data.

Rose diagrams showing orientations of scours in water depths greater than 110 m on the northeastern part of Grand Bank display a large spread in scour directions with the main trend lying between NW-SE and NE-SW. This is approximately normal to the bathymetric contours in the area. The reason that icebergs in the northeastern sector tend to scour in an up-slope (or down-slope) direction is is in all likelihood related to the dominant current direction in this area. The large spread in orientations confirms the randomness observed in this zone by Fader and King (1981) and Lewis and Barrie (1981). In contrast, the scours in the sector east and southeast of the Hibernia area display a preferred N-S orientation, approximately parallel to the bathymetric contours. This is more in keeping with the directionality of the bank edge currents which sweep along the contours.

Discussions surrounding the scour orientations in the Avalon Channel area and western portions of the bank can be found in the Avalon Channel detailed study (Section 2.6).

2.5.4 Degradation and Infilling of Scours

Recognizing that mobility of sand across the seabed results in continued degradation of iceberg furrows, Fader and King (1981) suggested that the present number of observable furrows above the 110 m water depth represents the minimum number of furrows formed since the transgression of this area 10,000 to 12,000 years ago. Amos and Barrie (1982), and Barrie et al. (1984) suggest that significant migration of bedforms (megaripples) occurs over scours and otter-board trawl marks in the Hibernia region indicating that obliteration of scours may be significant. Gaskill et al. (1985) have developed a model for iceberg scour frequency on eastern Grand Bank which indicates that present day observations of scour density represent significantly fewer scours than the accumulated total number of scours since the rise in sea level. Their modelling shows that the number of present day observable scours reaches a state of equilibrium after a certain number of years of scouring subsequent to the rise in sea level. The actual number of years is dependent on scour depth distribution, sedimentation rate and iceberg flux data input to the model. Given a reasonable estimate of the model parameters, this rate of equilibrium may be reached within 2000 to 5000 years after the sea level rise. This type of dynamic equilibrium was also suggested by Lewis (1978) in the Beaufort Sea. This model indicates a state whereby the rate of iceberg scouring is in equilibrium with the rate at which older scours become no longer observable because of complete obliteration by sediment infilling. Given various assumptions as to long term continuity of scour rate, water depth, scour infill rate (sedimentation rate), and an exponential scour depth distribution, the model will predict scour densities over a given region. To obtain reasonable agreement between model estimates of observed scour occurrences and the number actually observed in shallower water (70-90 m) they find it necessary to invoke estimates of sediment infill rates 20 to 50 times higher than necessary for model agreement in deeper water. They suggest a lower iceberg flux in the 70-90 m water to account for the low number of observable scours. They also postulate that large icebergs grounding on the bank edge (in relatively deeper water) break up and reduce their draft before reaching shallower water (an average distance of 100 km) under the stress of scouring and ablation. This inference is supported by Lewis and Parrott (1987) who concluded from a controlled repetitive mapping program northwest of the Hibernia area that "modern iceberg scouring is a relatively infrequent occurrence on Grand Bank".

Iceberg sighting data compiled for the International Ice Patrol (IIP) between 1968-78 show a long term spatial distribution of iceberg locations that suggests the northern boundary of Grand Bank acts as a barrier to iceberg incursion onto the bank top (Figure 8). Enhanced models that predict expected scour densities and recurrence intervals will require a more complete understanding of the rates and processes of sediment mobility and infill. The possibility of long term changes in iceberg flux must also be considered in any long term scour model.

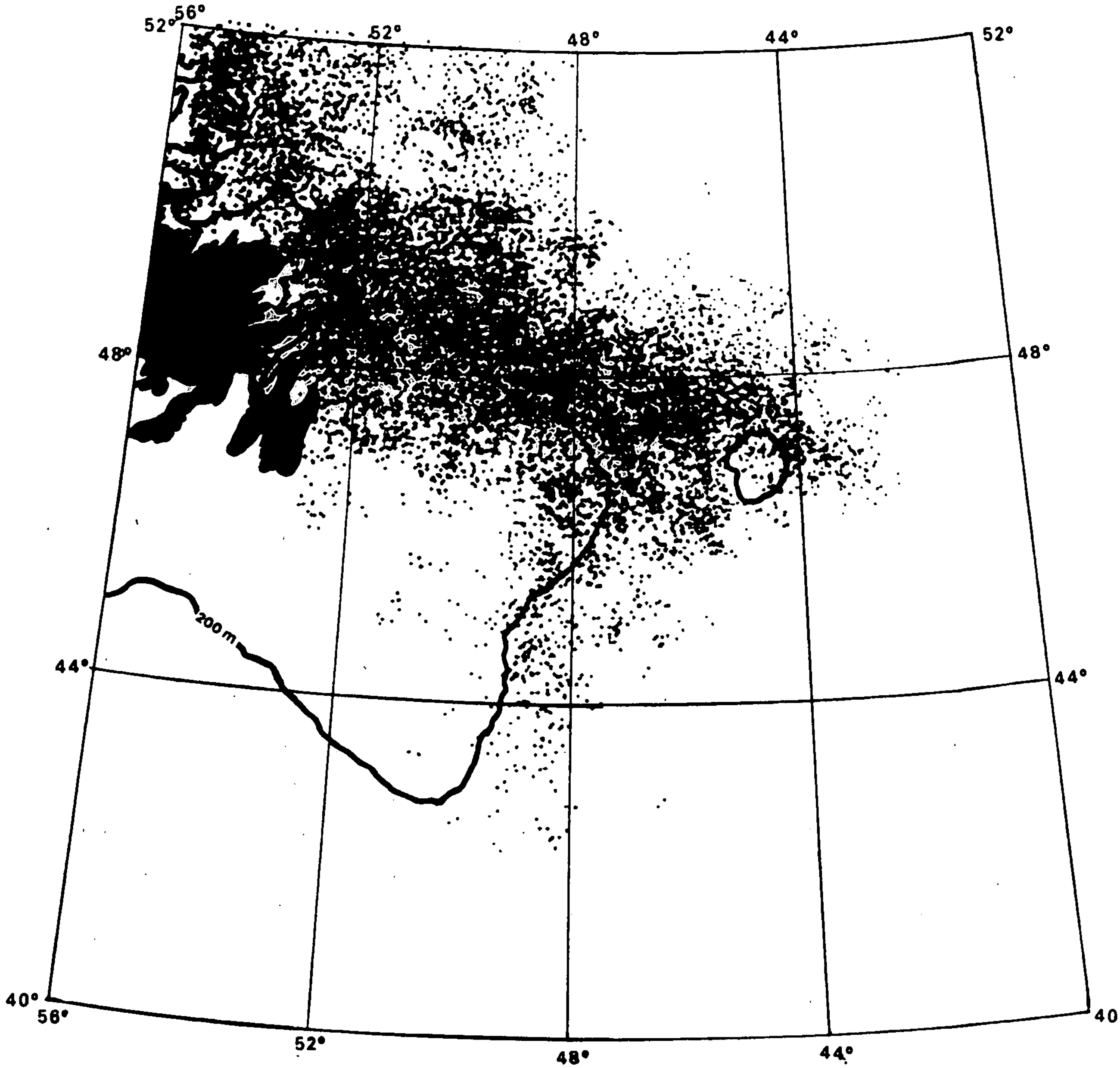

Figure 8 Iceberg sightings from an eleven year period (1968-1978) on the Grand Banks (based on International Ice Patrol Data compiled by S.J. D'Apollonia).

2.6 AVALON CHANNEL DETAILED STUDY

2.6.1 Introduction

The Avalon Channel area of the Grand Banks has one of the greatest concentrations of well preserved iceberg scours in the Grand Banks region. The seabed in the Avalon Channel has undergone a dynamic history of scouring and exhibits some of the largest observed scours of all the ESRF study regions, high concentrations of icebergs pits, and two separate recognizable scour populations. Some of the scour parameters show strong water depth and/or geologic dependencies. The need for documentation of scour size and distribution, and some discussion of age relationships warranted further study with respect to implications for offshore resource development, particularly routing of pipelines to shore facilities.

2.6.2 Setting

The Avalon Channel has a general N-S orientation and is best defined along the east coast of the Avalon Peninsula. To the north it opens into deeper water (approximately 180 m), while the southern end bends around the Avalon Peninsula and continues south into Haddock Channel. It is deepest just east of Cape Race and Ballard Bank where there is an isolated basin of 207 m water depth (Chart 4).

The western margin of the Avalon Channel is marked by a steep slope where the rugged Precambrian bedrock surface approaches or crops out at the seabed. Most of the channel floor consists of a thin cover of glacial deposits overlying well indurated bedrock of Cambro-Devonian age (King et al. 1986).

Quaternary surficial glacial deposits within Avalon Channel consist mainly of glacial till which blankets almost the entire channel floor, yet rarely exceeds a thickness of 5 m (King and Fader 1980). Most of the iceberg scours occur in this unit. In the deeper water of the channel, a statified glaciomarine unit overlying the till also shows evidence of scouring.

Despite the presence of modern icebergs (Figure 6), most of the iceberg scours in the Avalon Channel are probably relict (king 1976; Fader and King 1981; Lewis and Barrie 1981) as they resemble the deep water relict scours north of Grand Bank.

2.6.3 Scour Density

A map of iceberg scour occurrences in the Avalon Channel area was produced as part of this study (Chart 4). It should be emphasized that a measure of scour density from sidescan sonograms can be difficult to quantify in areas where scour marks are not well preserved. The interpretation of sidescan sonograms is dependent on the quality of the sonogram (affected by sea state, fish height above the seabed and water column interference) and on the degree to which the scours have been reworked by post-scouring erosional and infilling processes. For these reasons, maps of scour density usually involve considerable interpretation, interpolation and smoothing.

Chart 4 shows four ranges in scour density (scours per square kilometre); 0 to 1.5, 1.5 to 3, 3 to 6, and >6. Scour density is primarily controlled by bathymetry, but other factors such as currents and sediment type, thickness and mobility may also be important controlling factors. Areas of low scour density occur generally above the 130 to 150 m isobath. Scours in this zone are highly variable in clarity, due to differences in age, degree of reworking, and shallow scour depth. The scours are generally short, discontinuous and often very irregular in plan shape. Figure 9 shows representative scours from one such area.

In the deeper water (roughly 130 to 200 m) scour occurrences are usually more numerous with only rare exceptions. The seabed in much of the area is characterized on the sidescan sonograms by a network of discontinuous scours infilled to varying degrees by sand. This is illustrated in Figure 10. In some places the sand all but completely covers the scoured surface. It is often difficult to measure scour

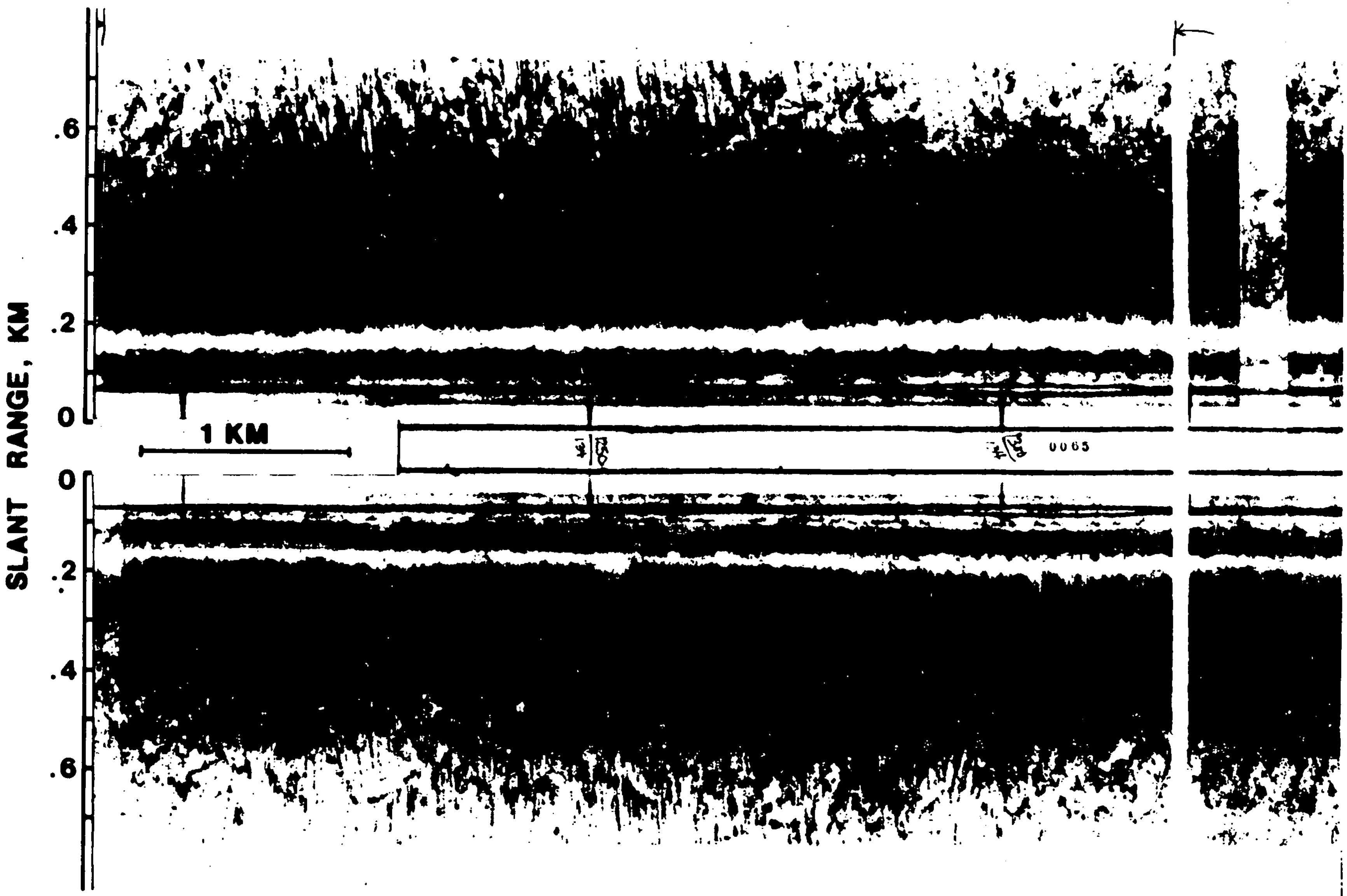

Figure 9. Representative scours from an area of low scour density on Grand Bank.

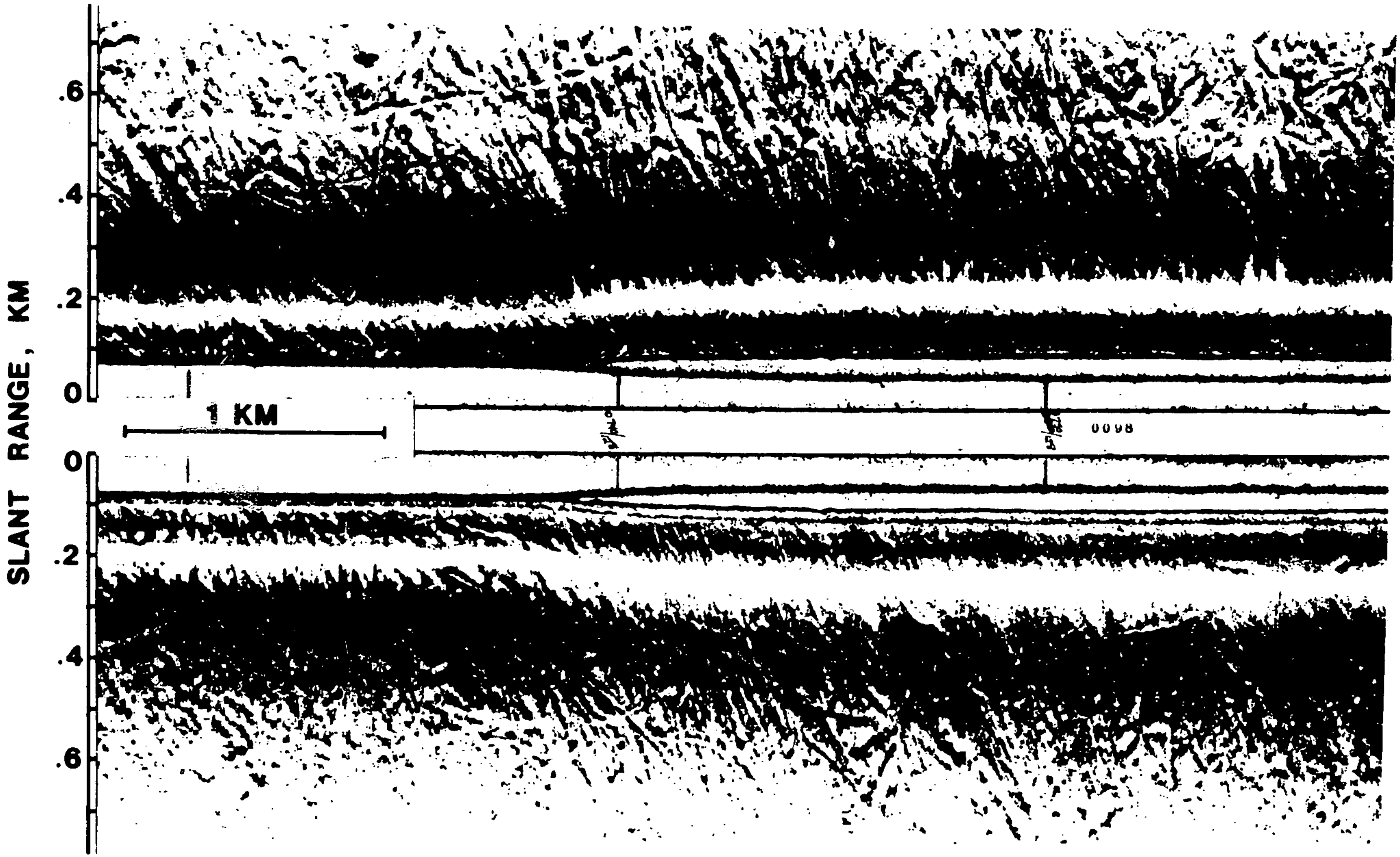

Figure 10. Representative scours from an area of high scour density on Grand Bank.

parameters in this area due to infilling by sand and intense degradation by currents. This network of scours corresponds to Zone 1 mapped by Fader and King (1981) northeast of the Hibernia area. They interpret this degraded scour network to be a relict population formed before the Holocene transgression more than 10,000 years B.P. The shallower areas of the bank (<110 m) were reworked during the sea level rise and those scours in water depths greater than 110 m were infilled by subsequent sediment redeposition.

In addition to these relict scours, numerous smaller but fresher looking scours are present in all but the deepest areas of the channel. These are considered to be equivalent to a population recognized by Fader and King (1981) and Lewis and Barrie (1981) in the Hibernia/Ben Nevis area and interpreted as the accumulated scourage since the last sea level rise (i.e. since 10,000 B.P.). As such, they are in a temporal sense part of the scour population found on the bank top. This population is not defined distinctively by statistical methods. Recognition is based mainly on the relative clarity (apparent freshness) of the scours on the sidescan sonograms.

The scour density map (Chart 4) shows three areas of heavy scour occurrence, the largest being in relatively deep water at the northern end of the channel, shown as "Area 1" on the chart. Note that the areas of highest scour density within "Area 1" are immediately southward of relative bathymetric highs, the tops of which have undergone comparatively less scouring. It is possible that icebergs from the north, circle around these shallower areas and ground on their leeward flanks. This is further indicated by the rose diagrams of scour orientation which show a strong E-W scour component, even though the icebergs would have entered the general area from the north. A similar scour pattern has also been observed to exist on the southeastern Baffin Island Shelf (see Section 4.6.2).

"Area 2," delineated in Chart 4, is another area of high scour density. This occurs in a N-S oriented bathymetric trough open to the relatively deep water of the Avalon Channel to the north but shallowing to bank depths southward and separated from the main trend of the Avalon Channel to the west by a northward projecting ridge. The high scour density appears to be the result of currents which funnel into this trough carrying icebergs from the north. The icebergs scour primarily along the eastern flank of the trough, parallel to the contours but apparently become trapped, unable to scour into the shallower areas.

The third area of dense scouring, just east of Cape Race (see "Area 3"), includes densities greater than 10 per square kilometre. Orientations are strongly parallel to the bathymetric contours along the flank of the basin. As in "Area 2," the highest densities occur on the eastern side of the channel. The cause of this condition is unclear, but it may indicate that icebergs were derived from the west.

The occurrence of iceberg pits or craters is common along the eastern flank of the Avalon Channel in the water depth range of 100-120 m. Why they are restricted to certain locales is not well understood. Fader and King (1981) suggest that this may be due to harder surficial materials or close proximity of the harder bedrock surface below. On the Baffin Shelf, Geonautics personnel have observed sharp boundaries between zones of linear scours and iceberg pits which correspond respectively to contacts between glacial till and Tertiary bedrock (with a surficial sediment veneer).

The till thickness over Cambro-Devonian bedrock is variable in the Avalon Channel area and often less than 2 m. Unfortunately, many of the zones with prevalent pit occurrences on sidescan sonograms do not have accompanying profiler coverage and the relationship of scour morphology and cover thickness cannot be adequately described.

The largest area of Chart 4 has very low scour densities (<1.5 per km^2). Most of this area is in water depths less than 130 m, but in a few locations drops to 160 m depth. At the northernmost end of the map in the deep water at the entrance to Avalon Channel, scour occurrence is very low in 330 m water depth, presumably because icebergs pass over this relatively isolated basin, unable to scour in the greatest depths. It should be noted that this scarcity may be somewhat artificial, due in part to the relative insensitivity of the sidescan instrument in such deep water. Part of this area has scours up to 3 m in depth as revealed by DTS records. Of further note in this area is the increase in scour density in a southward direction at the northern end of the Avalon Channel, presumably caused by the gradual shallowing of water depth with consequent increase in iceberg groundings.

Numerous survey passes over the shallow water in the southernmost portion of the chart area show only very few scours, with a complete absence of scours in most areas. Several reasons may be cited for the sparseness and discontinuous nature of the scours in this area. As discussed in a following section, areas with present water depths less than approximately 110 m were transgressed by the sea at least 10,000 years ago, thus obliterating any record of previous scours. Secondly, current reworking of the scoured material involving degradation through erosion and infilling is probably significant in this shallow water zone. However, direct evidence for these processes is much more difficult to recognize on the sidescan and profiler records. In comparison, the scours below the Holocene low sea level stand have thick post-scour infill sediments. Results of studies done primarily in the Hibernia and Ben Nevis area and eastward into deeper water (Lewis and Barris 1981; Barrie et al. 1984; Fader and King 1981; Amos and Barris 1982) infer significant sediment movement and degradation in areas shallower than 100 m.

The discontinuous, irregular plan shape of the scours and their shallow depth in this area of low scour density could also be due, at least in part, to smaller iceberg sizes in the shallower water depths. These would be less likely to scour deeply or in a continuous, linear fashion in part because of their lack of momentum, but also due to the variability of storm or surface currents which take over as the driving mechanism (Lewis and Barrie 1981). In studies of icebergs on the Labrador Shelf, Woodworth-Lynas et al. (1984 a and b) observed irregular motion of some icebergs. They attribute the irregular and looped trajectories to secondary rotary currents generated either by semi-diurnal tides, inertial currents, or current shear. In addition, there are probably fewer icebergs which pass across the relatively flat bank top because the primary driving force for the icebergs is the current through the Avalon Channel which would tend to steer and hold the icebergs through the deeper water of the channel. Digressions from this pattern that bring the icebergs over the bank top possibly arise from secondary driving forces produced by storm generated currents and strong winds.

2.6.4 Scour Widths and Depths

Scour widths and depths in the Avalon Channel area are presented in Chart 5. The depths constitute maximum depth measurements for each 2 km sample area and are divided into four categories. Some contouring of the depth data was possible. However, because of the irregular survey line density, some contours are open ended or entirely missing.

The chart shows three areas of relatively high scour depth (>2 m). The largest of these areas is at the northern entrance to the Avalon Channel where the deepest scours are up to 6 m deep. Examination of this chart in conjunction with the scour density chart (Chart 4) shows that the area of deepest scours corresponds to an area of medium scour density, and more significantly, the deepest scours occur where the seabed rises fairly steeply from approximately 330 m to the average depth of the Avalon Channel at approximately 200 m. This scour depth relationship is shown in a plot of average maximum scour depth versus water depth for scours at the northern entrance to the Avalon Channel (Figure 11). It shows a nearly constant increase in scour depth from 60 m to 270 m water depth. Scour depth peaks at 270 m water depth at an average maximum of 3.6 m and then decreases with increasing water depth below this point. The reason for the drop in scour depth in water depths greater than 270 m is not clear. There is no apparent change in the nature of the geologic unit, nor is there reason to expect higher sedimentation rates (to infill the scours) in the deeper

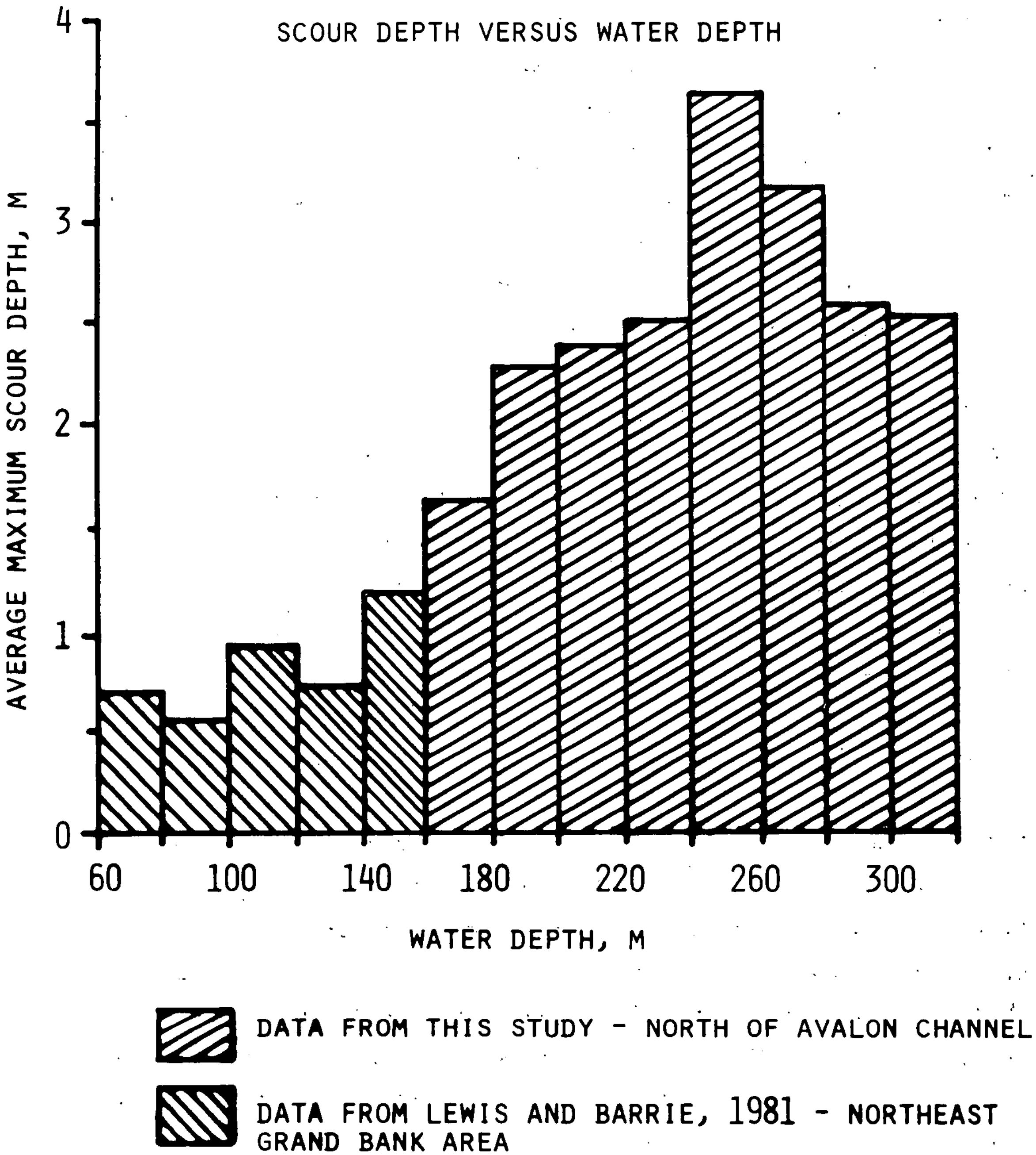

Figure 11. Histogram of average maximum scour depth (per two kilometre sample area) versus water depth for scours on the northern edge of Grand Bank.

water. Given that the largest icebergs are most likely to scour the deepest, the chart data suggest conditions whereby the largest icebergs, carried south by the Labrador current, pass over the deepest basin (>330 m) at the northern end of the Channel with insufficient draft to scour. However, they then impinge on the slope, scouring deeply. Unable to adjust their draft sufficiently to enter the Channel, they change course and follow along the northern edge of the bank. Where the largest icebergs impinge upon the slope entering the channel, scour densities are not high, presumably because of the relative scarcity of large icebergs which can reach this depth. However, scour density increases and scour depth decreases in the shallower area of this slope, presumably reflecting the grounding of the more numerous, but smaller, icebergs.

Another area of deep scours lies in and around the small basin approximately 10-20 km east of the southern end of the Avalon Peninsula. Some of the scours in deeper water (180-200 m) of this basin are extreme in size. Figure 12 illustrates a scour in till with huge berms and an overall relief of 14 m as measured from the Huntec DTS profile data. This is the largest of any of the scours measured for the entire east coast. Many scours in this population are often just marginally visible on the sidescan sonograms in part because they are so large, but mainly because they have been considerably degraded (note rounded nature of berms in Figure 12) and are covered in most cases with a gravel lag which eliminates textural differences between berms and troughs. While some scours show little evidence of infilling on the sub-bottom profiler records, others are more than half-filled with material which is in turn capped by a gravel lag.

These large (older) scours must reflect a population of more massive icebergs with large scouring keels and driven by strong forces. This poses questions as to their source and why they scour so deeply in relatively isolated basins. To enter the basins at approximately 205 m water depth near the southeastern coast of the Avalonn Peninsula where the largest scours occur, the most probable direction of iceberg approach is from the north, driven by a component

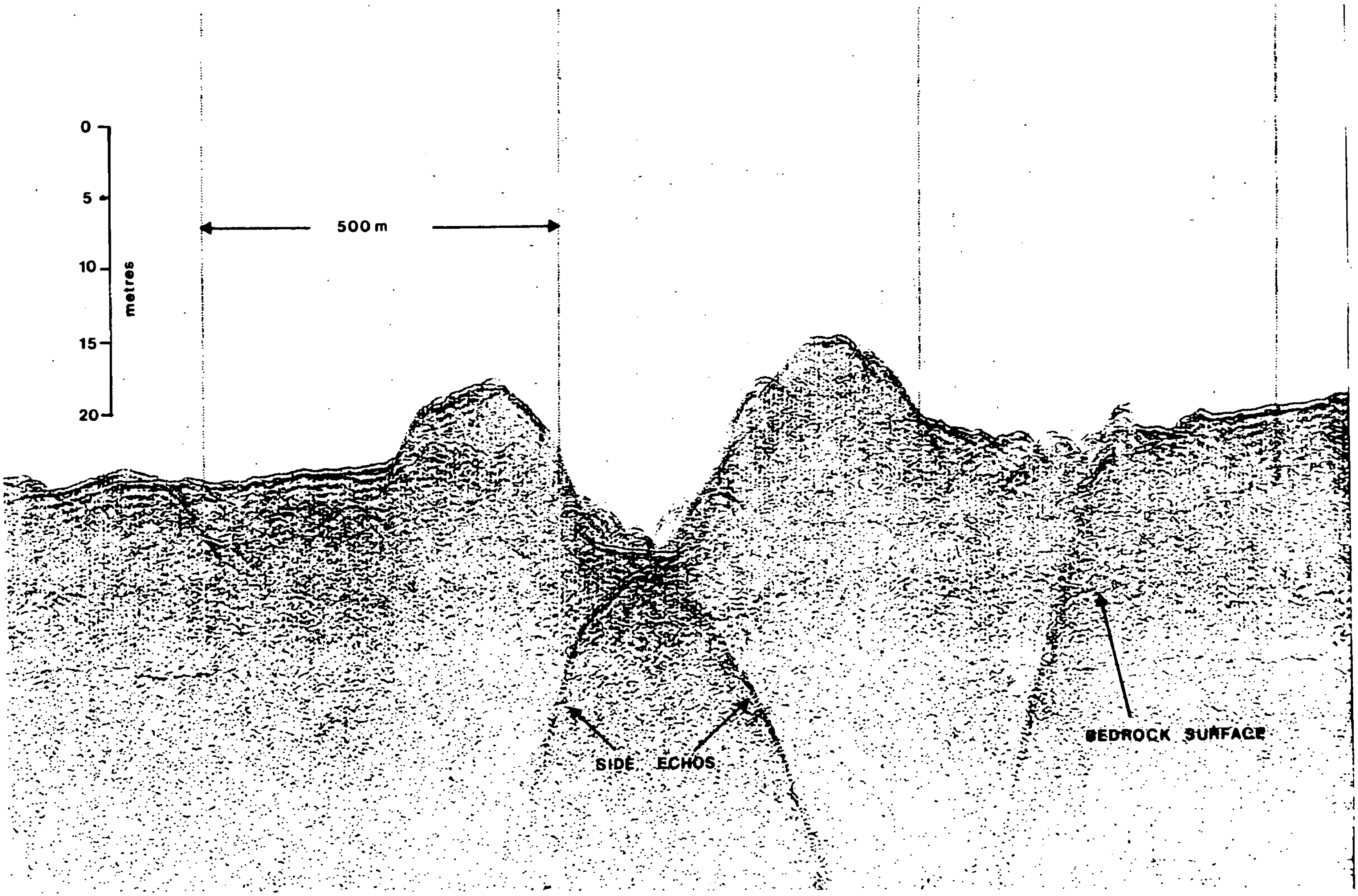

Figure 12 Huntec DTS profile across a very large iceberg furrow in the southern Avalon Channel. Vertical exaggeration = 20x.

of the Labrador Current. In order to scour in the basin, icebergs entering the basin from other directions would have to first cross barriers of 130 m water depth or less, while the sill immediately north of the basin is between 150 m and 160 m deep. Even so, icebergs approaching from the north would have to adjust their draft by 45 to 55 m to produce the observed scours in the deepest part of the basin. This increase of draft, whether by rolling or tilting would represent a change of 30-35 percent, a rare occurrence according to the most recent studies (Bass and Peters 1984). If the icebergs which scoured in this basin did enter from outside, then the reduced degree of scouring in areas surrounding the basin is problematic. This may be due in part to the sediment thickness around the basin; much of the surrounding area consists of glacial till of less than 2 m thickness which cannot, of course, record the deeper scours. However, it is possible that the larger and older scour population was produced by icebergs derived from a proximal source. Icebergs calving off the Avalon ice cap, directly into the basin area could have been confined to the deeper areas of the basin until they ablated enough to escape.

Depth analysis for the scours along the survey lines south of 47°N latitude within the detailed study area included measurement of representative scour depths rather than only maximum depths as on the other survey lines. The frequency distribution of scour depths for this area (Figure 13 and Chart 5) show a strongly exponential function with a cut-off at 7 m and an average of 1.7 m. The high number of small values reflects the fairly broad area of coverage in shallow water where scours are relatively shallow. Given that sediment transport and local infilling occurs in the shallower water to a greater extent than in the deep water, the shape of this distribution may not truly reflect the initial scour depth distributions (there would be fewer shallow scours). The reader is referred to a study by Gaskill et al. (1985), of how the observable scour depth distributions on eastern Grand Bank may reflect initial scour depths given various sedimentation rates and time spans.

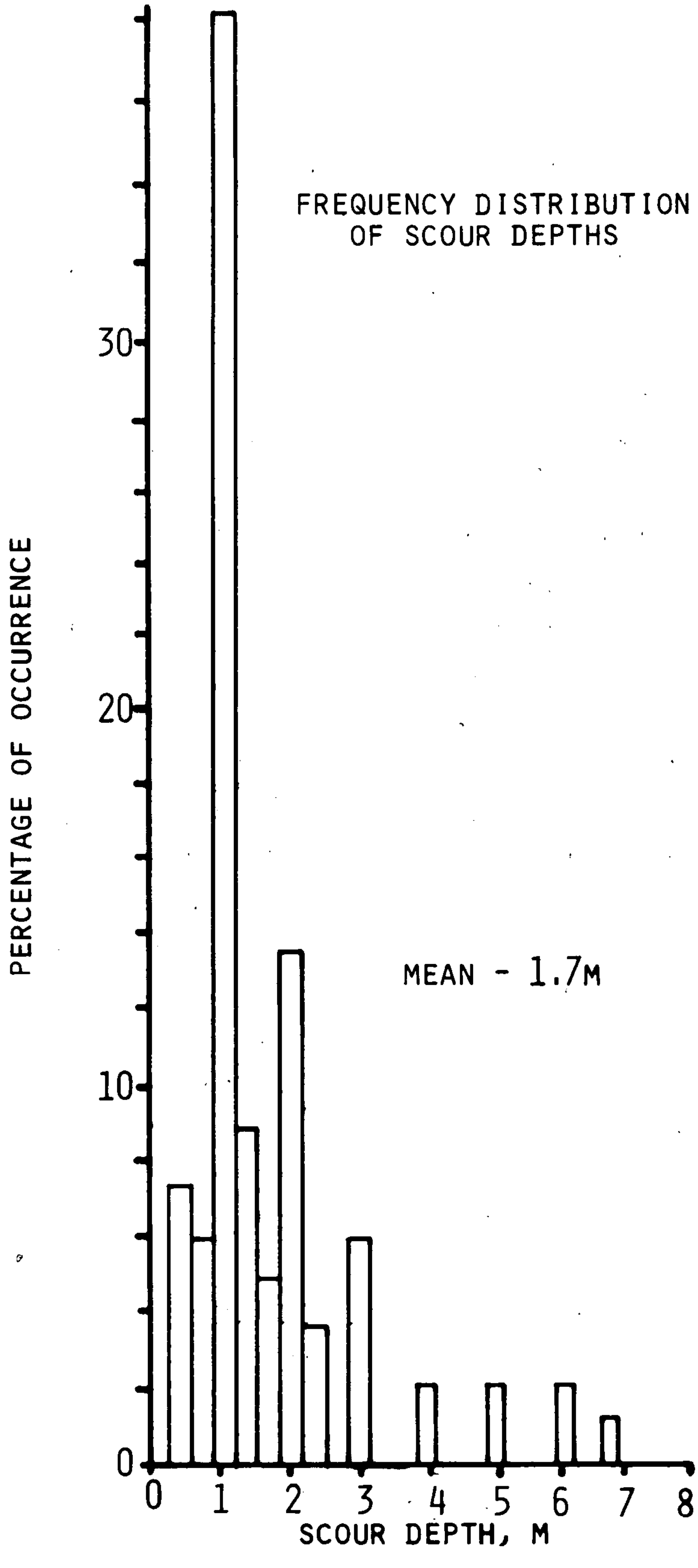

Figure 13. Distribution of scour depths for southern Avalon Channel area (south of 47°N latitude) for scours in both shallow and deep water (80 - 200 m).

A plot of scour depth versus water depth for the same data set is shown in Figure 14 and on Chart 5. Scours of 2 m depth are common in water depths of 100 to 200 m. However, in deeper water the scours can be much deeper. A line delineating the probable upper scour depth limit versus water depth shows this increase in scour depth with greater water depth.

Scour widths are displayed on Chart 5 in the form of frequency distribution histograms. Scour width distributions for all areas examined show a strong exponential distribution. The average scour width in the southern end of the Avalon Channel, both in shallow and relatively deep water (200 m) is quite narrow at 45-46 m. In contrast, further north (in the area east of St. John's), the average scour width is significantly greater (70 m) while average water depth is also greater. This increase in scour width with greater water depth is consistent with the finding of Lewis and Barrie (1981) on the northeastern Grand Banks, and can be attributed to an increase in iceberg size in greater water depths.

2.7 GRAND BANKS REPETITIVE DATA ANALYSIS

An attempt was made as part of the update study to compare the site-specific data with the regional data base in areas where the two covered the same area on the seabed. Overlapping data sets are listed within the inventory of wellsite data in Appendix 6. The reasons for the comparison were twofold. First, scours which had been mapped in areas which overlapped would be correlated between the two sets to ensure that the identification of scours was consistent. Secondly, any additional scours seen on later data could provide an indication of present scouring rates. For the purpose of this work, only site-specific data could be utilized as it contains detailed locations of each scour and/or pit mapped.

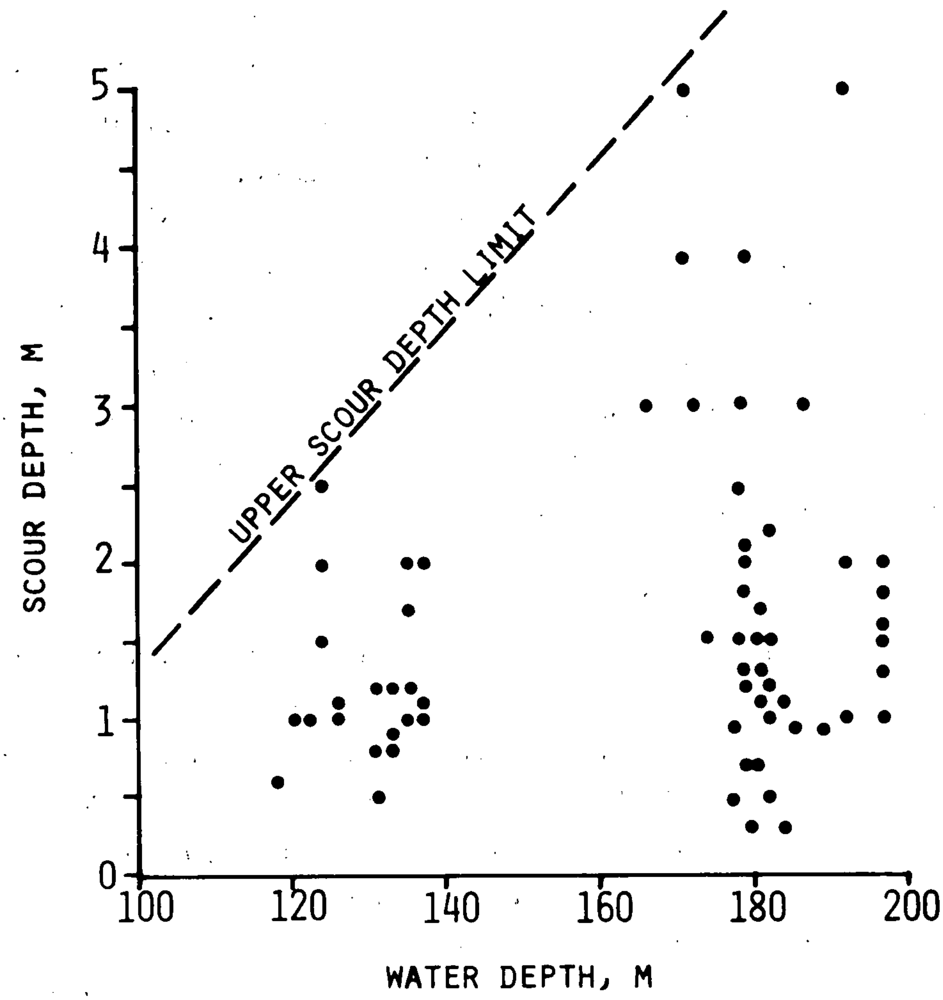

Figure 14. Plot of scour depth versus water depth for scours in southern Avalon Channel area (south of 47°N latitude). An upper scour depth limit is suggested by the dashed line. Scours in deep water are probably relict. The apparent lack of scours between 140 and 160 metres water depth is probably due to sparse data coverage.

Only examples where the wellsite and regional surveys were conducted a minimum of two years apart were used. This ensured that at least one ice season had affected the area. As well, ice flux statistics for the region were analyzed to determine the years with the greatest possibility of iceberg/seabed interactions. Most of the regional surveys utilized a 70 kHz (BIO) sidescan sonar system with a total swath width of 1.5 km (750 m per channel). The site-specific data were normally collected using a higher resolution 100 kHz sidescan sonar system with maximum swath width of 600 m (300 m per channel). Data from cruise 83-033 (Hudson) were not utilized due to the small amount of data analyzed (total of 16 sample segments).

The boundaries for each wellsite survey to be included in the comparison were entered by corner coordinates into computer files, with any scours or pits mapped on the site also plotted. Where regional lines crossed the wellsite areas, the coordinates of each regional sample interval to be compared were also entered. At this point the number of scours in each sample area was compared to the wellsite information.

An initial computer comparison of data from BIO cruise 80-010 (Hudson) with four useable wellsites (Archer Flank, 1982; Mara, Dominion and Voyager, 1983) showed a large number of discrepancies between the data sets. It was found that in certain areas scours were evident on one data set but did not necessarily show up on the corresponding data. A review of the original regional sidescan data for cruise 80-010 and comparison with the 1:10,000 scale surficial geology and seabed features maps produced for each wellsite confirmed that irreconcilable differences exist in the identification of scours.

It was found that neither of the two survey types was consistently lower or higher in scour occurrences. Features mapped on either the regional or site-specific surveys were rarely observed on the equivalent area.

The following reasons are suggested as an explanation for the discrepancies observed:

(i) The two types of survey equipment used resulted in observations of features at different scales. The 70 kHz BIO sidescan system has a slower firing rate and wider range than 100 kHz systems, having a total swath of 1.5 km in contrast to less than 0.5 km swath for the 100 kHz systems. This system is well suited for regional surveys, but its lower frequency results in decreased resolution. The wellsite surveys were conducted using 100 kHz sidescan sonar systems which have higher resolution, possibly explaining why features observed on site-specific data acquired using 100 kHz sidescan records were not evident on regional lines.

(ii) The orientations of survey lines influence the appearance of a given iceberg scour. If a linear scour is surveyed by parallel and perpendicular traverses it will appear well defined in the parallel traverse and poorly defined on the perpendicular. The sidescan fish emits an acoustic pulse on either side which is perpendicular to the survey track. If a scour running parallel presents an extended continuous reflective surface (such as the scour trend or berm) a strong signal is returned. The scour image is strengthened by the relatively high number of reflections received while the towfish passes along the length of the feature. If a linear scour is perpendicular to the ship's track relatively fewer reflections are received and generated, therefore, no strong image is provided and the scour will appear poorly defined, if at all apparent. For this reason, scours which have been recognized and mapped from one survey orientation may not necessarily be as strongly evident in data acquired from a different direction.

(iii) Positioning for the majority of the regional surveys involved the use of Loran-C equipment. For the Grand Banks region this system has an accuracy of +/- 40 to +/- 60 m under ideal conditions. By contrast, site surveys employ integrated navigation systems with accuracies on the order of +/- 10 m. This factor makes correlation of data sets difficult, especially when considering that conditions for navigation were often less than ideal when regional surveys were conducted.

(iv) The regional data in the areas concerned is often of poor to average quality. The outer ranges commonly experience distortion from thermocline interference, which obscures seabed features, or, may be interpreted as scouring by even inexperienced interpreter. The data quality in a regional survey often suffers from effects of weather in terms of excessive towfish motion and ambient noise. Wellsite surveys are normally conducted under optimum survey conditions.

The conclusion of the data comparison is that repetitive data analysis is not feasible using data from different instruments and disparate survey lines. In areas of low scour density (such as over much of the Grand Banks) the various sources of error effectively play a role in masking the data. It might be expected that in areas of high scour density this masking effect would be minimized by the sheer abundance of features, both recent and relict. In a case where it is ensured that survey equipment, line orientations, navigation, data quality and equipment settings are compatible it should be possible to conduct such a repetitive data analysis, as was recently suggested by Geonautics (1987) and accomplished by Lewis and Parrott (1987) and Lewis et al (in press).

3.0 LABRADOR REGION

3.1 REGIONAL SETTING

For the purposes of this study, the Labrador region is considered to include the continental shelf and slope between 51° and 61° north latitude, an area of some 200,000 square kilometres (see Figure 15). The Labrador Shelf can be divided into two parts - an outer shelf characterized by large, shallow, flat-topped banks separated by transverse depressions known as saddles, and an inner shelf which is generally shallow and topographically rugged. A broad, discontinuous longitudinal channel known as the Labrador Marginal Trough separates the outer and inner shelf areas and also marks the transition from Precambrian crystalline basement rocks in the west to Mesozoic/Cenozoic coastal plain strata in the east.

A minimum of three major episodes of glaciation are known to have affected mainland Labrador and parts, if not all, of the adjoining shelf. While the extent and timing of these events as they apply to the shelf is uncertain (Fillon and Harmes 1982; Josenhans 1983; Josenhans et al. 1986), their effect on shelf morphology and geology was profound. Glacial ice advancing eastwards from Labrador is believed to have plucked out the Labrador Marginal Trough (Grant 1972, McMillan 1973) and deepened and widened the saddles between banks (Josenhans 1983) while at the same time leaving extensive deposits of till and glacio-marine sediments over much of the shelf (Grant 1972, McMillan 1973, Fillon 1980, Josenhans 1983, Josenhans et al. 1986). In general, these deposits are thin over the inner shelf and thickest in the bottom of the saddles on the outer shelf. Table 4 lists the sequence of geologic units recognized on the Labrador Shelf and used during this study. A map of the distribution of these units has recently been published by Josenhans et al. (1986).

Iceberg-seabed interaction is a common occurrence on the Labrador Shelf, with an average of about 2000 icebergs per year swept southward

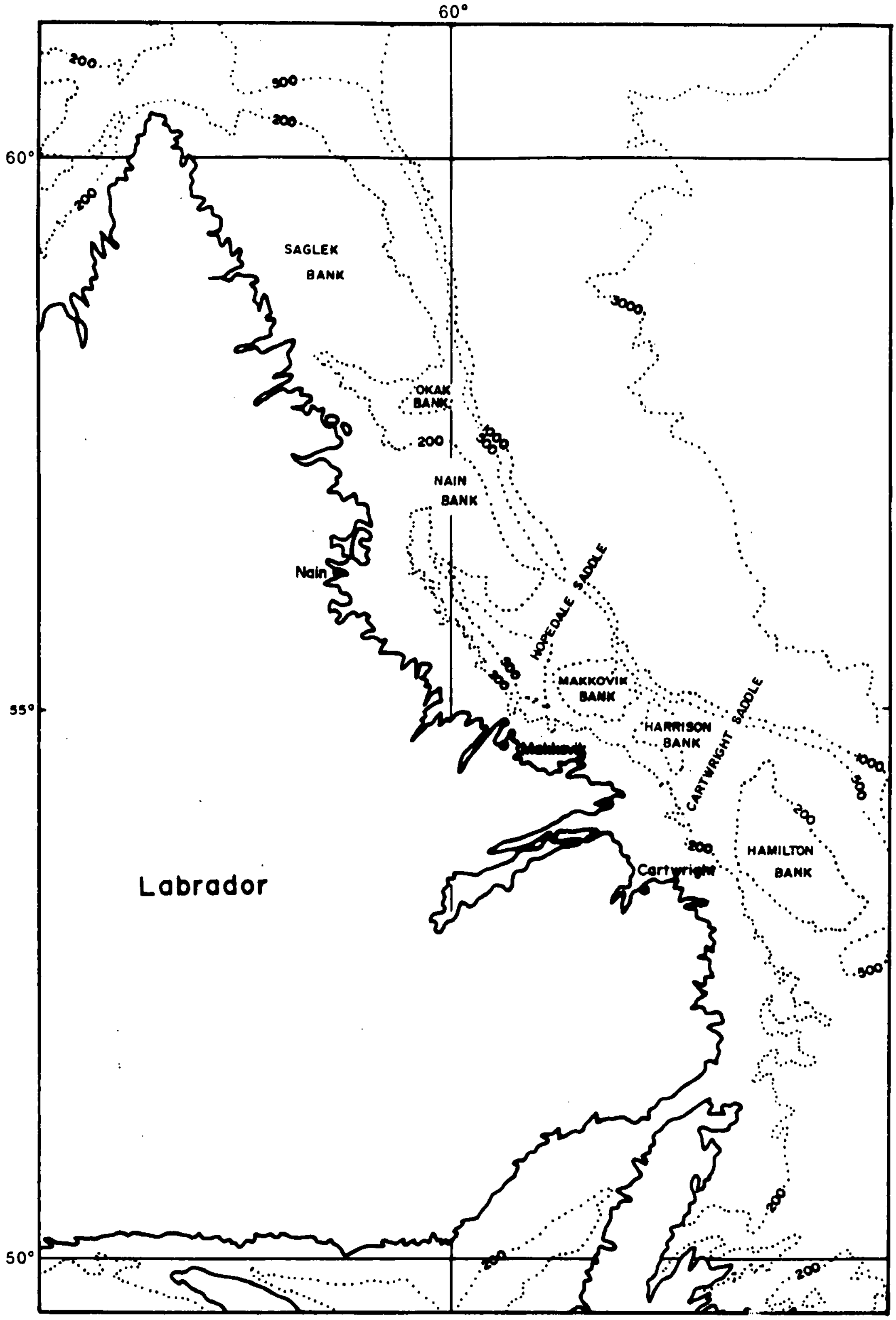

Figure 15. Major physiographic features of the Labrador Shelf.

TABLE 4

GEOLOGIC SEQUENCE, LABRADOR SHELF REGION

(after Josenhans 1983, Josenhans et al. 1986)

SEQUENCE	DESCRIPTION OF GEOLOGIC UNIT
5	Post-glacial sediments. Includes well-stratified ponded clay and silt in saddles and marginal trough and widely distributed ice rafted detritus.
4	Glaciomarine sediments. Well-stratified to non-stratified pebbly, sandy mud deposited as pro-glacial material or from floating ice shelf.
3	Glacial till. Typically acoustically homogeneous and unstratified with an undulating upper surface. Three separate till units (lower, middle and upper) have been recognized over much of the region. Deposited beneath a grounded ice shelf.
2	Mesozoic/Cenozoic coastal plain sediments. Gently eastward dipping, semi-consolidated clastic sediments. Restricted to outer shelf area.
1	Precambrian and Paleozoic acoustic basement. Restricted to inner shelf areas west of Labrador Marginal Trough.

along the shelf by the Labrador current (Ebbesmeyer et al. 1980). These icebergs constitute a major obstacle to the safe development of offshore resources in the region. As a result, much time and effort has been spent in recent years documenting the size, abundance, drift trajectories and scouring patterns of these icebergs (Murray 1969, Dempster 1974, Gustajtis and Buckley 1978, Hotzel and Miller 1983, Woodworth-Lynas et al 1984a, 1984b, Todd 1984 and Todd et al. 1988). The east coast ice scour data base provides information on the size, form and abundance of existing ice scours, together with an assessment of the regional trends observed.

3.2 DATA COVERAGE

A complete listing of cruise data analysed and compiled during this and previous studies is given in Appendix 3. Chart 6 illustrates the position of regional survey lines and wellsite locations.

3.3 DATA COMPILATION - METHODOLOGY AND LIMITATIONS

Prior to the initiation of data compilation, an effort was made to identify all existing sidescan and Huntec data suitable for analysis which had not previously been analyzed and entered into the data base (d'Apollonia 1983). Once existing records had been identified, those suitable for compilation and analysis were chosen on the basis of data quality, regional coverage and local geologic and bathymetric considerations. In general, Huntec records alone were not analysed unless sidescan existed nearby, due to the difficulty in positively identifying scour features from the Huntec records. A brief description of the attributes of the data finally selected for compilation and analysis is given below.

1) Cruise 80-031; Hudson Strait: Huntec and sidescan records for this line were assessed because of its location between the

northern Labrador Shelf and southeastern Baffin Island shelf. Unfortunately, the data are of very poor quality.

2) <u>Cruise 82-054; Lines 11 and 12:</u> These lines cover the transition from Precambrian to Tertiary bedrock (the marginal trough) along the west side of Saglek Bank.

3) <u>Karlsefni Trough Mosaic:</u> Three separate cruises (79-019, 81-045, 83-030) have been run in this area as part of a repetitive survey program. All three were compiled and analysed during this study. Results are presented in the detailed study for the Labrador region. These results provide information on the comparison between regional and mosaic data and relationships between scours, geology and bathymetry.

4) <u>Cruise 83-030; Line 4:</u> Data on this line are of high quality and cover a number of bathymetric zones (banks and saddles) and geologic units.

5) <u>Cruise 80-035; Lines 2, 4 and 5:</u> These lines were chosen because they provide good east-west coverage across the shelf and also cross 83-030, Line 4 at right angles. Line 2 is of very poor quality and not usable.

6) <u>Cruise 82-054; Line 22:</u> This line crosses the south end of Nain Bank and illustrates the transition from bank to saddle. It also crosses a number of geologic units including a relict lateral moraine along the north margin of the saddle (Josenhans 1983; pers comm. 1984). Data quality is generally good.

7) <u>Cruise 82-054; Lines 28, 29 and 30:</u> These lines provide good coverage of the northern margin of Makkovik Bank and the adjoining portion of Hopedale Saddle. As such, they compliment the data along Line 22. Recent exploration in this area (Bjarni, South Labrador) demands better knowledge of iceberg grounding and

scouring patterns.

8) Cruise 79-018; Line 7 and Tie Line: These lines are located over the inner shelf and marginal channel areas just north of Groswater Bay, an area which is otherwise poorly represented.

9) Cruise 77-021; Groswater Bay area: This line also covers a portion of the inner shelf. Only a short segment has usable data.

10) Cruise 73-027; Hamilton Bank: This data potentially covers most of Hamilton Bank. Only a small portion of it is of sufficient quality to be of any use.

11) Cruise 83-030; Line 8: Good quality data providing a complete transect from east to west across Hamilton Bank.

12) Cruise 84-035; Deep Water SeaMARC Data: Wide range, deep water data collected east of Hamilton, Harrison and Makkovik Banks and the east end of Saglek Bank. No Huntec records over most of the Labrador sections. Data quality variable and scour density often low to nil.

In general, most of the records analysed were of sufficient quality for confident ice scour analysis. As a rule, there were very few problems with water column interference on the sidescan records and data quality was good to water depths of approximately 300 m (or greater on the SeaMARC data).

3.4 OTHER DATA SOURCES

Industry data are available in the region in the form of site-specific wellsite surveys. Although some of these data are presently available to the public, it is considered likely that the same lack of compatibility would exist as was noted on the Grand Banks between the site-specific and regional data base. As a result, these data have not been incorporated into the east coast ice scour data base. Appendix 6 provides a listing of released industry data collected within the region up to 1988.

3.5 SCOUR SUMMARY

Scour data for the Labrador region are presented on Chart 7. For purposes of discussion and statistical analysis, we have divided the shelf into three bathymetric zones as follows: (i) all areas shallower than 150 m. This includes all bank top areas interpreted to be completely reworked by modern scouring (Josenhans pers comm. 1984, Woodworth-Lynas et al. 1984a); (ii) All areas deeper than 150 m and shallower than 230 m. This includes both possible relict and modern scours. Data on iceberg draft distributions for this region (Hotzel and Miller 1983) and interpretive analysis of sidescan records (Josenhans pers comm. 1984) indicate that modern scouring occurs only rarely below 230 m water depth; (iii) All areas deeper than 230 m. It is believed that most scours in these water depths are relict. Due to the nature of the sidescan system used to survey the seabed, data quality is generally poor to non-existent in water depths greater than 300 m, except on the available SeaMARC records.

The distribution of iceberg scours on the Labrador Shelf shows negligible recognizable trends on a regional scale. In a very general sense, scour densities are greatest over shallow water portions of Saglek Bank (water depth <200 m) and decrease southwards along the shelf. As a rule, however, areas of high scour densities occur almost anywhere above approximately 250 m water depth. Recent studies (Woodworth-Lynas et al. 1984a,b; this report, Baffin-Davis Region) indicate that icebergs may scour in areas previously assumed to be sheltered (e.g. behind topographic highs or in basins). Estimation of the potential risk of scouring in any given area therefore must take into account the local current regime and iceberg size and flux as well as the potential for icebergs to alter their drafts (Lewis and Bennett 1984, Woodworth-Lynas et al. 1985).

In a regional sense, scour orientations over the Labrador Shelf demonstrate a south-southeasterly trend, reflecting the dominant control of the translatory Labrador Current on iceberg drift patterns (Chart 7). In the shallower water over bank tops it would appear that additional influences attributable to storms and inertial and tidal rotary currents (Woodworth-Lynas et al. 1984a, Todd 1984 Todd et al. 1988) become significant. This results in the more random patterns in scour orientation evident over Saglek, Makkovik and Hamilton Banks in the <150 m depth range. Detailed studies of scour orientations and iceberg drift patterns over Saglek and Makkovik Banks carried out by Todd (1984) and Woodworth-Lynas et al. (1984a and b, 1985) confirm these findings.

In deeper water areas, where translatory currents are dominant, bathymetry controls iceberg drift trajectories, and hence scour patterns, in two ways. Large scale topographic features can create eddies in the residual current causing icebergs to move in open, looped trajectories. This is evident at the mouth of Hopedale Saddle (Chart 7) and is also cited as one of the reasons for the random drift of icebergs across Makkovik Bank (Woodworth-Lynas et al. 1984a). In addition to this secondary effect of steering currents, and hence icebergs, parallel to bathymetry, it has been postulated that icebergs, once in contact with the seabed, will have a tendency to move along a given slope rather than in some direction normal to it (Lien 1983). In this way topography imposes a direct control on scour morphology. The net result of this primary and secondary influence of topography on iceberg drift trajectories is that most scours tend to be oriented sub-parallel to slopes and are long and straight to broadly curvilinear. This is evident in many areas on the Labrador Shelf and is particularly noteworthy on the northwest end of Nain Bank (see Chart 7).

Narrow zones of short, irregular scours and craters were noted in numerous locales on the Labrador Shelf. These zones invariably correspond to sharp breaks in seabed slope and are believed to be the result of icebergs impinging on the seabed with insufficient momentum and/or too large a draft to allow them to move upslope into shallower water. As a result the icebergs scour a short distance or simply ground and stop, producing a crater. These zones are found to occur over a range of water depths supporting the intuition that it is the change in slope rather than the bathymetry which is the controlling factor.

Average scour depths for the Labrador region range from 1.1 m on Hamilton bank to 1.6 m on Makkovik and Harrison Banks. Maximum depths of 5.0 to 6.0 metres are most common, although an anomalous 11.0 metre deep scour has been observed in the marginal trough west of Hamilton Bank. This scour is excessively deep and is similar to one reported in the Avalon Channel (Avalon Channel Detailed Study, Section 2.6). Both are believed to be relict and were probably created by large icebergs derived from nearby glacier fronts during the last glaciation.

Average scour widths on the Labrador Shelf range from 28 m on Hamilton Bank to 40 m on Nain Bank. The widest scour (326 m) was observed on Saglek Bank. In general, it is found that scour widths show little correlation with scour depth, water depth, or geology. However, in all areas, the relatively oldest scours are invariably the widest.

3.6 SAGLEK EAST MOSAIC AREA (KARLSEFNI TROUGH) DETAILED STUDY

3.6.1 Introduction

Several sidescan mosaics have been produced for the Atlantic Geoscience Centre at various locations on the Labrador Shelf and were made available to Geonautics Limited for a detailed study during this project. The objectives of this study are:

(i) To illustrate the relationship of scour parameters (depth, width, orientation and shape) to the environment (physiography, water depth, currents and sediment type).

(ii) To investigate the interrelationships of scour parameters themselves (width, depth, berm height).

(iii) To compare findings with published data from the area.

The Saglek East mosaic (Hudson 79-019 cruise) collected by C.F.M. Lewis (AGC) and compiled by C-CORE was judged to be the most suitable for detailed analysis. Accompanying Huntec DTS coverage and bathymetric and geologic maps (both compiled by H. Josenhans, AGC) provided excellent control.

3.6.2 Setting

Saglek Bank is the largest and most northerly of the Labrador Banks. Near its southern end, it is partially bisected by the Karlsefni Trough which has a general east/west orientation across the bank. Basins in the trough reach a maximum of approximately 205 m water depth while the bank top on either side is typically 130 m deep. The northern flank of the trough is generally steeper than the southern flank. The basins in the trough itself are almost completely isolated thus restricting the ability of icebergs to scour in the deepest areas without significant dynamic adjustments of their draft. The Saglek East mosaic, situated on the relatively steep northern flank of Karlsefni Trough, covers an approximate area of 27 square kilometres (Figure 16).

Most of the mosaic area on Saglek Bank is covered by a thick sequence (up to 100 m) of overconsolidated glacial drift (Fillon 1970 and Josenhans, pers comm. 1984). Josenhans (1983) has recognized

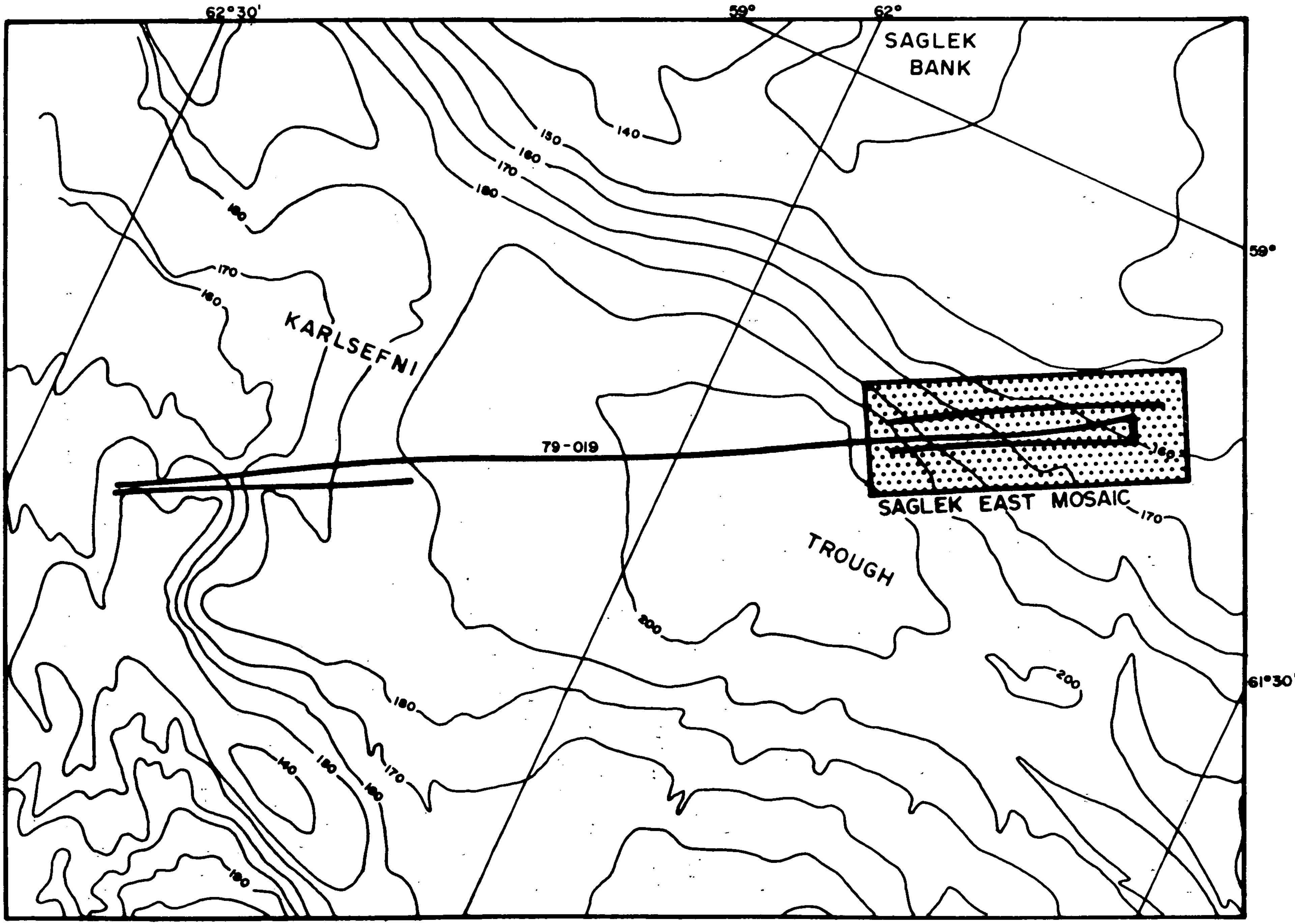

Figure 16. Ship's track (Hudson 79-019) across Karlsefni Trough and Saglek Bank showing location of Saglek East mosaic.

three surficial geologic units on the basis of Huntec DTS and airgun profiles. The stratigraphically lowermost (oldest) unit within the Karlsefni mosaic belongs to the middle till (Unit 3B) of the three tills recognized on the Labrador Shelf (Josenhans 1983). It crops out at the extreme eastern end of the mosaic area in approximately 155 m water depth, where it is heavily scoured. Ten to fifteen metres of younger sediment cover the till at the western end of the mosaic. Though several coring attempts have been made in this unit, they have been unsuccessful due to the over-compacted and/or gravelly nature of the sediment (Josenhans pers comm. 1984).

Overlying the till is a softer unit of glaciomarine material (Unit 4) which is characterized on the DTS profiles by its stratification. The degree of stratification is variable, ranging from well-stratified in the southern-most portion of the mosaic area in water depths greater than 170 m, to poorly-stratified in the central part of the mosaic (generally 160-170 m water depth), and non-stratified above 160 m to a point where it pinches out against the till on the eastern end of the mosaic. These sub-units are illustrated in Figure 17. Fillon (1980) has dated this unit at approximately 26,000 y B.P.

Josenhans (pers comm. 1984) believes that the degree of stratification in this unit reflects the degree to which it has been reworked through relict and present day iceberg scouring, inferring complete reworking of this unit and destruction of the stratification in the shallower water depths.

Overlying the glaciomarine unit, in water depths greater than 175 m, a younger, soft, silty sediment covers most of the bottom of Karlsefni Basin. The thickness of this unit does not exceed 1.5 m within the mosaic area and many of the scours penetrate completely through this unit into the glaciomarine unit below.

Geologic evidence indicates that in water depths of less than 175 m within the mosaic area, there has been little sedimentological

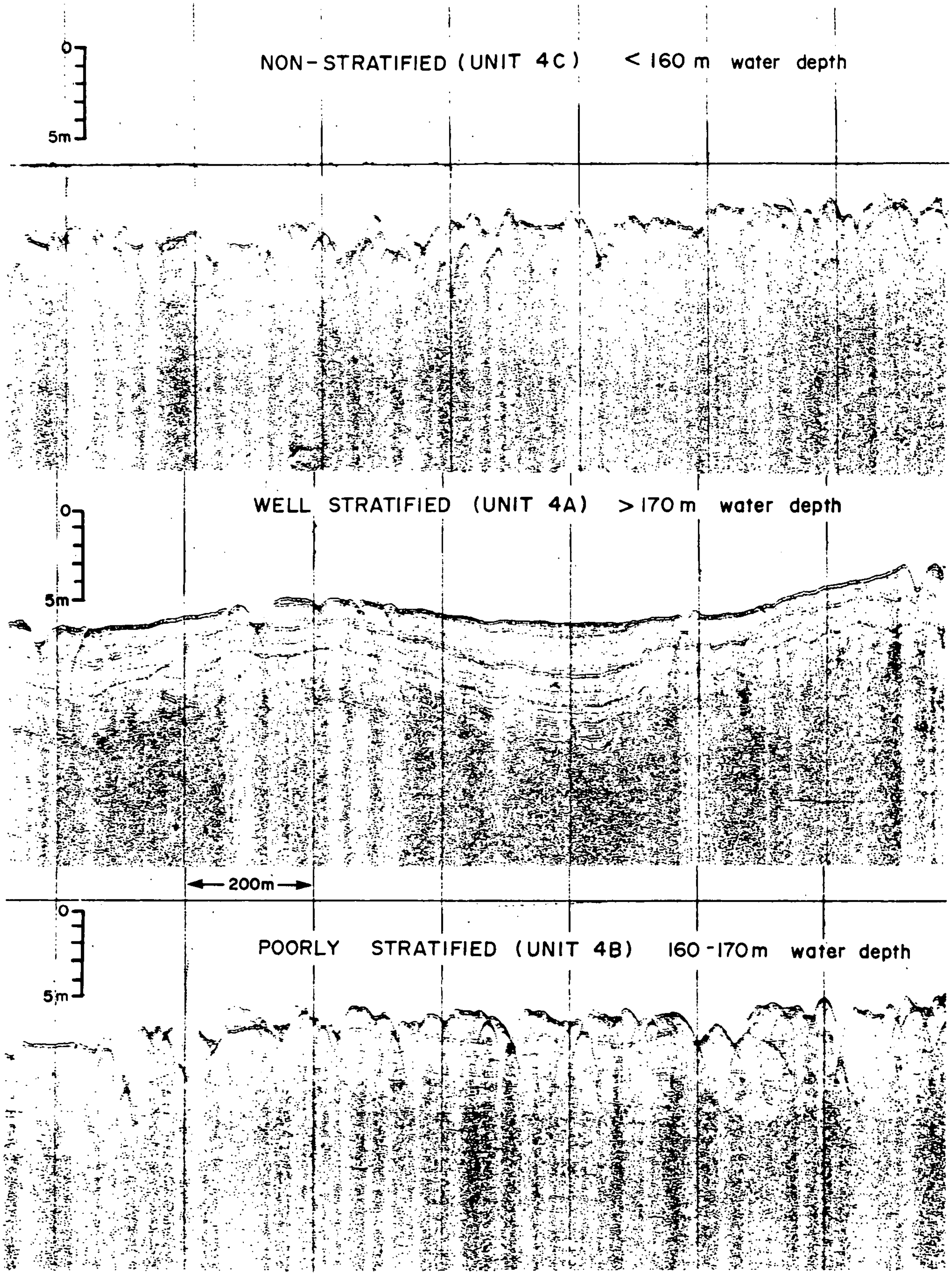

Figure 17. Representative Huntec DTS profiles from Saglek East mosaic (Hudson cruise 79-019).

modification (by reworking or infilling). The scours occur in glacial deposits dated at approximately 26,000 y B.P., with post-scour infilling deposits less than 0.5 m thick. This translates into a maximum infill rate of slightly less than over 2 cm per 1,000 years. Thus, scour parameter measurements such as depth, width and length are not significantly affected by post-scouring processes in this mosaic area.

3.6.3 Methodology

As the mosaic data constitute a different type of analysis in comparison to the regional analysis technique, they were entered into a separate System 2000 data base. All of the same parameters measured for the regional type of analysis are included.

The sidescan mosaic is shown in Figure 18. All recognizable scours on the mosaic were first traced as shown in Figure 19. Measurements of width, length, plan shape and orientation were recorded for each scour from this tracing. This was followed by a detailed correlation of scours between the sidescan mosaic (length, width) and the Huntec DTS data (depth, berm height). This correlation, though time consuming, provides for a much more complete study leading to better understanding of the scouring process. Water depths at the start and end of each scour were also noted from the bathymetric postings map shown in Figure 20. The data base includes, in all, measurements for 313 scours.

3.6.4 Scour Frequency

One of the more readily apparent observations on the mosaic is the change in density of scour occurrences from east to west observed on both the profile and sidescan data (Figures 17 and 18). Figure 21 shows the frequency of scours per square kilometre versus water depth. (The table of calculations for this plot is shown in Appendix 3.) There is a nearly linear trend of decreasing number of scour occurrences with increasing water depth. It should be noted, however, that the frequency of scours in the shallower water depths (150-160 m)

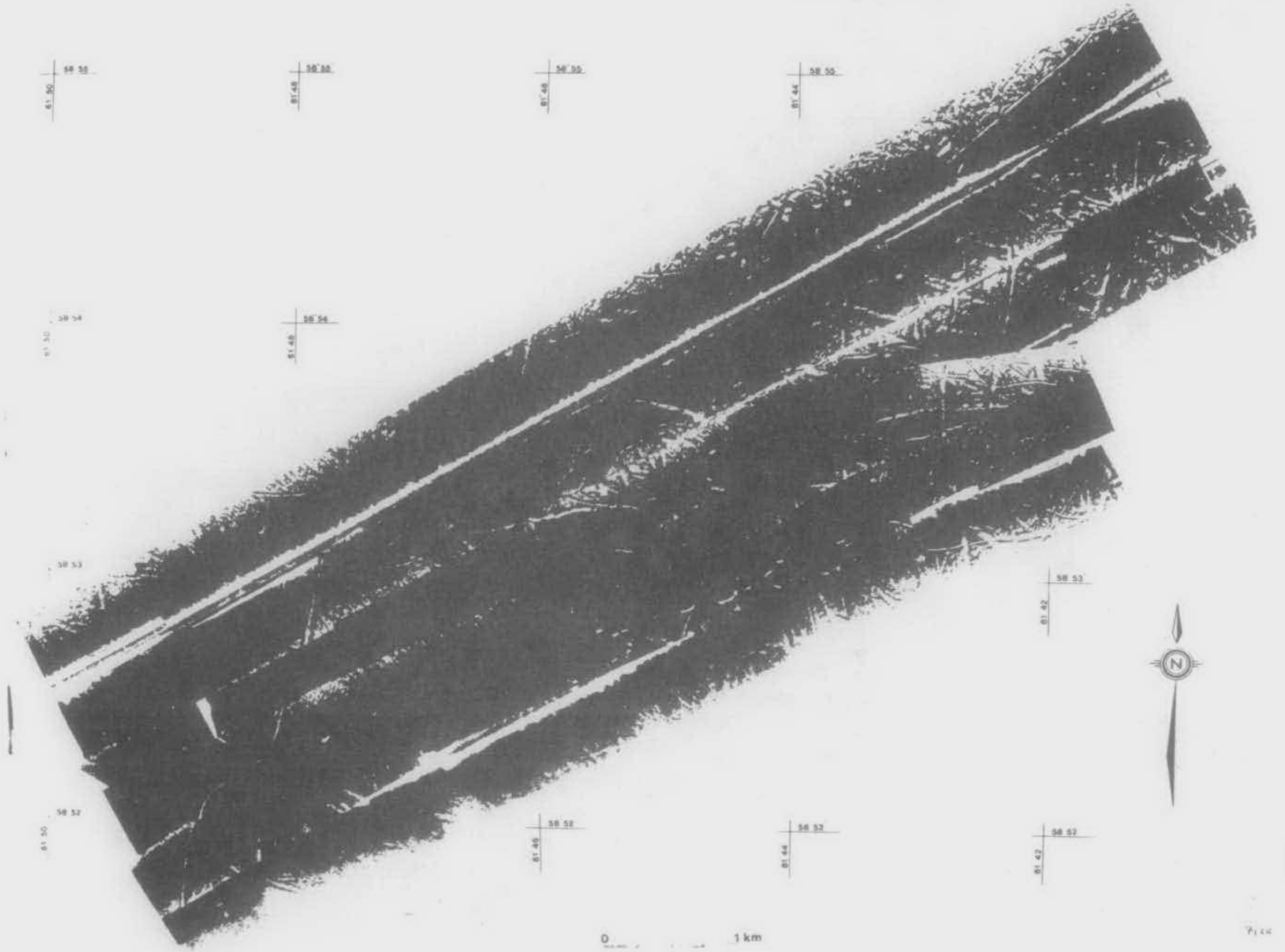

Figure 18. Saglek East sidescan sonar mosaic.

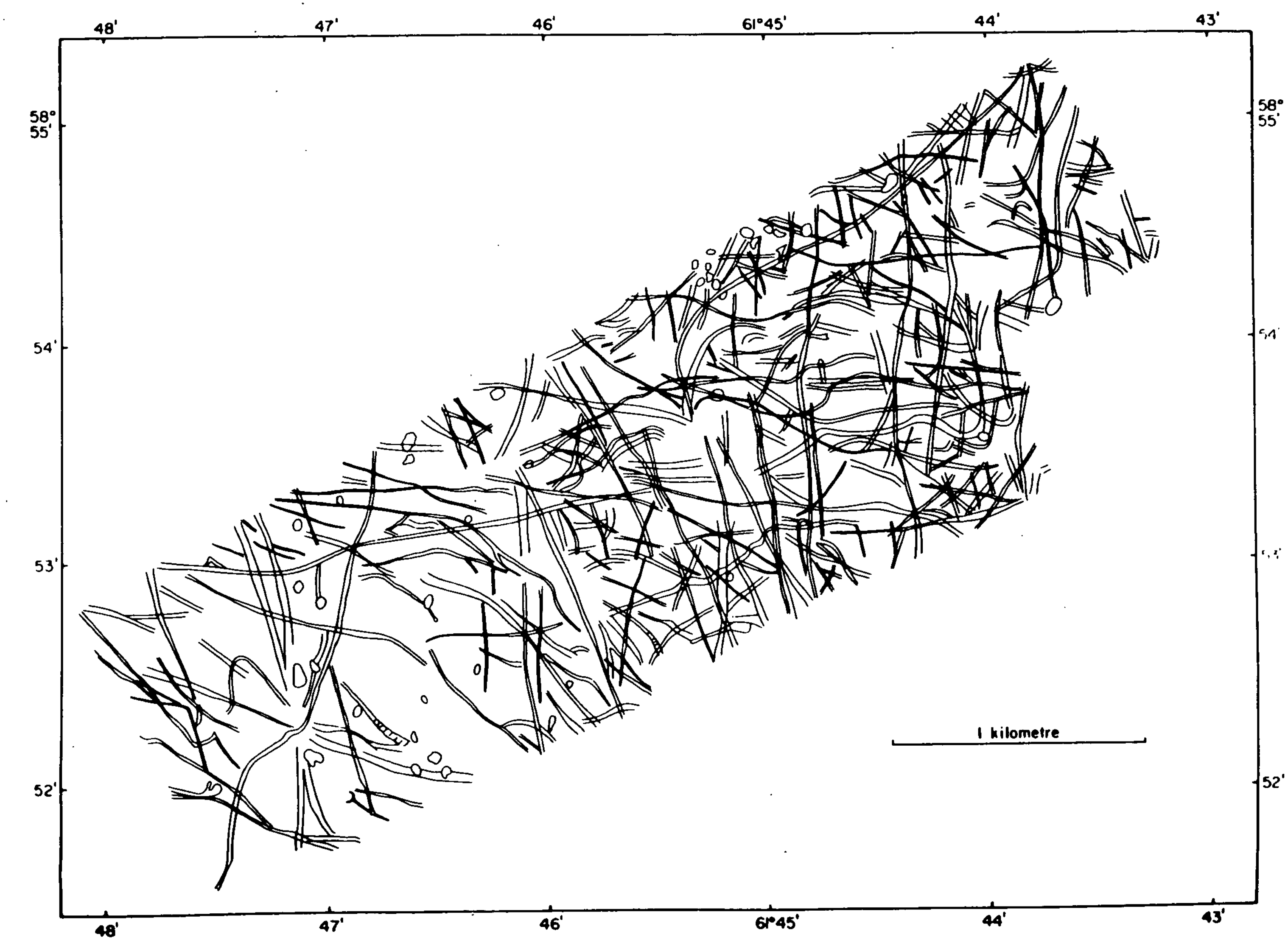

Figure 19. Tracing of scours from mosaic shown in Figure 18.

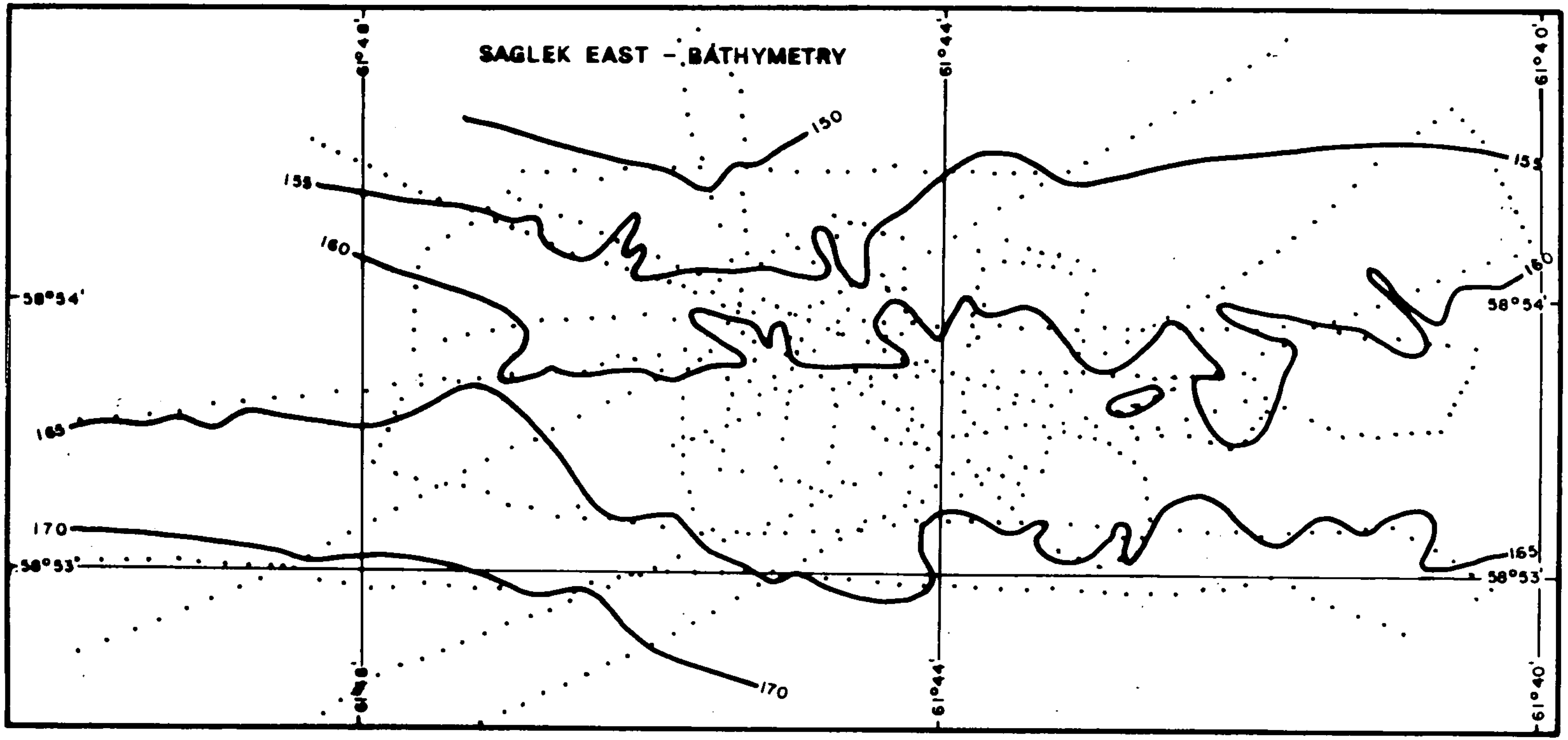

Figure 20. Water depth postings for Saglek mosaic area (courtesy H. Josenhans, BIO).

FREQUENCY OF SCOURS / KM^2 vs. WATER DEPTH
SAGLEK MOSAIC

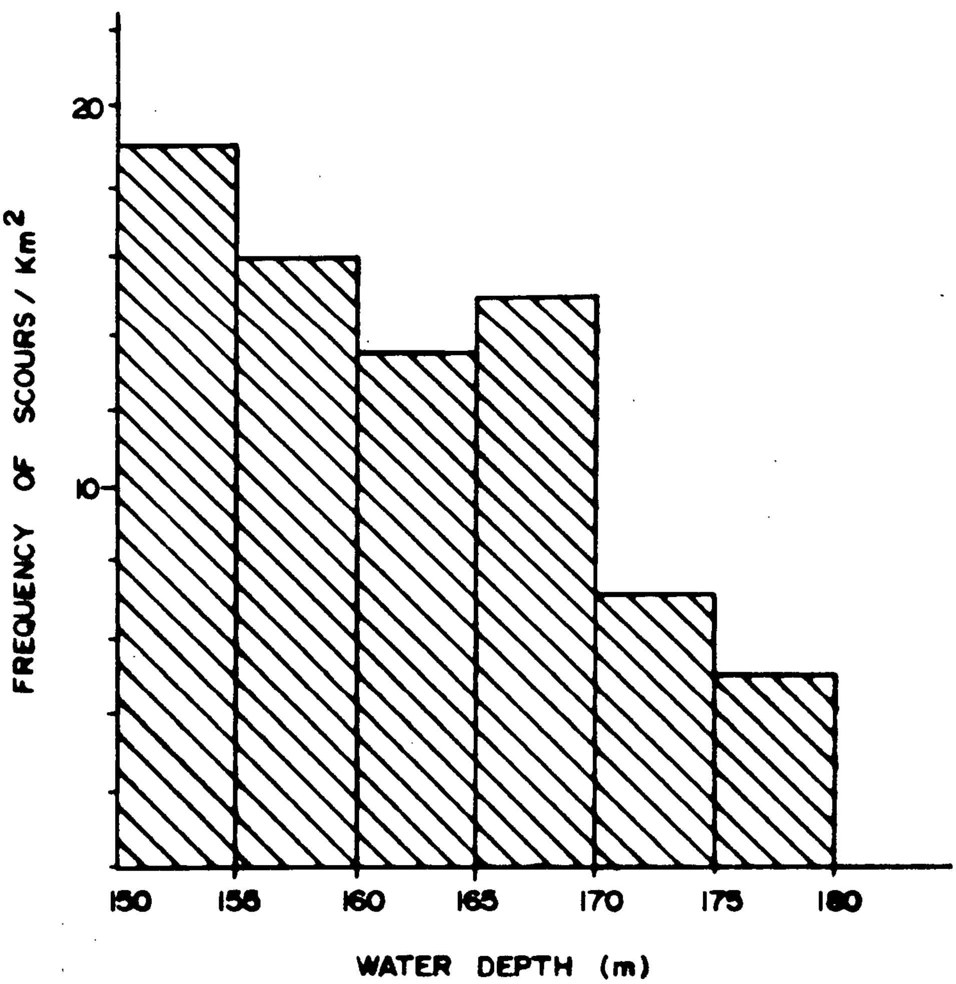

Figure 21. Relationship of scour density with water depth for Saglek East mosaic showing a nearly linear trend. Scour count may be underestimated in the shallower water depths.

may be considerably under-estimated. This possibility is suggested by a close inspection of the mosaic data (Figure 18) in this water depth range which shows that the seabed between all of the easily recognized iceberg scours (as depicted in the tracing, Figure 19) is rough and hummocky. It is believed that all of the surficial sediment in this area has been completely modified by iceberg interaction, and that initial scours are no longer recognizable because their characteristic linear aspects have been destroyed during later re-scouring. Thus, tracings of recognizable scours (Figure 19) tend to show under-estimated scour frequencies. If this is true, the plot in Figure 21 would assume a more exponential shape with even greater scour densities in shallow water.

An additional factor which tends to introduce error into the frequency of scour measurements is the misalignment of scours across adjacent sidescan lines due to unavoidable inaccuracies associated with assembly of the mosaic. Not only does this make correlation of scours difficult but more frequent counts of shorter scours will result.

Scour frequency plots such as this are necessary for making estimates of iceberg scouring recurrence rates when used in conjunction with present-day iceberg flux data. For example, frequency distributions for present day iceberg drafts (Hotzel and Miller 1983) for Labrador icebergs show that the frequency of icebergs with larger drafts drops off steeply from 12.5 percent with drafts of 140 m to 1.2 percent with drafts of 220 m (see Figure 22). The Hotzel and Miller draft distribution shows the same general decrease in frequency of icebergs capable of scouring between 150 and 180 m water depth as does the plot of scour density in this water depth range shown in Figure 21. If one can assume that there were similar iceberg draft distributions throughout the history of scouring in this area, then there appears to be a good relationship between iceberg draft distributions and frequency of scour occurrences for a given water depth. Given iceberg flux information and iceberg draft distribution,

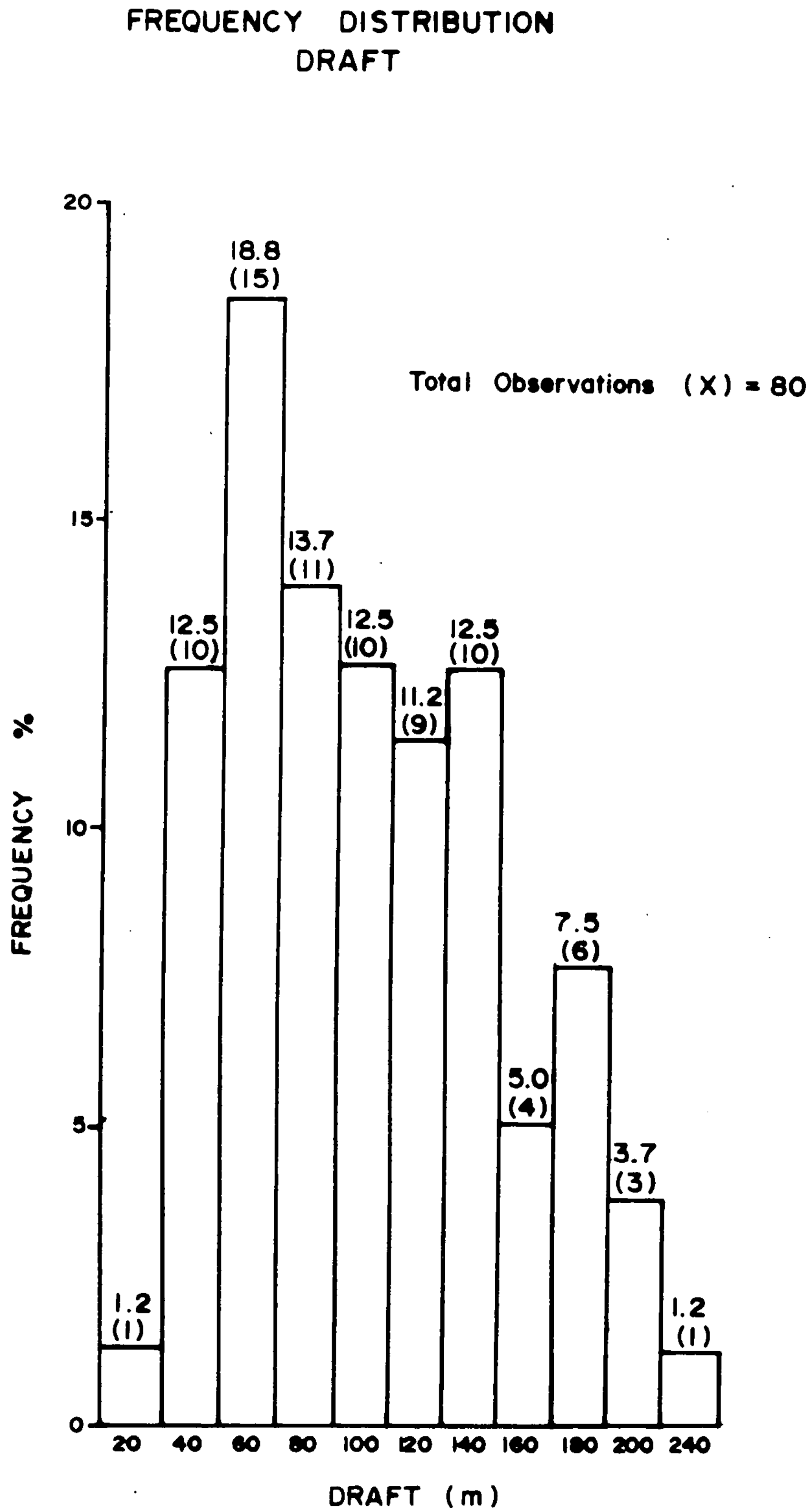

Figure 22. Frequency distribution of Labrador iceberg drafts (after Hotzel and Miller 1983)

in conjunction with the scour density versus water depth relationships, it may be possible to make some inferences about scouring rates. It should be noted also, that past relative sea levels, though not well understood in this area, would have to be accounted for, as the water depths shown in Figure 21 would be affected.

3.6.5 Scour Orientation

Figure 23 shows rose diagrams for all scours in the Saglek East mosaic area. For those scours that are arcuate or sinuous, orientations of individual segments were plotted. The rose diagram in Figure 23 shows two major components of scour orientation; the strongest mode is in an ESE-WNW direction (approximately 110°-290°) while the secondary mode is strongest in the north-south direction. This compares favourably with the rose diagram compiled by Barrie (1980) on the same mosaic (Figure 23) with the difference being that the north-south component is stronger and the east-west component is strongest in the 80-90° direction. This diagram was based on over 200 orientation measurements.

There is a change in general scour orientation from one end of the mosaic to the other as illustrated in Figure 24. This figure shows scour orientations for the eastern end of the mosaic. The dominant mode is in a north-south orientation while the strong east-west component of Figure 23 (representing the whole mosaic area) is much diminished in this plot. This part of the mosaic is in the shallowest water depth but it is not clear if the scour orientations are water depth dependent.

3.6.6 Scour Depth Distributions

A plot of scour depth distributions for 198 scours measured in the mosaic area in water depths from 150 to 180 m is shown in Figure 25. The distribution is strongly exponential with approximately 65 percent of the scours measuring less than 1.2 m deep and less than 2 percent of the scours over 4.5 m deep. This same exponential relationship has

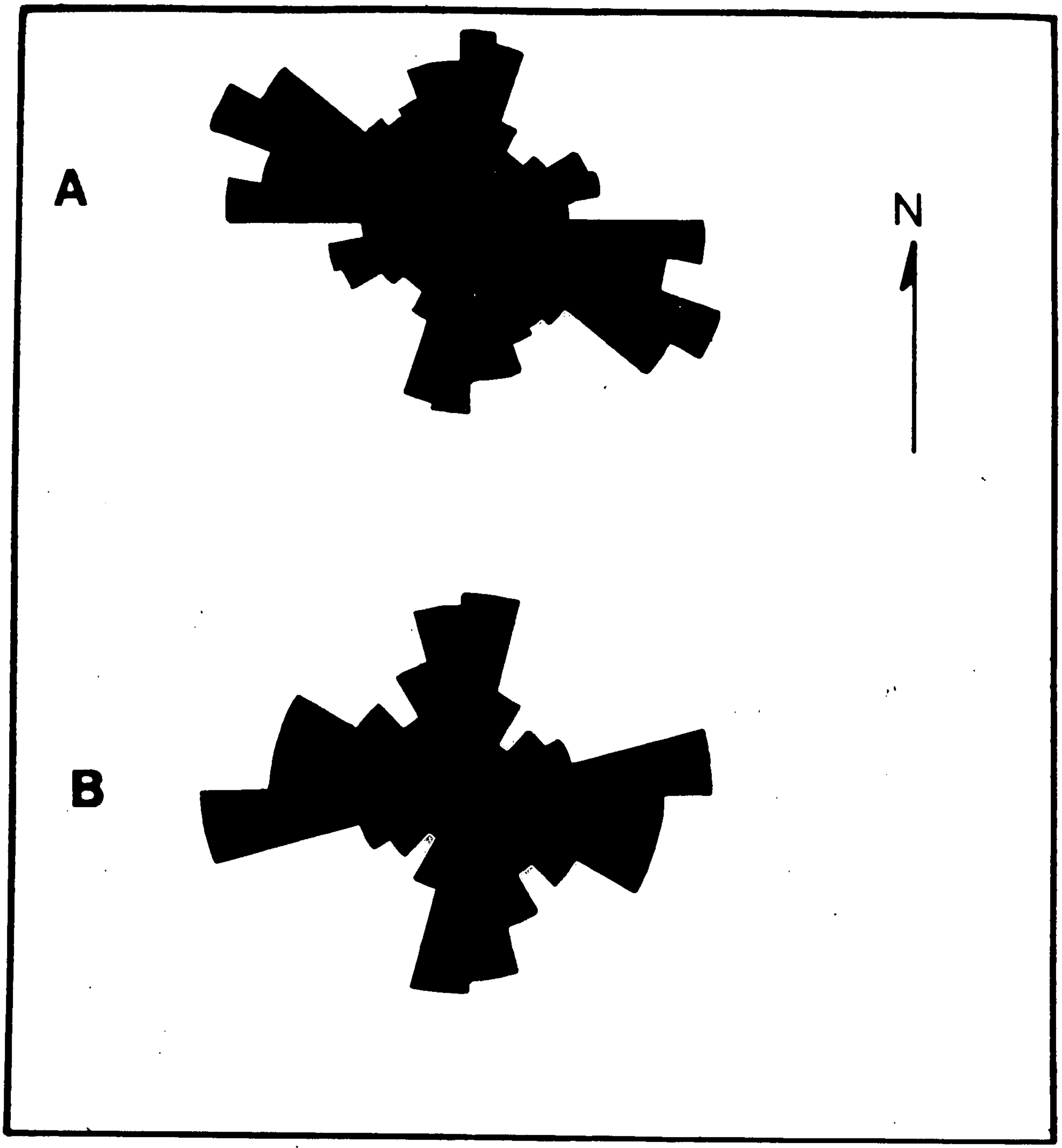

Figure 23 Rose diagrams illustrating iceberg scour orientations for: A) all measured scours in Saglek mosaic area as analyzed in this study; and B) the same mosaic area as measured by Barrie, 1980.

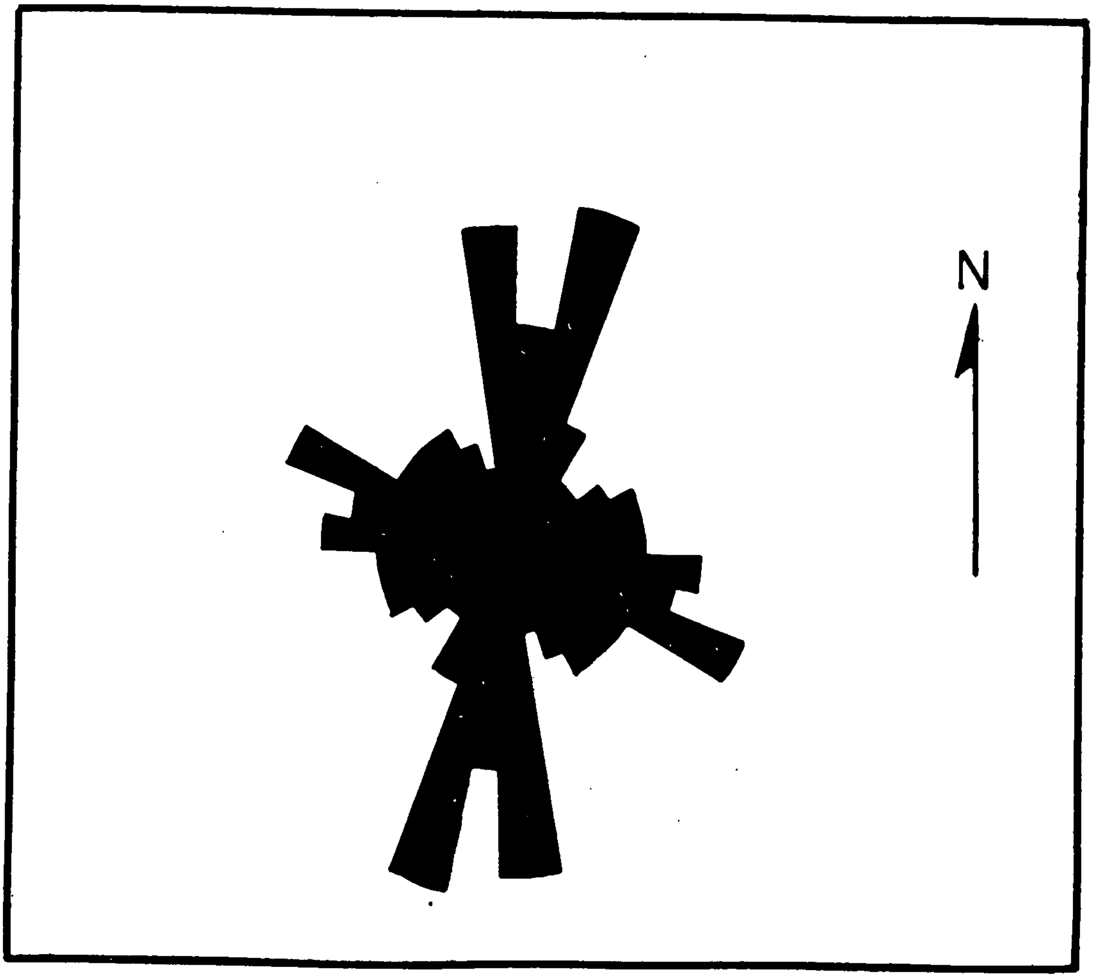

Figure 24. Rose diagram showing scour orientations for the eastern end of the Saglek East mosaic (east of 61°43' W longitude). Note the strong N-S component for this area in contrast to the strong E-W component for scours across the whole mosaic in Figure 23. The eastern end of the mosaic has the shallowest water depth.

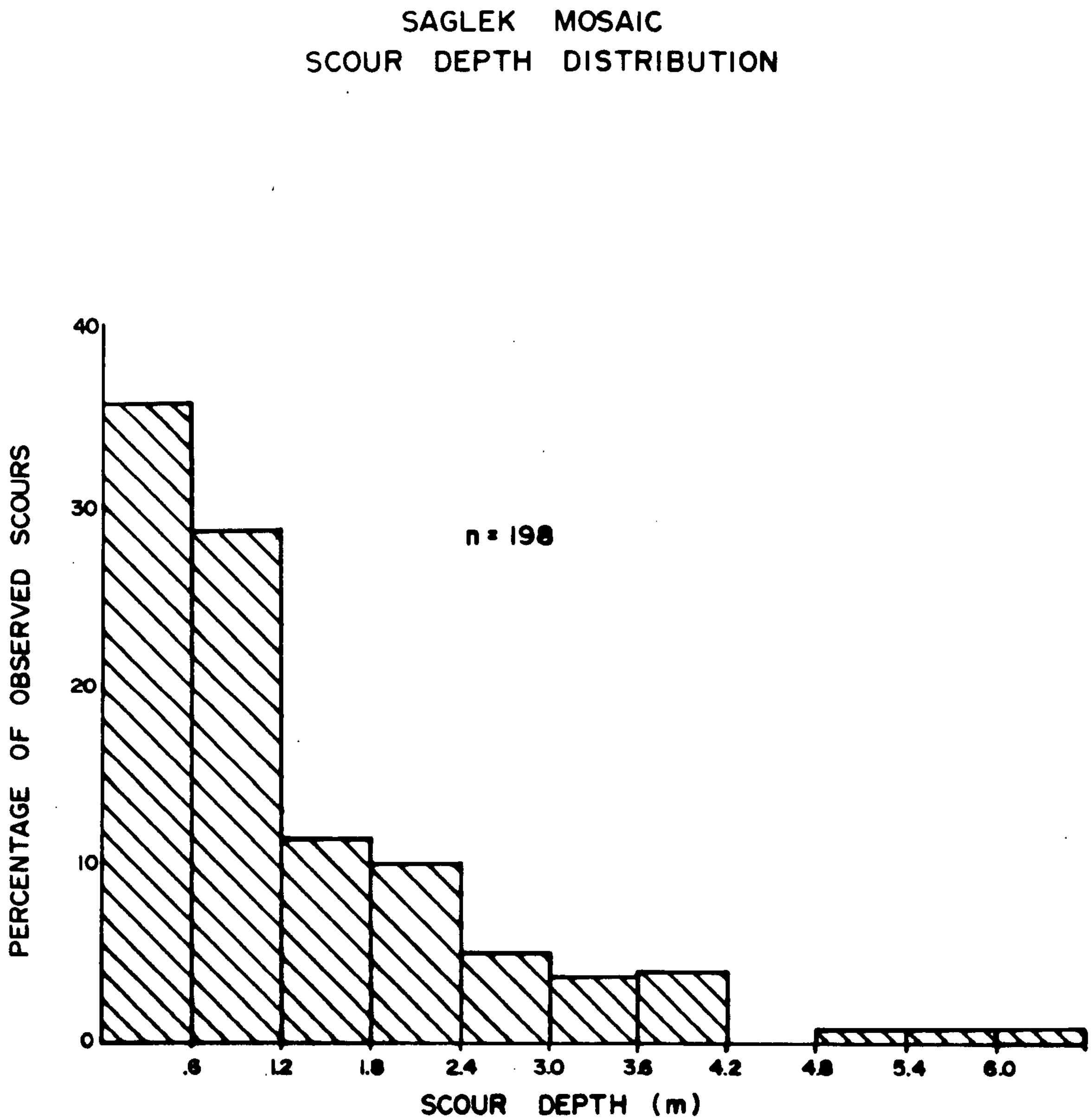

Figure 25. Scour depth distributions for 198 scours from the Saglek East mosaic area showing strong exponential function, probably largely due to the exponential distributions of iceberg mass and drafts.

been noted by Lewis (1978) and Barnes et al. (1982) in the Beaufort Sea; by Guigne et al. (1983) in the Davis Strait; and by Barrie (1980) at and near the Saglek East study area.

The scour depth distributions plotted by Barrie (1980) (Figure 26) includes data from the Saglek East study area and another mosaic farther west in the Karlsefni Trough. Comparison with data from this study (Figure 25) shows that the roughly exponential shape of the curve is similar but the magnitude of scour depths measured by Barrie (1980) are extreme. The upper limit of scour depths is greater than this study's measurement by a factor of two and the discrepancy is even greater for shallower scour depths. Barrie reports a mean scour depth of 5 m and extreme depth of 17 m as opposed to a 1.7 m mean and 6 m extreme by measurements from this study. Though part of the area examined by Barrie is not included in our data set, our analysis of regional data indicates that scours of extreme depth are not present. Barrie (pers comm 1985) has confirmed that a scaling error gave rise to the anomalous scour depth measurements in the Barrie (1980) report.

The exponential distribution of scour depths shown in Figure 25 is probably less an artifact of sediment infill and scour degradation than it is a function of the distribution of the draft (and hence, mass) of icebergs, which has a roughly exponential distribution in the water depth range of the study area (Figure 22).

Depth of scour is also a function of the geotechnical properties of the scoured material (Chari and Peters 1981). The material most till-like in character probably has the greatest strength within the mosaic area. This unit also displays a shallower mean depth of scour, as expected. A simple correlation between scour depth and sediment strength is difficult, however, because of the fact that the till outcrops in shallower water than the other geologic units and the iceberg population in shallower water would generally include smaller icebergs which are unable to scour as deeply.

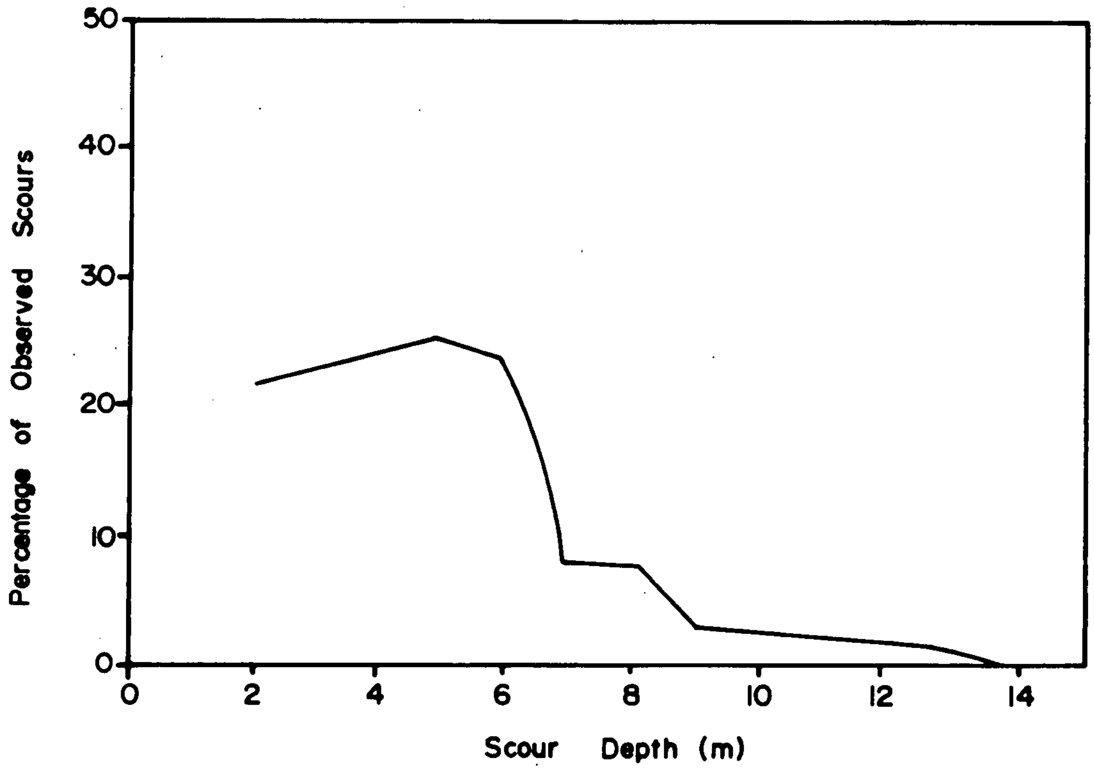

Figure 26 Scour depth distribution for the Saglek East mosaic area and another mosaic in the western Karlsefni Trough. (from Barrie 1980). Though the distribution is also exponential (for scour depths >6m) the absolute scour depths are extreme in comparison to those in Figure 25.

Scour depth versus water depth relationships were also examined for the mosaic area. In general, mean scour depths were found to increase from 1.0 to 1.5 m in water depths of 150 to 170 m and decrease slightly below this to a depth of 180 m. This differs fromthe findings of Barrie (1980) who found a decrease in scour depth from 8.0 m to 5.0 m in the 160 m to 180 m water depth range. Frequency distributions of scour depths for six water depth intervals were plotted as shown in Figure 27. The plot for the 175 to 180 m water depth range is suspect due to the small sample size (N=8). Scours of over 4 m depth have been observed nearby but not within the mosaic area in this water depth. Most of the distribution plots show an exponential dropoff of deep scour occurrences, with the deepest scours (up to 6 m) occurring in the 160-165 m water depth range. Apart from this, the distributions do not appear to differ significantly.

3.6.7 Dynamic Adjustment of Iceberg Draft

An overlay of the bathymetric map (Figure 20) over the mosaic tracing (Figure 19), immediately illustrates that many of the larger scours traverse a significant range of water depth. This range in water depth can only be accounted for by dynamic adjustment of the draft of the scouring iceberg by processes such as rotation and tilting, possibly in combination with tidal fluctuation or mass wasting of the iceberg. A plot of water depth ranges for 228 scours of varying lengths (Figure 28) shows that 67 percent of scours in the area have a water depth range of 2 m or less. This includes most of the short scours as well as any longer ones which are oriented roughly parallel to the bathymetric contours. Approximately 5 percent of scours have a 6 to 8 m water depth range while about 1.5 percent (5 scours) range over more than 10 m in water depth, the maximum being almost 15 m. Of those scours with a large range, it is interesting to note that their orientations have a strong north-south component which indicates that most have scoured in a direction nearly perpendicular to the bathymetric contours. Whether the icebergs scoured in an up-slope or down-slope direction is unclear from the mosaic. Much

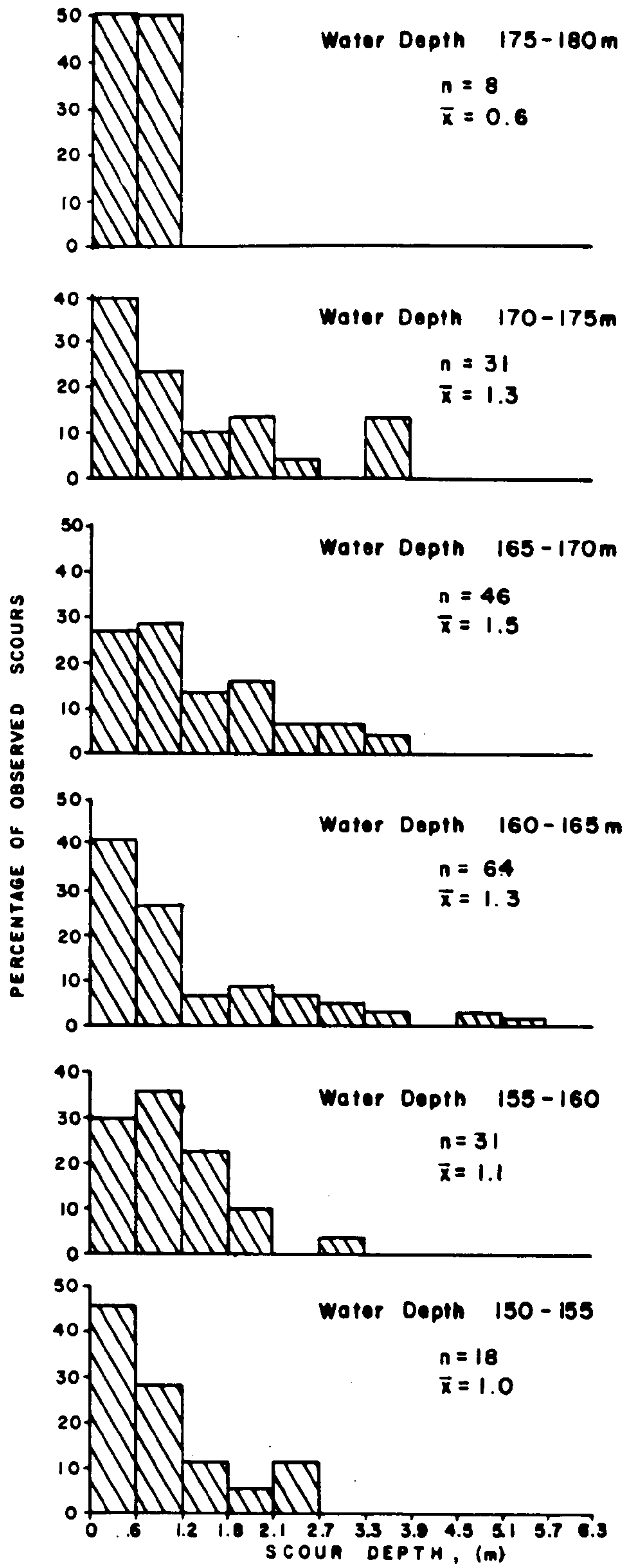

Figure 27. Distributions of scour depth for various water depth intervals, Saglek East mosaic.

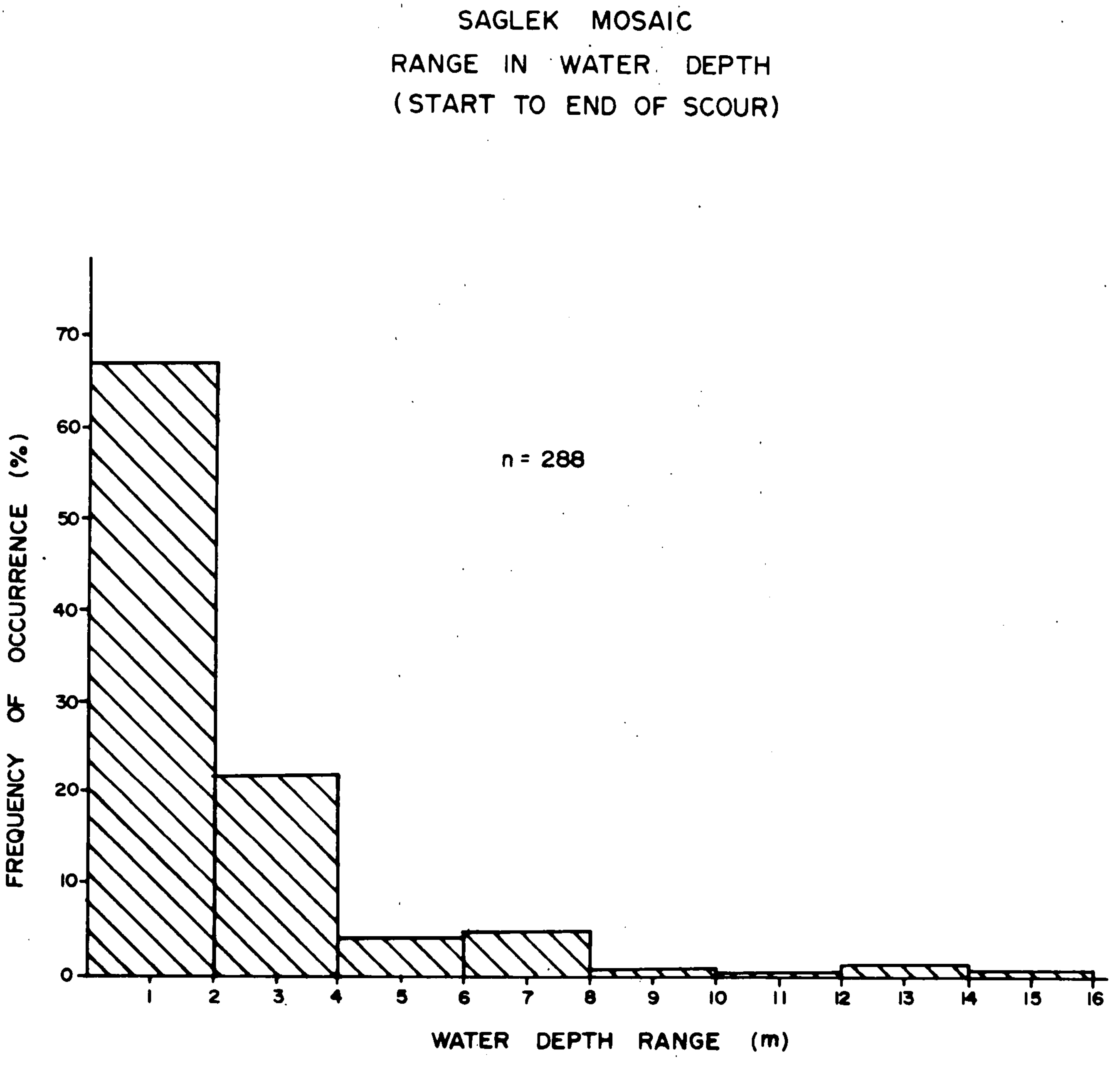

Figure 28. Frequency distribution of the ranges in water depth over which 288 scours passed in the Saglek East mosaic area. This illustrates that icebergs altered their draft by as much as 15 m while continuously scouring through processes such as rotation and tilting, possibly in combination with tidal fluctuation, or mass wasting of the iceberg.

recent interest has been focused on the ability of icebergs to adjust their draft. Independant studies have found that draft adjustments do indeed occur with changes of 25 percent being relatively common and increases in draft being equally as likely as decreases (Bass and Peters 1984, Lewis and Bennett 1984, Woodworth-Lynas et al. 1984a,1984b; Woodworth-Lynas et al, 1986).

3.6.8 Variation in Displaced Sediment Volume During Scouring

Where long scours are profiled at different locations there is often a difference in scour depth along the same scour illustrating changes in the forces exerted on the substrate by the iceberg, alteration of the keel dimensions, or differences in sediment strength. Figure 29 shows the frequency distribution of differences in scour depth (plotted from the table in Appendix 3) as measured at different locations along individual scours. This plot provides an indication of the variability in scour depth which can occur along a scour. No attempt was made to document relationships between scour depth changes and seabed slope. It is, however, interesting to note that the majority of differences occur within the normal range of resolution in measuring scour depths from Huntec records (i.e., 0.5m). As such, much of the variability may simply be a function of measurement methods or interpreter variability (see Section 1.5).

It is believed that an estimate of the actual amount of material displaced (in cross-sectional area), rather than changes in scour depth, would provide a more accurate indication of the variation in scouring forces and processes. The cross-sectional area, termed "scour profile area," is approximated here by assuming a triangular shape, whereby:

Scour profile area = 1/2 depth x width

(Calculations of scour profile area based on this formula are shown in Appendix 3.)

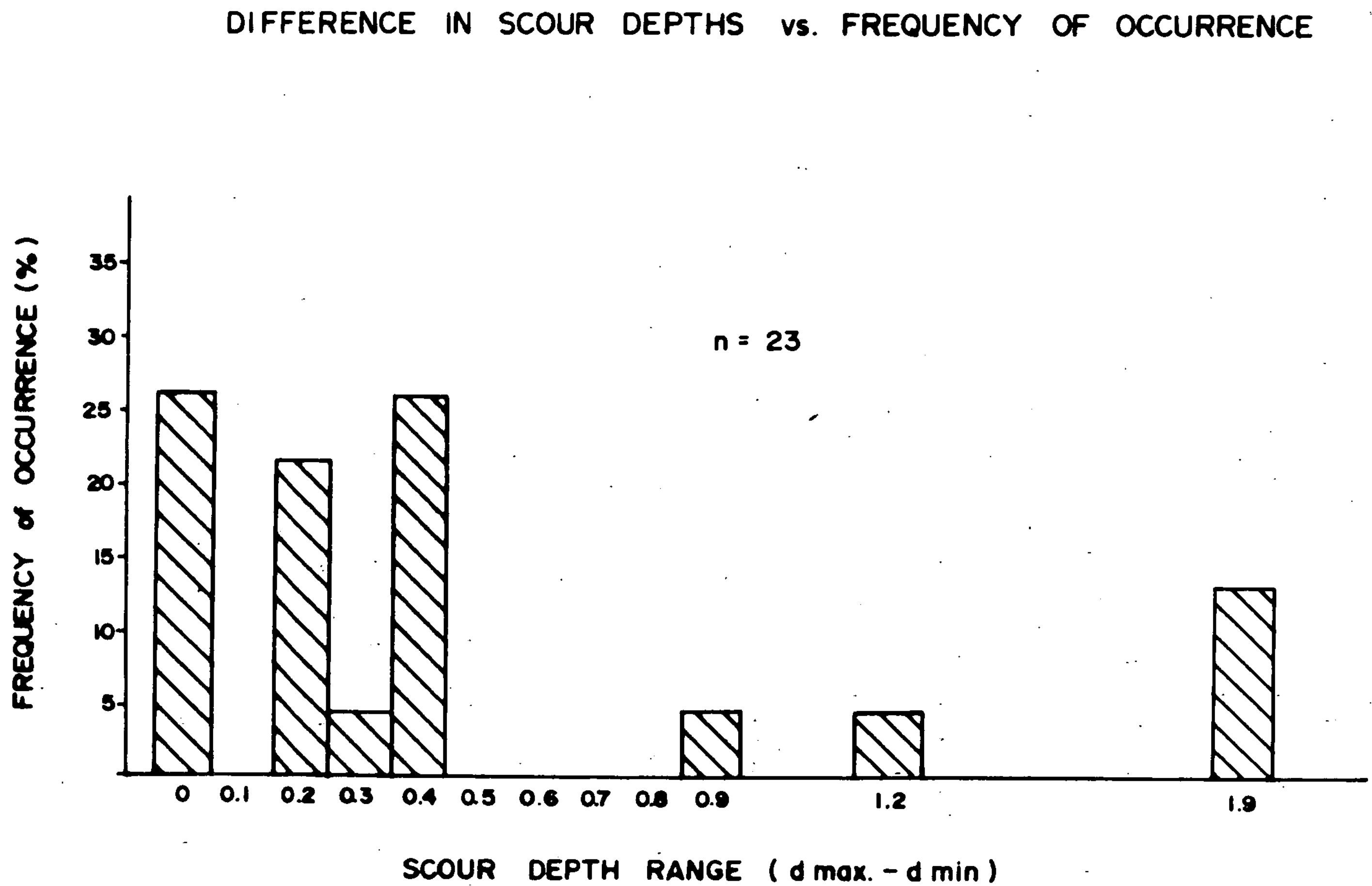

Figure 29. Frequency distribution of ranges in scour depths (maximum depth minus minimum measured depth) along individual scours as measured from profiler records where double or multiple passes across different positions of the same scour were made for 23 different scours. This plot, though incomplete, provides an indication of the variability in scour depth which can occur along a scour.

It is recognized that modelling of scour profile shape as being flat-bottomed (rectangular) versus V-shaped (triangular) is equally valid but, for the purposes of the discussions here, would only impact on the magnitude of individual estimates. Relative values remain the same using either method.

As scour profile areas vary greatly depending on the size of the scour, comparison of change in this parameter along a scour are best made by examining the frequency distribution of the ratio of profile areas at different crossings of the same scour (as opposed to differences in scour profile area along a scour). Figure 30 shows such a plot. Changes in the amount of material displaced by icebergs along individual scours in this area are usually less than a factor of 2 (47 percent); however, there are rare occurrences of changes of one order of magnitude.

A cursory review of depth and width measurements tabulated in Appendix 3 indicates that the relative contributions of depth and width to the observed changes in scour profile are roughly equal. That is, a decrease (or increase) in depth is not necessarily accompanied by a decrease (or increase) in width.

A check to see how scour profile area varies with geologic unit shows no significant differences between Unit 5A and the glaciomarine sediment (Unit 4) despite the fact that the sediments likely have different geotechnical properties. Apparently, other controlling factors such as water depth (and therefore iceberg size) are of greater significance.

Time constraints did not allow investigation of any upslope-downslope relationships with the scour profile area calculations during this study. A full treatment of this topic has subsequently been undertaken in a separate ESRF study (Woodworth-Lynas et al. 1986).

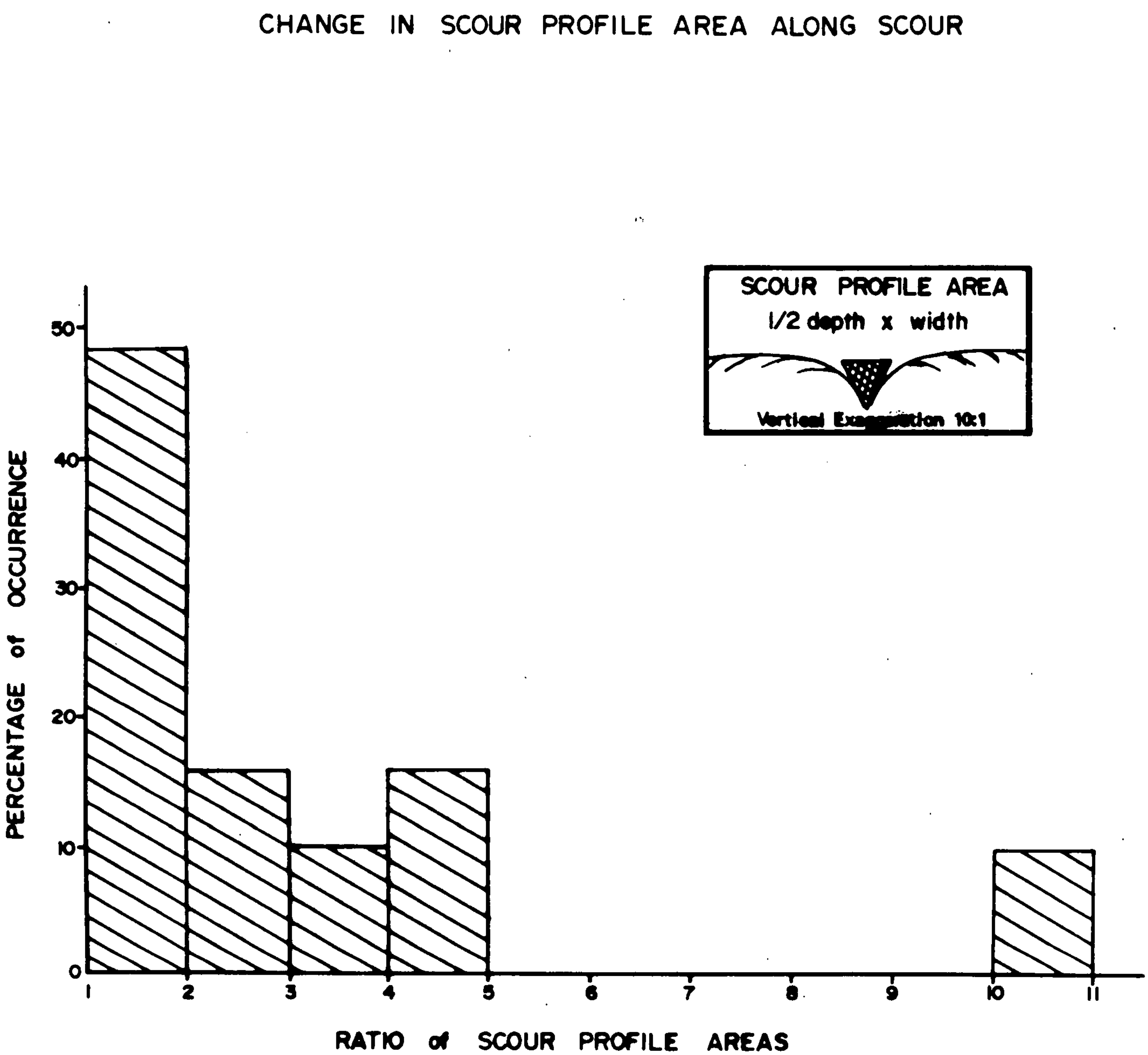

Figure 30. Frequency distribution of the ratio of "scour profile areas" as measured from profiler (depth) and sidescan (width) records and calculated as shown. "Scour profile area" is an approximation of the amount of material displaced (in cross-sectional area) by the scouring process. The plot shows the degree of variation in amount of sediment that is disturbed along individual scours. e.g. - The amount of material displaced by a scouring iceberg changes by a factor of 4 to 5 in 16% of scour occurrences in the mosaic area.

The scours were not examined for evidence of changes in iceberg dynamics (i.e. rotation, keel shape, etc.) which might have caused changes in scour depth or profile area. The depth and width changes along several scours, shown in Appendix 3, provide an indication of the amount of variability of these parameters along individual scours.

3.6.9 Scour Width-Depth Relationships

Scatter-plots of scour width versus scour depth for each geologic unit show little relationship between these two parameters except that the widths were consistently greater (commonly 20 times) than the depths. The plots (Figure 31) show a general increase in scour depth with increased width, but scatter about this trend is high. No differences in the width versus depth plots were observed from one geologic unit to another.

3.6.10 Scour Lengths

The frequency distribution of lengths of 313 scours for the mosaic area is shown in Figure 32. In general the plot shows a distribution with a strong component towards the short scours. Most of the scours (61 percent) have lengths of between 100 and 600 m while scours of extreme length (3-4 km) are rare. A sharp drop-off in the number of short scours (less than 100 m) may be in part an artifact of the failure to recognize shorter features as iceberg scours because of their lack of linear continuity.

The distribution of scour lengths over 3 km is not representative because the sample area has a north-south width of 3 km and therefore any scour length measurements greater than this will be scours with general east-west orientations only. Also, scour lengths overall will be biased somewhat toward the shorter classes since most scours are truncated at the margins of the mosaic.

A comparison of scour lengths in the shallow and deeper areas of the mosaic shows that they differ only slightly. In the shallow water depths (150-155 m) where scours are most dense, average length is

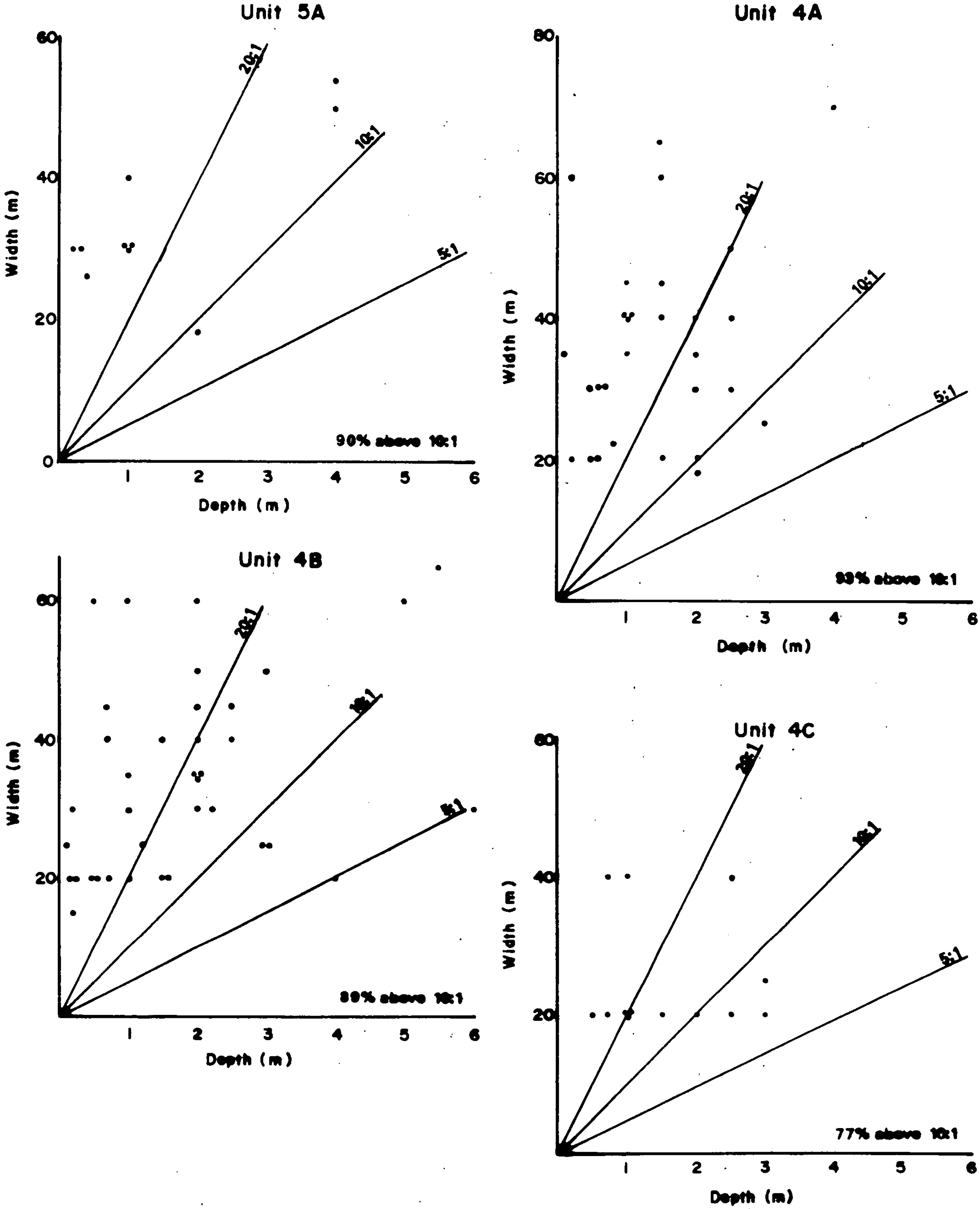

Figure 31 Scour width versus scour depth for the various geologic units and sub-units in the Saglek East mosaic area. Most show little trend in their relationship. In all plots, most scours are more than 10 times wider than they are deep. The ratios are expressed as scour width to scour depth.

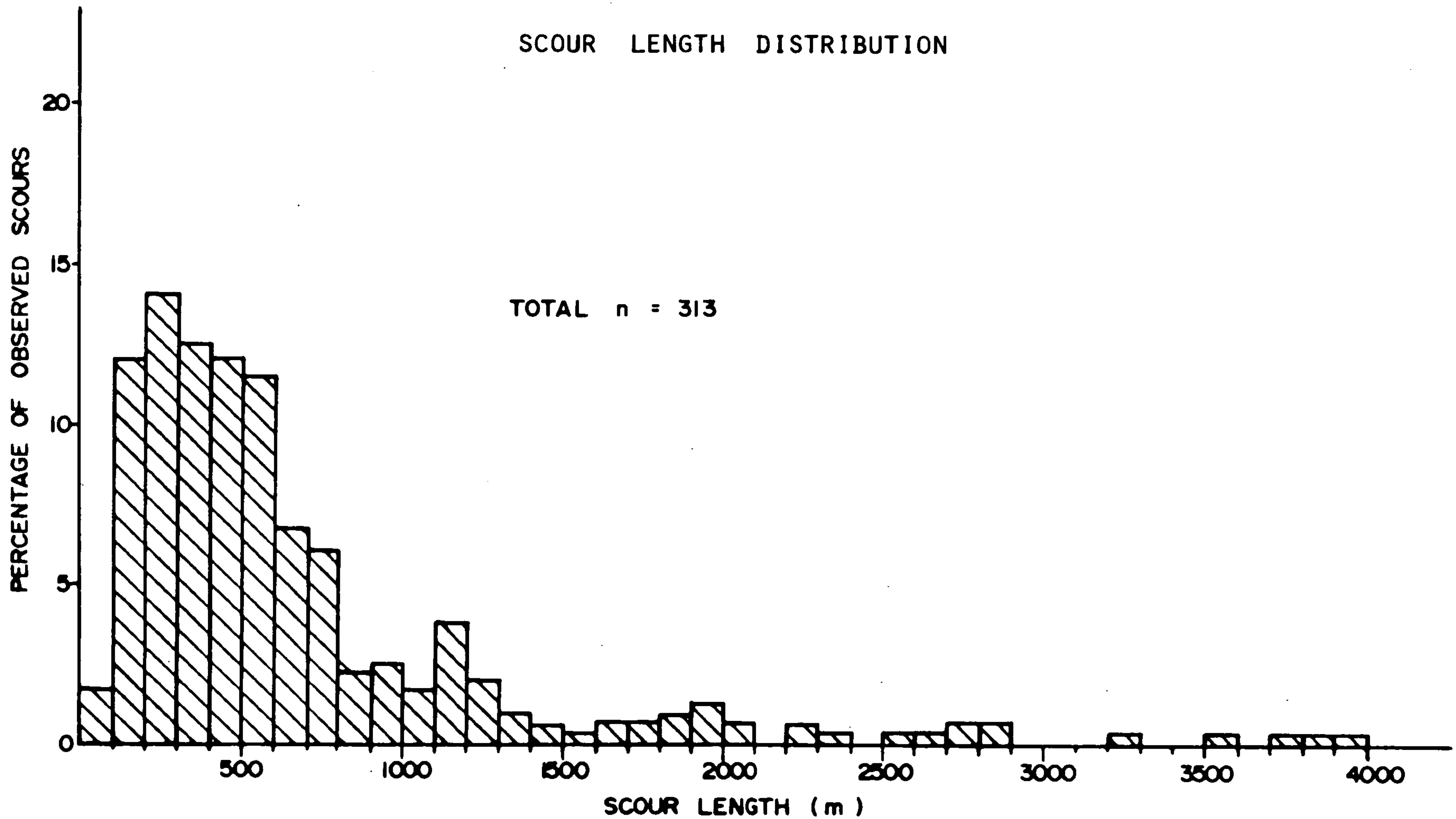

Figure 32 Frequency distribution of scour lengths from the Saglek East mosaic area showing the skewed modal relationship which flattens considerably beyond lengths of 2 km. It should be noted that this distribution is possibly biased toward the shorter scours owing to incomplete mapping of the scours beyond the boundaries of the seafloor mosaic.

approximately 650 m with a minimum of 120 m and maximum length of 2 km. The deeper water depths (170-175 m) are characterized by an 850 m average length ranging from 80 m to 3.8 km. This represents approximately a 25 percent difference in mean lengths.

The shorter scour lengths in shallower water are most likely related to the greater density of scours. In densely scoured areas, the earlier scours would tend to be dissected to some degree by later iceberg groundings. This sheds some doubt on the usefulness of scour length measurements in very heavily scoured areas.

3.6.11 Scour Depth-Berm Height Relationships

A scatter plot of berm height versus scour depth for scours across the whole mosaic area (Figure 33) shows that there is little overall relationship between the two.

However, an apparent statistical relationship was found between scour depth and berm height for scours in specific geologic units. The ratio of scour depth to berm height shows a trend of increasing value for scours in each geologic unit from the non-stratified glaciomarine unit through to the well-stratified unit and the younger Unit 5A. This is illustrated in Figure 34. The table of calculations is shown in Appendix 3. The non- and poorly-stratified units which occur in shallower water have mean ratios of 2.2 and 2.6 respectively with smaller standard deviations than the well-stratified and younger (post-glacial) deposits in deeper water with mean ratios of 3.9 and 4.0 respectively.

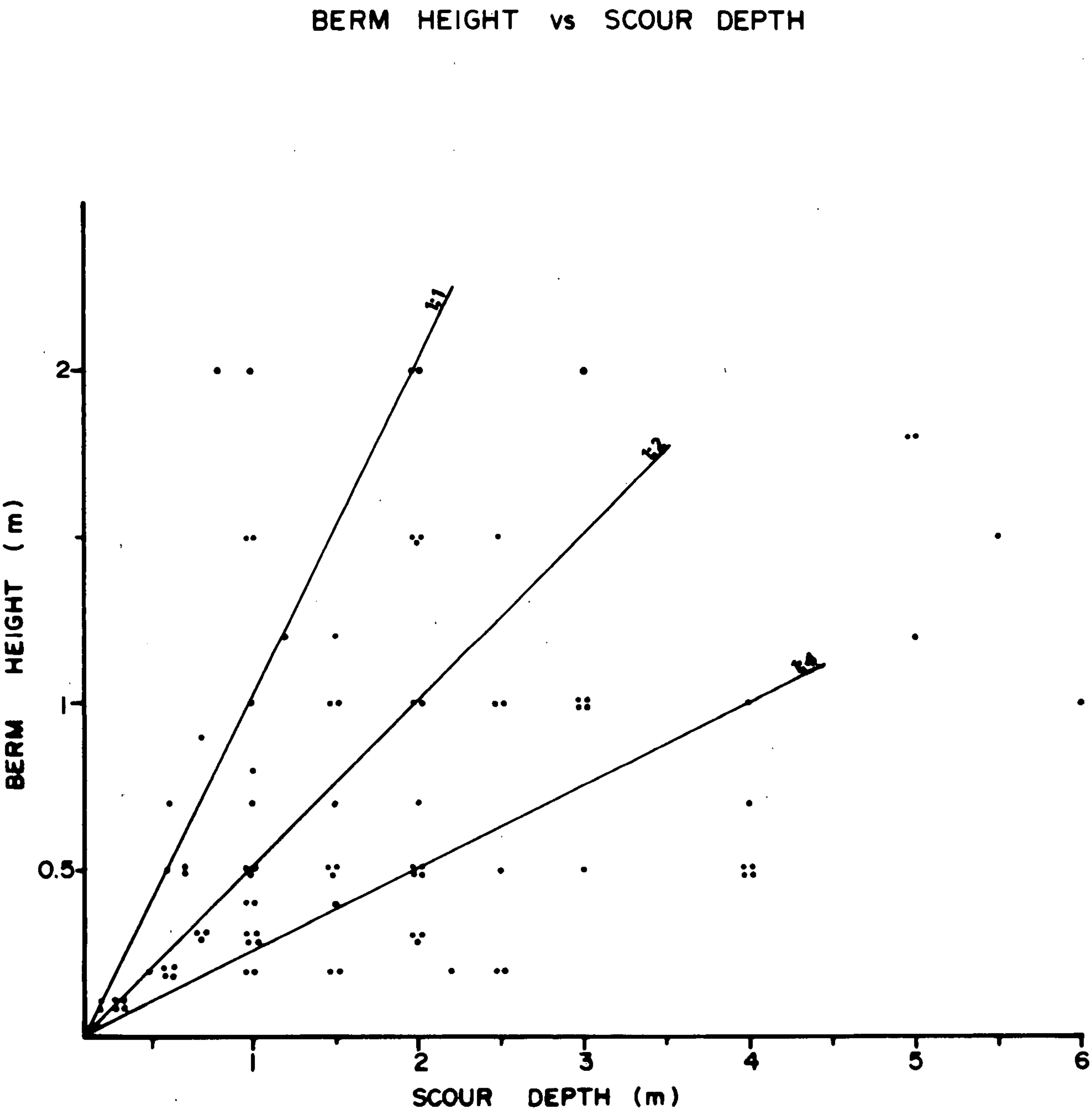

Figure 33. Scatter plot of berm height versus scour depth for 87 scours of the Saglek East mosaic area indicating that little relationship exists.

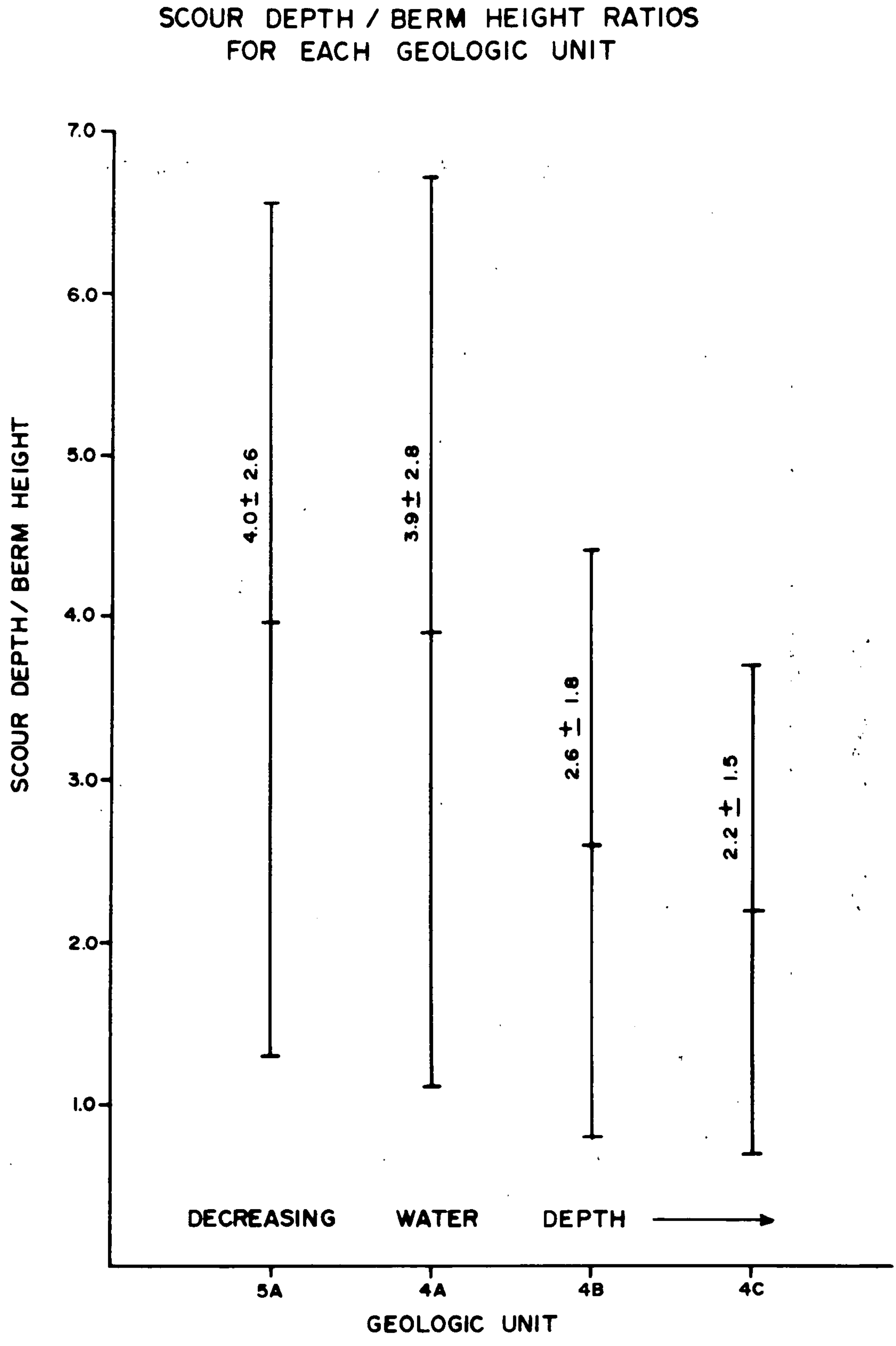

Figure 34. Mean and standard deviations of scour depth/ berm height ratios for each of the geologic units in the Saglek East mosaic area. Unit 5A is the least competent while unit 4C is the most till-like in character, is covered by a gravel lag, and is probably the sediment of greatest strength. As discussed in the text, the lower scour depth/ berm height ratios for these units may be due to this strength difference.

Though it is difficult to isolate factors, such as water depth difference or iceberg population, these ratio changes with geologic unit may be explained in terms of the geotechnical character of the sediment. It is reasoned that a softer sediment would be capable of being scoured more deeply than a more competent material and, for a given size iceberg, would probably deform more plastically and be less likely to develop (or retain without slumping) a high-standing berm than would a stronger material. Thus, scour depth/berm height ratios would be relatively higher for softer, less competent sediments.

3.6.12 Scour Planform Shapes

The plan view shape of a scour reflects the resultant of all component forces acting on the scouring iceberg. Figure 35 shows that in this study area straight scours are most common (69 percent) while only 27 percent are arcuate, and less than 2 percent follow a sinuous path.

As straight scours are presumably the result of dominant, relatively strong, uni-directional iceberg driving forces, their high frequency of occurrence should reflect the predominance of these types of forces in the area throughout the scouring history. As a simple test of this hypothesis, scour depths for each type of scour shape were compared to see if straight scours generally scoured to greater depth in the sediment due to possibly greater driving forces. Mean depth of scour for sinuous scours is 1.5 m while the average depth for arcuate scours is 1.4 m. Straight scours are, in fact, deeper at 2.0 m. Depth distribution plots for each planform shape (see Figure 36) further suggest that scour depths do differ for straight scours. Although some depth data are lacking for sinuous scours (N=17); the distribution appears to be different than that for the straight scours. While neither the arcuate nor sinuous scours exceed a 3 m depth, over 20 percent of straight scours are greater than 3 m deep. Although further work is desirable to evaluate any effect from the different sample sizes, the plots strongly suggest that scour depths for straight scours are deeper than for other planform shapes.

RELATIVE ABUNDANCE OF SCOUR PLANFORM SHAPES

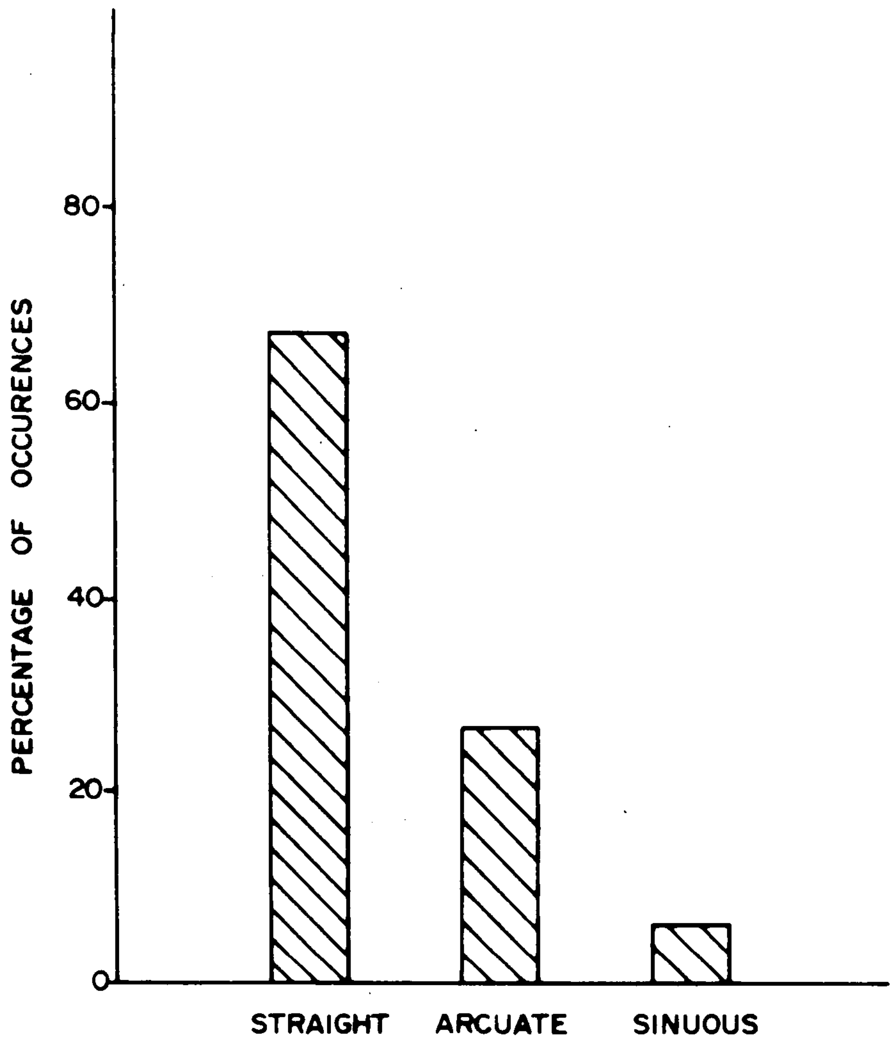

Figure 35. Relative abundance of straight, arcuate, and sinuous scours in the Saglek East mosaic area. Scours with only slight arcuate shape (less than 5° bends) were classed as straight scours.

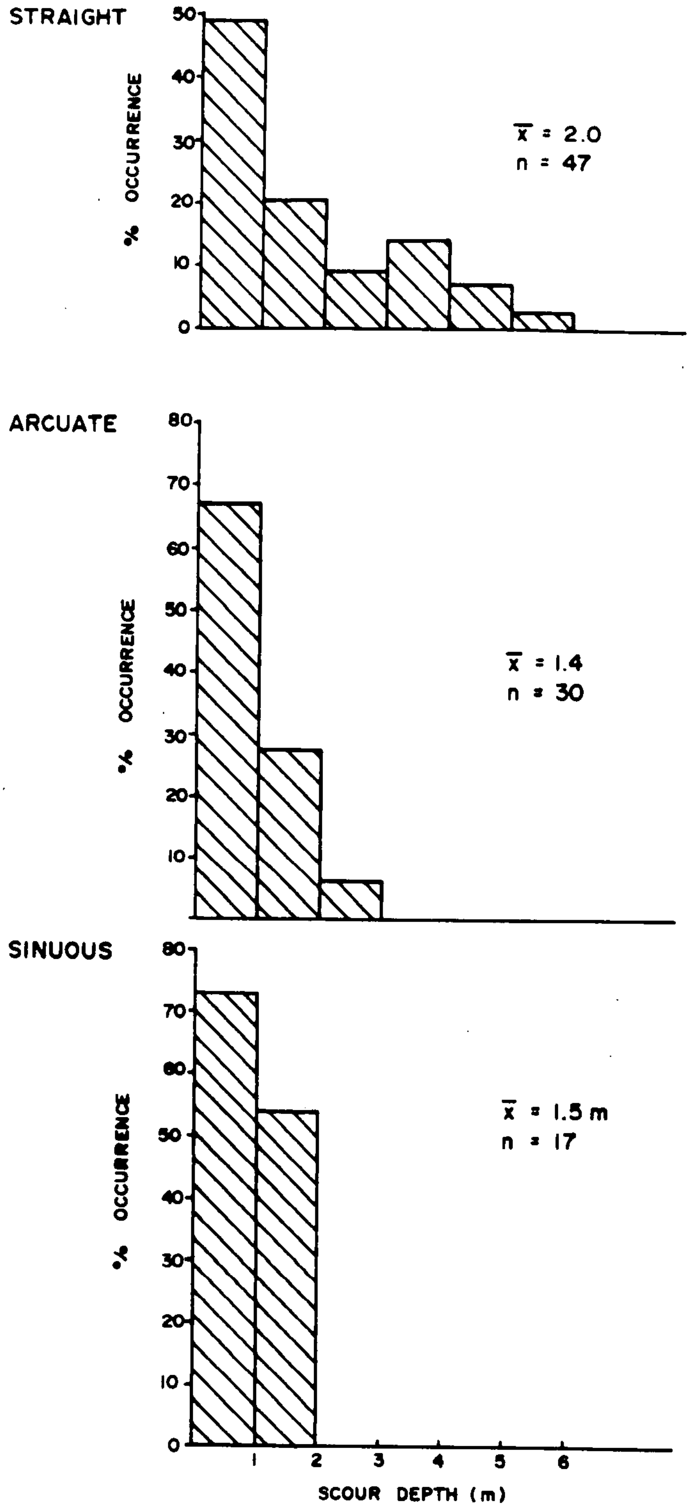

Figure 36. Frequency distributions of scour depths for straight, arcuate and sinuous scours in the Saglek East mosaic area. Straight scours exhibit both the greatest average depth and greatest maximum depth of scour. This could be related to presumably stronger and prevailing driving forces which could result in both straight scours and greater ploughing forces.

3.6.13 Iceberg Craters and Pockmarks

Numerous circular or oblong craters occur throughout the mosaic (Figure 19). Their identity is somewhat uncertain, but it is thought that some are iceberg craters while others are pockmarks formed by the venting of subseabed water or gas.

There are 38 craters in all, ranging from 40 to 140 m in diameter, with an average diameter of 85 m. Many of these occur at the start or end of scours or are superimposed on a scour. They are most prevalent in the softer sediments (Unit 5A and part of Unit 4).

Distinction of iceberg craters from pockmarks is difficult because both are of similar form and dimension. However, pockmarks, unlike craters, only develop in soft cohesive sediments which act as a recording medium for the escape of gas or water from below. In contrast, craters usually occur in more consolidated material, such as till. In addition, pockmarks rarely exhibit berms whereas craters are highly variable in this respect.

Geonautics personnel have observed instances in other areas where pockmarks are closely associated with iceberg scours, sometimes as a string of pockmarks running nearby and parallel to the scours (Geonautics 1980). It is possible that some of these crater-like features in the mosaic area are pockmarks produced through disturbance of the seabed by icebergs and the subsequent release of gas or water from the sediments.

3.6.14 Repetitive Surveying

As a portion of the Karlsefni Repetitive Survey Study, the mosaic study area has been surveyed several times since 1976 (BIO cruises 76-023, 77-021, 78-029, 79-019, and 81-045); however, only the latter two cruises include accompanying sidescan coverage and therefore provide a basis for comparison of the area over a two-year period.

Visual inspection of the two mosaics proved very difficult in terms of a scour-by-scour comparison. Though many identical scours were found, some scours display a strikingly different character, often to the extent that certain scours visible on one mosaic are not recognized at all on the other. In addition, some angles between identical scours on each mosaic differ by several degrees, making comparison difficult. These incongruities probably arise as the result of slight inaccuracies in replaying of the sidescan records to a 1:1 aspect ratio (identical along-track and across-track scales). This is partly a result of inaccuracies in ship speed and navigation.

This comparison also raised other questions as to the effect of varying survey parameters such as instrumentation and survey track orientation (direction of insonification by sidescan). These factors are addressed in the following section.

3.7 SAGLEK EAST MOSAIC - DATA BASE VALIDITY STUDY

Detailed analysis of the Saglek East mosaic, with correlations of scours on individual sidescan records, mosaiced sidescan data, and profiler data provide an excellent data base with which to test the validity of some of the analysis techniques and results of the regionally based studies. These tests include:

i) A comparison of iceberg scour counts (per 100 m) from the three types of data (Huntec DTS, raw sidescan and mosaiced sidescan).

ii) A statistical comparison between measurements of scour orientations as gathered from the mosaic with measurements of the same parameter taken from a single survey line through the centre of the mosaic using the regional analysis technique.

iii) A comparison of measurements of scour lengths, widths and orientations as obtained using the regional analysis technique, where the representative scours to be measured are selectively chosen by the interpreter, with the same type of measurements for scours selected by random sampling.

iv) A comparison of scour counts, orientations and depths for two data sets covering the same area within the mosaic but surveyed at different orientations and at different times.

3.7.1 Scour Count Comparisons For Huntec DTS, Sidescan and Mosaiced Sidescan Data

Figure 37 shows plots of total scour count per 100 m along the three survey tracks which pass across the Saglek East mosaic area. A total of 12 km of data were analysed. All scours visible on each data type were recorded. Comparisons between Huntec and sidescan were made for data from the same, rather than adjacent, survey line in all cases. Plots for individual geologic units are shown from the shallowest to deepest water depths (Unit 4C (non-stratified) to Unit 5A).

The plots illustrate that significantly different scour counts result depending upon the type of data analyzed. In areas of fairly dense scouring (Units 4A, 4B and 4C) scour counts are greatest using the DTS profile data, with a progressive decrease in recognizable scours on the raw sidescan records and the sidescan mosaic. Ideally, the counts should be the same for each instrument type utilized. It is possible that the discrepancy between data sets arises because smaller indentations seen on Huntec DTS profiles are not visible as scours on the sidescan record because, (a) they are of too little relief to be detected by the instrument at such steep angles of incidence immediately below the fish; (b) they have too little textural difference to be recorded or (c) the features are, in fact,

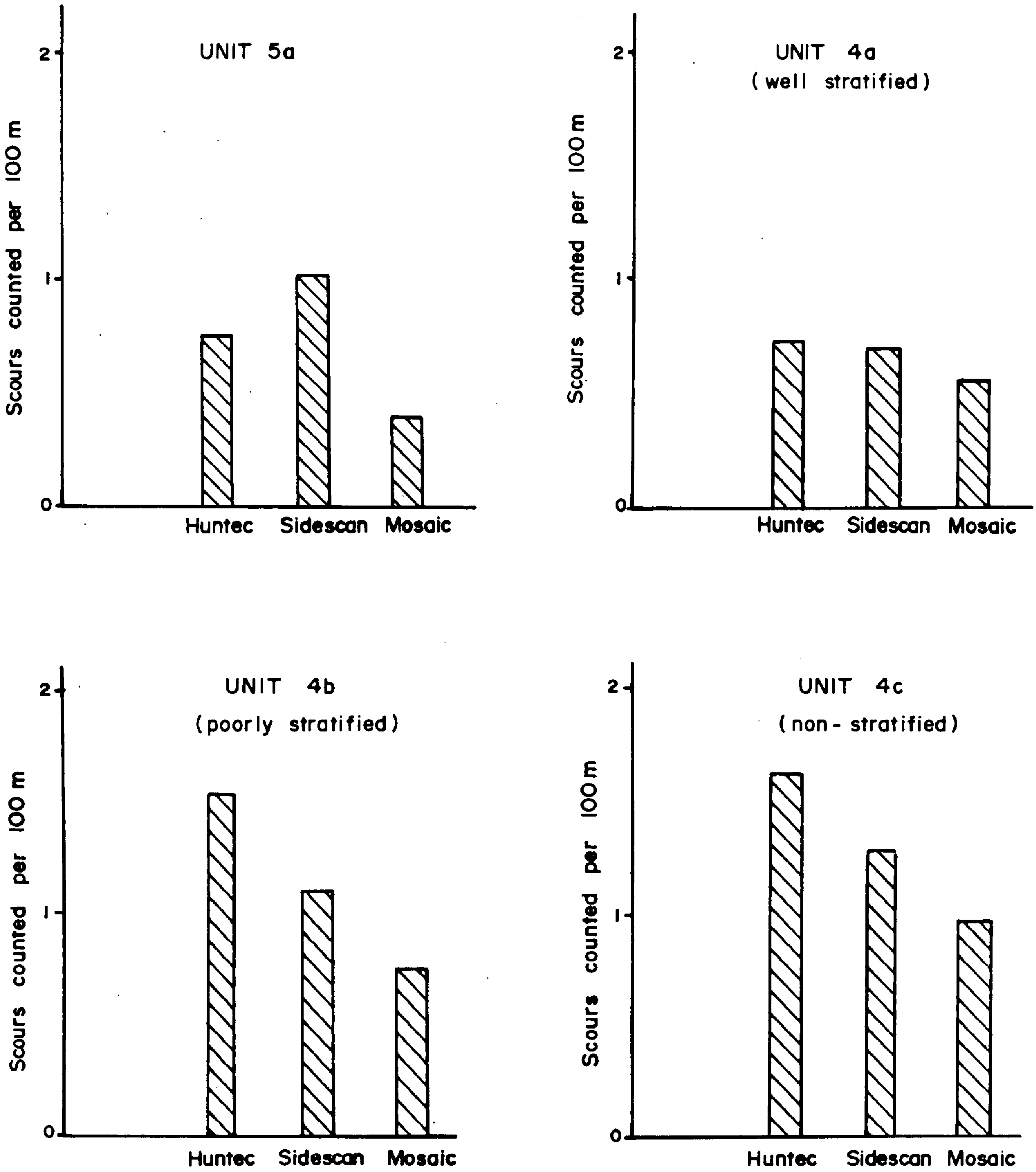

Figure 37. Comparisons of the total scour count per 100 m for the three available data types. A breakdown into individual geological units from 4C (non-stratified) to unit 5A is presented.

not scours but rather adjacent berms from separate scours. The fact that fewer scours were counted on the mosaic relative to the raw sidescan records may be attributed to loss of resolution in the replay to 1:1 aspect ratio and a decrease in scale of the sidescan display.

The plot in Figure 37 representing scours in Unit 5A is anomalous in that the count from the sidescan data is high relative to the others. Aside from the fact that the scour population is low (N=22), and thus lacks statistical credibility, there were several long, very narrow scours visible on the raw sidescan that were too shallow to be seen on the Huntec DTS profile. These features were not evident on the processed mosaic data, suggesting some data loss.

In summary, the areas of most dense scouring are characterized by the greatest discrepancy between scour counts for different data sets. More scours are recognized on the Huntec DTS profiles than on the raw sidescan records while the mosaic displays the fewest scours. These findings may be unique to this area and to other areas of high density scouring, because in many areas of low scour density, such as much of the Grand Banks, scours are often not visible at all on the profiles and are only recognizable on sidescan records where textural differences between berms and troughs occur.

3.7.2 Comparison between Regional and Detailed Analysis Techniques

Analysis of regional survey line data, similar to the technique carried out for the Grand Banks, Labrador, Baffin-Davis Shelf and Lancaster Sound regions, attempts to represent the most prominent aspects of existing iceberg scours and their dimensions. It is, however, important to assess to what degree this regional analysis technique (measurement of selected "representative" scour features along regional survey lines) reflects the local iceberg scour population. To this end, orientations as measured from a selected sample of scours on a single survey line through the centre of the mosaic area were compared with the mosaic data set, which is much more complete and covers 2 to 3 times the area. The measurements from five 2 km long sample areas along the middle survey line were compiled as per the regional analysis technique and then combined for comparison with the entire mosaic data set. Two rose diagrams are presented in Figure 38, displaying the orientations of the two measured groups. There appears to be a distinct difference in these trends. This significance of this result is discussed in the next section.

3.7.3 Comparison Between Operator Selected and Random Selection Techniques

In order to define potential bias introduced by interpreter selection of "representative" scours from each sample area (as opposed to random selection) two areas were analyzed by the two methods. As a control, every recognizable scour within the sample areas was measured. These areas had both previously been measured with the interpreter having chosen representative scours. After all scours had been traced onto a sheet of mylar film and numbered, a random selection of scours was carried out using a random number generator. The average values of length, width and orientations for all three analyses were compared, with the following results:

Hudson 79-019, Day 232   0732-0744

	Operator Selected	Random	All Scours Measured
Length:	682.5 m	307.6 m	281.4 m
Width:	34.8 m	24.1 m	27.26 m
Orientation:	(See Figure 39)		

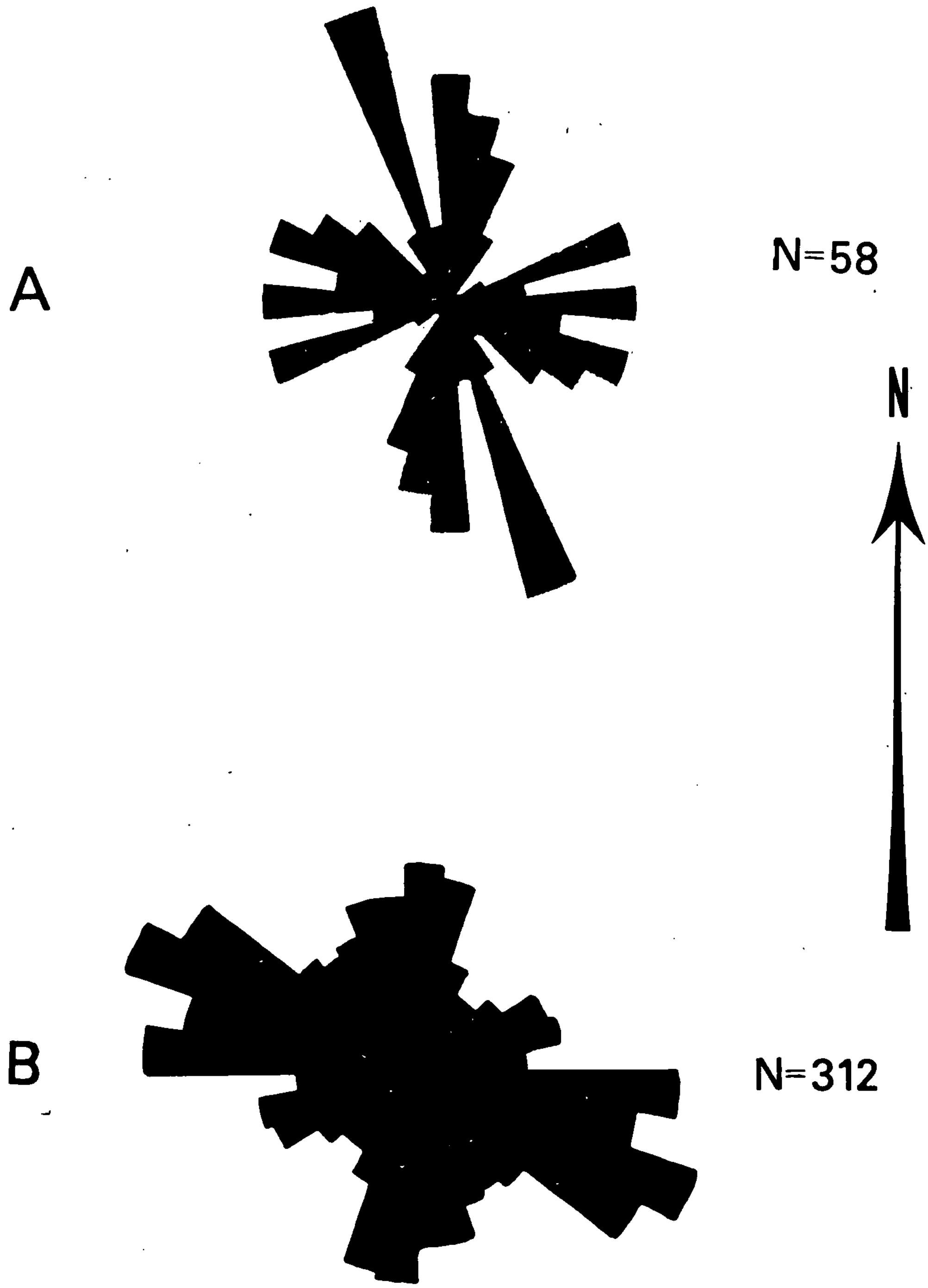

Figure 38. Rose diagrams illustrating iceberg scour orientations for: A) scours selected from a single survey line through the Saglek East mosaic area and B) all measured scours within the mosaic.

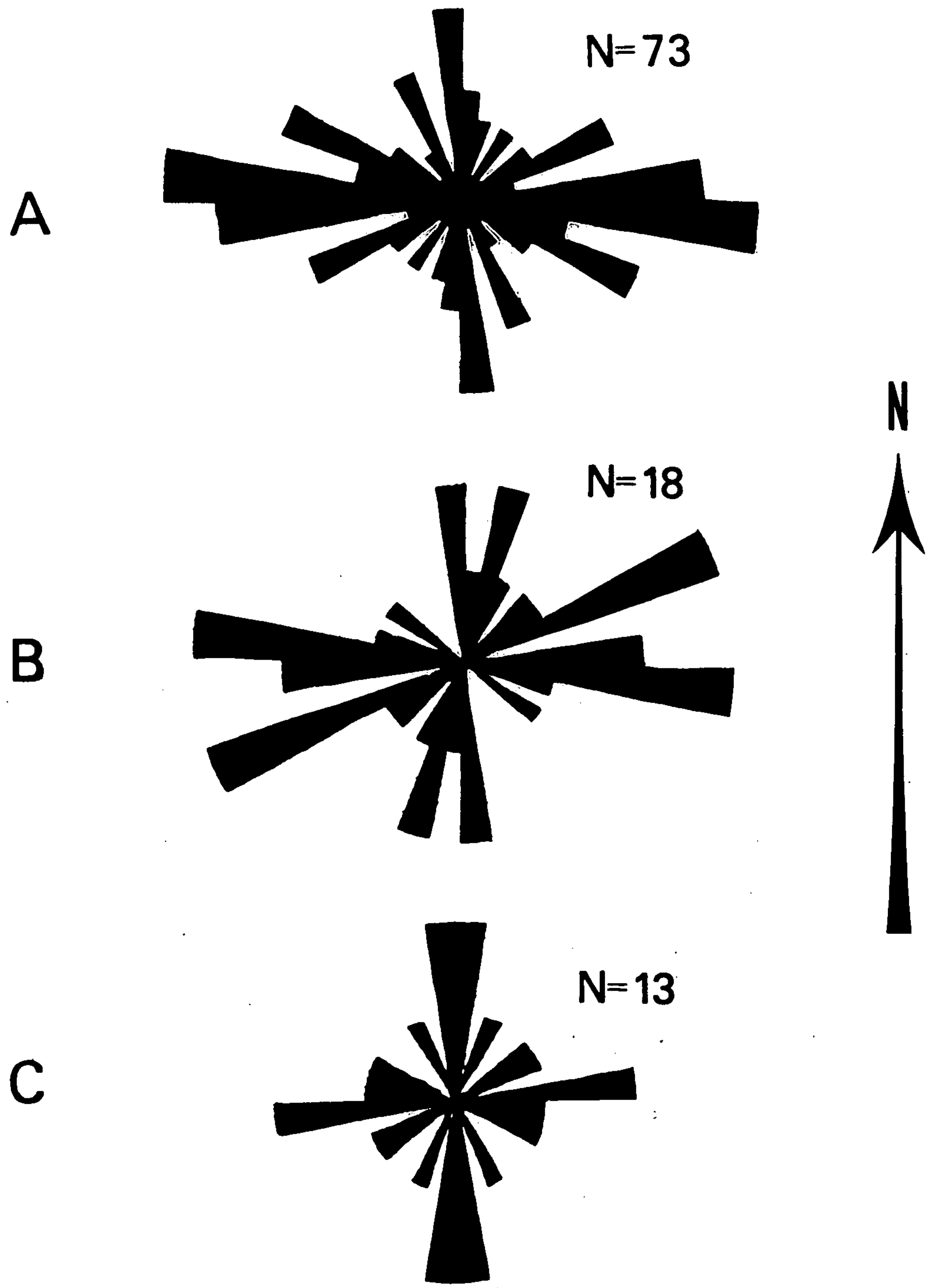

Figure 39. Rose diagrams of measured iceberg scour orientations for one sample area from Hudson 79-019 where A) includes all recognizable scours, B) consists of a randomly selected set, and C) is an interpreter selected set.

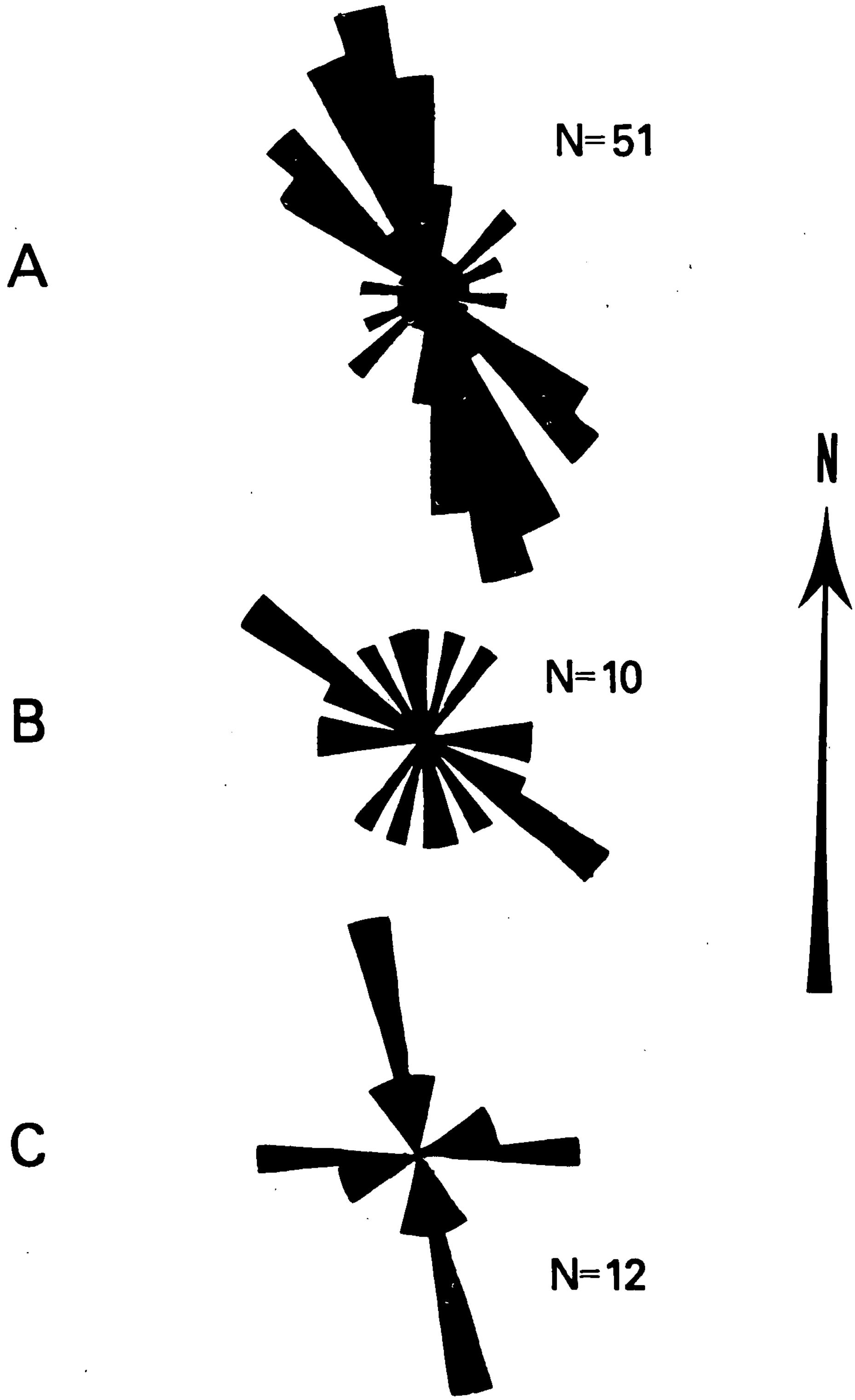

Figure 39 (cont.) Rose diagrams of measured iceberg scour orientations for one sample area from Hudson 83-030 where A) includes all recognizable scours, B) consists of a randomly selected set, and C) is an interpreter selected set.

Hudson 83-030, Day 284 1008-1020

	Operator Selected	Random	All Scours Measured
Length:	812.7 m	340.9 m	456.6 m
Width:	27.3 m	24.0 m	29.9 m
Orientation:	(See Figure 39)		

The inferences which may be drawn are limited by the low number of areas analyzed. Some lengths are much longer in the interpreter-selected group than in the random or complete groups, suggesting that bias causes the interpreter to select scours of greater length as representative. Bias may also be present towards the greater widths, but this is not clearly evident from the results. Rose diagrams of scour orientations (Figure 39) indicate that while the random selection process produces orientations which are close to the overall values, interpreter-selected orientations appear to be biased towards orientations which are more nearly parallel to the overall trend of the survey line. This same effect is illustrated in Section 3.7.2 above.

3.7.4 Effects of sidescan survey track orientation

As part of the repetitive survey plan in the Karlsefni Trough, a sidescan and Huntec DTS survey line was run across the eastern end of the mosaic area as part of Hudson cruise 83-030. This line is oriented approximately perpendicular to the 79-019 mosaic survey lines.

In order to make a scour by scour comparison, all scours which occur within the dimensions of the mosaic were measured and all those scours on the mosaic that fall within the 1983 sidescan coverage area, were identified by numeral. This provided the basis for a statistical comparison of the two data sets.

A visual comparison alone proved difficult and not highly successful. There are 72 scours visible on the 1983 sidescan record and 74 for the same area on the 1979 mosaic; however, only six scours could be positively cross-correlated between data sets. Presumably part of the problem with a visual cross-correlation stems from the fact that while the mosaic is corrected for along track/across track scale differences (1:1 aspect ratio), the 1983 data still has this inherent distortion (approx. 2:1 aspect ratio). The 1983 data would be better reprocessed to a 1:1 aspect ratio for comparison. This problem with visual comparisons of the two data sets is very similar to problems discussed previously in Section 2.7.

Statistical comparisons of scour depth distributions for both data sets are shown in Figure 40. Both plots show the exponential distribution seen on plots for the complete mosaic data set (Figures 25 and 26). The plots differ only in that a lesser number of small scours are visible in the 1983 profile and there are no deep scours in the 4 m range. The differences may be due in part to the smaller sample (N=24) for the 1983 data, as opposed to a sample of 57 measurements for the 1979 data. This suggests little effect due to different survey track orientation on the distribution of scour depths.

Rose diagram plots of the orientations of the scours in each data set are presented in Figure 41. It is apparent that a difference exists between the two, mainly in the absence of a series of NNE trending features observed in the mosaic data but not in the 1983 (83-030) survey data. It is considered that this is likely due to survey line orientation, which, as discussed previously, appears to affect the recognition of iceberg scours in certain orientations relative to the ship's track.

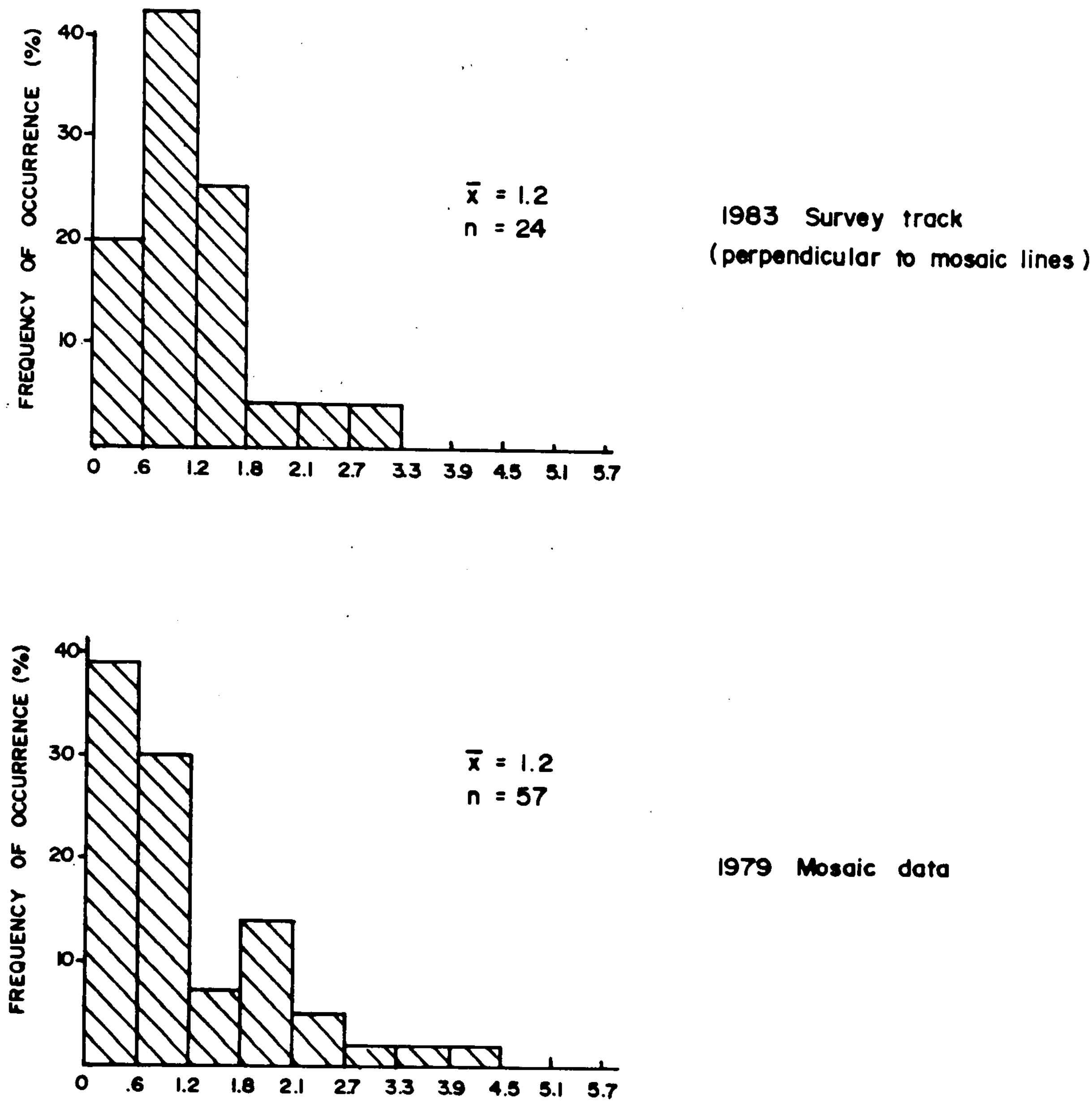

Figure 40. Comparison of scour depth distributions for a portion of the Saglek East mosaic surveyed both in 1979 (79-019) and 1983 (83-030).

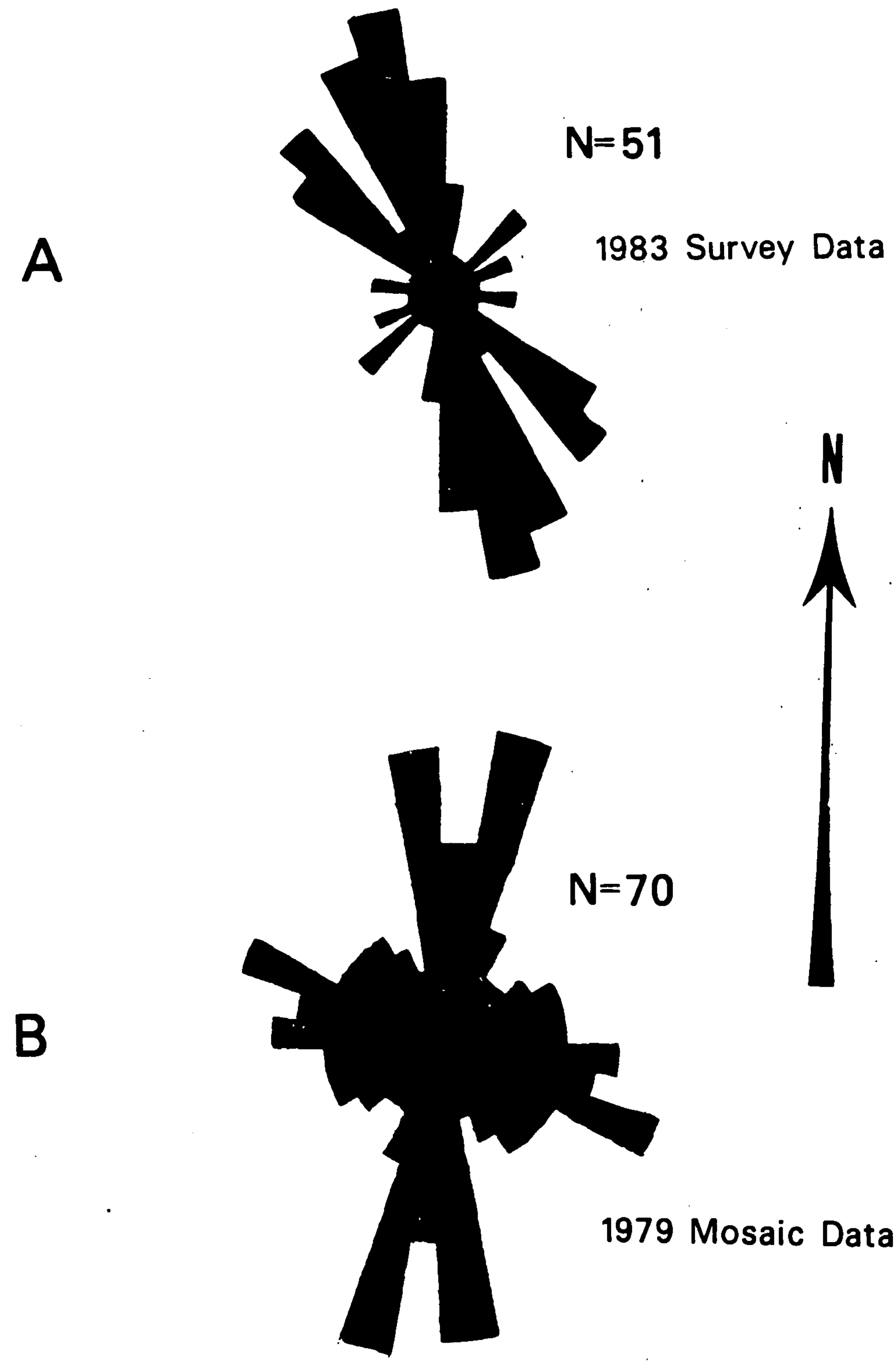

Figure 41. Rose diagrams of scour orientations for the area surveyed by both the Saglek East mosaic and Hudson cruise 83-030.

4.0 BAFFIN ISLAND-DAVIS STRAIT REGION

4.1 INTRODUCTION

The Baffin Island-Davis Strait region (hereafter referred to as the Baffin-Davis region) covers the continental shelf of southeastern and northeastern Baffin Island from Resolution Island in the south to Bylot Island in the north (see Figure 42). South of Cape Dyer the shelf is much wider than to the north, reaching a maximum width of 230 km east of Cumberland Sound. Relief on this portion of the shelf is lower, water depths are generally greater with no marked bank areas such as those which characterize the continental shelf adjacent to Newfoundland and Labrador, and there is no indication of an extensive marginal channel system like that which borders the inner shelf zone along Labrador. Water depths in Cumberland Sound (1289 m) and Frobisher Bay (615 m) are much greater than shelf areas nearby. North of Cape Dyer the shelf is narrow, averaging 50 km in width and characterized by numerous shallow (<200 m) bank areas which generally extend the full width of the shelf, separated by deep, steep-sided troughs, the best known of which are Buchan, Scott and Broughton Troughs. East of Cape Dyer, a region of relatively shallow water, commonly referred to as the Davis Strait sill, separates Baffin Basin from the northern Labrador Sea basin.

The geology of the Baffin Island Shelf is complex and, except for the southeast portion, only partially understood. The pre-Quaternary bedrock geology has been studied by Brian MacLean and others at the Atlantic Geoscience Centre. The reader is referred to publications by Praeg et al. (1986), MacLean (1985) and MacLean et al. (1982) for a comprehensive review of the present understanding of the geologic and tectonic history of this region. The surficial or Quaternary geology of this region is best known on the southeast portion of the shelf where four separate units have been recognized from seismic data on the basis of acoustic character, supplemented by widely spaced grab samples (Praeg et al. 1986).

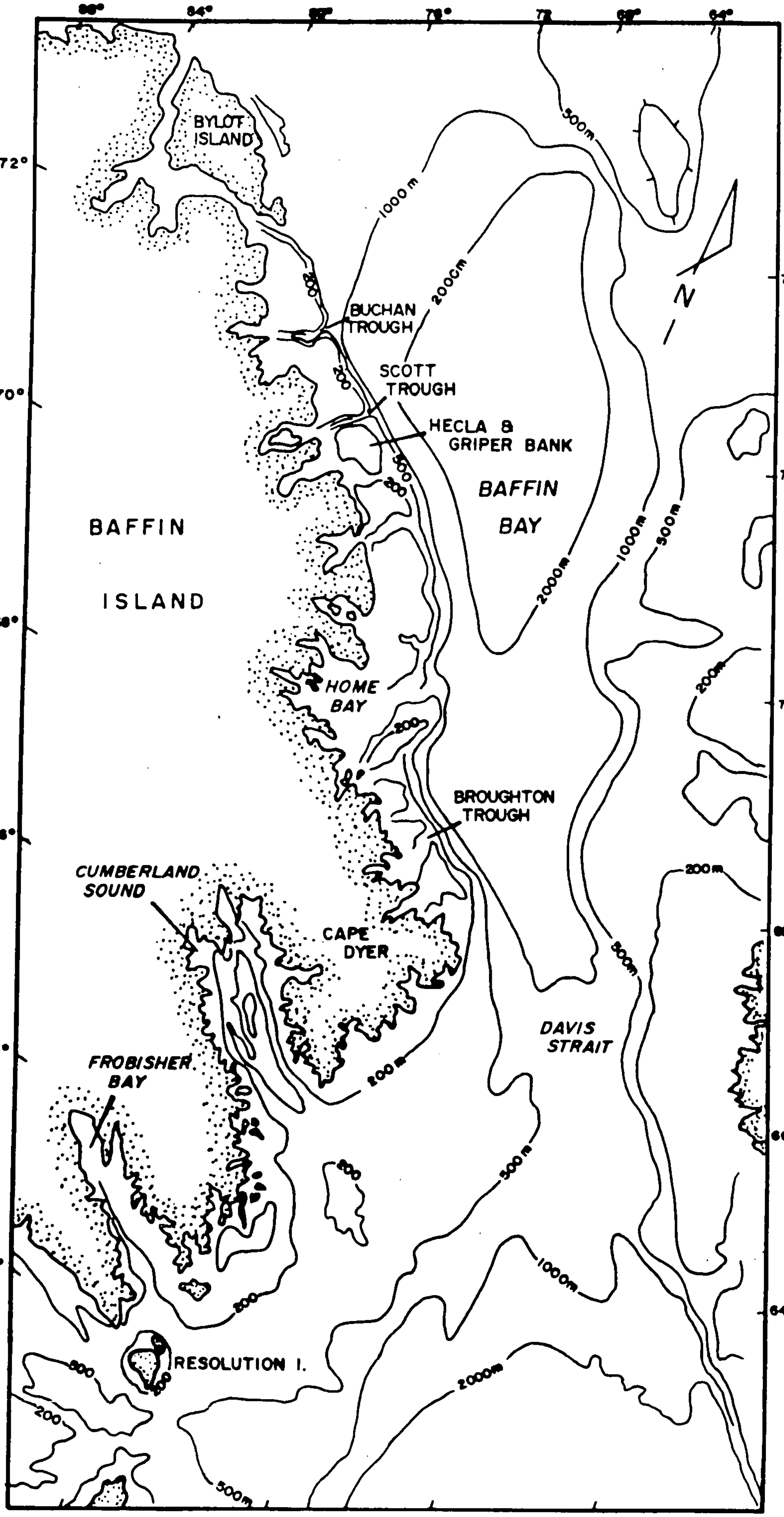

Figure 42. Physiography of Baffin-Davis study region.

These four units, plus the underlying bedrock, form the basis for the geologic sequence used in data compilation during this study. A brief description of this geologic sequence is given in Table 5. A set of maps showing the distribution and thickness of these units is given by Praeg et al. (1986).

Iceberg flux in the Baffin-Davis region is high with estimates of as many as 2,500 icebergs per year being swept from Greenland counter-clockwise around the Baffin Basin, along the northeast and southeast coasts of Baffin Island and then southward across the Labrador Shelf (Murray 1969). As a result, shelf areas in the Baffin-Davis region have been intensely scoured both by icebergs and, in shallow inshore areas, heavy pack ice. Evidence of iceberg scours in 500-600 m water depth (Lewis et al. 1980) suggests that at least a portion of the ice scours observed on the shelf are relict. Differentiation of modern and relict scours is important since it is the distribution and characteristics of modern ice groundings which are of interest when considering the safe development of offshore resources in the region. Compilation of the form and distribution of existing ice scour features represents one step towards the resolution of this problem.

4.2 DATA COVERAGE

A complete listing of cruise data analyzed and compiled during this and previous studies is presented in Appendix 4. Survey lines are illustrated on Chart 8. Data compiled during ESRF update studies represents all usable sidescan and Huntec data up to 1985 on file at BIO and not previously entered into the data base.

4.3 OTHER DATA SOURCES

Industry data are available in the region in the form of site-specific wellsite surveys. Although some of these data are presently

TABLE 5

Geologic Sequence for Baffin-Davis Region

(after Praeg et al. 1986)

UNIT OR CODE NUMBER	DESCRIPTION OF GEOLOGIC UNIT
5	Sand and gravel occurring locally as a thin lag over bedrock or till on parts of inner shelf in water depths less than 200 m. Possibly developed as basal transgression product.
4	Tiniktartuq silt and clay (informal). Basinal or ponded silt and clay. Interpreted as post-glacial, possibly with an ice-rafted component. Distribution restricted to floors of Frobisher Bay and Cumberland Sound, and in local depressions east of Frobisher.
3	Davis Strait silt (informal). Muddy sand and gravel in which silt/clay content may exceed 50 percent. Interpreted as pro-glacial or glaciomarine in origin. Well to poorly stratified. Generally intensely scoured.
2	Glacial till. Recognized by its acoustically transparent nature and lack of coherent expression on high resolution seismic records. Typical of till deposits in other east coast offshore areas. Deposits range from a few metres to 100 m or more in thickness.
1	Includes: Mesozoic/Cenozoic coastal plain sediments. Usually distributed on outer shelf areas. Mainly of Tertiary age. Pre-Cenozoic bedrock. Precambrian acoustic basement (1A), and Cambro-Ordovician sequence (1B).

available to the public, it is considered likely that the same lack of compatibility would exist that was noted on the Grand Banks between the site-specific and regional data bases (see Section 2.7). As a result, this data has not been incorporated into the regional ice scour data base. Appendix 6 provides a listing of released industry data collected within the region up to 1988. The location of wellsite surveys are provided on Chart 8.

4.4 DATA COMPILATION: METHODOLOGY AND LIMITATIONS

In general, all 1985 and earlier BIO sidescan and Huntec DTS data available for the Baffin Island shelf not already analysed and entered into the data base were considered for this study. On the southeast shelf this includes a number of east-west lines of sidescan and Huntec data in the area east of Cumberland Sound. The Huntec records are generally good to water depths of 600 m or more while the sidescan is only useful to 300 m. On the northeast shelf very little sidescan data were available for analysis which necessitated analysis of a certain amount of Huntec data alone. This led to problems in interpretation of scour features in a number of areas, especially in deeper water where certain sediment failure features were found to resemble scours in size and shape.

4.5 SCOUR SUMMARY

Chart 9 illustrates percent seabed disturbance, scour depth, scour width and scour orientation data for the Baffin-Davis region. With the exception of the area east of Cumberland Sound, looked at as part of a detailed study (next section), data coverage in the region tends to be sporadic. Any discussion of regional variations in scour characteristics can therefore only be made on a very superficial level.

Density of scouring is generally high in all areas shallower than 200 m. Areas of low scour density probably reflect local current observations, topographic sheltering or, possibly, hard, inpenetrable seabed conditions. The latter case is especially common in nearshore areas (<100 m) where surficial cover is generally thin and strong currents may quickly degrade any scours produced (Pereira and Gillespie 1985). Below 300 m water depth, scour density decreases (Geonautics Limited 1980) although scours have been observed in as much as 715 m of water (Praeg et al. 1986; this study). Scours in deeper water are generally deeper, straighter and longer than those on the bank tops. This is generally believed to reflect the fact that the icebergs which produce the deep water scours are larger and are driven by more consistent translatory currents (Gustajtis 1979).

A strong influence of contour-parallel, south-southeasterly currents on scour orientations is evident throughout the region (Chart 9). There is little evidence of deviation from this pattern at the present level of data analysis.

Scour depths average 1.1 in the area between Buchan and Scott Troughs to 2.1 m east of the Cumberland Peninsula. Maximum depths of 4.0 to 5.0 m are common and a single scour 11.5 m deep was measured and input to the data base during the original compilation (d'Apollonia 1983). This scour occurs south of Hecla and Griper Bank in 200 m of water. Numerous authors (Syvitski et al. 1983, MacLean 1985) note that scour depth is strongly affected by the type of sediment being scoured. This is examined in more detail in the Baffin-Davis detailed studies to follow.

Average scour widths in the Baffin-Davis region range from 36 m over Hecla and Griper Bank to 42 m between Buchan and Scott Troughs. The widest scour (306 m) is also the deepest (11.5 m). No statistical correlation between scour width and any other parameter (scour depth, water depth, sediment type) is evident and it would appear that keel shape is the single most important factor controlling the width of scours. A detailed analysis of scours on the southeast Baffin Island continental shelf by Woodworth-Lynas (1983) demonstrates that the relatively older scours are the widest. These results are borne out by this study as well (see Section 4.6.2).

4.6 BAFFIN-DAVIS STRAIT DETAILED STUDIES

Two detailed studies of scour relationships have been carried out in the Baffin-Davis region. The first attempts to document differences in scour morphology over varying substrates. The second combines systematic regional survey coverage with a knowledge of detailed bathymetry and surficial geology to illustrate the full potential use of the ice scour data base.

4.6.1 Detailed Study I

Ice scour morphology (particularly depth) is known to be controlled, at least in part, by the geotechnical properties of the material being scoured (Chari and Peters 1981). Researchers on the Baffin Shelf have observed marked changes in scour character across surface lithologic boundaries (MacLean 1985) and from area to area (Syvitski et al. 1983). The detailed study described here represents an attempt to document these changes.

Two regional lines located east of Cape Mercy were chosen for study purposes. Both traverse a contact between glacial till (Unit 2) and glaciomarine sediment (Unit 3). These two sediment types are assumed to contrast significantly with respect to their geotechnical properties. Seabed gradient in the area of the contact is low (20 m over 4 km) thus minimizing any possible influence of water depth variation on scour morphology. Scours were measured over a distance of two kilometres on either side of the contact and it is assumed that iceberg flux does not vary significantly over this 4 km distance.

The study results indicate that scour character varies between the two geologic units. Differences are best illustrated on the sidescan sonograms which show scours in the glaciomarine unit tend to be generally straight, continuous, well defined and consistently oriented. In contrast, the scours in till tend to be poorly defined, discontinous, randomly oriented and include a significant number of craters or pits. On the Huntec DTS record scours appear to be more numerous but smaller in the till unit than those in the glaciomarine sediment (Figure 43).

A statistical comparison of average depths, widths, and berm heights measured for each of the two geologic units suggests that scour depths are greater in the till unit by 0.5 m while the same scours are on the average 10 m narrower than those in the glaciomarine material. Berm heights tend to be slightly larger in the glaciomarine units although the difference is not likely significant considering the margins of error involved in estimating and measuring this parameter. Further analysis reveals that the ratio of scour depth to berm height is lower for the glaciomarine unit (mean = 1.2 m) than for till (mean = 1.7 m) indicating higher berms for a scour of a given depth in the former. These results are opposite to what was found in similar calculations for the Saglek East mosaic detailed study (Section 3.6.11). The average amount of material displaced for every metre of seabed disturbed along a scour is 25.1 m^3 for the till and only 22.5 m^3 for the glaciomarine unit. This calculation assumes a roughly triangular scour profile such that the average scour profile area is equal to one half the average scour width times the average depth.

Some of the above results are at odds with the qualitative assessment of the Huntec and sidescan records and with intuitive and theoretical concerns. Acoustically defined till (Unit 2) is believed to form only beneath grounded ice (King 1970) and is generally assumed to be gravelly, over-compacted and therefore resistant to penetration

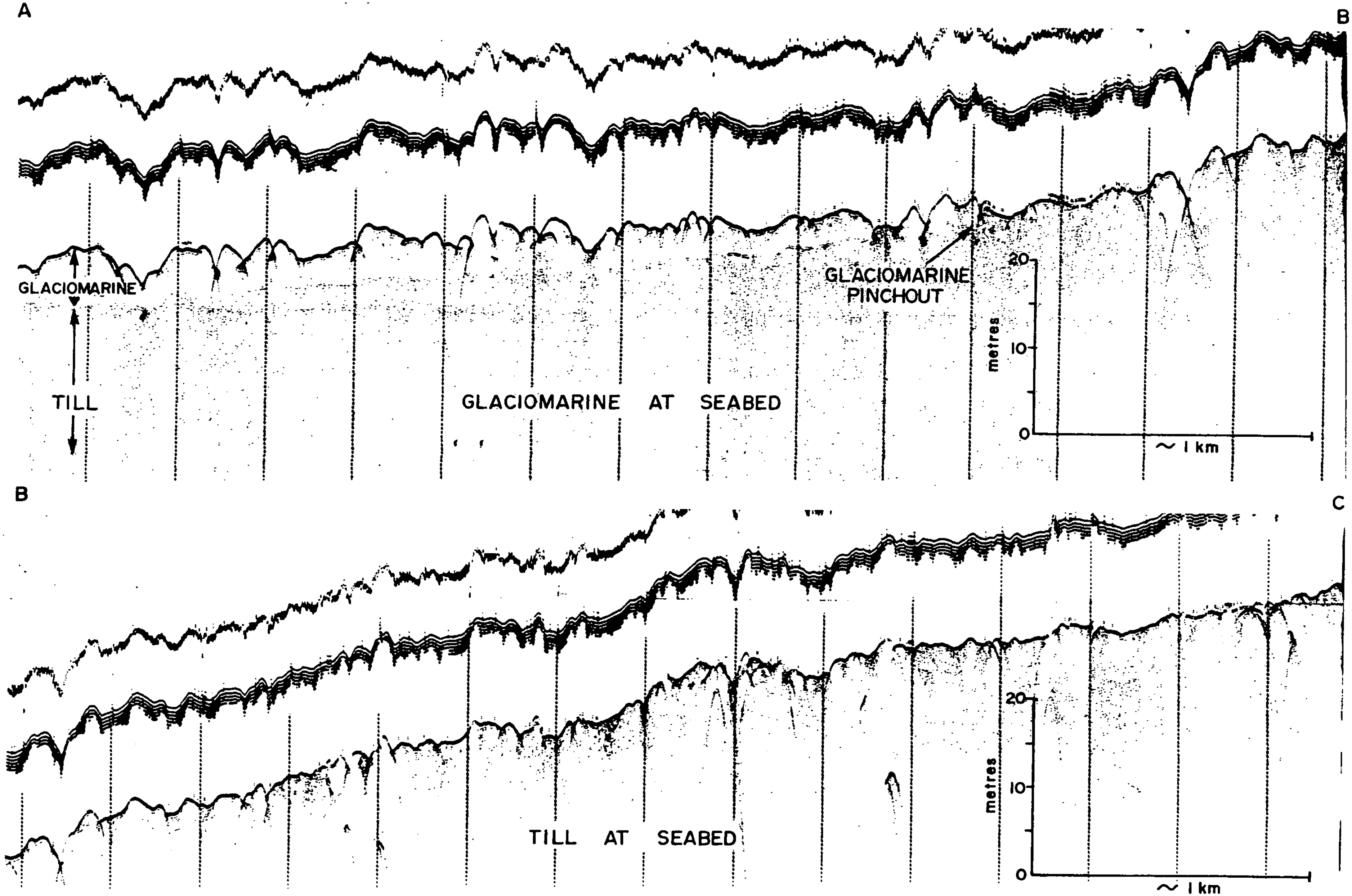

Figure 43. Huntec DTS profile across a glaciomarine/till contact showing the different character of scours in each unit.

by icebergs. Glaciomarine material on the other hand, is predominantly a muddy sediment deposited from floating ice and, therefore, much softer and more easily deformed. As such, the findings of this study, particularly concerning scour depths and average amount of material displaced, would appear to be exactly the opposite of what is expected. The only explanation to be offered is that the softer glaciomarine material is more easily eroded and therefore berm heights may be lessened and scour troughs partially filled in by the continuous action of currents. This hypothesis is supported by scour widths which are greater in the glaciomarine material. However, there is little evidence for the presence of any post scour infill on the Huntec records.

Despite the localized nature of this study and the relatively small data set, the findings suggest certain aspects of the effects that ice scouring have on surficial sediment. In light of the importance attributed to surficial sediment type, hydraulic regime and sediment budget in controlling scour character (Syvitski et al. 1983, Josenhans and Barrie 1982, Lewis et al. 1982) further research is necessary. In particular, quantitative documentation of variations in the geotechnical properties of tills and glaciomarine sediments on a regional scale may be useful. The geotechnical character of till may be expected to vary depending upon its texture, mineralogy, exact mode of deposition and post-depositional history (including sea level changes). It is expected that these variations would be at least partially reflected in the resulting scour morphology.

4.6.2 Detailed Study II

Relatively closely spaced, systematic regional sidescan and Huntec coverage in the area east and north of Cumberland Sound, combined with recently compiled surficial geology maps and bathymetric charts for the same area provide an opportunity to compare the influence of geologic and bathymetric factors with the observed scour characteristics.

The study area covers roughly 65,000 km^2 east and north of Cumberland Sound (Figure 44). The continental shelf in this area is roughly 200 km wide and characterized by a generally smooth to gently sloping seabed. A bedrock controlled trough extends southward into the northeast corner of the area and a slight depression extends across the shelf from the mouth of Cumberland Sound.

Detailed geological and geophysical studies including seismic reflection and refraction, magnetometer, gravity, Huntec DTS and sidescan sonar surveys, as well as surface sampling and shallow drilling have been carried out within the study area over the past decade (Grant 1972, MacLean et al. 1977, 1978, MacLean and Falconer 1979; MacLean et al. 1982). Huntec DTS and sidescan sonar data collected during two separate BIO research cruises (HU 80-028 and HU 80-035) are employed as a data base for this study. Lines trend east-west at roughly 10-15 km spacing in water depths of up to 350 m.

In nearshore areas (<100 m), the seabed is characterized by predominantly Precambrian bedrock overlain by a thin, discontinuous cover of mixed sand and gravel. In deeper water, deposits of glacial drift (till) and glaciomarine sediments of varying thickness predominate. Local pockets of recent silts and clays occur in deeper water near the shelf edge and in Cumberland Sound.

Results of the data analysis are presented on Charts 10 and 11. Initial implications of these results are discussed here. The data set utilized is available as an integral part of the east coast ice scour data base.

Chart 10 illustrates percent seabed disturbance, maximum scour depth and orientation data superimposed on a bathymetric base. Three separate areas, outlined on Chart 10, are particularly interesting. Area 1 is dominated by a local relative seabed high, east of Cape Mercy. This high is elongate in a north-south direction and heavily scoured on both its northern, "upstream" (with respect to the Baffin

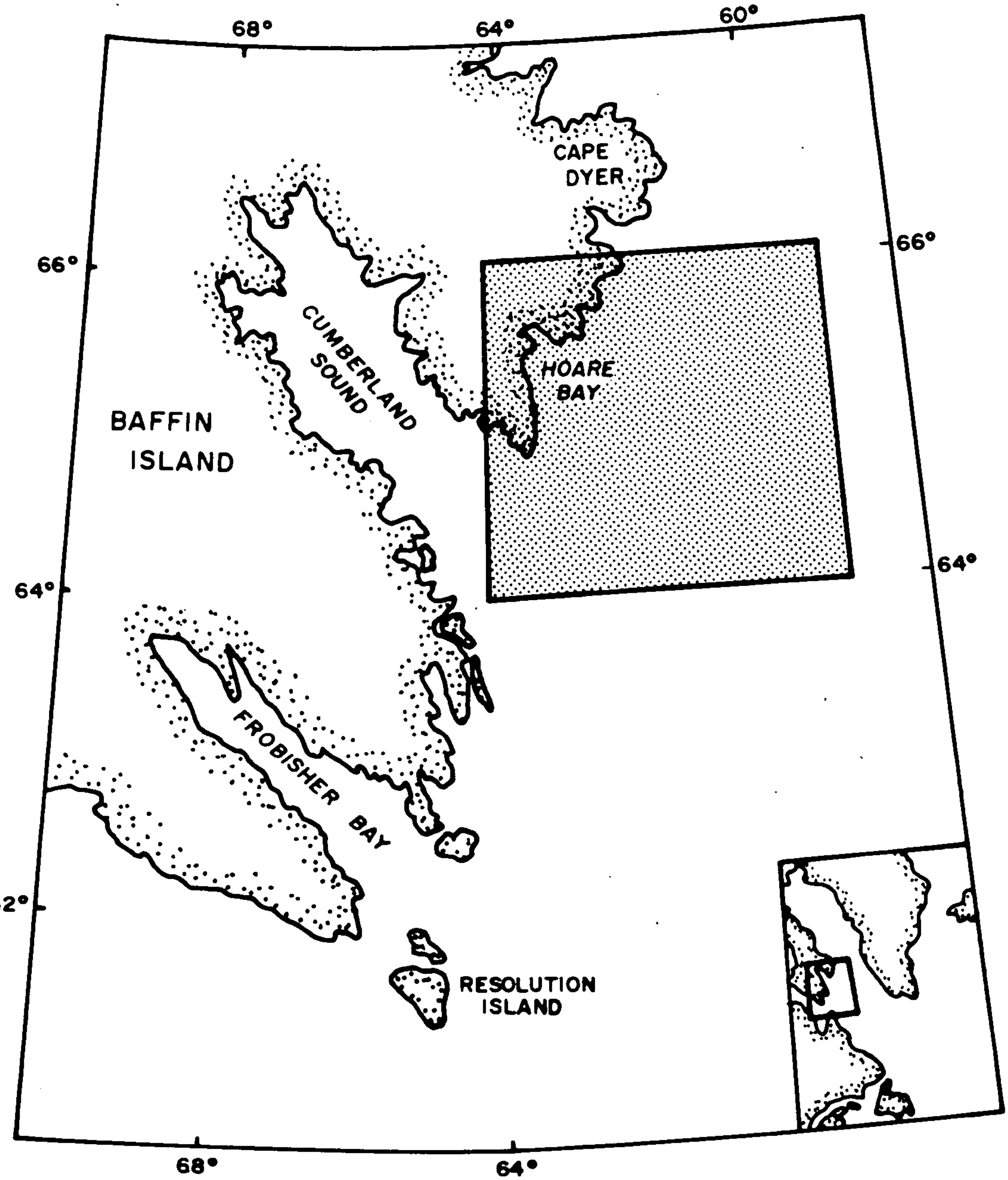

Figure 44. Location of Baffin-Davis Region Detailed Study II.

Current and iceberg flux, as inferred from scour orientation measurements), and southern, "downstream", ends while scour density is low over its eastern and western flanks and moderate over the top. Heavy scouring on the northern end may be explained by exposure to southward drifting icebergs. The reason for high scour density on the "downstream" end and lack of scouring along the flanks, is more problematic. Local current fluctuations, possibly created by the seabed topography itself, would appear to be the most reasonable explanation. A similar situation has been reported by Woodworth-Lynas et al. (1984a) who observed higher numbers of grounding and scouring icebergs behind a bathymetric barrier across the north end of Makkovik Bank and suggest this is due to bathymetrically controlled currents which divert icebergs around the ridge. Once behind the barrier, some of these icebergs become entrained in rotary currents (eddies) as reflected by their looped trajectories, (Woodworth-Lynas et al. 1984a; 1984b) and may, as a result, be carried back against the regional current. A similar scenario seems plausible here to explain high scour density on the "downstream" end of the ridge in question. Obviously, in light of suggestions to shelter seabed installations behind large berms and the need to identify areas with low scour potential, the phenomenon observed here, and on the Labrador Shelf, requires further investigation.

Area 2 on Chart 10 covers a southeast trending ridge and trough oriented perpendicular to iceberg flux (as inferred from scour orientations). Low scour density within the trough itself reflects sheltering by the ridge and a general inability of most icebergs to increase their drafts after crossing the ridge. A similar situation occurs in the Karlsefni trough on Saglek Bank (see Section 3.6). High scour density is observed on shallower portions of the ridge, whereas low density of scours is observed along the seaward side of this ridge.

In contrast to the pattern discussed above, it is the deeper portions of the entrance to Cumberland Sound which appear to have sustained the heaviest scouring (Area 3). Farther east along the depression which extends from the mouth of the Sound, scour density is again reduced in the deeper areas. Scour orientations trend nearly parallel to the trough in this area. Considering the anomalous scour density distribution and orientations, and the depth of water in the entrance to Cumberland Sound, it may be that the scour population observed here is relict and not related to the modern iceberg regime. However, in light of the poor quality of sidescan records over this particular area, additional data is required to confirm the validity of the observed pattern.

Existing data for the detailed study area indicates low scour densities in nearshore areas. This most likely reflects a shortage of data and poor scour registration due to the presence of a generally thin surficial cover unit over hard bedrock, rather than a low rate of ice keel groundings. The incidence of sea ice and small icebergs impacting the seabed every year in these areas would in fact be expected to far exceed that of large icebergs scouring in deeper water.

Chart 11 illustrates the distribution of two parameters, percent disturbance of the seafloor by scouring and maximum scour depths, superimposed on the surficial geology of the area. Aside from the apparent low scour density over a portion of Unit 2 (Baffin Shelf Drift), there appears to be no obvious regional correlation between seabed geology and percent disturbance or scour depth. Two small areas of stratified Davis Strait Silt (Unit 3a) are characterized by low scour density but also coincide with depressions on the seafloor. It is believed these bathymetric depressions protect the seabed from scouring and therefore preserve the character of Unit 4a. These observations support the distinction between Units 4a and 4b which is based on the degree of disturbance by icebergs.

The apparent lack of correlation between maximum scour depths and geologic unit on Chart 11 is surprising considering the relationship between the geotechnical properties of the seabed (i.e. sediment strength) and scours made by icebergs (Chari and Peters 1981). An obvious complicating factor here is water depth. A number of studies have suggested that scour depths are controlled to a certain extent by water depth, mainly as a function of the size and momentum of the icebergs (Lewis 1978, Lewis and Barrie 1981), the hypothesis being that larger icebergs scour in deeper water and, because of their increased mass, have the potential to produce deeper scours.

In an attempt to separate the effects of water depth and geology on scour depth, plots of mean maximum scour depth versus water depth are shown for each geologic unit within the study area (Figures 45 and 46). For each unit, mean maximum scour depth is expected to show a general increase with water depth. Based on the available data set, no such simple relationship is evident. Complicating factors include insufficient data for a given bathymetric interval, bathymetric control on the distribution of certain geologic units (for instance, Unit 3 is never found in water depths of less than 250 m) and control of scour depth by the thickness of the surficial unit. This latter factor is particularly suggested by Unit 3b which is often observed on sub-bottom profiles to be completely penetrated by scours, with no evidence of disturbance of the underlying material (see Figure 47). In addition, an assumption that the geotechnical properties of a given geologic unit are everywhere equivalent is probably not valid. A plot of data from all of Unit 2 (Figure 46) incorporating as large a data set as possible over as wide a range of water depths as possible (150 to 350 m), indicates a preferred mean maximum scour depth between 240 and 260 metres. It is interesting to note that this is very similar to the relationship found on northeastern Grand Bank (Section 2.6).

A frequency distribution curve for maximum scour depth of the complete detailed study data set indicates a roughly exponential distribution (Figure 48). This agrees with the findings of other

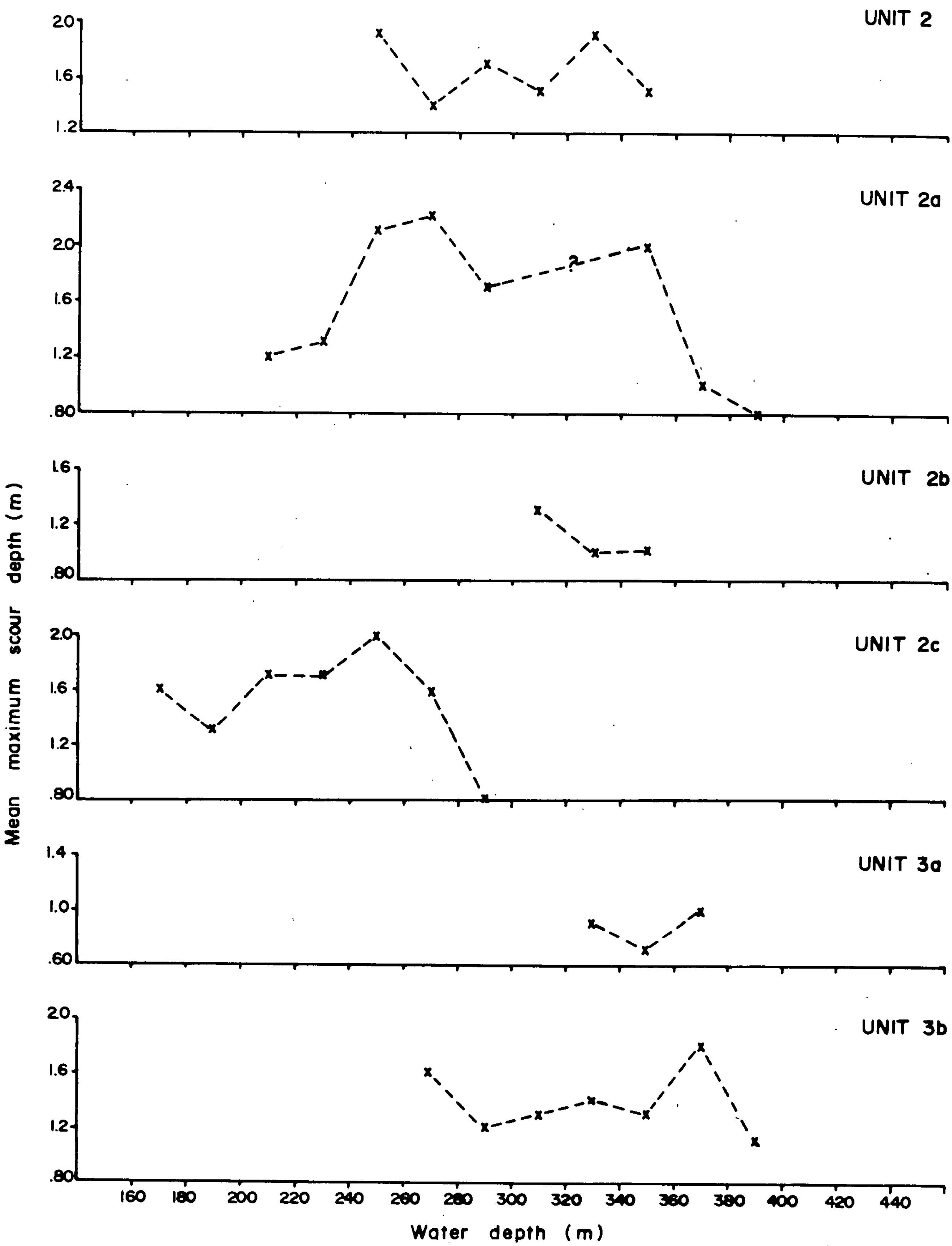

Figure 45. Loci of mean maximum scour depths for each geologic unit scoured in the Detailed Study II area.

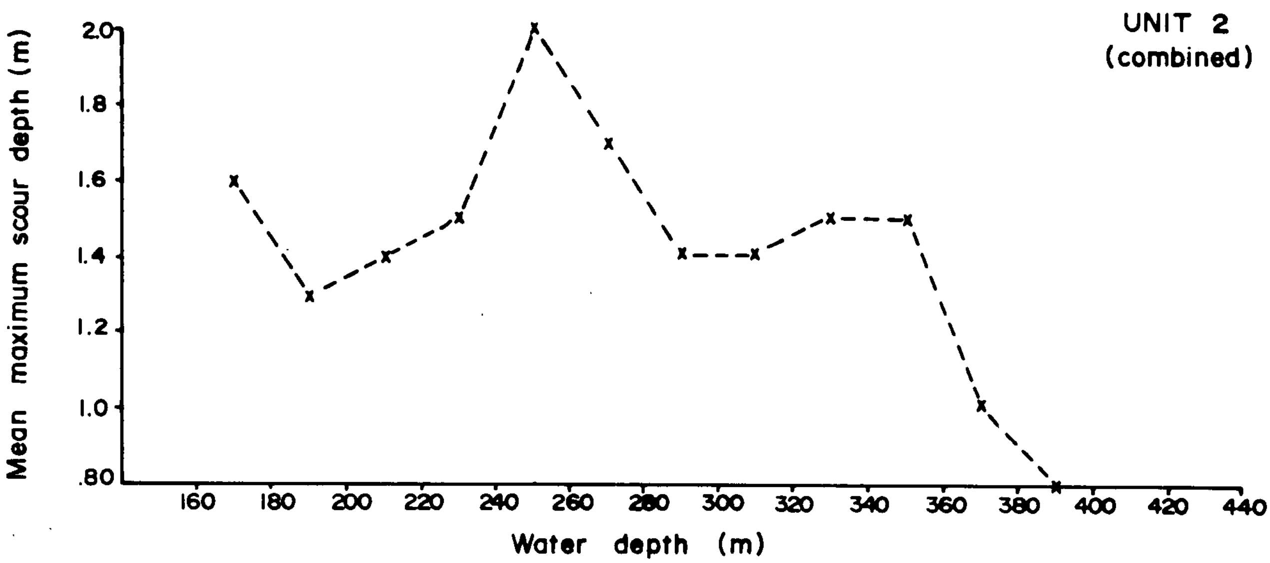

Figure 46. Locus of mean maximum scour depth for geologic unit 2 (till) in the Detailed Study II area.

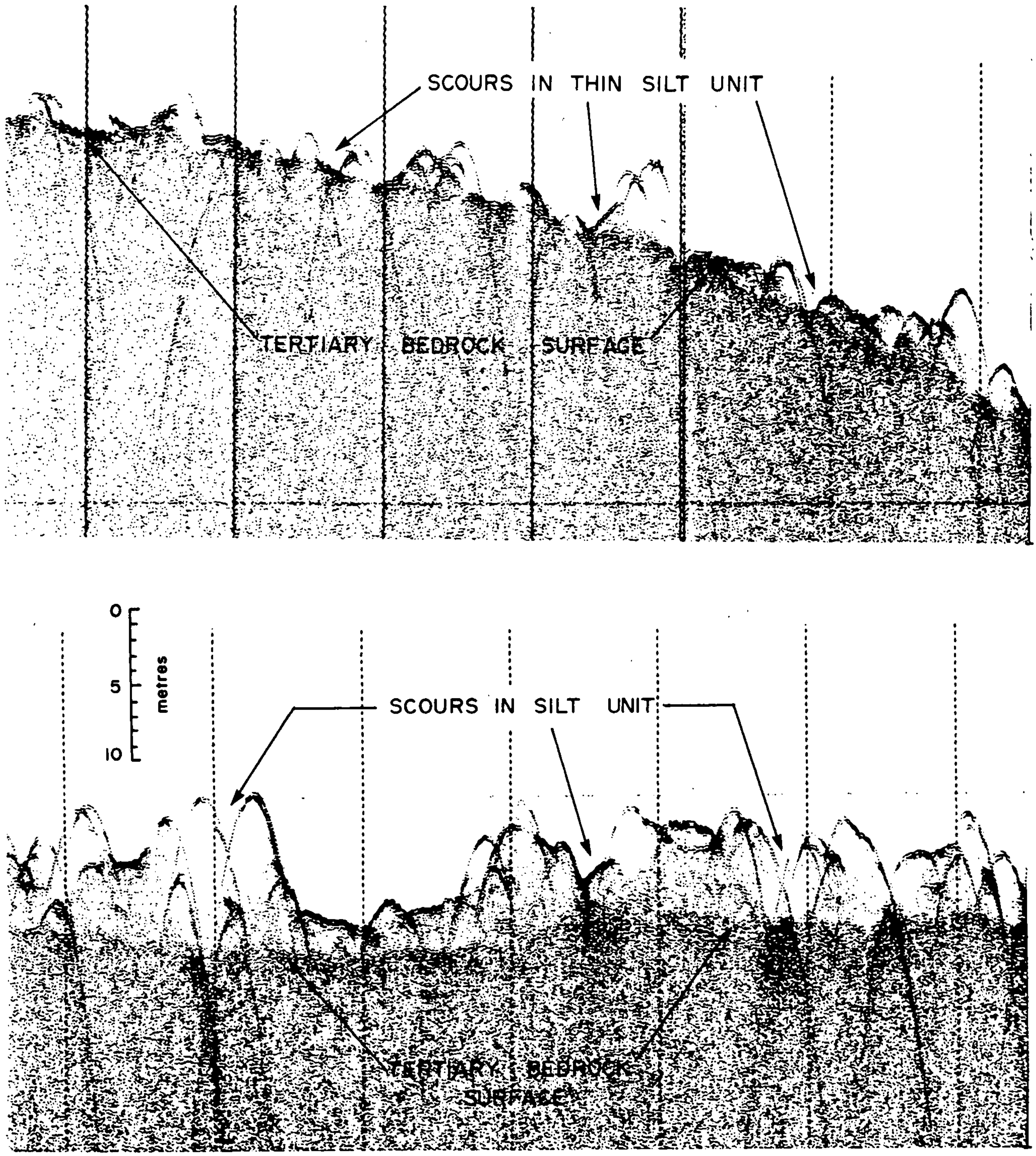

Figure 47. Iceberg scours in the Davis Strait Silt unit offshore of Cumberland Sound. The deepest scours penetrate the upper, relatively soft unit to its base both in areas of thin and thicker cover (above and below) but are never observed to cut the Tertiary bedrock surface beneath the Davis Strait Silt.

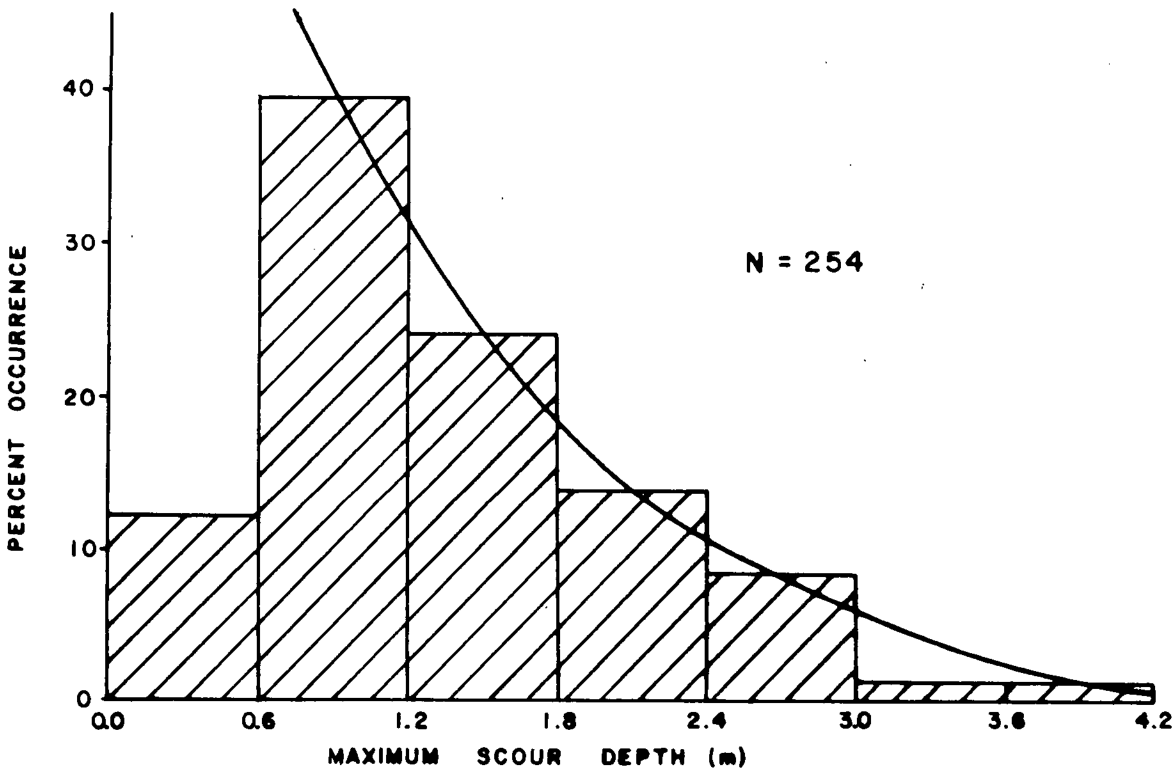

Figure 48. Maximum scour depth vs. percent occurrence. Total data set, Baffin Detailed Study II.

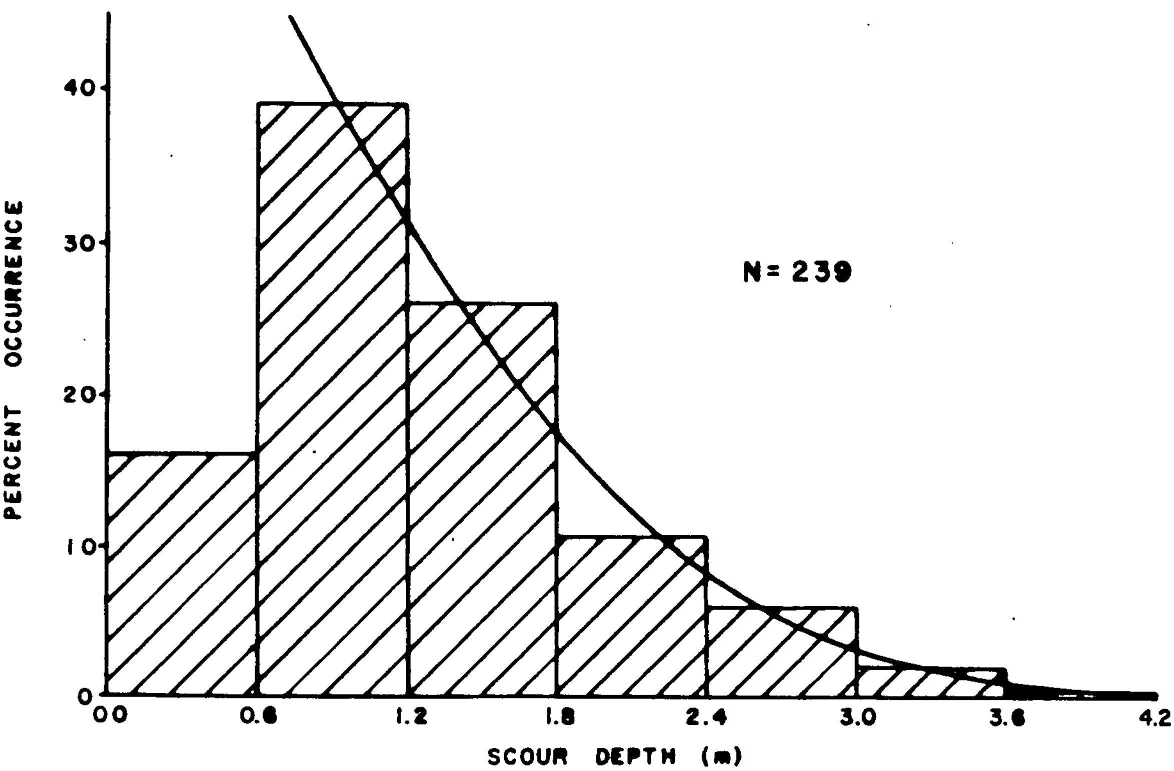

Figure 49 Scour depth vs. percent occurrence. Update data only, Baffin Detailed Study II.

workers carrying out studies in widely separated areas (Lewis 1978, Barrie 1980), and also with findings for the other ESRF regions in this report. The low numbers of scours apparent in the 0.0-0.6 m size class probably reflects the inability of the interpreters to confidently recognize and measure features of this small size. A plot of depth frequency for all measured depths (Figure 49; ESRF update data only) is remarkable in its resemblance to the curve for maximum depths and indicates a high degree of compatibility between pre-ESRF data (maximum depths measured only) and update data.

For pre-ESRF data, the average maximum scour width measured was 92 m. This contrasts with an average maximum of 56 m and an average width of 42 m for the latest update data. It would appear that whereas the eye is automatically drawn to the deepest scour on a Huntec record, the same obviously does not apply to the measurement of scour width from sidescan sonograms. Woodworth-Lynas (1983) documents oldest scours (as defined by cross-cutting relationships) as being widest. Since the oldest scours are generally poorly preserved (due to hydraulic reworking and segmentation by younger scours), they would be much less likely to be measured on a routine basis. Instead, preference is given to the sharpest, most continuous scours which, according to the data presented here, tend to be relatively narrow. This presumably applies to the entire ESRF data base and caution is advised when combining pre-ESRF and update data for purposes of regional statistical analysis of scour widths. For engineering purposes, the measurements of the maximum scour widths within sample areas should be considered to provide a conservative set of data relating to the lateral extent of seabed disturbance by individual iceberg scouring events.

5.0 LANCASTER SOUND REGION

5.1 INTRODUCTION

The Lancaster Sound region covers all of Lancaster Sound from Baffin Bay in the east to Barrow Strait in the west, all adjoining fiords and inlets (Strathcona Sound, Croker Bay, Maxwell Bay), and most of Jones Sound (Figure 50). Lancaster Sound itself is essentially a broad trench with depths of 900 metres at its eastern entrance, becoming gradually shallower towards the west until finally reaching a sill at 180 metres across Barrow Strait. The northern margin of the sound is much steeper than its counterpart, being controlled by a Mesozoic - Tertiary fault along the south side of Devon Island (Lewis et al. 1977). Rectilinear faults, possibly of the same age, control the major fiords in the region.

Islands in the Lancaster Sound region are underlain by flat-lying to gently undulating Paleozoic carbonate rocks. Lancaster Sound itself, and other main channels in the surrounding area (Jones Sound, Prince Regent Inlet), are grabens produced during a Cretaceous-Tertiary down-faulting episode (Kerr 1977) and are thus probably underlain by carbonate rocks. A major basin occupying the northern half of western Lancaster Sound contains a 1,300 m sequence of poorly consolidated Tertiary-Pleistocene clastic sediments (Lewis et al. 1977). A similar, but smaller, basin underlies Barrow Strait.

Studies of the Quaternary sedimentary history of Lancaster Sound indicate that net accumulation is occurring only in isolated basins off northwest Baffin Island and northern Somerset Island (Buckley 1971, Bornhold and Lewis 1976). In other areas, particularly in nearshore zones and Barrow Strait, a combination of vigorous current activity and iceberg scouring contribute to net erosion of the seabed (Wise 1971, Lewis et al. 1977).

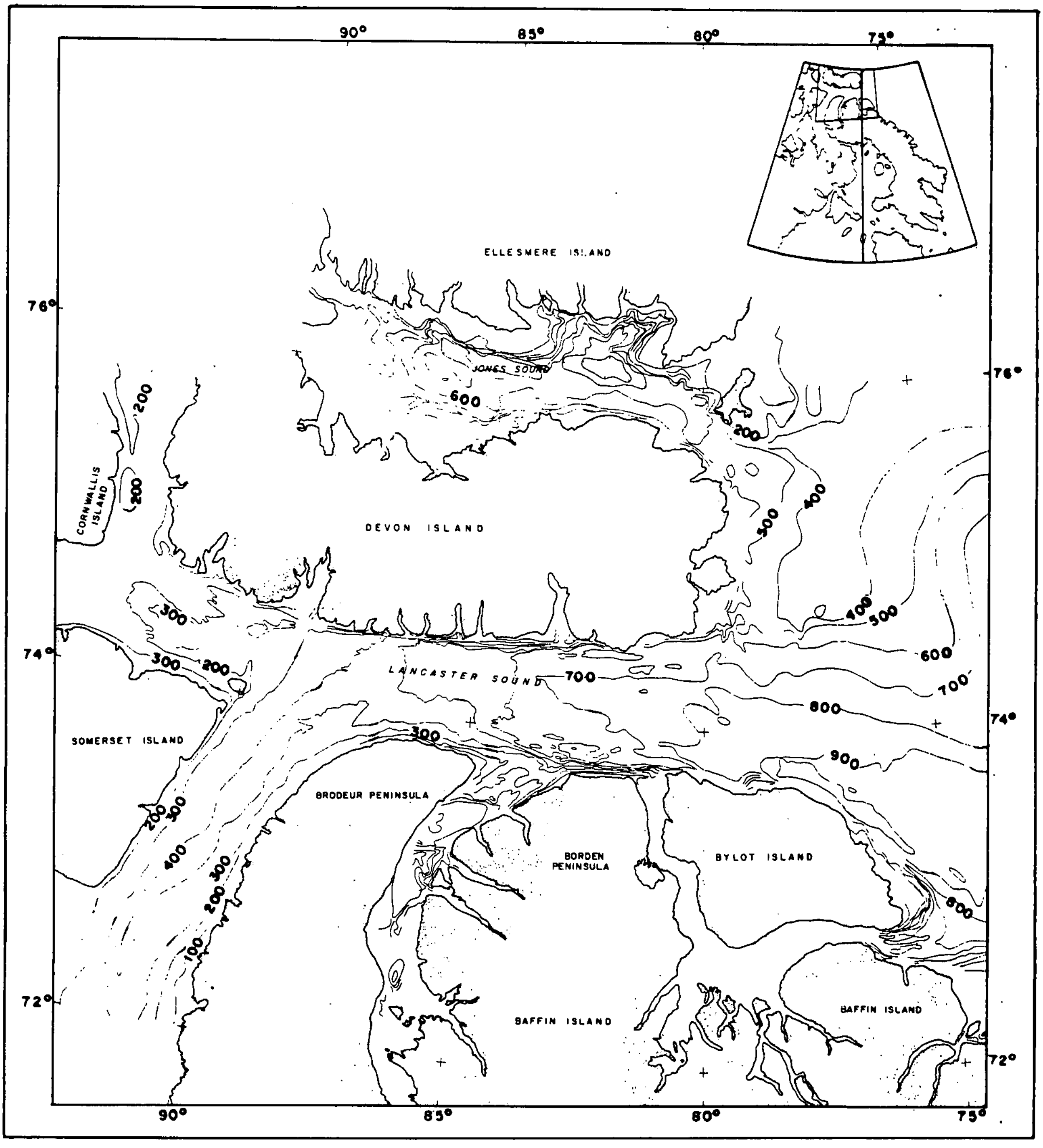

Figure 50. Physiography of Lancaster Sound Region.

The floor of Lancaster Sound is covered in large part by firm, silty mud with varying admixtures of sand and gravel (Lewis et al. 1977). Sediments generally become more clay-rich towards the deeper water region near the eastern entrance to the Sound while inshore areas are generally sandier and commonly blanketed by a subangular gravel lag (Wise 1971; Lewis et al. 1974; Birschl 1982). Investigations near glacier margins along the south shore of Devon Island reveal the presence of coarse, bouldery till deposits in these areas (Lewis et al. 1977).

The major fiords in the region are characterized by a gravel lag in shallow water and fine muds or sandy turbidites in the deep basins. Little is known of the surficial geology of Jones Sound.

Table 6 lists the generalized geologic sequence employed during data compilation for this report. Notably, analysis of existing sidescan and Huntec data revealed no significant deposits of till within the region although Lewis et al. (1977) suggest that portions of the patchy sand/gravel veneer over bedrock in nearshore areas (Unit 5) may represent reworked till. The extensive silty muds with admixtures of sand and gravel mentioned earlier appear as a stratified to unstratified, often heavily scoured unit on high resolution seismic records (Unit 3). These have been interpreted as pebbly glaciomarine muds deposited from a floating ice shelf (Lewis et al. 1977) but may also contain a significant component rafted by drift ice.

A Green Paper published by DIAND on the use and management of the Lancaster Sound region (Dirschl 1982a) concludes that iceberg hazard is higher in the eastern part of Lancaster Sound than anywhere else in the Arctic Archipelago. This not only poses a problem for offshore exploration in the region but also threatens shipping, being the eastern entrance to the Northwest Passage. Hence, detailed knowledge of both modern iceberg flux through the area and the record of scouring on the sea floor is essential when planning for the safe development of regional resources.

Table 6

Geologic Sequence, Lancaster Sound Region

UNIT OR CODE	DESCRIPTION OF GEOLOGIC UNIT
5	Sand and gravel veneer. Restricted to nearshore areas. Represents reworked glaciomarine material and glacial till (?). May exist as lag over bedrock or as veneer capping older sediments. May include ice rafted sediments.
4	Ponded silt and clay. Recent sediment. Found only in isolated basins off NW Baffin Island and northern Somerset Island (Lewis et al. 1977).
3	Glaciomarine. Silty mud with varying admixtures of sand and gravel. Covers extensive regions of Lancaster Sound. Heavily scoured in places. Well-stratified on Huntec DTS records where not scoured.
2	Glacial till. Full extent unknown. Generally restricted to glacier margins along south Devon Island. Coarse, bouldery, unsorted deposits.
1	Consolidated bedrock. Predominantly flat-lying to gently dipping Paleozoic carbonates. Minor Tertiary-Pleistocene clastics in NW Lancaster Sound and Barrow Strait.

5.2 DATA COVERAGE

A listing of the cruises from which data has been compiled is given in Appendix 5.

5.3 OTHER DATA SOURCES

No alternative data sources for the Lancaster Sound region have been identified thus far. A moratorium on all petroleum exploration activity currently exists for the region. Due to environmental and biological concerns, this ban may become permanent (OILWEEK May, 1984).

5.4 DATA COMPILATION - METHODOLOGY AND LIMITATIONS

There is a paucity of survey data for Lancaster Sound region. In general, all available data of suitable quality has been analysed and compiled into the data base.

5.5 SCOUR SUMMARY

Due to the lack of sidescan and Huntec coverage, relatively little is known about ice scour distribution and variability in the Lancaster Sound region (Chart 12). However, existing records and published information permit the following general observations.

Nearshore, shallow water (<50 m) areas throughout the region are characterized by an abundance of short scours and craters wherever surveyed (Lewis et al. 1977). These features are interpreted to be related to sea ice impacts similar to those found in the Beaufort Sea (Lewis et al. 1977). In many cases, an ubiquitous nearshore gravel and cobble pavement may inhibit scour development. Detailed studies carried out in Radstock Bay (Lewis et al. 1977) reveal that ice scouring is most prominent on the seaward side of shoals and exposed headlands in this area, again suggesting action by drifting sea ice. Due to generally steep seabed gradients (up to 45°), the nearshore scour zone tends to be extremely narrow.

In deeper water portions of Lancaster Sound (>50 m), abundant evidence of scouring by drifting icebergs exists, both in the published literature (Lewis et al. 1977, Lewis et al. 1980) and on the records analysed for data base compilation. The furrow-like scours have been described as being "typical" (Lewis et al. 1980) and generally appear relatively fresh (see Lewis et al. 1977). Abundant scour features are present along portions of Huntec records from cruise 76-025 in water depths >250 m; these features are almost certainly relict scours (e.g. see Lewis et al. 1977). The stiff, muddy character of sediments at the seafloor and presumed very low sedimentation rates over most of the area ensure that iceberg scours are registered and preserved.

Data base statistics on scour dimensions and abundance tend to show low to moderate scour densities over much of the area in water depths of 200-250 m or less. High scour densities exist over the sill at the entrance to Barrow Strait. In this area scour depths are restricted by the thickness of surficial cover (see Lewis et al. 1977). Measured scour widths for the region average 33.7 m with a maximum recorded width of 68 m. Lewis et al. (1979) report moderate scour depths of 2 m over the sill across the mouth of Maxwell Bay on Devon Island (100-160 m water depth). Scours on the seaward side of shoals and headlands at Radstock Bay are approximately 3 m deep, 6 m wide and 30 m long (Lewis et al. 1977). These were very likely produced by wind driven sea ice.

Iceberg drift patterns, prevailing winds and surface water circulation are all fairly well known for Lancaster Sound itself (Riggs et al. 1980, Dirschl 1982a, b). During the period 1958-1976, 1,400 icebergs were observed in the Sound. Most are believed to be Greenland icebergs carried in by an incursion of the Baffin Current. Maximum drafts of 300 m have been recorded. Eighty-three percent of the observed icebergs did not penetrate farther than 100 km into the Sound and only six percent reached Barrow Strait. Most hugged the south shore of Devon Island where an estimated 1-2 icebergs per day converge on shore (Dirschl 1982a).

Considering the above discussion of scour occurrence and iceberg drift in the Lancaster Sound region, a number of targets for further study come to light. More detailed studies are required in Barrow Strait especially regarding iceberg provenance considering the high density of scouring, apparently by relatively few icebergs. More data on scour frequency, depth and degradation are required along the southeast coast of Devon Island where iceberg flux is high. No available data on scours or geology yet exists for Jones Sound.

6.0 DISCUSSION AND RECOMMENDATIONS

6.1 SUMMARY DISCUSSION

As it now stands, the East Coast Ice Scour Data Base represents a significant, comprehensive source of information concerning iceberg scour characteristics and distribution on the eastern Canadian continental margin. Systematic measurement of iceberg scour parameters and related seabed characteristics relevant to sea bottom engineering concerns have been made from available regional and site-specific sidescan sonar and sub-bottom profiler data collected by the Atlantic Geoscience Centre and offshore oil exploration companies. This data base is complimentary to a similar ESRF-sponsored ice scour data base compiled for the Beaufort Sea region Gilbert and Pederson 1986 but is much more comprehensive in terms of the size of the area it encompasses and the volume of survey data utilized during compilation.

Present data base holdings represent the result of work by a number of individuals over the past several years. d'Apollonia and Lewis (1981) first established the data base with funding available through the Panel on Energy Research and Development (PERD). Subsequent additions to the data base were made by d'Apollonia (1983) and Todd (1984). The Environmental Studies Revolving (now Research) Funds awarded Geonautics Limited separate contracts in 1983 and 1984 to update the data base through incorporation of available regional and site-specific survey data. The result is a data base containing scour measurements from some 5074 separate three square kilometre seabed sample areas extracted from AGC regional survey data, and a detailed scour catalogue for northeastern Grand Bank compiled from a total of 25 site-specific survey data sets collected by Mobil Oil Canada Ltd. and its partners under Canada Oil and Gas Lands Administration (COGLA) guidelines. An additional 67 site surveys carried out on the Grand Banks, Labrador Shelf and Baffin Island Shelf by various operators have been reviewed for suitability of future inclusion in the existing data base and this information is presented as an inventory in this report. The inventory includes all surveys for which reports were available as of March 1988.

Preliminary analysis of scour information contained in the east coast ice scour data base (site-specific data not included) was carried out by Geonautics Limited as part of the latest update studies. This analysis included: (i) a review of the magnitude of several potential sources of error and variability in the data base holdings (validity study); (ii) a compilation of regional iceberg scour characteristics based on existing data base holdings; and (iii) a detailed study of local iceberg scour characteristics and controls for each of the study regions (excluding Lancaster Sound).

(i) Validity

The validity study examined three separate issues which are categorized as (i) errors; (ii) interpreter variability; and (iii) natural variability. Errors in the data base were considered to include blatant mistakes such as improper coding by the analyst, keypunch entry errors and scaling (measurement) errors. Based on reanalysis of a random sample of 50 sample areas, keypunch entry errors were found to be much less than 1%, while scaling and/or analyst entry errors exist for less than 3% of the data base entries. Interpreter variability was found to result in variance of roughly 10 to 30% for parameters such as scour depth, scour width and berm height. This variance largely reflects the subjective nature of interpreting acoustic records. Isolated instances of much higher variability were also documented, but are generally restricted to areas of complex seabed geological conditions such as exist in nearshore areas (eg. ice scours in areas of bedrock outcrop partially covered by sand and gravel). Finally, remeasurement of scour widths in at least two places along each of 127 scours has shown that the natural variability of this parameter may be as high as 50%, with an average of 20 to 25%. It is assumed that the natural variabiliity of this parameter, and all others, is well represented by the sample of the total scour population which is contained in the data base, within the limits of interpreter variability identified above.

(ii) Regional Iceberg Scour Characteristics

At the regional level, data base holdings indicate that scour density and character do vary from area to area, most likely as a result of variations in the size of icebergs as they drift southward, changes in the relationship between the Labrador Current and major bathymetric elements (banks, troughs), and differences in relative sea level history over the past 10,000 year (post-Wisconsinan) period. As a general observation, scours are shallower, narrower and less linear in bank-top areas, reflecting formation by relatively smaller icebergs driven by weaker currents across seabed conditions which are relatively competent due to subaerial exposure and subsequent transgression during recent geologic history.

Scour depth distributions for any given area roughly fit an exponentially decreasing function and, to a point, average scour depth is observed to increase with water depth as noted by previous workers (Lewis and Barrie 1981; Barrie 1980). Scour depth and width statistics for the four study regions are summarized in Table 7. It has been observed that the maximum scour depth in any given sample area was consistently measured, whereas the widest scour (which is generally the oldest and most degraded) was usually not recorded during the most recent update procedure. For the purposes of scour risk assessment it should be remembered that the data base holdings represent a statistical sample of a cumulative population created over the past 10,000 years or more.

Recent data on iceberg drafts (Hotzel and Miller 1983) and interpretive observation of acoustic records both indicate that modern scouring of the seabed is rare in water depths greater than roughly 230 m. Also, as pointed out by d'Apollonia and Lewis (1981) and

TABLE 7

ICEBERG SCOUR SUMMARY

	Grand Banks	Labrador	Baffin-Davis	Lancaster
Average Scour Depth(m)	0.9*	1.35	1.6	2.0
	1.4**			
Average Scour Width(m)	29.6*	34	39	33.7
Maximum Scour Depth(m)	14.0	11.0	11.5	N/A
Maximum Scour Width(m)	97.0*	326	306	68

* water depths less than 90m

** water depths greater than 90m

others, scours are subject to hydrodynamic and benthic degradational processes which will ultimately lead to obliteration of any given feature. As such, the present data base holdings most likely represent somewhat of an underestimation of certain parameters such as scour depth, scour width, berm height, percent disturbance and scour occurrence since only a fraction of the scours measured can be considered to be "fresh".

(iii) Detailed Studies

In addition to the regional aspects of iceberg scouring on the Canadian east coast a number of detailed investigations of local scour regimes have also been carried out for each of the Grand Banks, Labrador and Baffin Island-Davis Strait regions. These studies serve to illustrate the level of information afforded by the data base and also reveal peculiarities in scour distribution and character which can arise under local conditions. While the details of these studies are presented in the body of this report, certain aspects of this work are worth summarizing here.

All three detailed studies demonstrate very well the role of local bathymetry and currents in controlling the distribution of iceberg scours. For instance, the results of the Saglek East detailed study illustrate not only the ability of icebergs to dynamically adjust their drafts while scouring up-slope and down-slope, as has also been revealed by Woodworth-Lynas et al. (1986), but also indicate that the amount of material displaced by the keel can vary by as much as 100%. At the entrance to the Avalon Channel, detailed studies show that as water depth decreases the number of scours increases and scour depths become shallower, presumably reflecting impacts by more numerous, but smaller, icebergs. In this area scours are generally oriented perpendicular to bathymetric contours indicating again that icebergs have been driven up-slope by the dominant current. Finally, results of the Baffin-Davis Detailed Study II have shown that eddies in the dominant current, possibly created by local bathymetric features, can result in icebergs impacting the seabed in areas which would otherwise be considered to be sheltered from such impacts. This phenomenon has also been observed on Makkovik Bank, Labrador Shelf (Woodworth-Lynas et al 1984a) and, together with the observation of existing scours which traverse significant changes in bathymetry, serves to indicate that the concept of bathymetric sheltering as a means of protecting seabed installations must always be considered in light of local oceanographic and bathymetric conditions, and the existing scour record.

The detailed study results also reveal some interesting trends in scour depth distributions. In all cases, the frequency distributions of scour depths are found to roughly fit decreasing exponential function. More interestingly, however, separate plots of mean maximum scour depths (per individual sample area) against water depth for the northern sector of Grand Bank and the southeast Baffin Island shelf both show a peak at 240 to 260 m water depth. While this correlation may be coincidental, it is equally as possible that it may represent an episode of iceberg flux common to the eastern Canadian margin. It is this type of evidence, with its obvious implications for a better understanding of the Quaternany and recent history of shelf areas, together with the quantitative measurements of critical scour parameters (such as depth) which make the existing east coast ice scour data base a valuable resource.

As a final observation, it is now evident from the results of this work, coupled with empirical and qualitative considerations, that the distribution and morphology of iceberg scours on the eastern Canadian margin are directly and indirectly controlled by a myriad of factors including the size of the iceberg, the shape of the keel, the strength of the keel, the nature of the driving forces, the geotechnical properties of the seabed and the nature of local hydrodynamic conditions as they may affect scour preservation/degradation.

6.2 RECOMMENDATIONS

(i) In terms of current vernacular, the east coast ice scour data base may be considered to represent a comprehensive geographic information system (GIS). Common to all such systems is the constant need for more and better information. As such, it is recommended that the ice scour data base be updated on a yearly basis through incorporation of ice scour information from ongoing AGC surveys and wellsite survey data as it becomes available.

(ii) In all future updates of the data base it is recommended that the analysis methodology documented in this report (Section 1.3) be adapted and adhered to.

As has been noted by d'Apollonia Associates (1987) and in Section 1.5 of this report, modifications to the method of analysis and data organization over time has led to inconsistencies in certain parameters. This, in turn, creates problems in performing valid statistical analysis of the data base holdings. It is felt that the expanded scour catalogue which is provided through the latest methodology will allow for a better understanding of the iceberg scouring process and its relationship with the seabed and environment.

(iii) Quality control procedures should be established and implemented in all future updates. An importan=t element in this process is duplicate analysis of random samples during the data analysis phase in order to best account for the "fatigue" factor. Other elements of data base verification are discussed by d'Apollonia Associates (1987).

(iv) Detailed and rigorous analysis of the data base holdings should be undertaken as the first step towards an improved understanding of the scour process.

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APPENDIX 1

VALIDITY STUDY HISTOGRAMS

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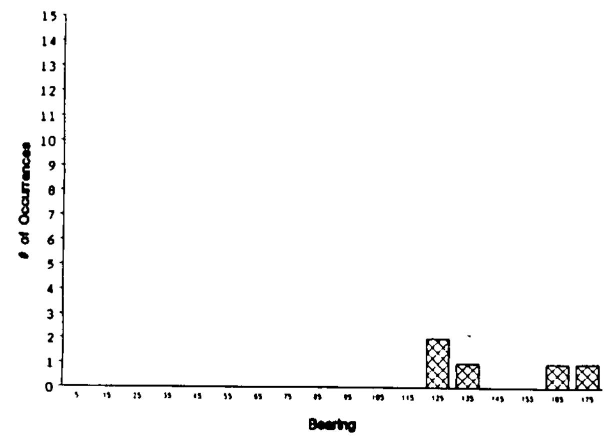

Remeasured

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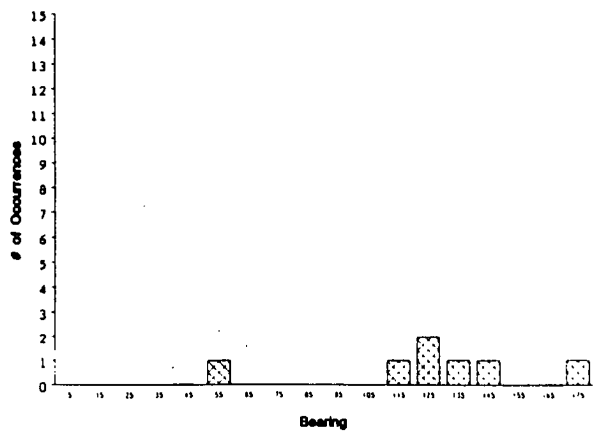

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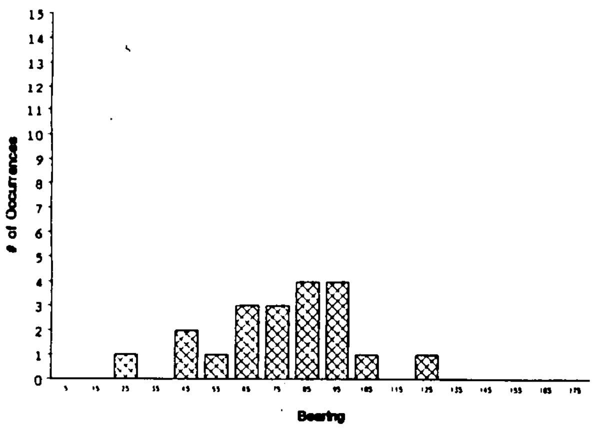

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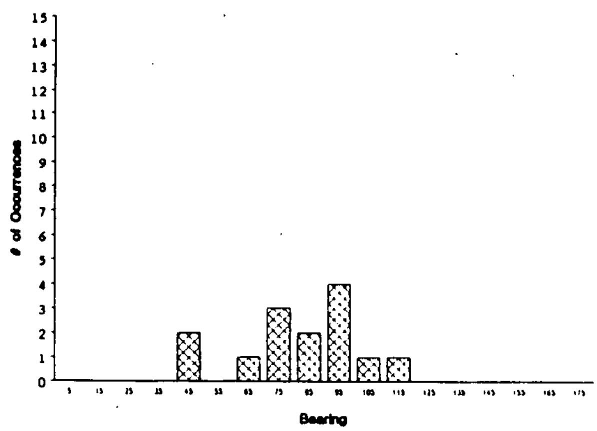

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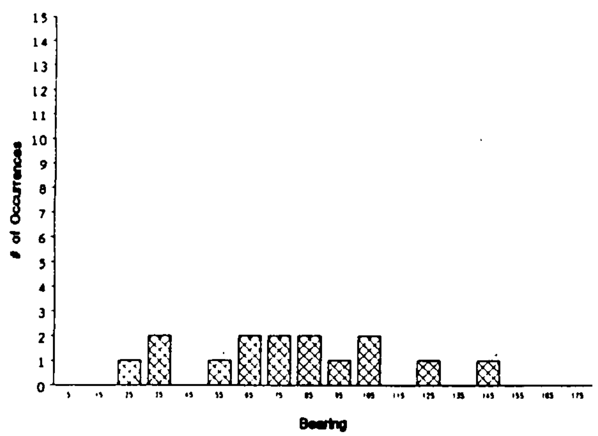

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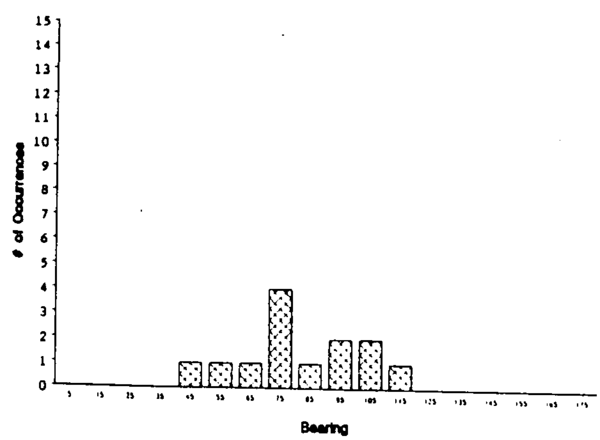

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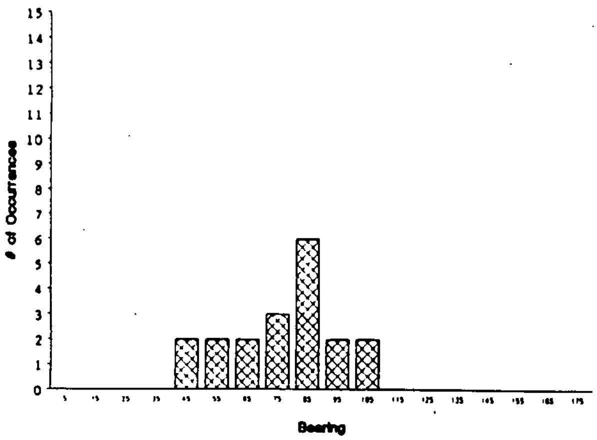

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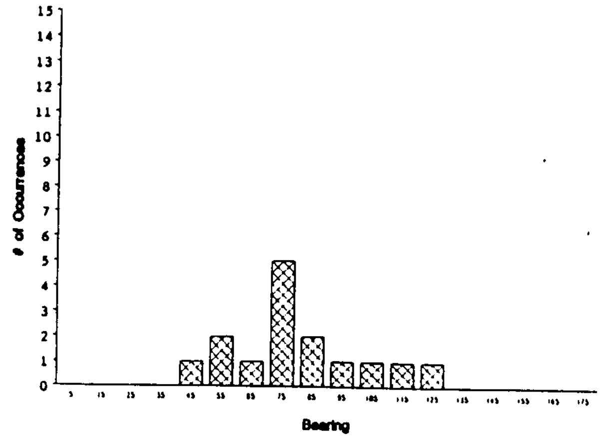

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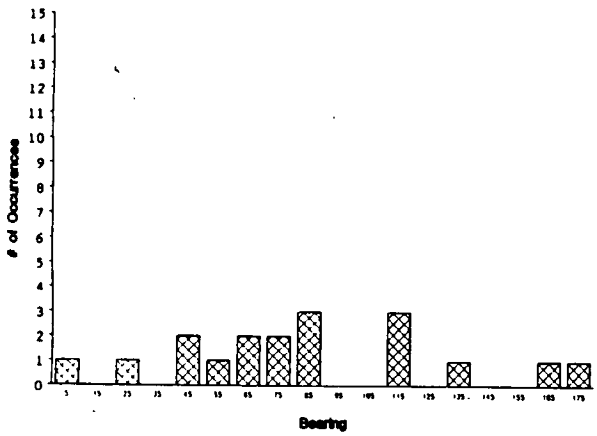

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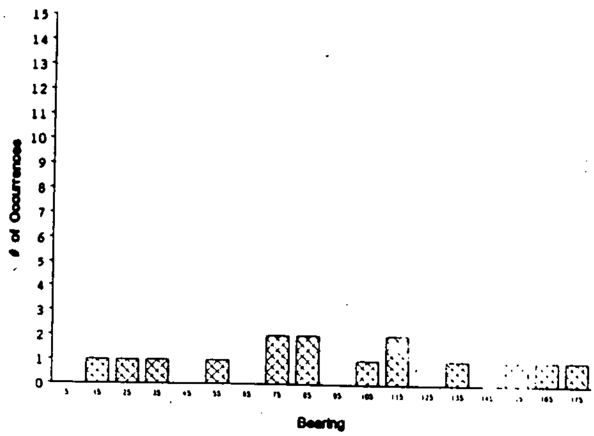

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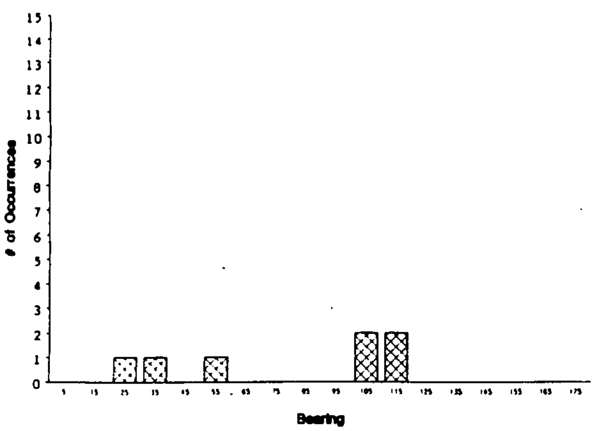

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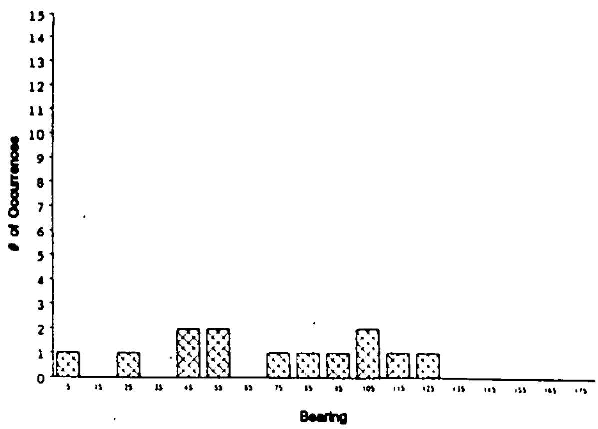

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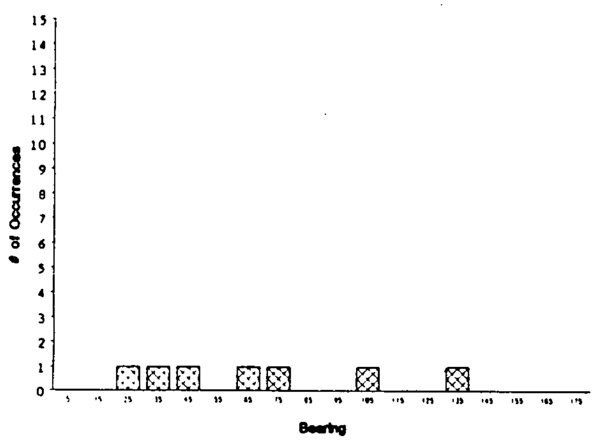

Remeasured

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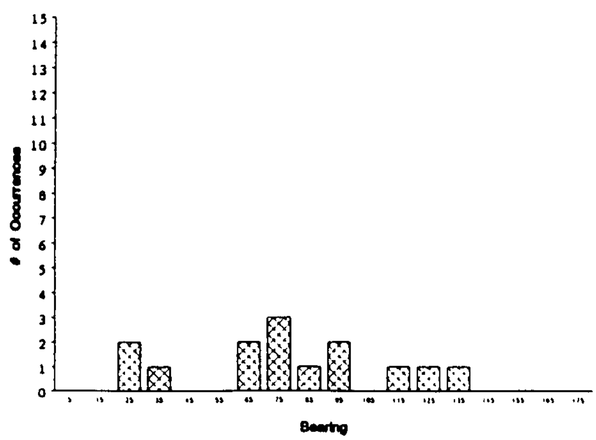
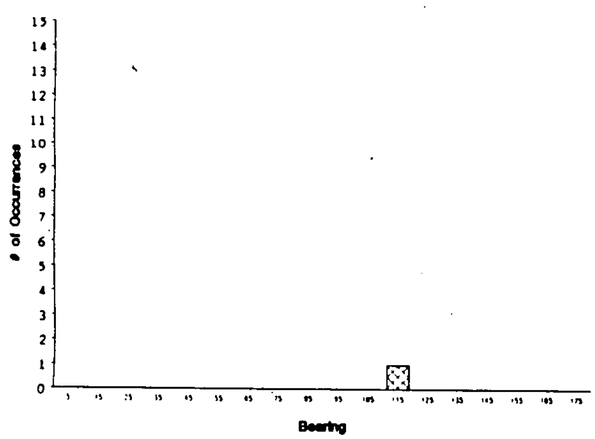


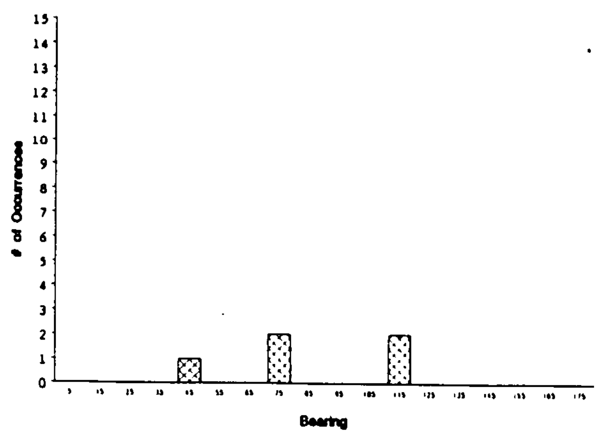
Existing

NAME=DAP CRUISE=78029 DAY=293 START=625 END=640



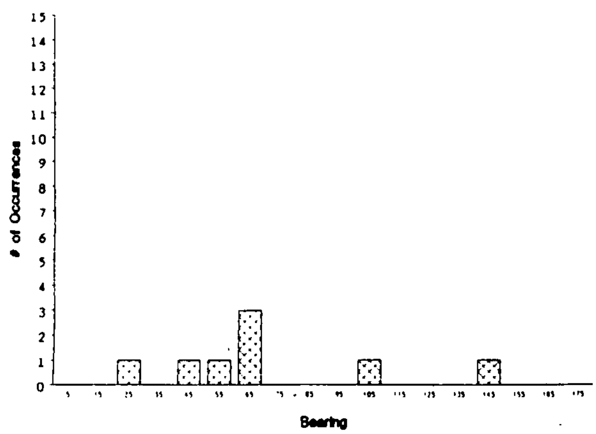
Remeasured

NAME=CUMMING CRUISE=78029 DAY=293 START=625 END=640



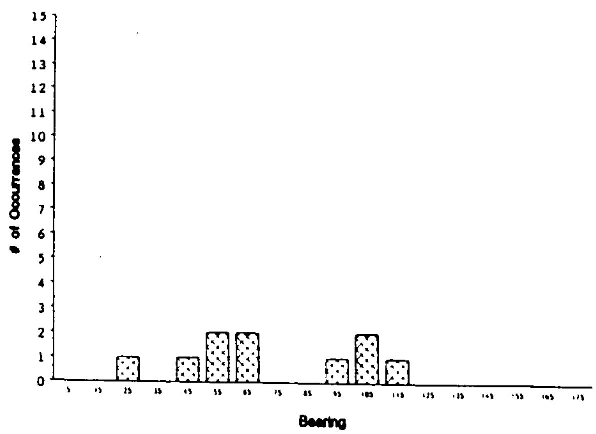
Existing

NAME=DAP CRUISE=78029 DAY=293 START=925 END=940



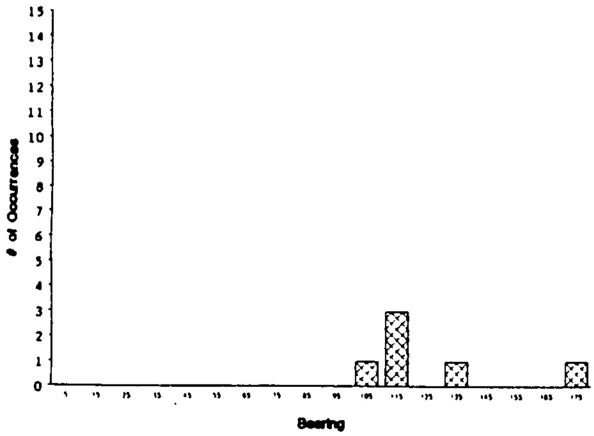
Remeasured

NAME=CUMMING CRUISE=78029 DAY=293 START=925 END=940



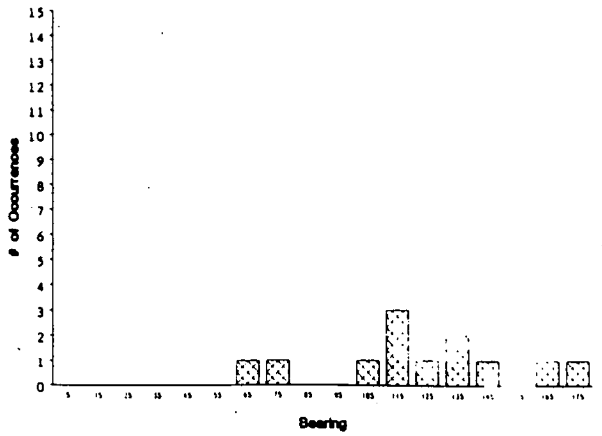
Existing

NAME=DAP CRUISE=78029 DAY=293 START=955 END=1010



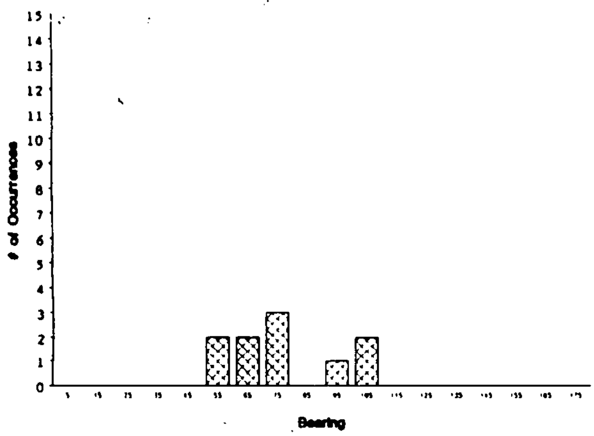
Remeasured

NAME=CUMMING CRUISE=78029 DAY=293 START=955 END=1010



Existing

NAME=DAP CRUISE=78029 DAY=293 START=2020 END=2035



Remeasured

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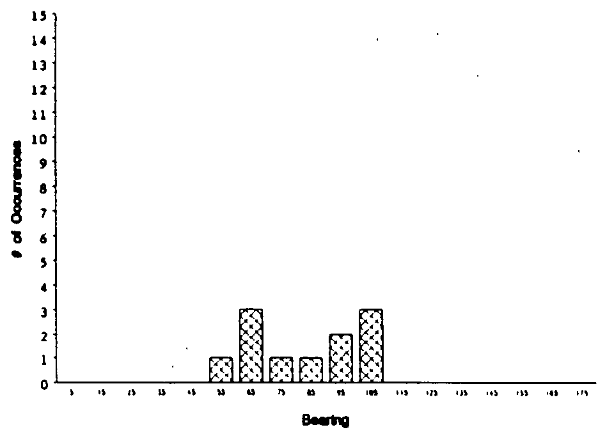
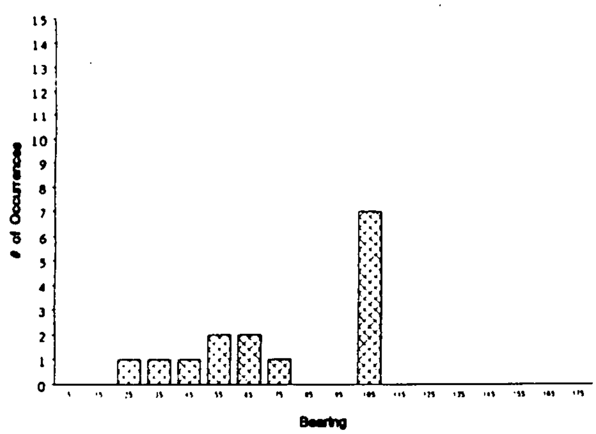


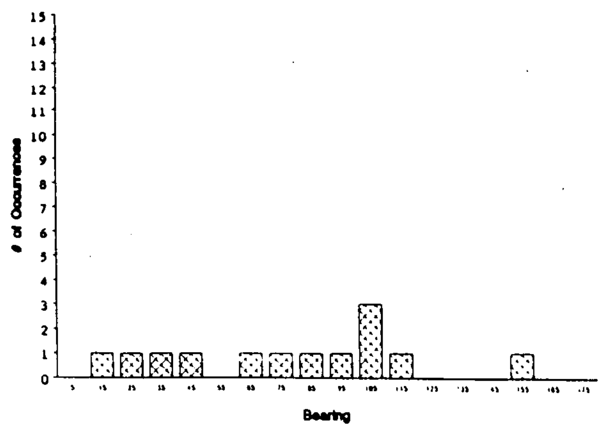
Existing

NAME=DAP CRUISE=78029 DAY=293 START=2050 END=2105



Remeasured

NAME=CUMMING CRUISE=78029 DAY=293 START=2050 END=2105



Existing

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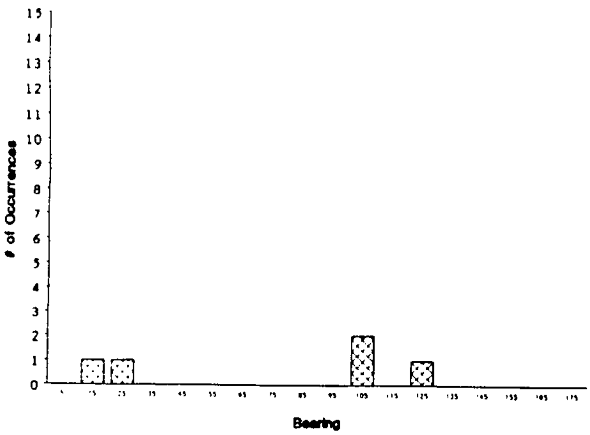
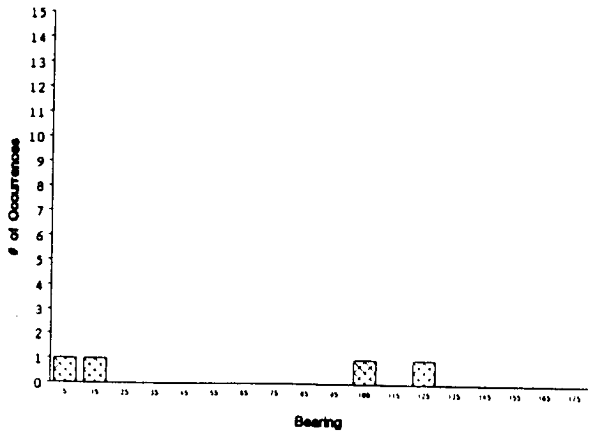


Remeasured

NAME=CUMMING CRUISE=78029 DAY=294 START=35 END=50



Existing

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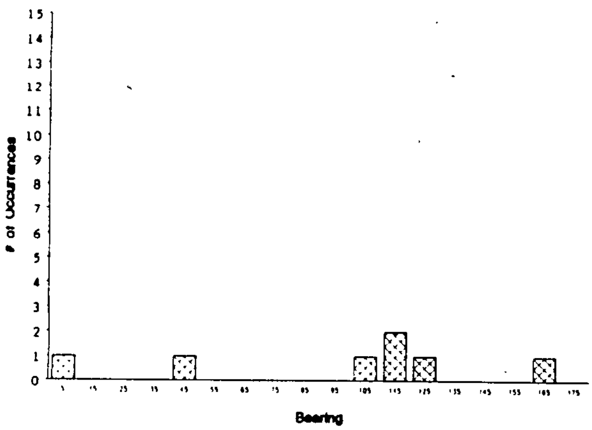
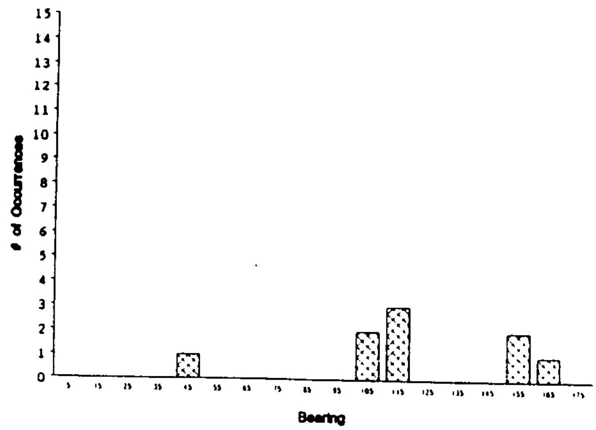


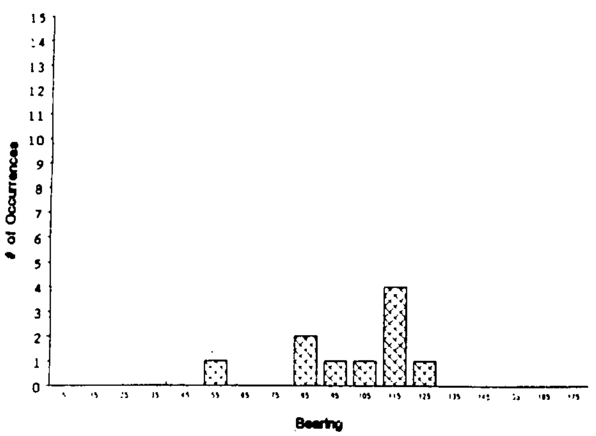
Remeasured

NAME=CUMMING CRUISE=78029 DAY=294 START=105 END=120



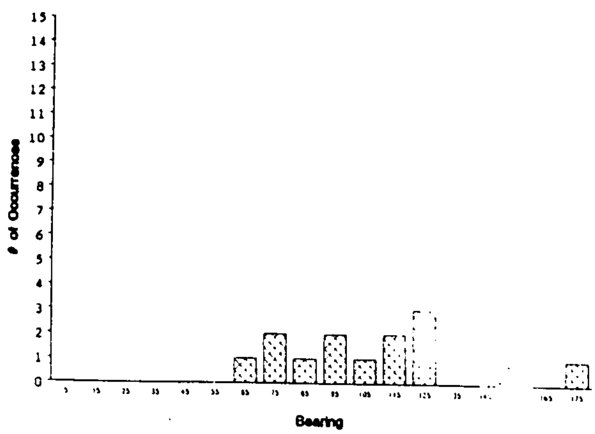
Existing

NAME=DAP CRUISE=78029 DAY=294 START=135 END=150



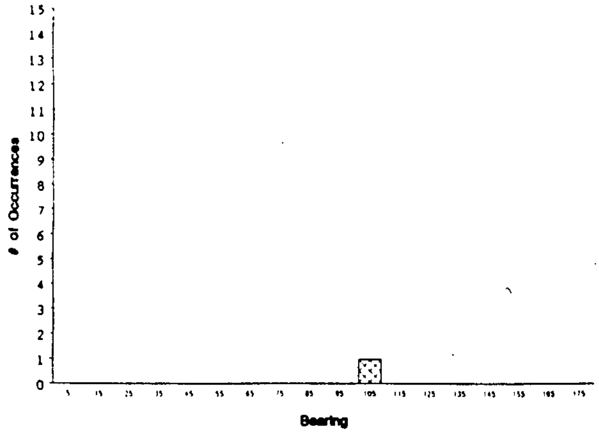
Remeasured

NAME=CUMMING CRUISE=78029 DAY=294 START=135 END=150



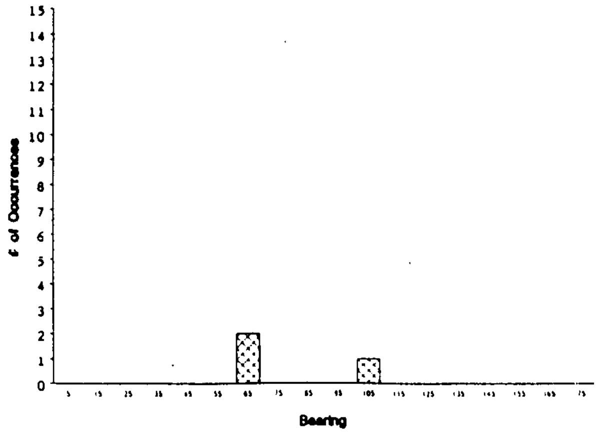
Existing

NAME=DAP CRUISE=79019 DAY=223 START=2220 END=2240



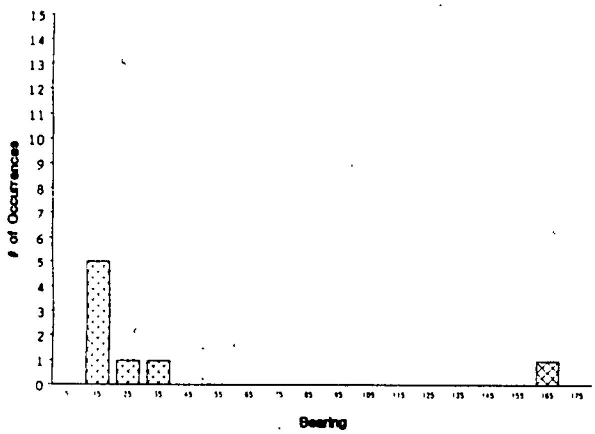
Remeasured

NAME=CUMMING CRUISE=79019 DAY=223 START=2220 END=2240



Existing

NAME=DAP CRUISE=79019 DAY=224 START=1440 END=1500



Remeasured

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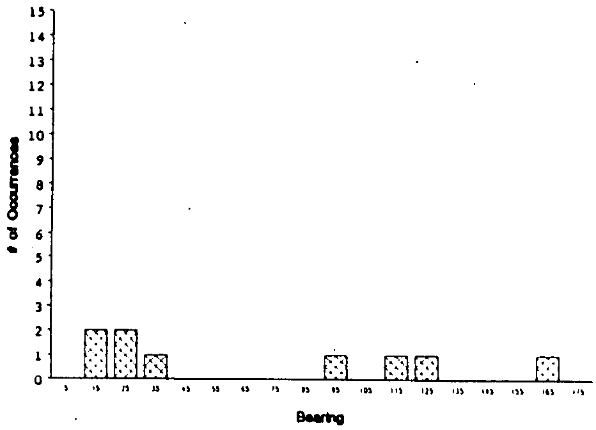

Existing

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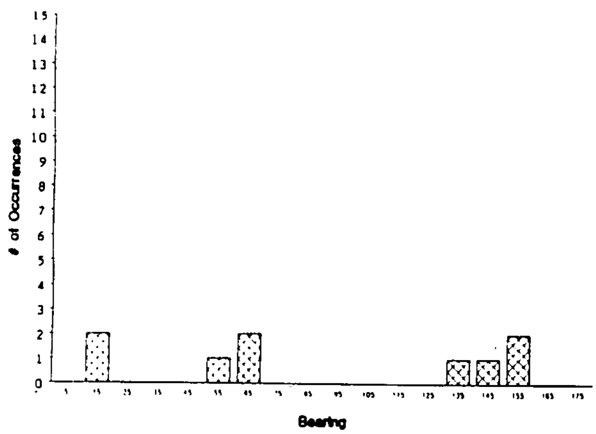

Remeasured

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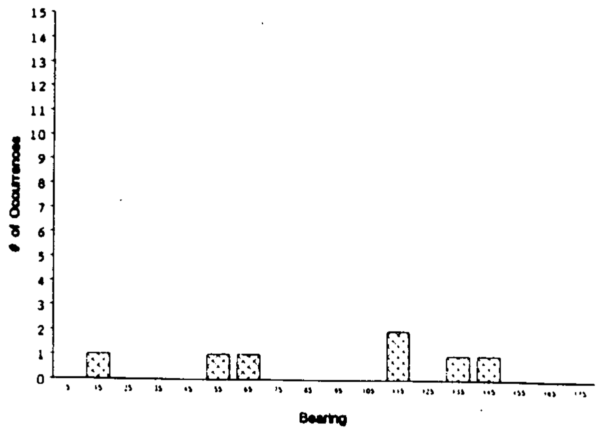

Existing

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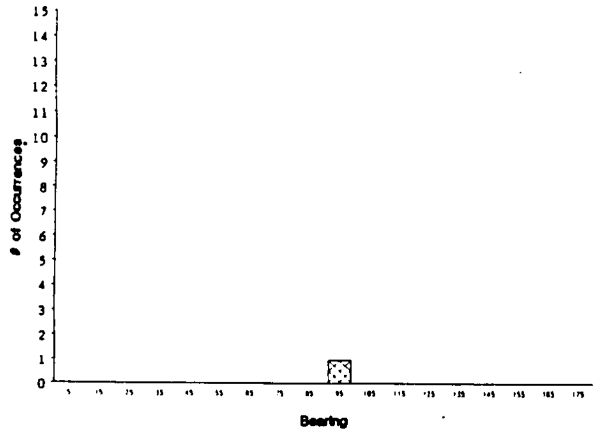
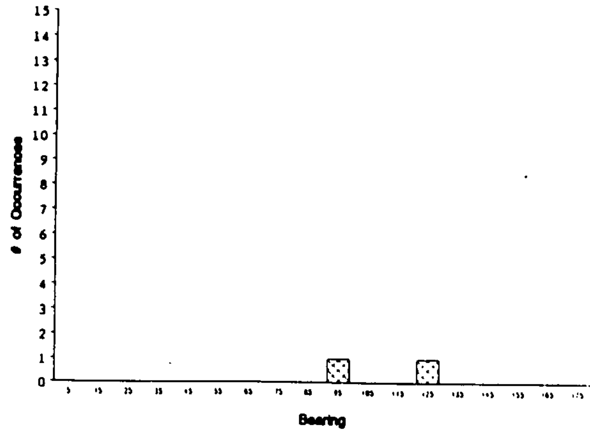


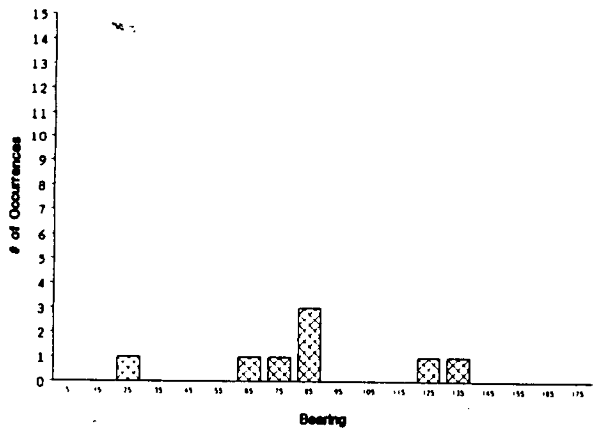
Remeasured

NAME=CUMMING CRUISE=79019 DAY=233 START=200 END=215



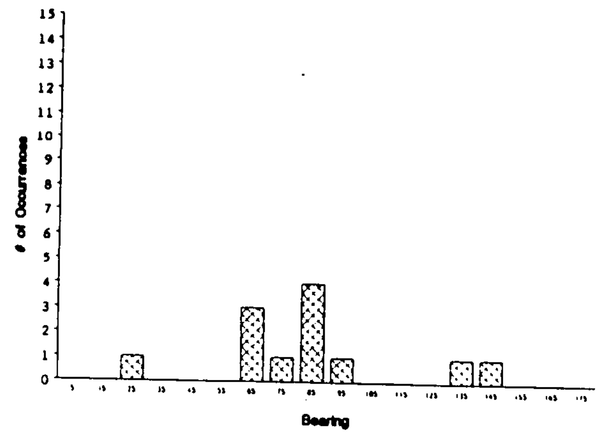
Existing

NAME=DAP CRUISE=79019 DAY=238 START=2300 END=2312



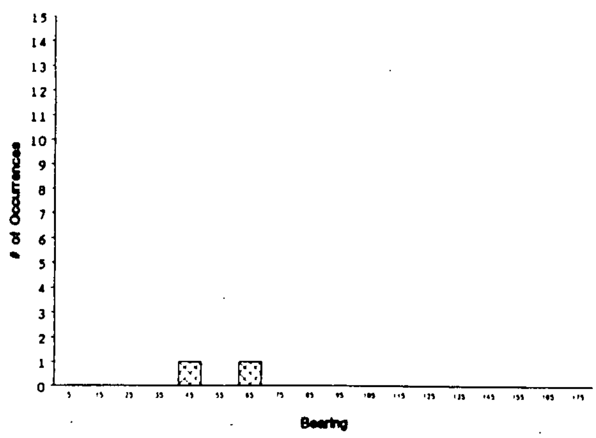
Remeasured

NAME=CUMMING CRUISE=79019 DAY=238 START=2300 END=2312



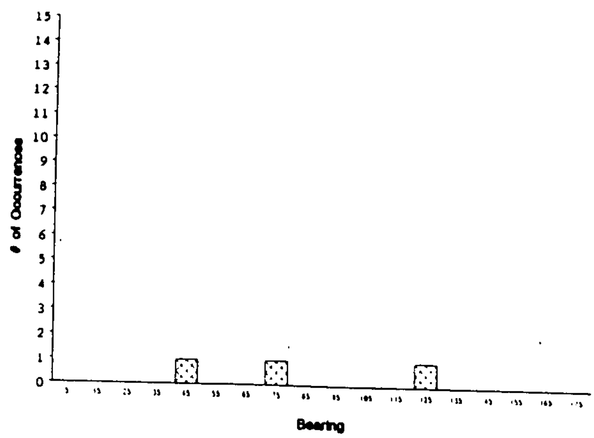
Existing

NAME=DAP CRUISE=79019 DAY=238 START=2346 END=2357



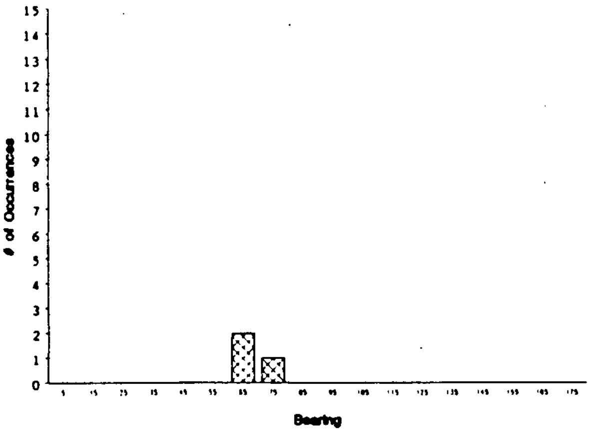
Remeasured

NAME=CUMMING CRUISE=79019 DAY=238 START=2346 END=2357



Existing

NAME=DAP CRUISE=80010 DAY=122 START=1400 END=1410



Remeasured

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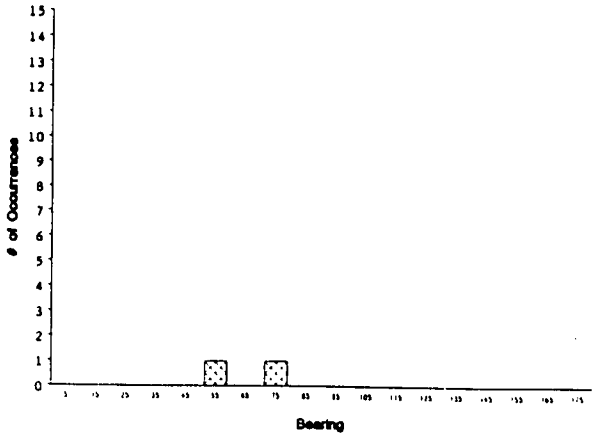
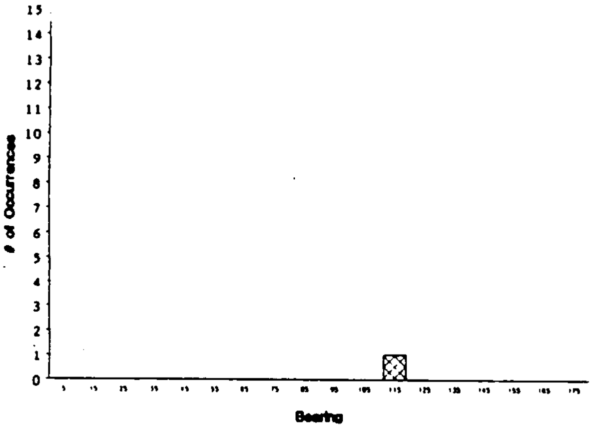


Existing

NAME=DAP CRUISE=80010 DAY=122 START=1440 END=1450



Remeasured

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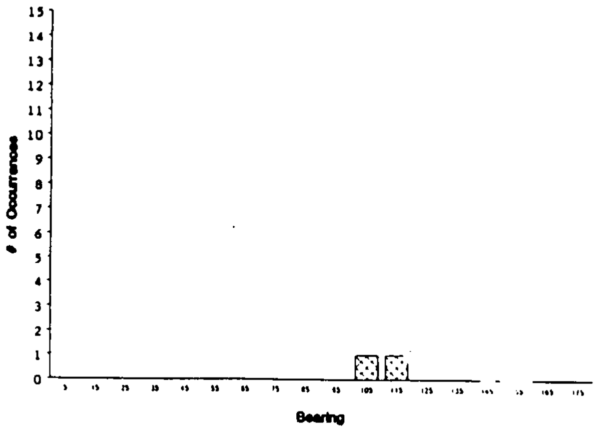

Existing

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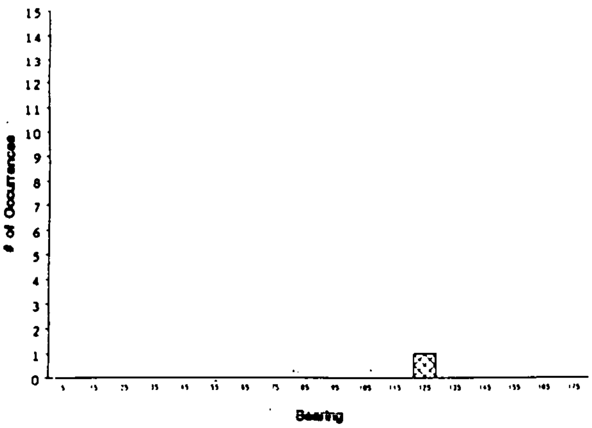

Remeasured

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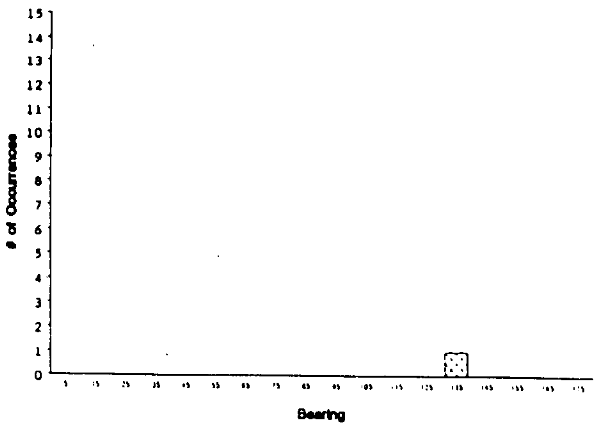

Existing

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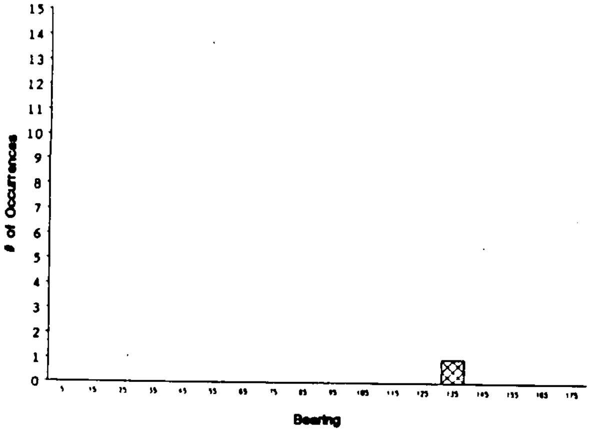

Remeasured

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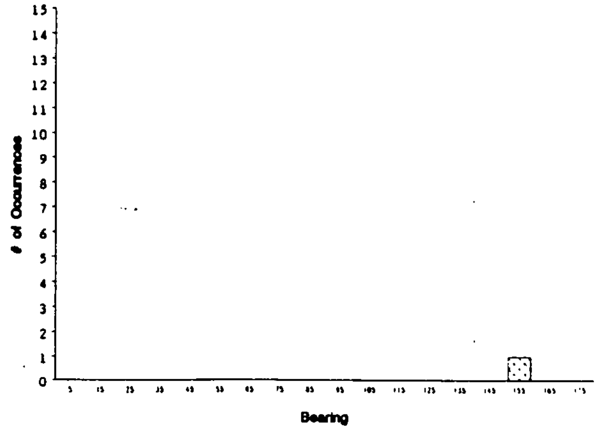
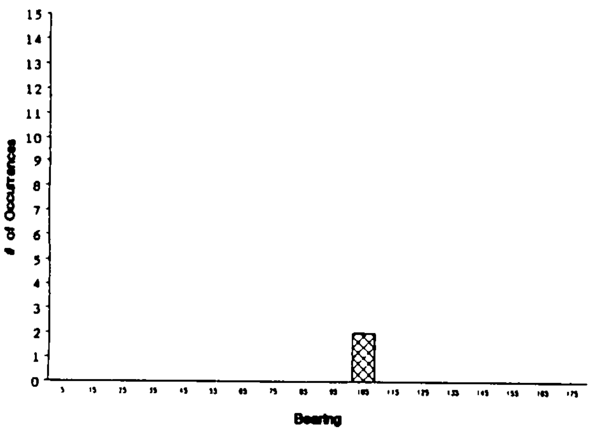


Existing

NAME=DAP CRUISE=80010 DAY=122 START=2010 END=2020



NO SCOURS MEASURED

Existing

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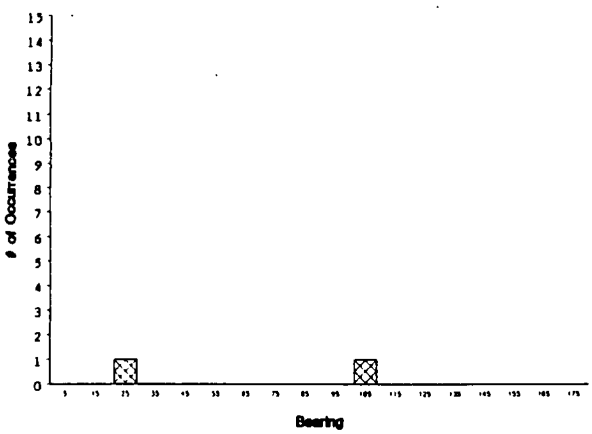
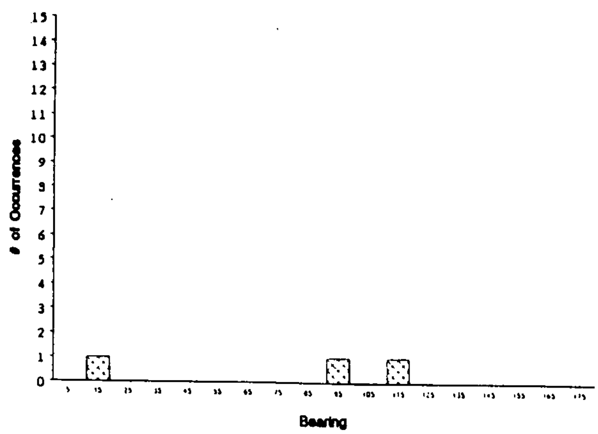


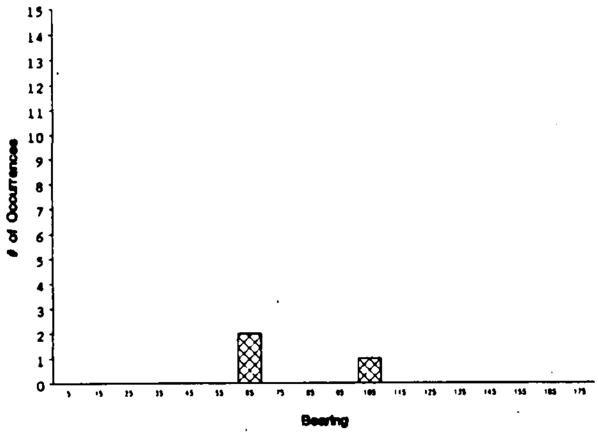
Remeasured

NAME=CUMMING CRUISE=80010 DAY=122 START=2250 END=2300



Existing

NAME=DAP CRUISE=80010 DAY=122 START=2310 END=2320



Remeasured

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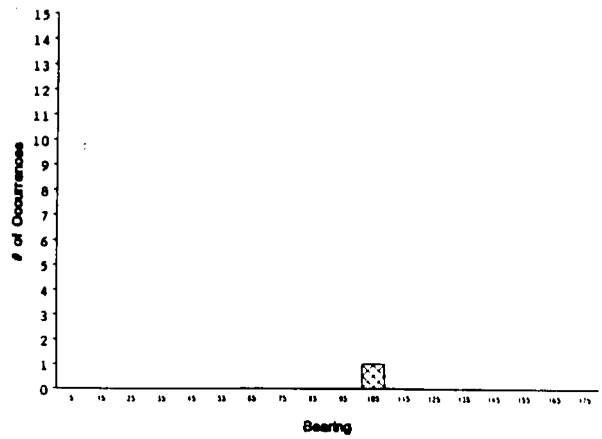
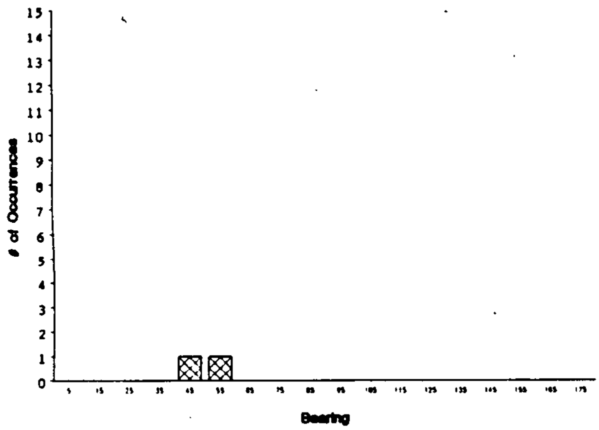


Existing

NAME=DAP CRUISE=80010 DAY=123 START=400 END=410

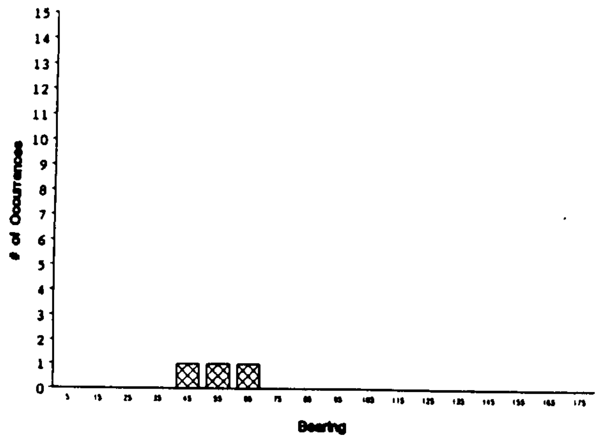


NO SCOURS MEASURED

NO SCOURS MEASURED

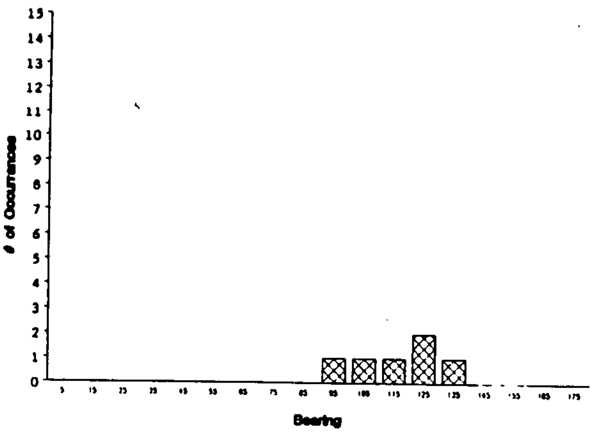
Remeasured

NAME=CUMMING CRUISE=77011 DAY=152 START=850 END=900



Existing

NAME=GILLESPIE CRUISE=77011 DAY=152 START=1024 END=1036



Remeasured

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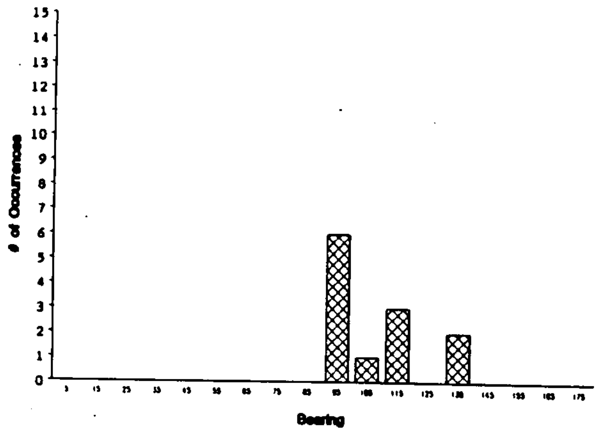
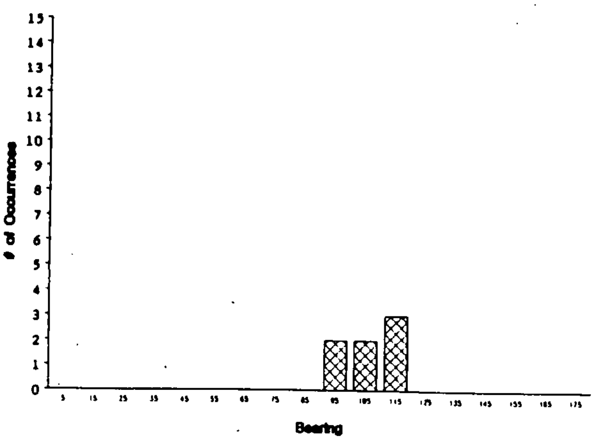


Existing

NAME=GILLESPIE CRUISE=77011 DAY=152 START=1048 END=1100



Remeasured

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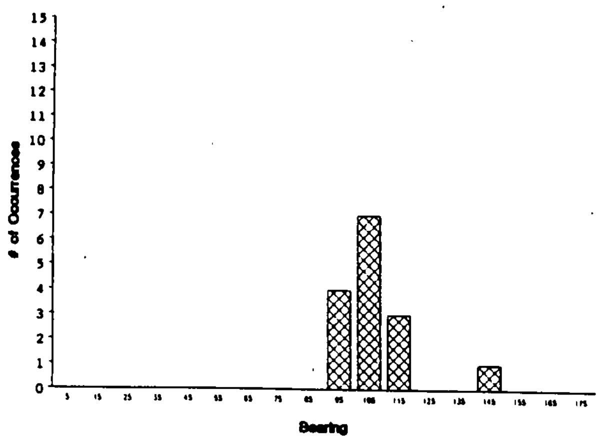

Existing

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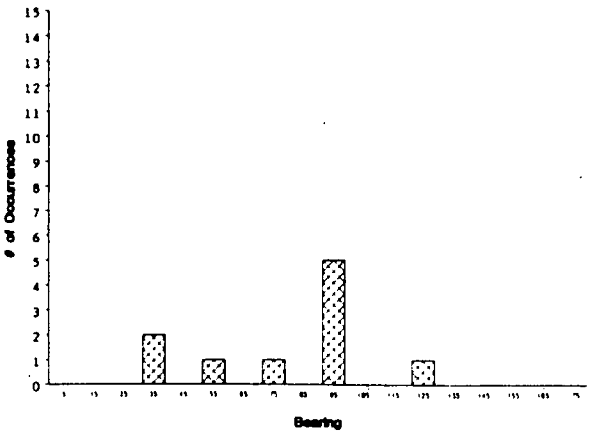

Remeasured

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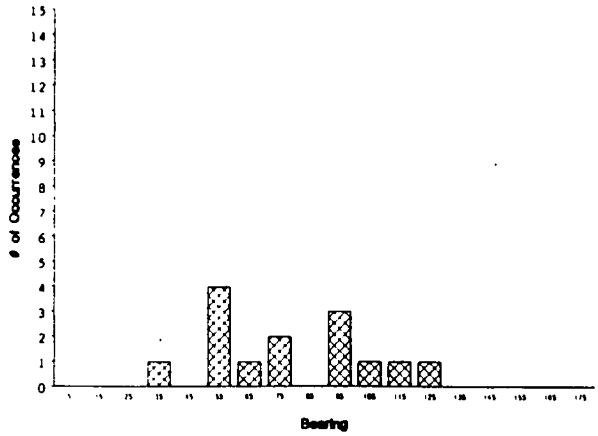

Existing

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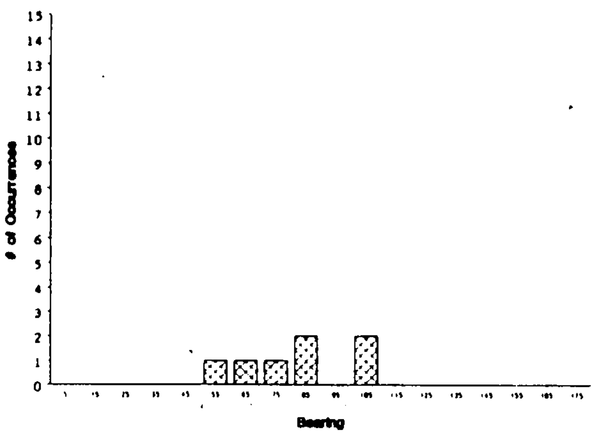
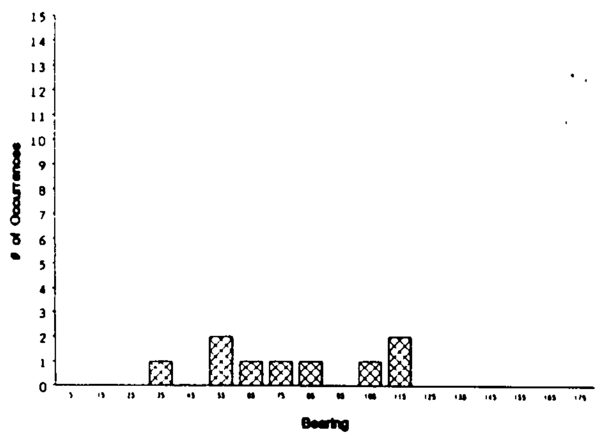


Remeasured

NAME=CUMMING   CRUISE=79019   DAY=232   START=800   END=812



Existing

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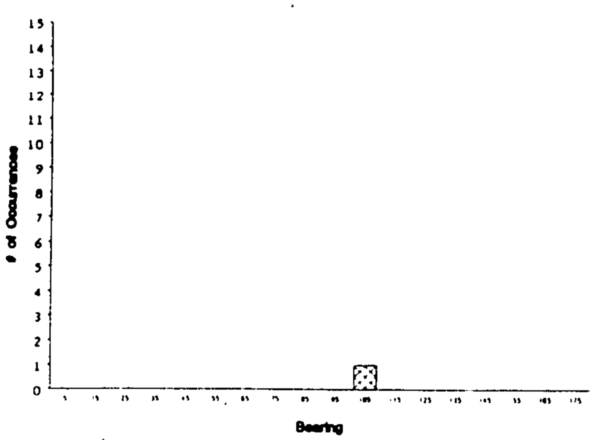
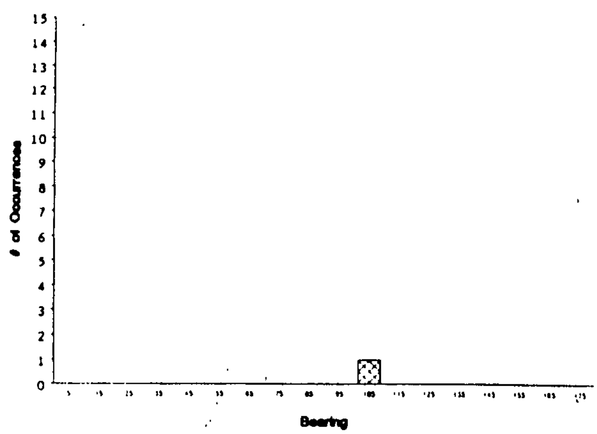


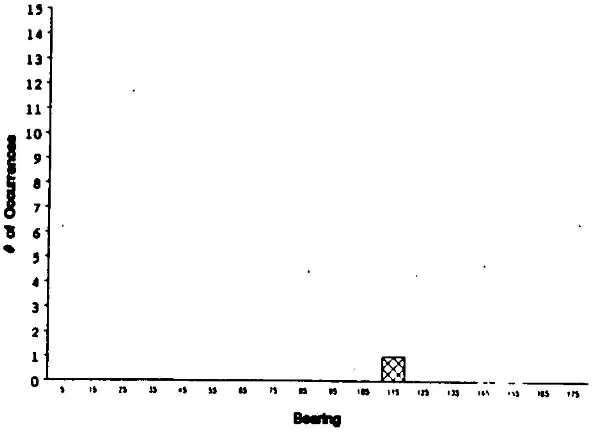
Remeasured

NAME=CUMMING   CRUISE=80010   DAY=125   START=450   END=500



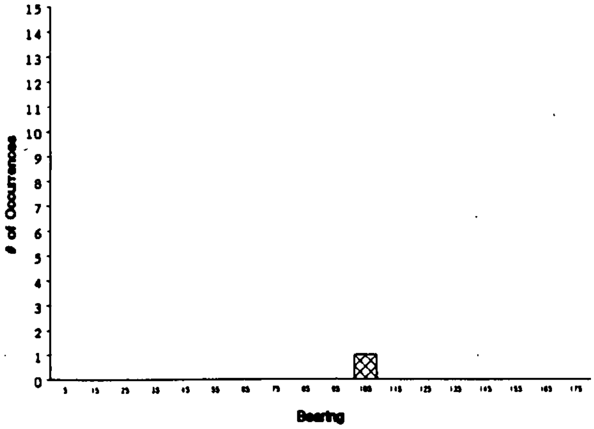
Existing

NAME=GILLESPIE CRUISE=80010 DAY=125 START=500 END=510



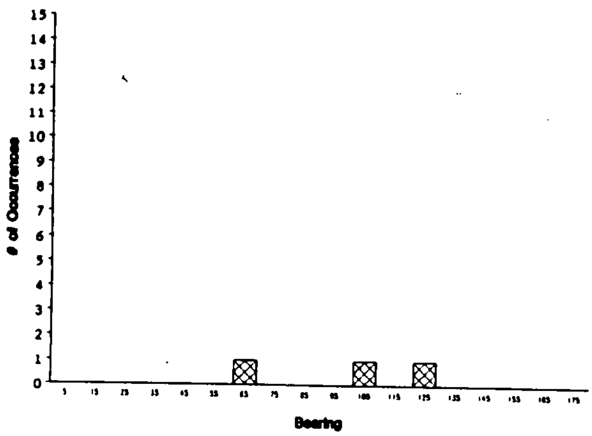
Remeasured

NAME=CUMMING CRUISE=80010 DAY=125 START=500 END=510



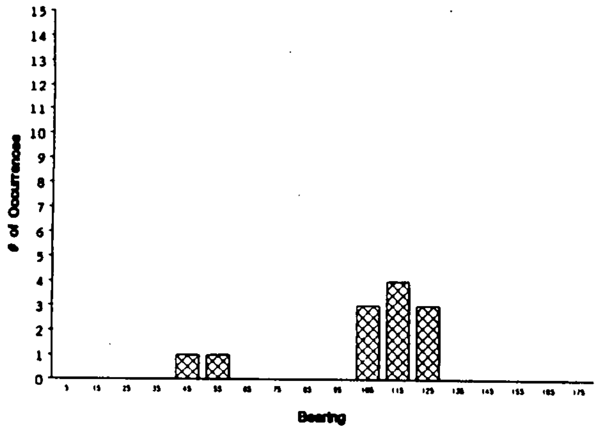
Existing

NAME=GILLESPIE CRUISE=80035 DAY=291 START=20 END=30



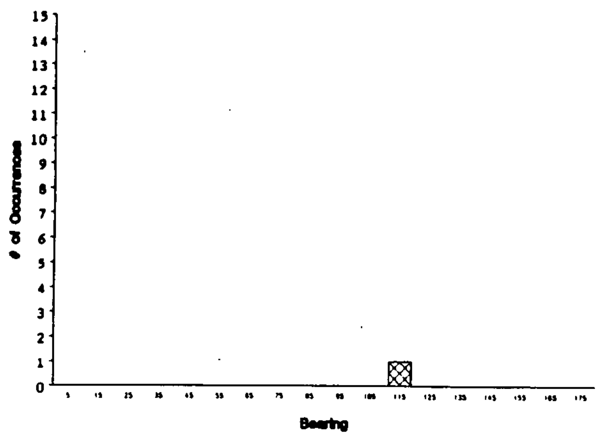
Remeasured

NAME=CUMMING CRUISE=80035 DAY=291 START=20 END=30



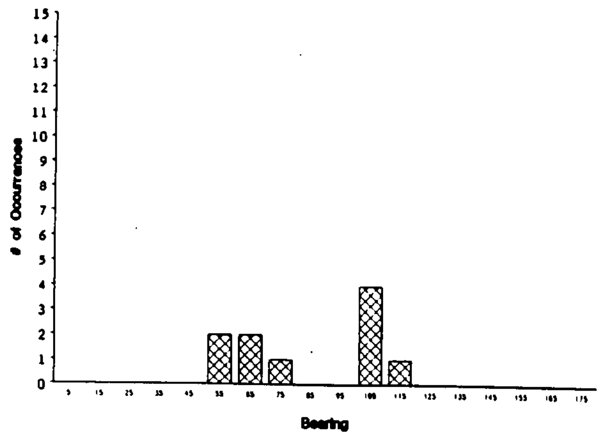
Existing

NAME=GILLESPIE CRUISE=80035 DAY=293 START=350 END=400

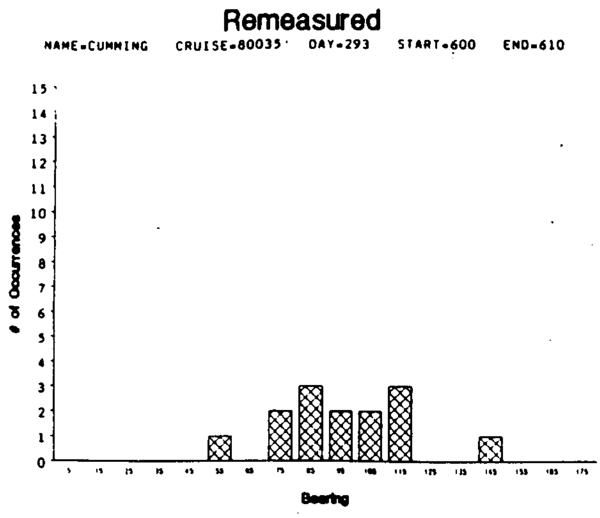


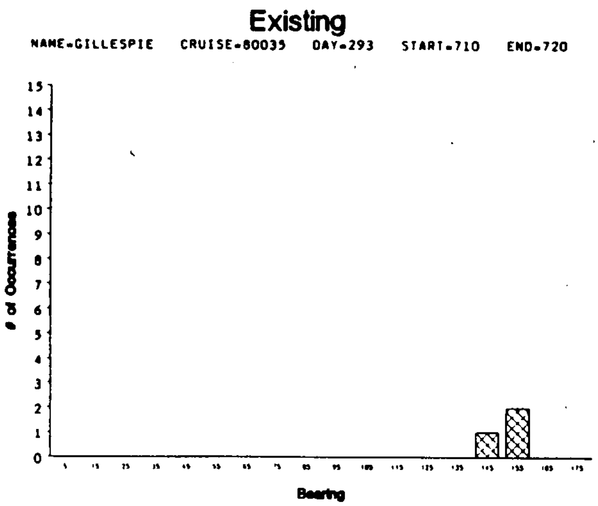
Remeasured

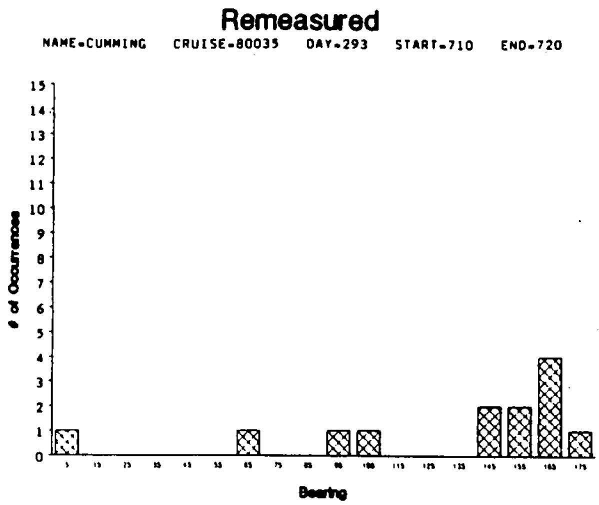
NAME=CUMMING CRUISE=80035 DAY=293 START=350 END=400



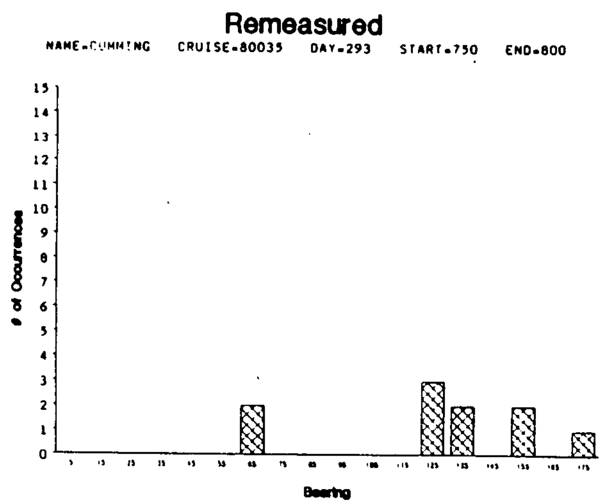
NO SCOURS MEASURED





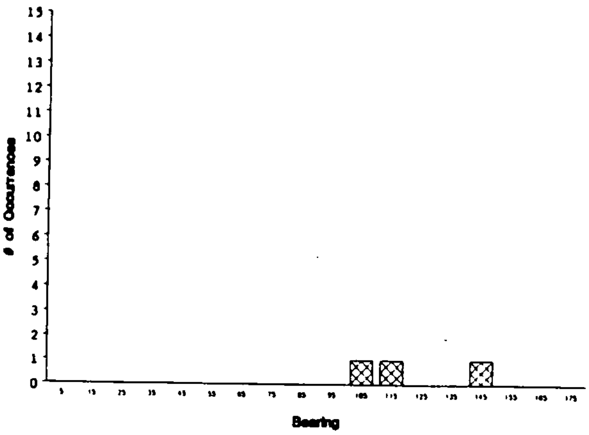


NO SCOURS MEASURED



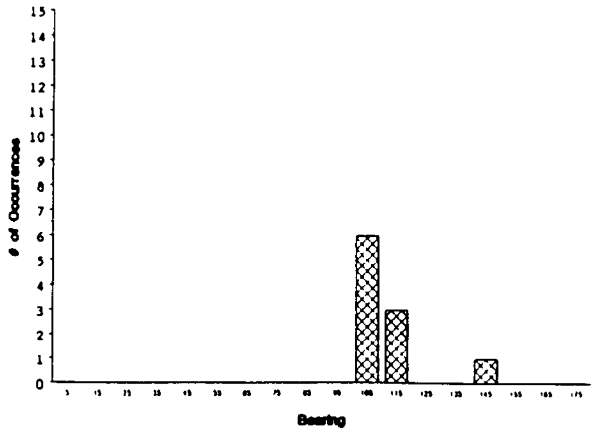
Existing

NAME=GILLESPIE CRUISE=80035 DAY=293 START=1422 END=1433



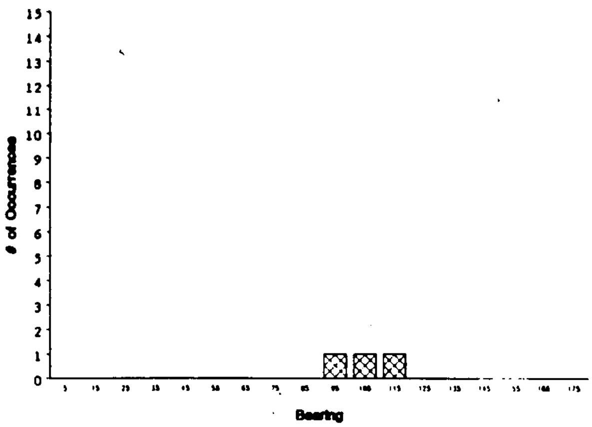
Remeasured

NAME=CUMMING CRUISE=80035 DAY=293 START=1422 END=1433



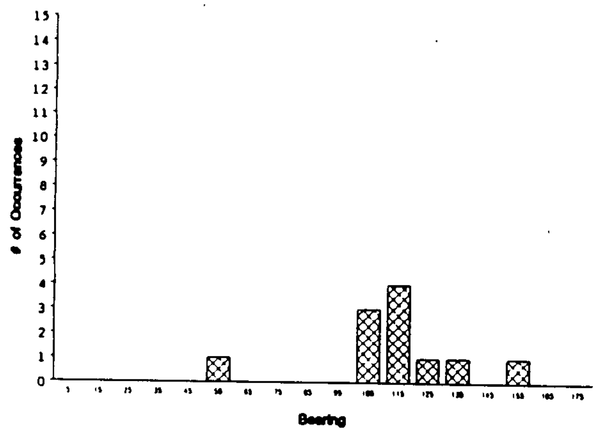
Existing

NAME=GILLESPIE CRUISE=80035 DAY=295 START=1710 END=1720



Remeasured

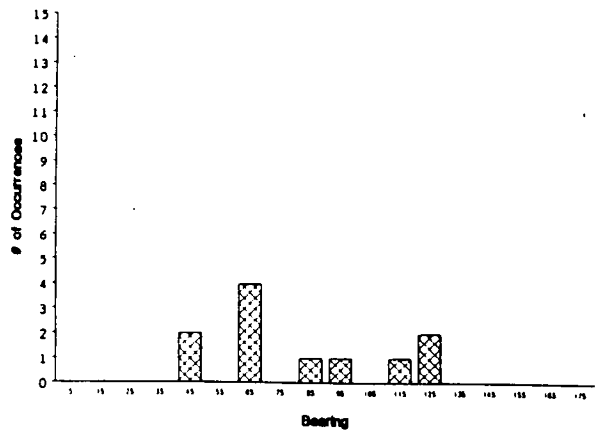
NAME=CUMMING CRUISE=80035 DAY=295 START=1710 END=1720



NO SCOURS MEASURED

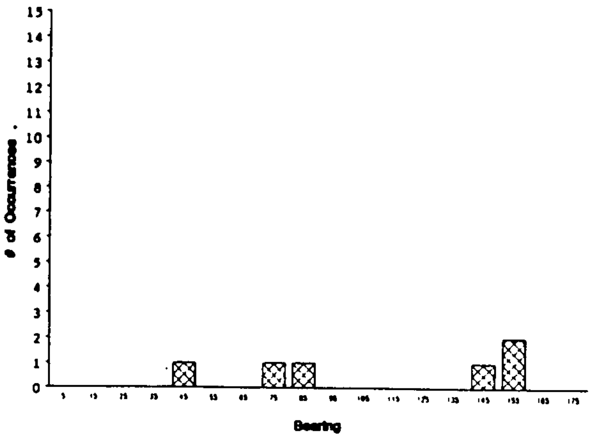
Remeasured

NAME=CUMMING CRUISE=80035 DAY=295 START=1750 END=1800



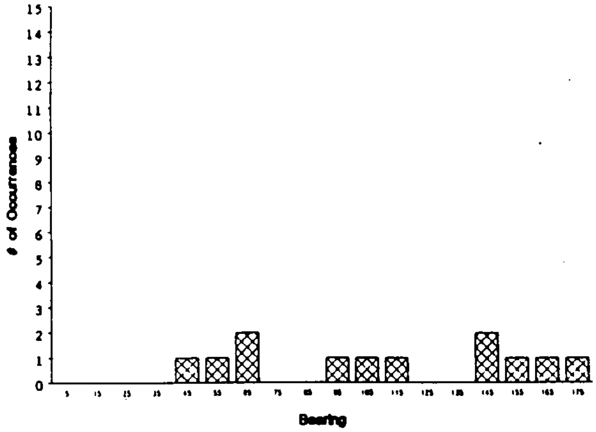
Existing

NAME=GILLESPIE CRUISE=81045 DAY=281 START=1440 END=1450



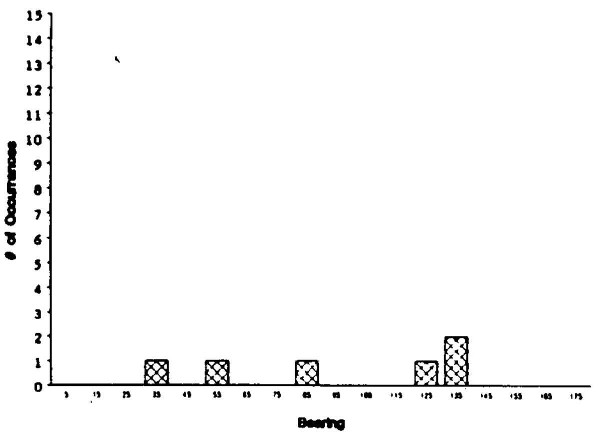
Remeasured

NAME=CUMMING CRUISE=81045 DAY=281 START=1440 END=1450



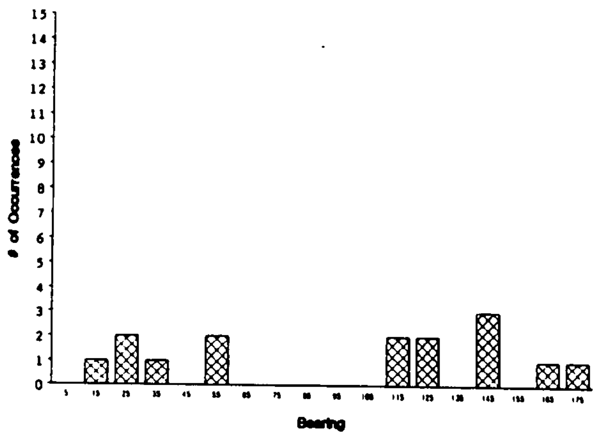
Existing

NAME=GILLESPIE CRUISE=81045 DAY=281 START=1555 END=1610



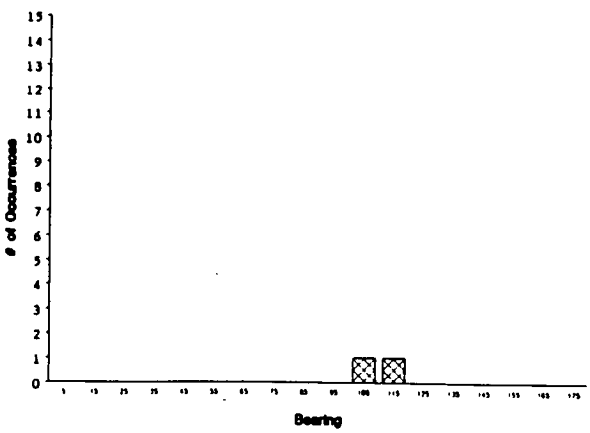
Remeasured

NAME=CUMMING CRUISE=81045 DAY=281 START=1555 END=1610



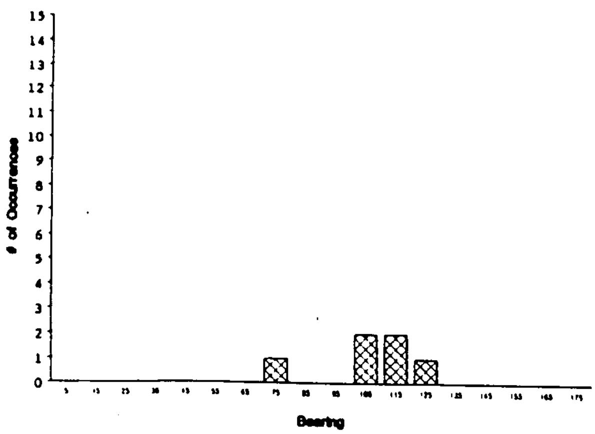
Existing

NAME=GILLESPIE CRUISE=81045 DAY=290 START=1630 END=1640



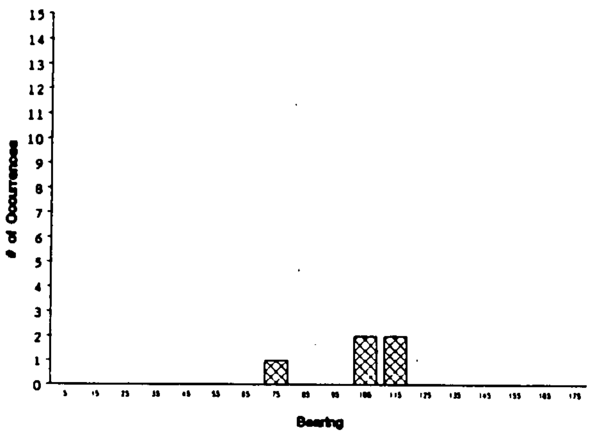
Remeasured

NAME=CUMMING CRUISE=81045 DAY=290 START=1630 END=1640



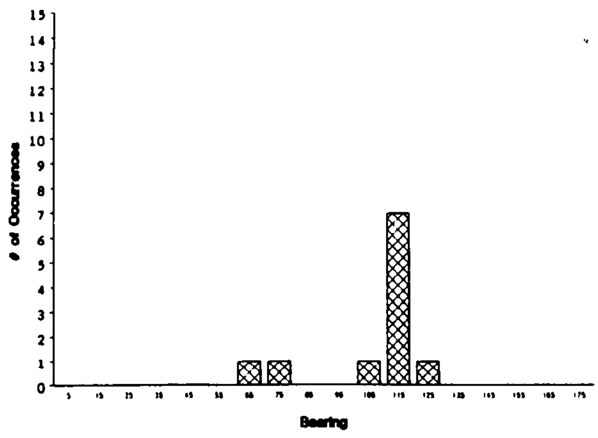
Existing

NAME=GILLESPIE CRUISE=81045 DAY=290 START=1720 END=1730



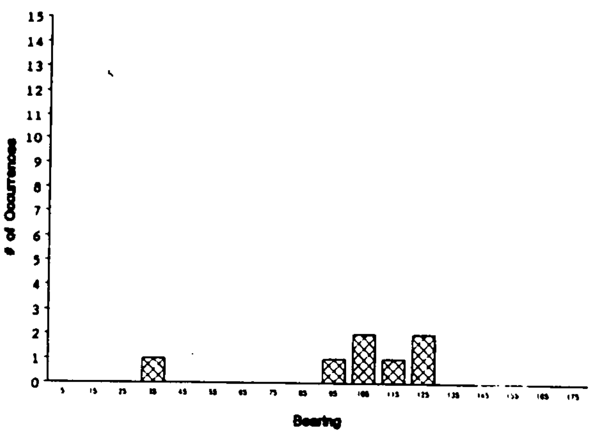
Remeasured

NAME=CUMMING CRUISE=81045 DAY=290 START=1720 END=1730



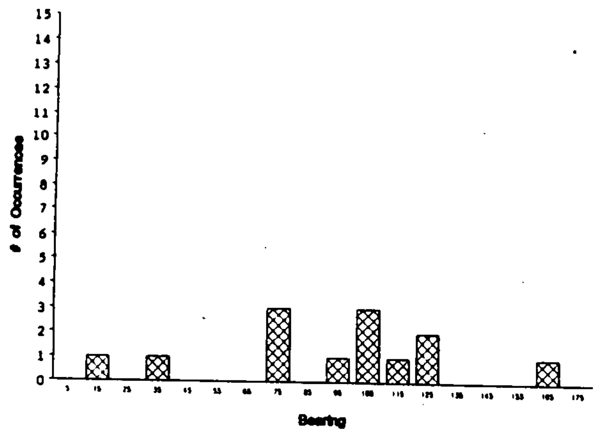
Existing

NAME=GILLESPIE CRUISE=81045 DAY=290 START=1800 END=1810



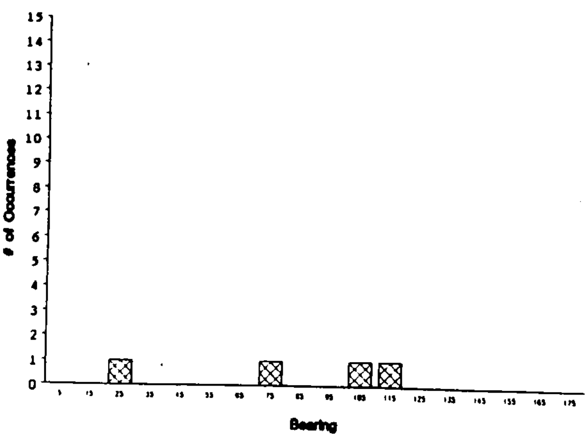
Remeasured

NAME=CUMMING CRUISE=81045 DAY=290 START=1800 END=1810



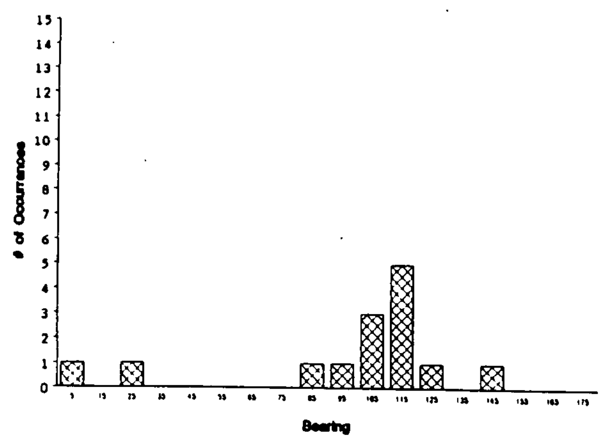
Existing

NAME=GILLESPIE CRUISE=81045 DAY=290 START=1900 END=1910



Remeasured

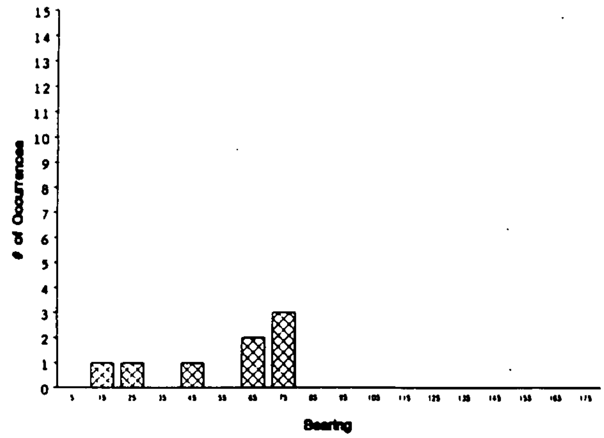
NAME=CUMMING CRUISE=81045 DAY=290 START=1900 END=1910



NO SCOURS MEASURED

Remeasured

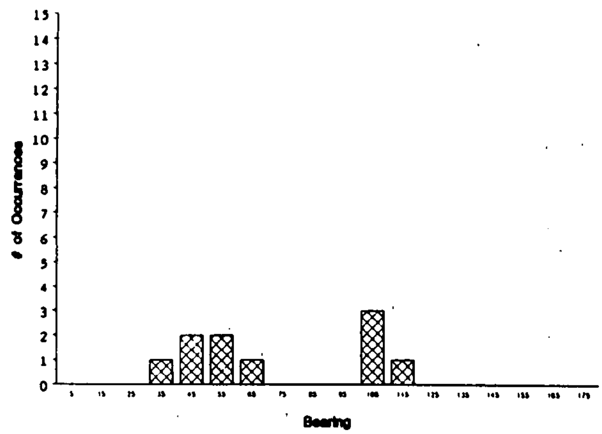
NAME=CUMMING CRUISE=81045 DAY=295 START=1240 END=1250



NO SCOURS MEASURED

Remeasured

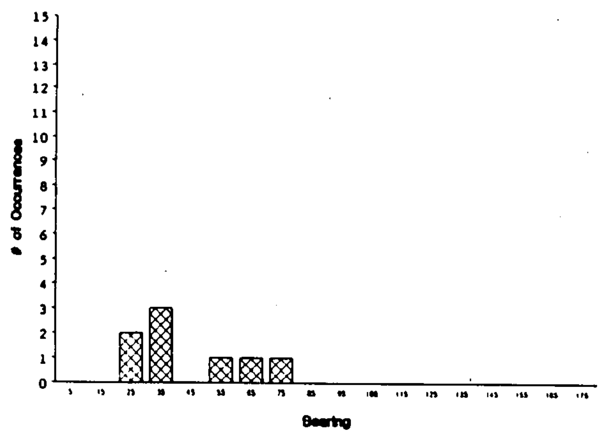
NAME=CUMMING CRUISE=81045 DAY=295 START=1400 END=1410



NO SCOURS MEASURED

Remeasured

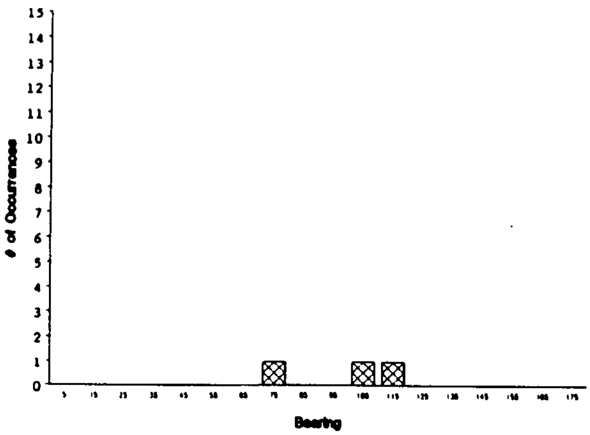
NAME=CUMMING CRUISE=81045 DAY=295 START=1410 END=1420



NO SCOURS MEASURED

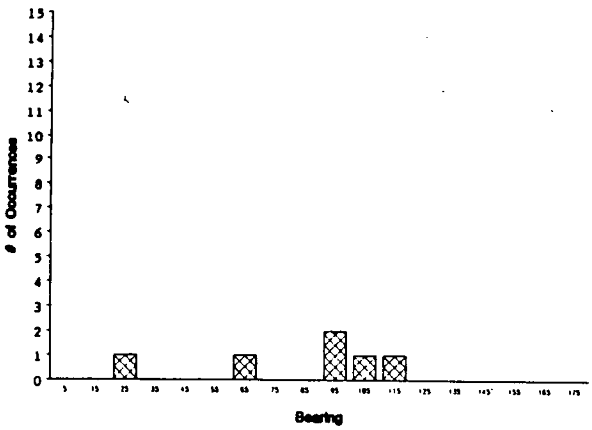
Remeasured

NAME=CUMMING CRUISE=81045 DAY=295 START=1620 END=1630



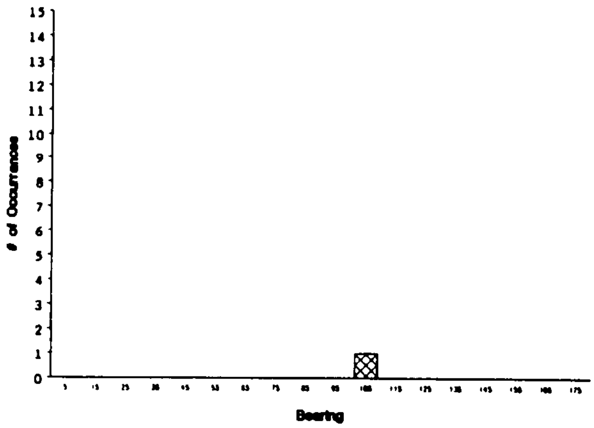
Existing

NAME=GILLESPIE CRUISE=84024 DAY=172 START=313 END=326



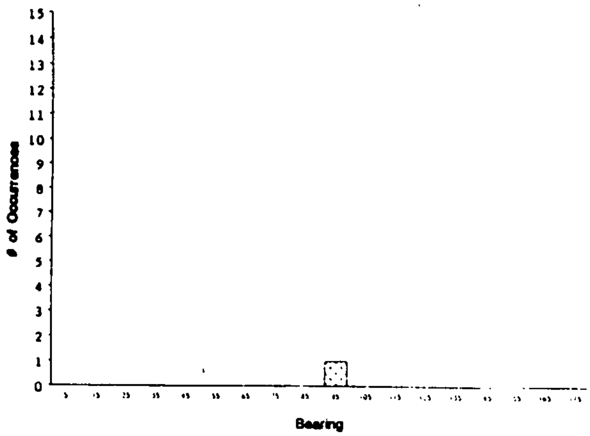
Remeasured

NAME=CUMMING CRUISE=84024 DAY=172 START=313 END=326



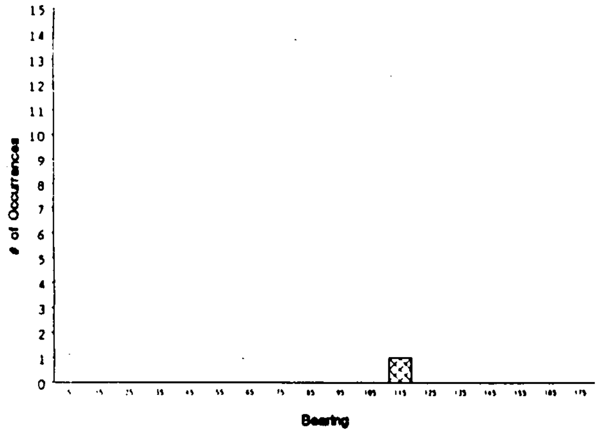
Existing

NAME=KING CRUISE=77011 DAY=152 START=202 END=214



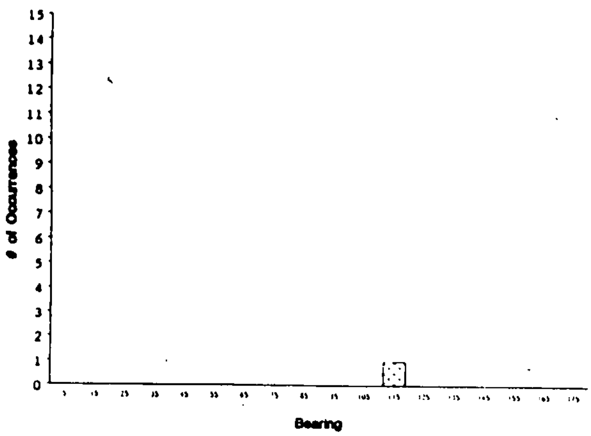
Remeasured

NAME=CUMMING CRUISE=77011 DAY=152 START=202 END=214



Existing

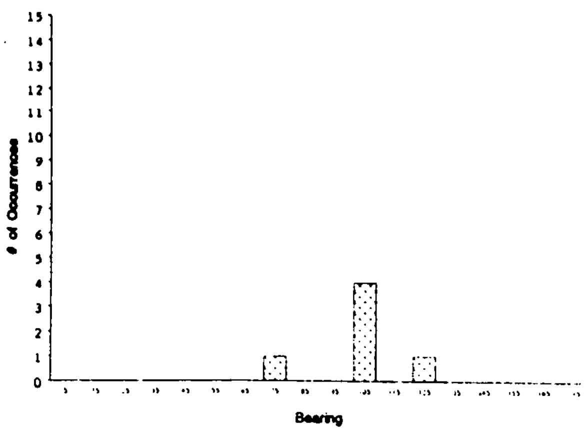
NAME=KING CRUISE=77011 DAY=152 START=259 END=312



NO SCOURS MEASURED

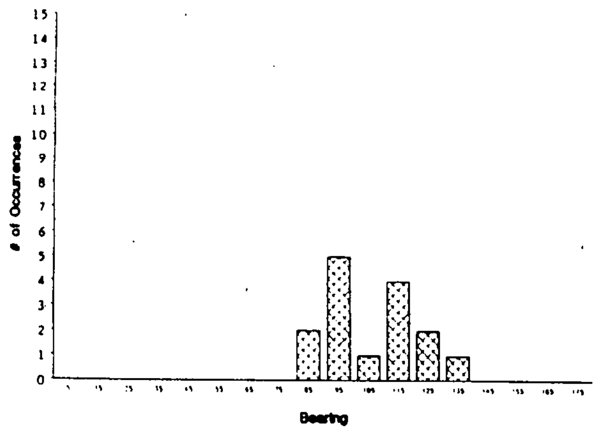
Existing

NAME=KING CRUISE=77011 DAY=152 START=526 END=538



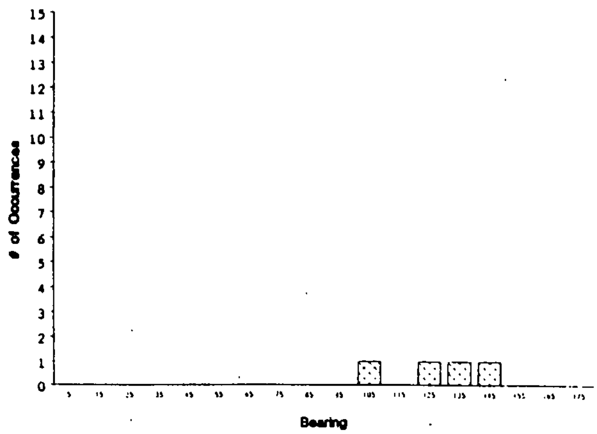
Remeasured

NAME=CUMMING CRUISE=77011 DAY=152 START=526 END=538



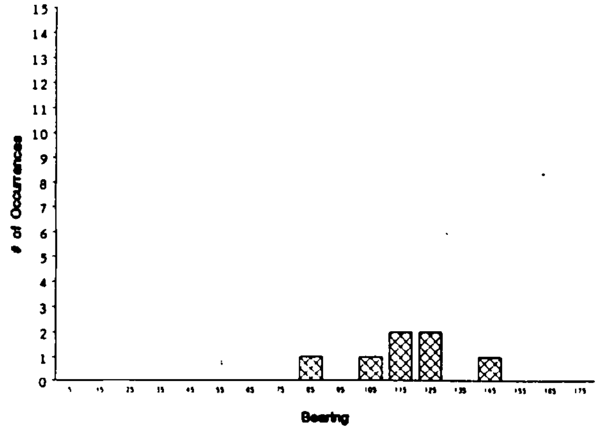
Existing

NAME=KING CRUISE=77011 DAY=152 START=558 END=610



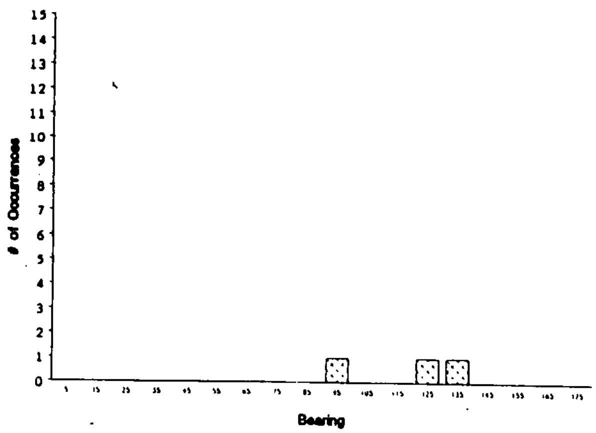
Remeasured

NAME=CUMMING CRUISE=77011 DAY=152 START=558 END=610



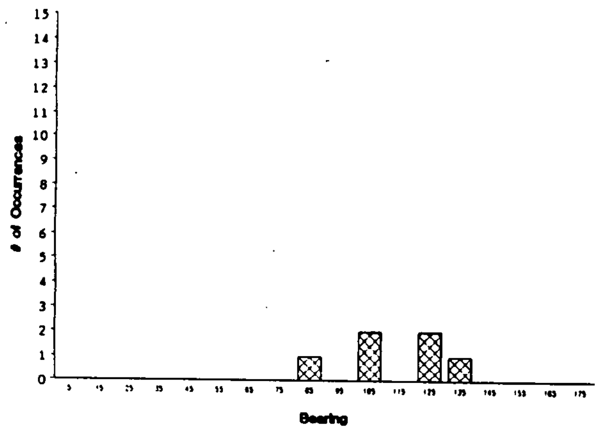
Existing

NAME=KING CRUISE=77011 DAY=152 START=610 END=621



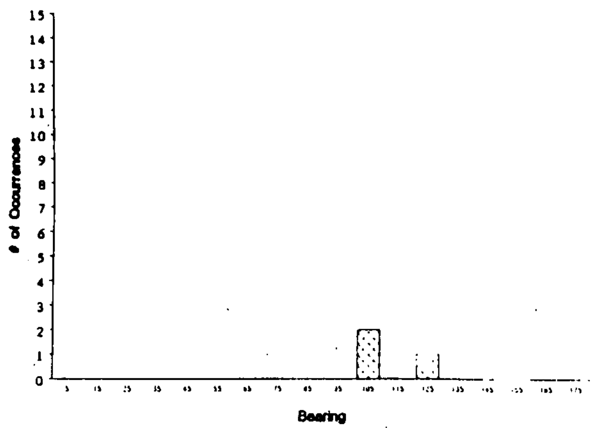
Remeasured

NAME=CUMMING CRUISE=77011 DAY=152 START=610 END=621



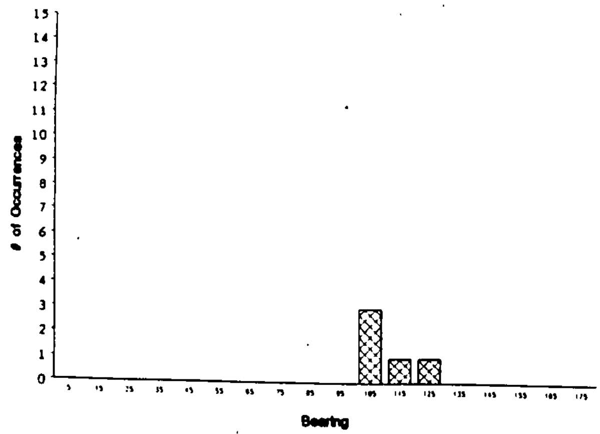
Existing

NAME=KING CRUISE=77011 DAY=152 START=632 END=644



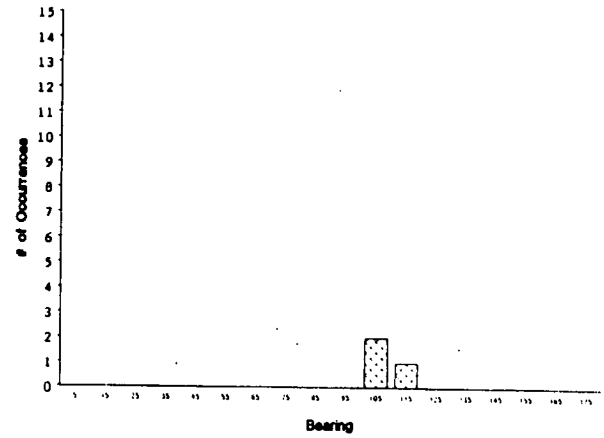
Remeasured

NAME=CUMMING CRUISE=77011 DAY=152 START=632 END=644



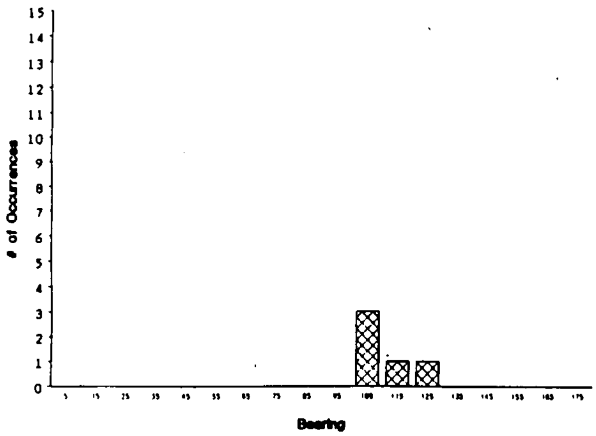
Existing

NAME=KING CRUISE=77011 DAY=152 START=644 END=655



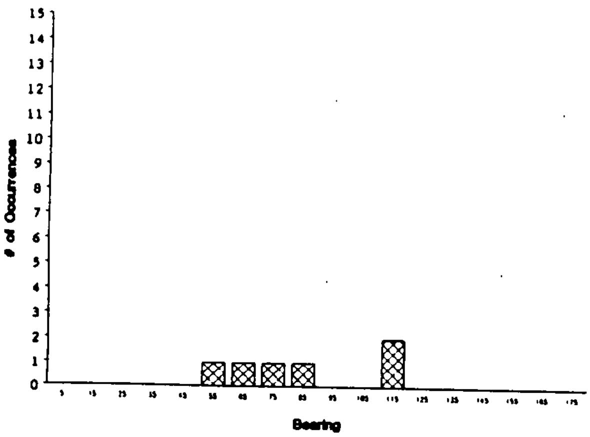
Remeasured

NAME=CUMMING CRUISE=77011 DAY=152 START=644 END=655



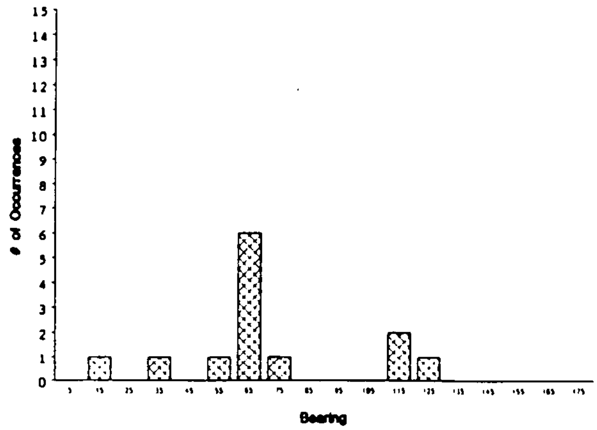
Existing

NAME=CARTER CRUISE=81045 DAY=281 START=930 END=940



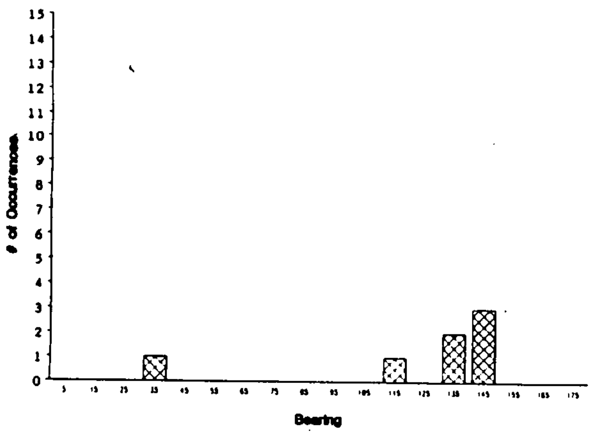
Remeasured

NAME=CUMMING CRUISE=81045 DAY=281 START=930 END=940



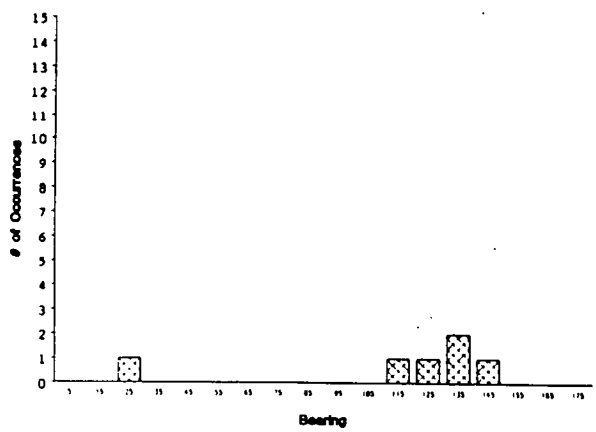
Existing

NAME=CARTER CRUISE=84024 DAY=170 START=1930 END=1945



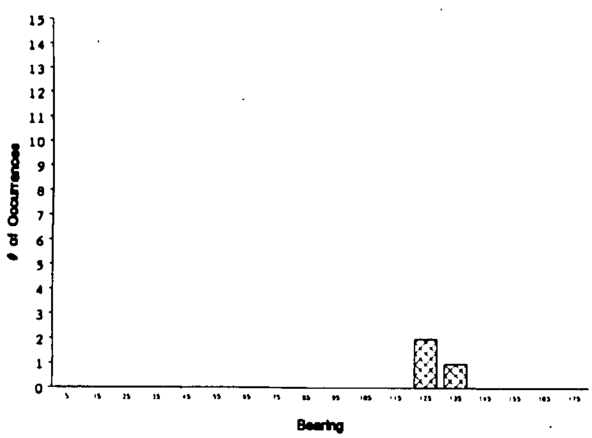
Remeasured

NAME=CUMMING CRUISE=84024 DAY=170 START=1930 END=1945



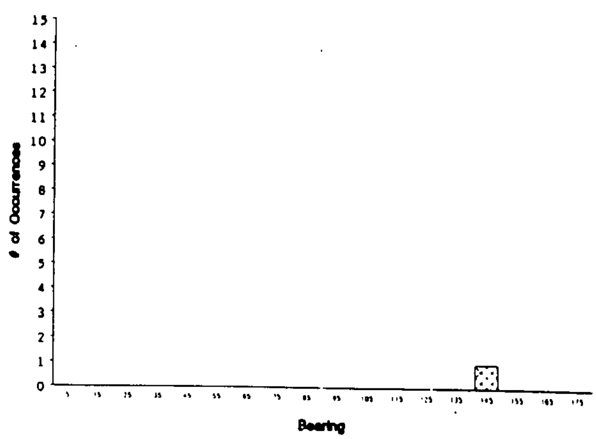
Existing

NAME=CARTER CRUISE=84024 DAY=170 START=2015 END=2029



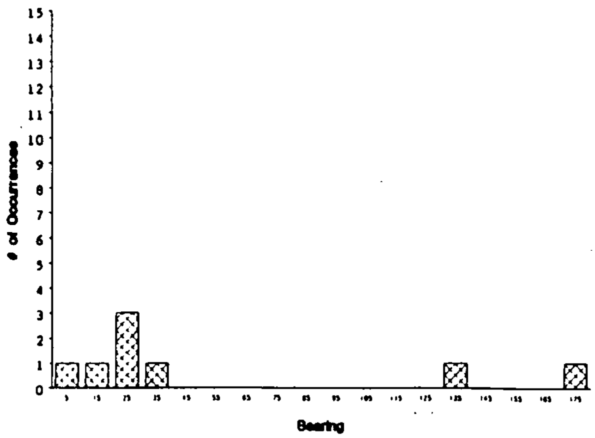
Remeasured

NAME=CUMMING CRUISE=84024 DAY=170 START=2015 END=2029



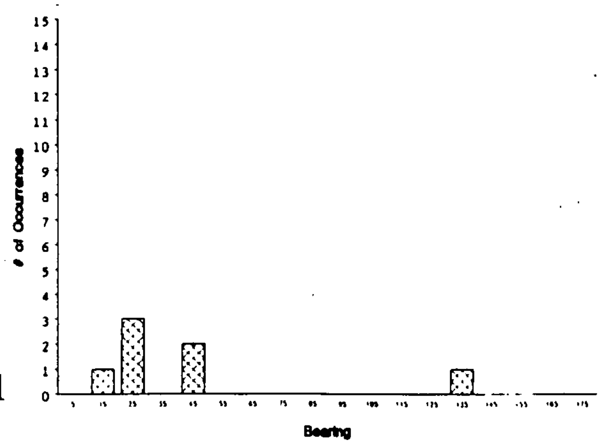
Existing

NAME=CARTER CRUISE=84024 DAY=170 START=2152 END=2205



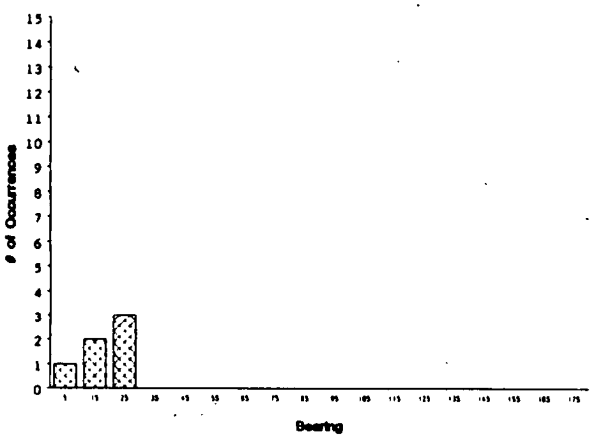
Remeasured

NAME=CUMMING CRUISE=84024 DAY=170 START=2152 END=2205



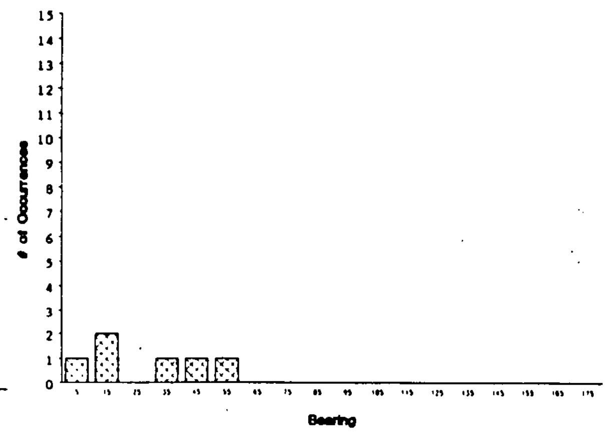
Existing

NAME=CARTER CRUISE=84024 DAY=170 START=2305 END=2328



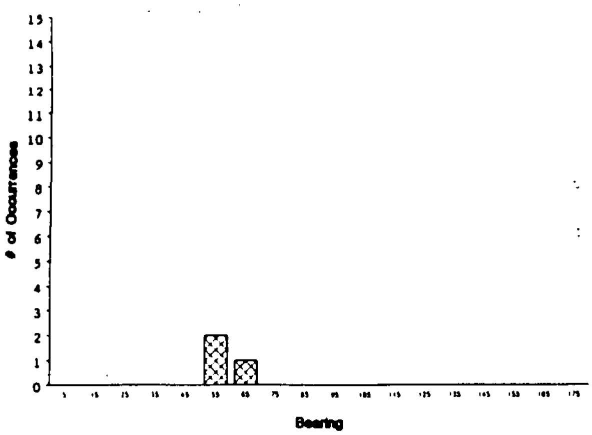
Remeasured

NAME=CUMMING CRUISE=84024 DAY=170 START=2305 END=2328



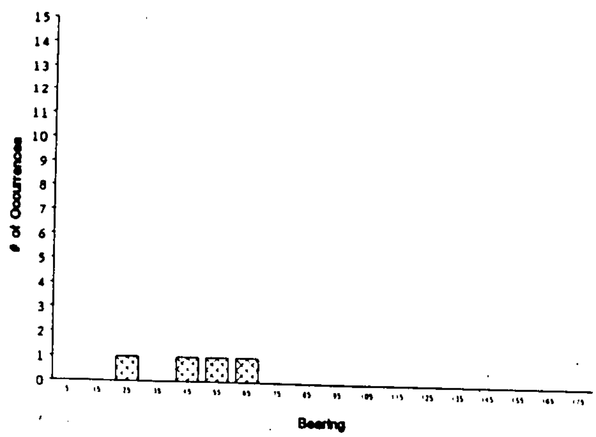
Existing

NAME=CARTER CRUISE=84024 DAY=171 START=33 END=57



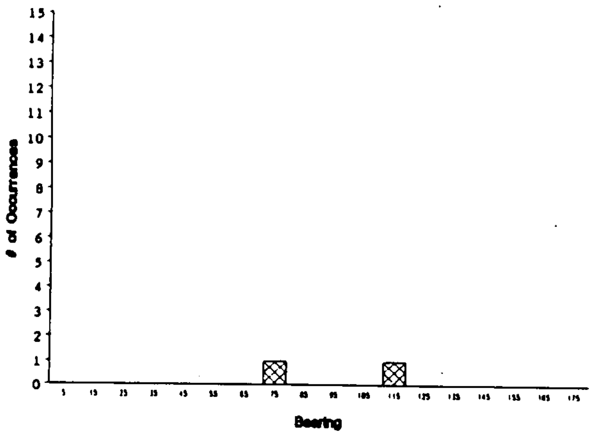
Remeasured

NAME=CUMMING CRUISE=84024 DAY=171 START=33 END=57



Existing

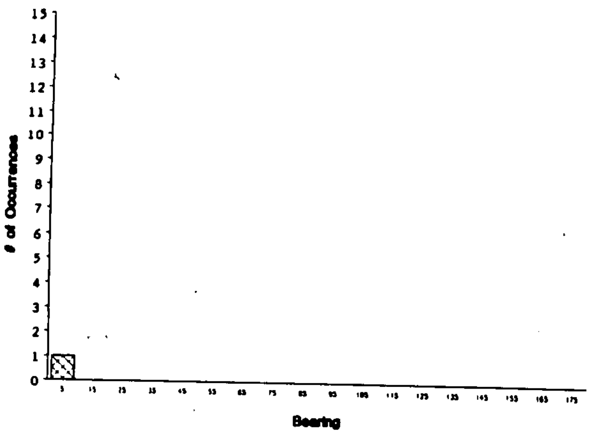
NAME=CARTER CRUISE=84024 DAY=171 START=153 END=206



NO SCOURS MEASURED

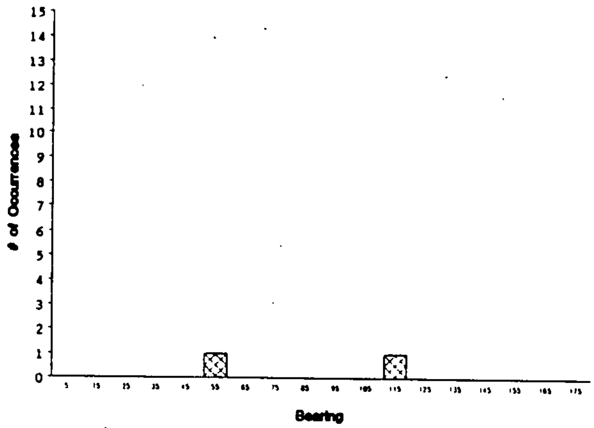
Existing

NAME=CARTER CRUISE=84024 DAY=171 START=817 END=828



Remeasured

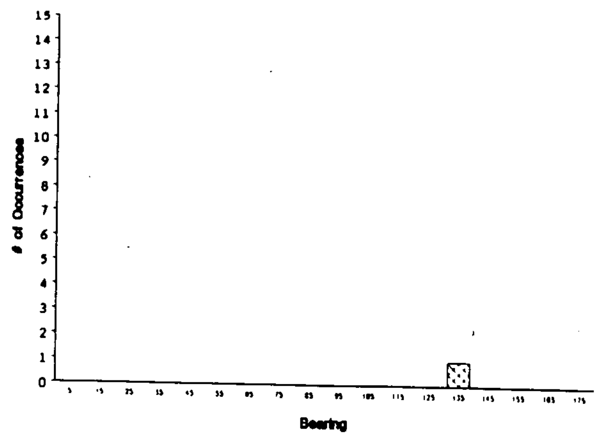
NAME=CUMMING CRUISE=84024 DAY=171 START=817 END=828



NO SCOURS MEASURED

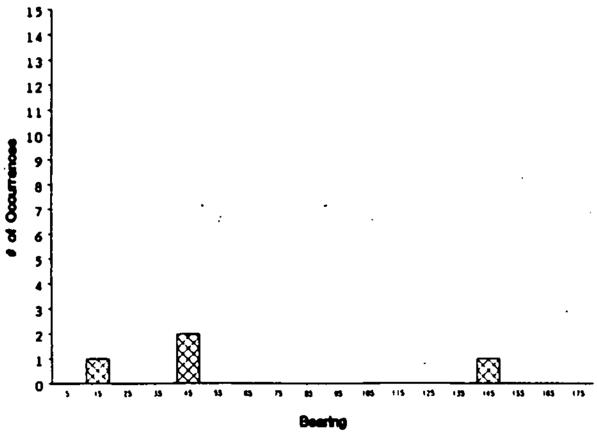
Remeasured

NAME=CUMMING CRUISE=84024 DAY=173 START=1303 END=1318



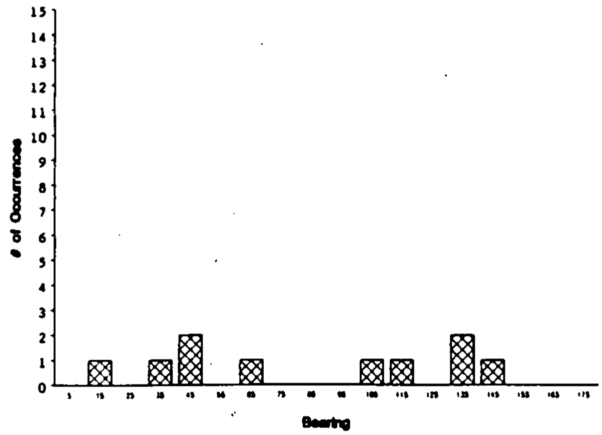
Existing

NAME=NICKS CRUISE=81045 DAY=281 START=102 END=113



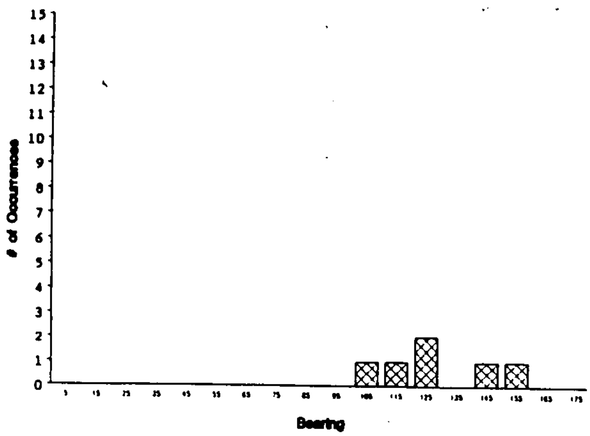
Remeasured

NAME=CUMMING CRUISE=81045 DAY=281 START=102 END=113



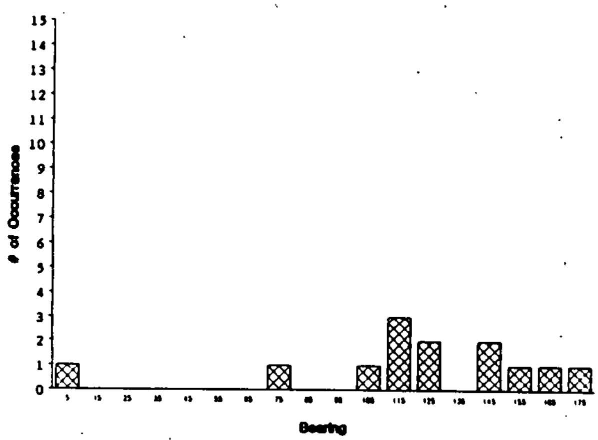
Existing

NAME=NICKS CRUISE=81045 DAY=281 START=352 END=400



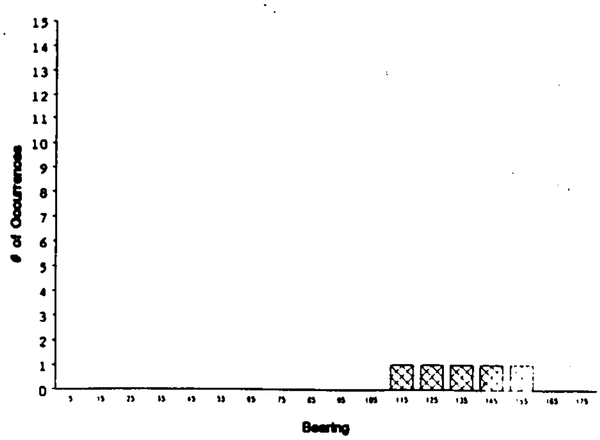
Remeasured

NAME=CUMMING CRUISE=81045 DAY=281 START=352 END=400



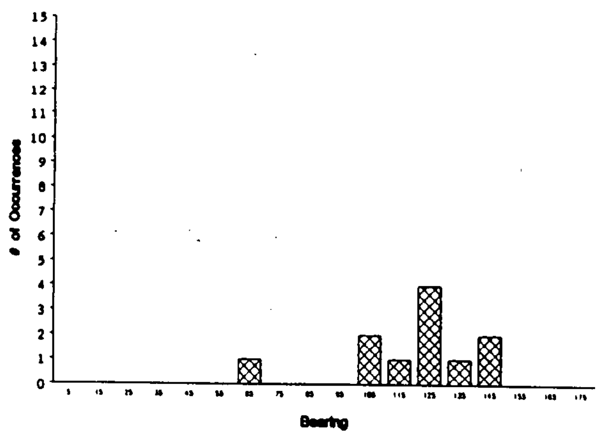
Existing

NAME=NICKS CRUISE=81045 DAY=281 START=400 END=409



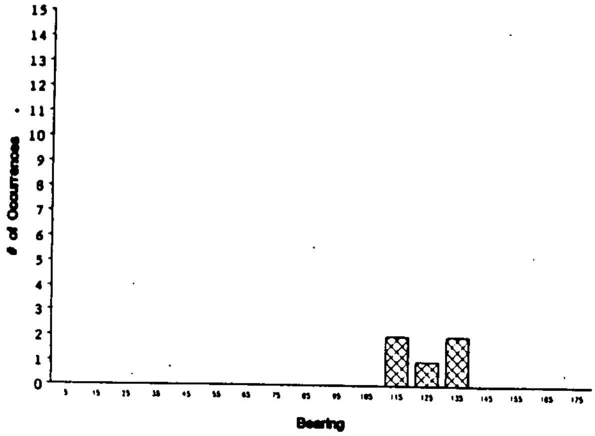
Remeasured

NAME=CUMMING CRUISE=81045 DAY=281 START=400 END=409



Existing

NAME=NICKS CRUISE=81045 DAY=281 START=409 END=417



Remeasured

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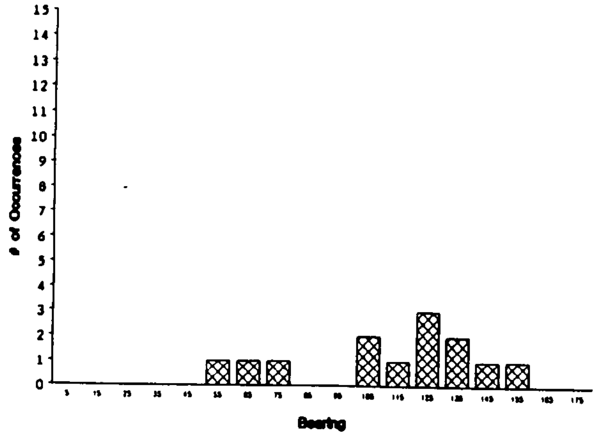

Existing

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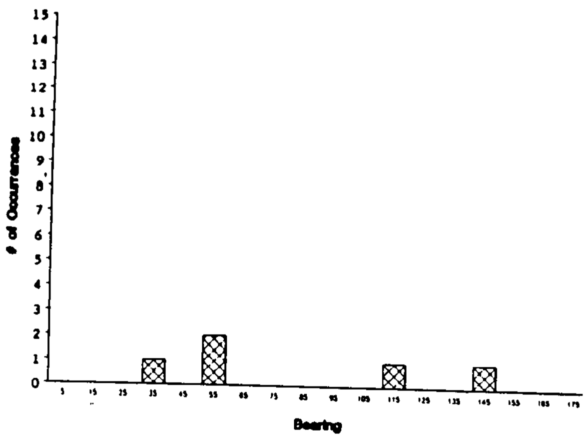

Remeasured

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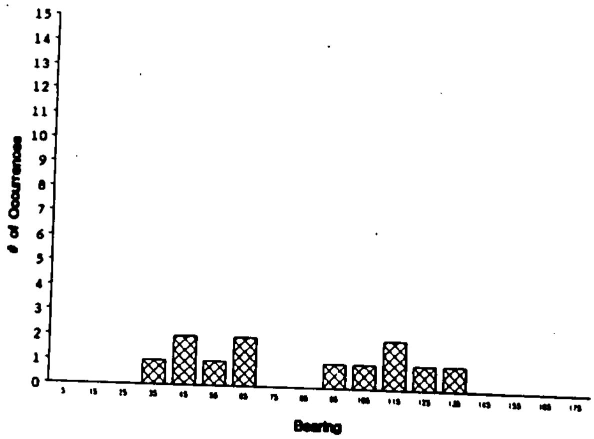

Existing

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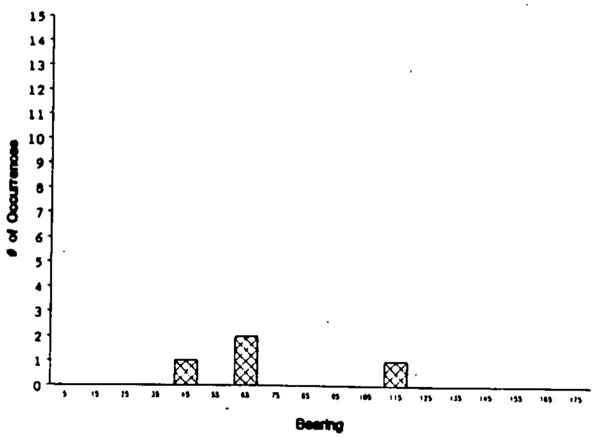

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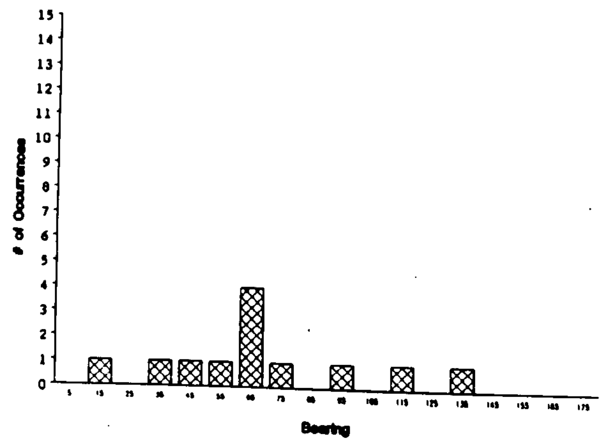

APPENDIX 2

GRAND BANKS SUPPORT DATA

AGC DATA ANALYSIS BY CRUISE, GRAND BANKS REGION

REGIONAL

Cruise	Area	Sample Areas	Total Kms Entered in Detail Huntec	Total Kms Entered in Detail Sidescan
78-023	NE Nfld. Shelf	169	169	169
80-010	Extensive Coverage of Grand Bank	1015	1015	922
81-012	Hibernia	32	--	32
77-011	Avalon Channel	144	144	142
81-045	N Avalon Channel	79	79	78
82-039	South-Central Grand Bank	19	19	19
83-033	Hibernia Area	16	16	16
84-024	South Avalon Channel	141	65	141
84-035	NE Grand Banks	69	--	69
C-Core/Cormorant 1984	Hibernia Area	238	--	238
8000 Series	Hibernia Area	136	136	136
	TOTAL	2058	1643	1962

GRAND BANKS REGION SITE-SPECIFIC DATA ENTERED

Site/Year	Area Km^2	Line Km
Ben Nevis (1979)	89.0	277
Cumberland (1981)	93.5	282
North Dana (1981)	73.8	214
South Dana (1981)	120.0	339
Hebron (1981)	164.3	449
Hibernia (1979)	30.9	130
Hibernia N (1980)	69.5	290
Hibernia S (1980)	50.4	168
Hibernia W (1981)	63.4	170
Ragnar (1981)	89.0	282
Rankin (1981)	287.9	818
Nautilus (1981)	87.1	268
Tempest N. (1980)	108.8	403
Trave/W. Rose (1979)	196.3	600
Mercury (1982)	144.0	422
West Flying Foam (1982)	140.0	434
White Rose Flank (1982)	313.3	888
Linnet (1982)	200	587
Mara (1983)	191	630
Dominion (1983)	58.4	188
Titus (1983)	62.2	210
Voyager (1983)	88.1	221
Saronac (1983)	171.6	640
Archer Flank (1982)	339.1	1086
Bonanza (1982)	112	345
Series 4000 (1980)	--	645
Series 8000 (1980)	--	1120
Total	3,343.6	12,106

APPENDIX 3

LABRADOR REGION SUPPORT DATA

DATA BASE HOLDINGS, LABRADOR REGION

Cruises Examined	Location	Sample Areas	Total Samples Entered in Detail	
			Huntec	Sidescan
73-027	Hamilton Bank	210	100	203
78-023	NE Nfld. Shelf	43	43	43
78-029	Saglek Bank	31	31	31
79-018	Harrison Bank	43	43	43
79-019	Makkovik to Saglek Bank	273	273	273
80-031	Hudson Strait & Eastward	--	--	--
80-035	Nain Bank	70	70	60
80-045	Karlsefni Trough	23	23	23
82-054	Main Bank	497	123	483
83-030	Hamilton to Saglek Bank	137	137	137
84-035	Hamilton Bank to Hudson Strait	268	--	268
Total		1595	843	1573

FREQUENCY OF SCOURS VS WATERDEPTH

SAGLEK EAST MOSAIC DETAILED STUDY

WATERDEPTH	NUMBER OF SCOURS	KM^2	$SCOURS/KM^2$
150-155	56	2.88	19
155-160	79	4.87	16
160-165	77	5.93	13
165-170	64	4.42	15
170-175	54	7.60	7
175-180	7	1.30	5

SAGLEK EAST MOSAIC DETAILED STUDY

RANGE IN SCOUR DEPTH ALONG LENGTH OF SCOUR

Scour No.	D1	D2	W1	W2	[D1-D2]	1/2D1xW1	1/2D2xW2	Profile Area Diff.	Profile Area Ratio
273	1.0	1.5	35	20	0.5	17	15	2	1.1
260	3.5	3.5	25	25	0.0	43	43	0	1
204	2.5	0.5	40	20	2.0	50	5	45	10
154	0.5	0.2	20	15	0.3	5	1.5	3.5	3.3
150	1.2	1.5	25	20	0.3	15	1.5	13.5	10
135	5.0	5.0	60	22	0.0	150	55	95	2.7
134	1.0	1.0	60	60	0.0	30	30	0	1
131	2.0	1.5	60	17	0.5	60	13	47	4.6
90	0.5	2.5	22	25	2.0	5.5	12.5	7	2.3
63	4.0	5.0	40	22	1.0	80	55	25	1.5
60	2.5	2.0	30	30	0.5	37.5	30	7.5	1.3
50	1.5	2.0	65	35	0.5	49	35	13.7	1.4
31	0.2	0.5	60	27	0.3	6	6.75	0.75	1.1
20	1.0	1.5	35	45	0.5	17.5	33.75	16.25	1.9
7	1.0	0.3	30	30	0.3	15	4.5	10.5	3.3
6	0.4	0.1	26	26	0.3	5.2	1.3	3.9	4
3	0.2	0.6	25	40	0.4	2.5	12	9.5	4.8
2	4.0	2.0	70	52	2.0	140	52	88	2.7
1	1.0	1.0	40	30	0.0	20	15	5	1.3

SAGLEK EAST MOSAIC AREA - WIDTH, DEPTH AND BERM HEIGHT MEASUREMENTS

GEOLOGIC UNIT	SCOUR WIDTH (m)	SCOUR DEPTH (m)	BERM HEIGHT (m)	RATIO OF DEPTH/HEIGHT
5A	40	1.0	1.5	0.7
post glacial	30	1.0	0.3	3.3
	42	--	--	--
	30	0.2	0.1	2.0
	54	4.0	0.7	5.7
	50	4.0	0.5	8.0
	26	0.4	0.2	2.0
	30	1.0	0.3	3.3
	30	0.3	--	--
	18	2.0	0.3	6.7
4A	30	0.6	--	--
well-stratified glaciomarine	40	1.0	0.5	2.0
	40	1.5	--	--
	70	4.0	0.5	8.0
	--	2.0	0.5	4.0
	18	2.0	0.3	6.7
	22	0.8	2.0	0.4
	45	1.0	0.3	3.3
	35	1.0	0.2	5.0
	45	1.5	0.2	7.5
	50	2.5	--	--
	30	0.6	0.5	1.2
	60	1.5	0.5	3.0
	40	2.5	0.2	12.5
	30	0.5	0.2	2.5
	60	0.2	0.1	2.0
	--	0.5	0.2	2.5
	40	1.0	--	--
	35	0.1	0.1	1.0
	65	1.5	0.2	7.5
	35	2.0	1.0	2.0
	20	0.5	0.5	1.0
	20	0.2	0.1	2.0
	40	1.0	0.3	3.3
	20	2.0	0.5	4.0
	30	2.5	0.5	5.0
	30	2.0	0.3	6.7
	--	4.0	0.5	8.0
	--	5.0	1.8	2.8
	20	1.5	0.7	2.1
	25	3.0	1.0	3.0
	40	2.0	1.5	1.3
	20	0.5	0.2	2.5

SAGLEK EAST MOSAIC AREA - WIDTH, DEPTH AND BERM HEIGHT MEASUREMENTS (CONT'D)

GEOLOGIC UNIT	SCOUR WIDTH (m)	SCOUR DEPTH (m)	BERM HEIGHT (m)	RATIO OF DEPTH/HEIGHT
4B	45	2.5	--	--
poorly	65	5.5	1.5	3.7
stratified	30	6.0	1.0	6.0
glaciomarine	60	0.5	0.7	0.7
	20	0.7	0.3	2.3
	30	2.2	0.2	11.0
	20	0.5	0.2	2.5
	25	3.0	1.0	3.0
	--	1.0	0.2	5.0
	45	0.7	0.3	2.3
	25	0.1	0.1	1.0
	20	0.2	0.1	2.0
	30	0.2	0.1	2.0
	25	3.0	1.0	3.0
	20	1.5	0.4	3.8
	40	2.0	1.5	1.3
	60	2.0	2.0	1.0
	--	1.5	1.0	1.5
	60	1.0	0.8	1.2
	--	1.0	0.4	2.5
	--	1.0	1.0	1.0
	60	5.0	1.2	4.2
	--	5.0	1.8	2.8
	--	2.5	1.0	2.5
	25	1.2	1.2	1.0
	50	2.0	0.7	2.8
	35	2.0	0.5	4.0
	20	0.5	--	--
	15	0.2	0.1	2.0
	40	1.5	1.0	1.5
	20	1.5	0.5	3.0
	35	2.0	0.5	4.0
	40	2.5	1.0	2.5
	50	3.0	2.0	1.5
	45	2.0	1.5	1.3
	20	0.2	--	--
	20	1.0	0.7	1.4
	30	1.0	0.5	2.0
	20	4.0	1.0	4.0
	40	0.7	0.3	2.3
	30	2.0	2.0	1.0
	35	2.0	0.5	4.0
	35	1.0	1.5	0.6

SAGLEK EAST MOSAIC AREA - WIDTH, DEPTH AND BERM HEIGHT MEASUREMENTS (CONT'D)

GEOLOGIC UNIT	SCOUR WIDTH (m)	SCOUR DEPTH (m)	BERM HEIGHT (m)	RATIO OF DEPTH/HEIGHT
4C	20	1.0	0.4	2.5
non-	20	2.0	1.0	2.0
stratified	20	0.7	0.9	0.8
glaciomarine	20	2.5	--	--
	40	1.0	2.0	0.5
	25	3.0	0.5	6.0
	40	0.7	0.5	1.4
	20	1.0	0.5	2.0
	40	2.5	1.5	1.7
	20	0.5	0.2	2.5
	20	3.0	1.0	3.0
	20	1.5	1.2	1.3
	20	1.0	0.3	3.3

APPENDIX 4

BAFFIN-DAVIS REGION SUPPORT DATA

AGC CRUISE DATA ANALYSED, BAFFIN-DAVIS REGION

Cruise Examined	Area	Sample Areas	Total Kms Entered in Detail Huntec	Sidescan
76-023	Scott Trough	10	20	20
78-029	S Baffin Shelf	171	342	342
76-025	SE Baffin Shelf Lancaster Sound	37	74	74
80-028	Baffin Shelf	392	784	606
80-035	SE Baffin Shelf	320	640	420
81-045	Baffin Shelf	262	384	512
84-035	SE Baffin, Hudson Strait	229	--	458
Total		2842	2244	2432

APPENDIX 5

LANCASTER SOUND SUPPORT DATA

AGC CRUISE DATA ANALYZED, LANCASTER SOUND REGION

Cruise Examined	Area	Sample Area	Total Kms Entered in Detail	
			Huntec	Sidescan
76-023	Lancaster Sound	15	0	29
76-025	Lancaster Sound	50	42	100
81-045	Lancaster Sound	55	0	110
Total		120	42	239

APPENDIX 6

WELLSITE SURVEY INVENTORY

GRAND BANKS SITE SURVEY INVENTORY

OPERATOR: B.P.

Site: Baie Verte J-57 | Centre Co-ordinate: 50°17'N; 51°08'W

Survey Year: 1984 | Grid Size (km): 3 x 3

Water Depth (m): 300-314 | Line Spacing(m)/Orientation: 500/N-S
500/E-W

Data Quality: Good | Report Status: Proprietary

Geologic Conditions: Homogeneous fine muddy sand to sandy mud with scattered gravel and coarser material.

Iceberg Scour Presentations: Mozaic presented; 208 scours measured but parameters not included in report (intense scouring)

Field Systems: Sounder, 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, grabs and photos.

Overlapping Data Sets: None

OPERATOR: CANTERRA

Site: Beothuk | Centre Co-ordinate: 46°24'N; 48°33'W

Survey Year: 1984 | Grid Size (km): 2.5 x 2.5

Water Depth (m): 91-93 | Line Spacing(m)/Orientation: 500/N-S
500/E-W

Data Quality: Fair | Report Status: Proprietary

Geologic Conditions: Predominantly fine to medium sand with some sand and gravel to gravel.

Iceberg Scour Presentations: No scours identified.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, grabs, photos.

Overlapping Data Sets: None

Comments: Megaripples along geologic boundaries. One line NE-SW through centre of site.

Site: Beothuk M-05 — Centre Co-ordinate: 46°25'N; 48°31'W

Survey Year: 1984 — Grid Size (km): 2.8 x 3.2

Water Depth (m): 96-98 — Line Spacing(m)/Orientation: 500/N-S, 500/E-W

Data Quality: Excellent — Report Status: Released

Geologic Conditions: Poorly graded fine to medium grained sand to poorly sorted gravel.

Iceberg Scour Presentations: Four scours mapped; Report states widths vary from 15 to 20 m and depths are < 0.5.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, grabs and photos.

Overlapping Data Sets: None

Comments: One line NE-SW through centre of site.

Site: Port au Port J-97 — Centre Co-ordinate: 46°16'38"N; 48°44'06"W

Survey Year: 1984 — Grid Size (km): 4 x 4

Water Depth (m): 69-73 — Line Spacing (m)/Orientation: 500/NW-SE, 500/NE-SW

Data Quality: Excellent — Report Status: Released

Geologic Conditions: Veneer of medium grained sand.

Iceberg Scour Presentations: No scours or furrows observed.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, grabs and photos.

Overlapping Data Sets: None

Comments: A mozaic was made showing a number of E-W striking lineations believed to be sand ribbons, not scours.

OPERATOR: CHEVRON

Site: Hibernia P-15 — Centre Co-ordinate: 46°44'58"N; 48°46'52"W

Survey Year: 1979 — Grid Size (km): 6.4 x 4.75

Water Depth (m): 78-84 — Line Spacing (m)/Orientation: 250-450/NW-SE; 350-850/NE-SW

Data Quality: Excellent — Report Status: Released

Geologic Conditions: Fine sand to coarse gravels.

Iceberg Scour Presentations: No scours identified.

Field Systems: Sounder, ORE 3.5 kHz profiler, ORE 100 kHz Sidescan, High Resolution Seismic, samples and photos.

Overlapping Data Sets: Polaris 1980, 80-010, 4000 Series (1980), C-CORE/Cormorant (1984), Mobil Hibernia P 15.

OPERATOR: ESSO

Site: Voyager Gabriel C-60 — Centre Co-ordinate: 47°19'10"N; 46°53'31"W

Survey Year: 1979 — Grid Size (km): 6.5 x 4.5

Water Depth (m): 1074-1134 — Line Spacing(m)/Orientation: 500/N-S; 500/E-W

Data Quality: No penetration on 3.5 kHz — Report Status: Released

Geologic Conditions: Clay/silt.

Iceberg Scour Presentations: No scours identified.

Field Systems: Sounder, 3.5 kHz Profiler, High Resolution Seismic.

Overlapping Data Sets: None

Comments: Sounder data lost post-survey. No sidescan data.

Site: Gabriel FP-82

Survey Year: 1980

Water Depth (m): 1116-1150

Centre Co-ordinate: 47°12'30"N; 46°56'20"W

Grid Size (km): 4.2 x 4.4

Line Spacing (m)/Orientation: 300-600/E-W
300-600/N-S

Data Quality: Good

Report Status: Released

Geologic Conditions: Clay/silt.

Iceberg Scour Presentations: No scours identified.

Field Systems: Sounder, High Resolution Seismic, Grab samples.

Overlapping Data Sets: None

Comments: Variable line spacing; no sidescan or profiler.

Site: FP-1

Survey Year: 1981

Water Depth (m): 1075-1135

Centre Co-ordinate: 47°01'14"N; 47°03'11"W

Grid Size (km): 4 x 4

Line Spacing(m)/Orientation: 300/N-S
300/E-W

Data Quality: No penetration on 3.5 kHz

Report Status: Released

Geologic Conditions: Silty sand.

Iceberg Scour Presentations: No scours identified.

Field Systems: Sounder, High Resolution Seismic, 3.5 kHz Profiler.

Overlapping Data Sets: 84-035

Comments: Grid spacing increases with distance from wellsite.

Site: FP-26

Survey Year: 1981

Water Depth (m): 1040-1135

Centre Co-ordinate: 47°56'37"N; 46°10'56"W

Grid Size (km): 5 x 22

Line Spacing(m)/Orientation: 400/N-S
280/E-W

Data Quality: No penetration on 3.5 kHz

Report Status: Released

Geologic Conditions: Sandy silt to silty sand with minor gravel.

Iceberg Scour Presentations: No scours identified.

Field Systems: Sounder, High Resolution Seismic, 3.5 kHz Profiler, Cores, Photos, Grabs.

Overlapping Data Sets: None

Comments: Grid includes FP-26, 30, 73; N-S lines only exist in area of wellsite.

Site: FP-30

Centre Co-ordinate: 47°56'35"N; 46°15'57"W

Survey Year: 1981

Grid Size (km): 5 x 22

Water Depth (m): 1150-1172

Line Spacing(m)/Orientation: 400/N-S
280/E-W

Data Quality: No penetration on 3.5 kHz

Report Status: Released

Geologic Conditions: Sandy silt to silty sand with minor gravel.

Iceberg Scour Presentations: No scours identified.

Field Systems: Sounder, High Resolution Seismic, 3.5 kHz Profiler, Cores, Photos, Grabs.

Overlapping Data Sets: None

Comments: Grid includes FP-26, 30, 73; N-S lines only in area of wellsite.

Site: FP-73

Centre Co-ordinate: 47°56'31"N; 46°25'00"W

Survey Year: 1981

Grid Size (km): 5 x 22

Water Depth (m): 1172-1176

Line Spacing(m)/Orientation: 400/N-S
280/E-W

Data Quality: No penetration on 3.5 kHz

Report Status: Released

Geologic Conditions: Sandy silt to silty sand with minor gravel.

Iceberg Scour Presentations: No scours identified.

Field Systems: Sounder, High Resolution Seismic, 3.5 kHz Profiler, Cores, Photos, Grabs.

Overlapping Data Sets: None

Comments: Grid includes FP-26, 30, 73; N-S lines only exist in area of wellsite.

<u>OPERATOR: HUSKY</u>

Site: <u>Conquest</u>
Centre Co-ordinate: 47°23'N; 48°43'W
Survey Year: 1984
Grid Size (km): 9 x 7.5
Water Depth (m): 142-150
Line Spacing (m)/Orientation: 500/NE-SW
500/NW-SE
Data Quality: Fair
Report Status: Proprietary
Geologic Conditions: Fine to medium grained sand.
Iceberg Scour Presentations: Number of scours and pits mapped with depths and widths given.
Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs, Photos.
Overlapping Data Sets: None

Site: <u>North Ben Nevis</u>
Centre Co-ordinate: 46°40'55"N; 48°25'23"W
Survey Year: 1984
Grid Size (km): 10.5 x 4.5
Water Depth (m): 101-104
Line Spacing (m)/Orientation: 500/NW-SE
500/NE-SW
Data Quality: Fair
Report Status: Proprietary
Geologic Conditions: Sandy gravel to gravel with sand ribbons; surficial unit less than 1.0 m.
Iceberg Scour Presentations: One scour mapped from sidescan giving width. A number mapped from DTS with width and depth (pits and scours).
Field Systems: Sounder, ORE Sidescan (100 kHz), Huntec DTS, High Resolution Seismic, Grabs, Photos.
Overlapping Data Sets: 80-010; 8000 series.

Site: <u>North Ben Nevis Rev-1</u>
Centre Co-ordinate: 46°43'N; 48°29'W
Survey Year: 1984
Grid Size (km): 3 x 3
Water Depth (m): 100-102
Line Spacing (m)/Orientation: 500/NW-SE
500/NE-SW
Data Quality: Very good
Report Status: Proprietary

Geologic Conditions: Sand to gravelly sand to gravel with some megaripples.

Iceberg Scour Presentations: Numerous scours and pits mapped with widths indicated. Report states that all scours are less than 0.5 m deep.

Field Systems: Sounder, ORE Sidescan (100 kHz), Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 8000 series.

Site: South Panther — Centre Co-ordinate: 47°02'N; 47°40'W

Survey Year: 1984 — Grid Size (km): 10.5 x 6

Water Depth (m): 182-200 — Line Spacing (m)/Orientation: 500/NE-SW, 500/NW-SE

Data Quality: Good — Report Status: Proprietary

Geologic Conditions: Fine sand with scattered coarser material.

Iceberg Scour Presentations: Numerous scours and pits mapped with width and depths given where possible.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 80-010

Site: South Panther Rev-1 — Centre Co-ordinate: 47°05'N; 47°43'W

Survey Year: 1984 — Grid Size (km): 7.5 x 5

Water Depth (m): 182-200 — Line Spacing (m)/Orientation: 500/NW-SE, 500/NE-SW

Data Quality: Fair to Good — Report Status: Proprietary

Geologic Conditions: Fine sand with scattered coarser material.

Iceberg Scour Presentations: Numerous pits mapped giving widths and depths.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 80-010

Site: <u>South Tempest Step-Out</u> Centre Co-ordinate: 47°05'N; 47°53'W

Survey Year: 1984 Grid Size (km): 6.0 x 5.2

Water Depth (m): 165-175 Line Spacing (m)/Orientation: 500/NW-SE
500/NE-SW

Data Quality: Fair to Good Report Status: Proprietary

Geologic Conditions: Homogenous fine sand with scattered coarser material.

Iceberg Scour Presentations: A few scours and numerous pits mapped with depths and widths given.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: Tempest North

Site: <u>White Bear</u> Centre Co-ordinate: 47°58'30"N; 47°11'00"W

Survey Year: 1984 Grid Size (km): 7.0 x 6.0

Water Depth (m): 159-166 Line Spacing (m)/Orientation: 500/NE-SW
500/NW-SE

Data Quality: Fair to Good Report Status: Proprietary

Geologic Conditions: Fine sand with scattered coarser material.

Iceberg Scour Presentations: Numerous pits and scours observed with widths and depths given.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: Tempest North

Site: <u>Burin Bonne Bay</u> Centre Co-ordinate: 46°31'N; 48°15'W

Survey Year: 1985 Grid Size (km): 10.5 x 4

Water Depth (m): 100-109 Line Spacing (m)/Orientation: 500/NW-SE
500/NE-SW

Data Quality: Good Report Status: Proprietary

Geologic Conditions: Sand to gravelly sand to gravel.

Iceberg Scour Presentations: Numerous pits and scours mapped with depths and widths given where possible.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 8000 Series.

Site: <u>Golconda/Regent</u>

Centre Co-ordinate: 46°55'N; 47°37'W

Survey Year: 1985

Grid Size (km): 9 x 17

Water Depth (m): 170-215

Line Spacing (m)/Orientation: 500/NNW-SSE, 500/ENE-WSW

Data Quality: Good

Report Status: Proprietary

Geologic Conditions: Homogenous fine sand with scattered coarser material.

Iceberg Scour Presentations: Numerous pits and scours mapped with widths and depths given.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: None

Site: <u>Phoenix</u>

Centre Co-ordinate: 47°43'N; 48°49'W

Survey Year: 1985

Grid Size (km): 2.5 x 2.5

Water Depth (m): 186-192

Line Spacing(m)/Orientation: 500/N-S, 500/E-W

Data Quality: Fair

Report Status: Proprietary

Geologic Conditions: Moderately graded medium to fine sand.

Iceberg Scour Presentations: Only pits identified on site; features mapped with depths and widths given where possible.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: None

OPERATOR: MOBIL

Site: Archer Flank

Survey Year: 1979

Water Depth (m): 114-132

Center Co-ordinate: 46°42'N; 48°04'W

Grid Size (km): 28.8 x 17 km

Line spacing (m)/Orientation: 400/N-S
4000/E-W

Data Quality: Good

Report Status: Released

Geologic Conditions: Thin 1-2 m veneer of medium to fine-medium sand overlying coarse sand and/or fine gravel. This coarser material occasionally outcrops at the seabed.

Iceberg Scour Presentations: Abundant (>60) scours mapped. Lengths from 100's of metres to 3.5 km, with NNE-SSW orientation of longer features. No widths or depths presented in report.

Field Systems: Sounder, Klein and ORE 100 kHz Sidescan, NSRF V-Fin profiler, High resolution seismic, Shipek Model 806 Grab Sampler, Photos.

Overlapping Data Sets: 8000 Series, 80-010

Comments: Trawler marks very common over the site. Scouring suggested to be both relict and recent.

Site: Ben Nevis

Survey Year: 1979

Water Depth (m): 96-102

Centre Co-ordinate: 46°34'46"N; 48°21'58"W

Grid Size (km): 12 x 7

Line Spacing (m)/Orientation: 400/NW-SE
2000/NE-SW

Data Quality: Fair to Good

Report Status: Released

Geologic Conditions: Fine to coarse gravel with patches of sand.

Iceberg Scour Presentations: 12 scours mapped but no parameters given.

Field Systems: Sounder, Dual ORE Profiler and 100 kHz Sidescan, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 80-010, 8000 Series, North Ben Nevis (PEX '84)

Comments: Scours are all quite short. The majority are visible on only one line.

Site: Trave/White Rose — Centre Co-ordinate: 46°55'N; 48°00'W

Survey Year: 1979 — Grid Size (km): 12 x 21

Water Depth (m): 115-149 — Line Spacing (m)/Orientation: 500/NE-SW
2000/NW-SE

Data Quality: Good — Report Status: Released

Geologic Conditions: Medium grained sand with minor amounts of gravel.

Iceberg Scour Presentations: Large number of scours mapped but no depths or widths.

Field Systems: Sounder, ORE Dual Profiler and Sidescan, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 80-010, 4000 Series.

Comments: There is a listing of feature locations on the sonogram records; includes widths and orientations.

Site: Hibernia North B-08 — Centre Co-ordinate: 46°47'06"N; 48°45'30"W

Survey Year: 1980 — Grid Size (km): 10 x 7

Water Depth (m): 78-86 — Line Spacing (m)/Orientation: 400/NW-SE
2000/NE-SW

Data Quality: Good — Report Status: Released

Geologic Conditions: Gravel with a sand veneer.

Iceberg Scour Presentations: Report doesn't mention scours.

Field Systems: Sounder, Dual ORE Sidescan and Profiler, High Resoluton Seismic, Grabs, Photos.

Overlapping Data Sets: 80-010, 83-033, 4000 Series, C-CORE/Cormorant (1984).

Site: Hibernia South L-44 — Centre Co-ordinate: 46°43'34"N; 48°52'26"W

Survey Year: 1980 — Grid Size (km): 5 x 10

Water Depth (m): 76-82 — Line Spacing (m)/Orientation: 400/WNW-ESE
1700/NNE-SSW

Data Quality: Good — Report Status: Released

Geologic Conditions: Gravel overlain by a veneer of sand.

Iceberg Scour Presentations: No scours observed.

Field Systems: Sounder, Dual ORE Sidescan and Profiler, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 80-010, 83-033, C-CORE/Cormorant (1984).

Comments: Numerous patches of ripples.

Site: Hibernia P-15

Centre Co-ordinate: 46°44'59"N; 48°46'51"W

Survey Year: 1980

Grid Size (km): 2.5 x 2.5

Water Depth (m): 80-82

Line Spacing (m)/Orientation: 100/NE-SW
200/NW-SE

Data Quality: Good

Report Status: Released

Geologic Conditions: Primarily medium sand with patches of coarser sand.

Iceberg Scour Presentations: One scour mapped; no parameters.

Field Systems: Sounder, ORE 100 kHz Sidescan.

Overlapping Data Sets: Polaris (1980), 80-010, 4000 Series (marginal), C-CORE/ Cormorant (1984), Chevron Hibernia P 15.

Comments: Only two lines to NW and three lines to NE.

Site: Tempest North

Centre Co-ordinate: 47°00'50"N; 47°50'45"W

Survey Year: 1980

Grid Size (km): 8 x 15

Water Depth (m): 144-162

Line Spacing (m)/Orientation: 400/NW-SE
2000/NE-SW

Data Quality: Good

Report Status: Released

Geologic Conditions: Medium to fine grained sand with some coarse material.

Iceberg Scour Presentations: Approximately 60 scours mapped with depth and orientation given.

Field Systems: Sounder, Dual ORE Profiler and 100 kHz Sidescan, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: White Bear; South Tempest Step-Out

Comments: Site contains South Tempest G-88 Wellsite.

Site: Cumberland

Centre Co-ordinate: 48°28'N; 50°00'W

Survey Year: 1981

Grid Size (km): 15 x 5.6

Water Depth (m): 189-235

Line Spacing (m)/Orientation: 400/N-S
4500/NE-SW

Data Quality: Poor

Report Status: Released

Geologic Conditions: Locally variable sand to gravel (30-40 cm).

Iceberg Scour Presentations: A possible scour on Huntec DTS but not certain.

Field Systems: Sounder, ORE Dual 100 kHz Sidescan and 3.5 kHz Profiler, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: None

Site: North Dana

Centre Co-ordinate: 47°13'N; 47°37'W

Survey Year: 1981

Grid Size (km): 10.6 x 6.8

Water Depth (m): 202-239

Line Spacing (m)/Orientation: 400/NE-SW
4500/NW-SE

Data Quality: Fair

Report Status: Released

Geologic Conditions: Smooth medium grained sand; no surficial geology chart prepared.

Iceberg Scour Presentations: No scours identified.

Field Systems: Sounder, Dual ORE 100 kHz Sidescan and 3.5 kHz Profiler, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: None

Comments: North and South Dana are adjoining and are contained in a single report.

Site: South Dana

Centre Co-ordinate: 47°10'N; 47°32'W

Survey Year: 1981

Grid Size (km): 14.4 x 8

Water Depth (m): 205-260

Line Spacing (m)/Orientation: 400/NE-SW;
4500/NW-SE

Data Quality: Fair

Report Status: Released

Geologic Conditions: Smooth medium grained sand; no surficial geologic chart produced.

Iceberg Scour Presentations: No scours identified.

Field Systems: Sounder, Dual ORE 100 kHz Sidescan and 3.5 kHz Profiler, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: None

Comments: Dana North and South are adjoining and are contained in a single report.

Site: <u>Hebron</u> Centre Co-ordinate: 46°32'30"N; 48°31'48"W

Survey Year: 1981 Grid Size (km): 14 x 12

Water Depth (m): 83-99 Line Spacing (m)/Orientation: 400/NE-SW
4000/NW-SE

Data Quality: Good Report Status: Released

Geologic Conditions: Sand to sandy gravels and gravelly sands.

Iceberg Scour Presentations: Five scours mapped; no parameters given.

Field Systems: Sounder, Dual ORE 100 kHz Sidescan and 3.5 kHz Profiler, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 80-010

Site: <u>Hibernia South J-34/G-34</u> Centre Co-ordinate: 46°43'35"N; 48°50'12"W

Survey Year: 1981 Grid Size (km): 5 x 10

Water Depth (m): 76-82 Line Spacing (m)/Orientation: 400/WNW-ESE
1700/NNE-SSW

Data Quality: Good Report Status: Released

Geologic Conditions: Gravel overlain by a veneer of sand.

Iceberg Scour Presentations: No scours observed.

Field Systems: Sounder, Dual ORE Sidescan and 3.5 kHz Profiler, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 80-010, 83-033, C-CORE/Cormorant (1984).

Comments: Reinterpretation of Hibernia South Survey

Site: Nautilus
Centre Co-ordinate: 46°52'N; 48°45'W

Survey Year: 1981
Grid Size (km): 7.5 x 4.5

Water Depth (m): 81-98
Line Spacing (m)/Orientation: 400/NE-SW
1800/NW-SE

Data Quality: Fair to Good
Report Status: Released

Geologic Conditions: Sand to sandy gravel to gravel.

Iceberg Scour Presentations: Five scours mapped; no parameters.

Field Systems: Sounder, Dual ORE 100 kHz Sidescan and 3.5 kHz Profiler, Huntec DTS, Grabs, Photos.

Overlapping Data Sets: 80-010, 83-033, 4000 Series.

Comments: NW-SE line spacing varies from 1800 to 2500 m.

Site: Ragnar
Centre Co-ordinate: 47°20'30"N; 47°51'00"W

Survey Year: 1981
Grid Size (km): 15 x 5.6

Water Depth (m): 184-222
Line Spacing (m)/Orientation: 400/ENE-WSW
4500/NNW-SSE

Data Quality: Fair
Report Status: Released

Geologic Conditions: Medium grained sand with minor gravel.

Iceberg Scour Presentations: Three scours identified but not mapped.

Field Systems: Sounder, Dual ORE 100 kHz Sidescan and 3.5 kHz Profiler, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: None

Comments: Huntec has better quality than ORE 3.5 kHz.

Site: Rankin
Centre Co-ordinate: 46°35'N; 48°50'W

Survey Year: 1981
Grid Size (km): 15 x 22

Water Depth (m): 70-82
Line Spacing(m)/Orientation: 400/N-S
4000/E-W

Data Quality: Fair
Report Status: Released

Geologic Conditions: Fine sand to gravel and cobbles.

Iceberg Scour Presentations: No scours observed.

Field Systems: Sounder, ORE Dual 100 kHz Sidescan and 3.5 kHz Profiler, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 80-010, 83-033, 8000 Series.

Site: West Flying Foam L-23

Centre Co-ordinate: 47°02'44"N; 48°40'17"W

Survey Year: 1981

Grid Size (km): 18 x 8

Water Depth (m): 90-103

Line Spacing(m)/Orientation: 400/N-S
4000/E-W

Data Quality: Excellent

Report Status: Released

Geologic Conditions: Primarily medium sands with some gravel.

Iceberg Scour Presentations: No scours observed.

Field Systems: Sounder, Huntec DTS, ORE 100 kHz Sidescan, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: None

Comments: Numerous trawl marks.

Site: West Hibernia

Centre Co-ordinate: 46°46'N; 48°52'W

Survey Year: 1981

Grid Size (km): 16 x 4

Water Depth (m): 75-84

Line Spacing (m)/Orientation: 400/NNE-SSW
3600/NW-SE

Data Quality: Fair to Good

Report Status: Released

Geologic Conditions: 65% of site dominantly gravel with remainder sandy gravel to sand.

Iceberg Scour Presentations: Four scours mapped but no parameters given; all scours poorly defined.

Field Systems: Sounder, ORE 100 kHz Sidescan, ORE 3.5 kHz Profiler.

Overlapping Data Sets: Polaris (1980), 80-010, 83-033, Hibernia South, Hibernia North (site surveys have only a marginal overlap).

Comments: Due to problems profiler only used for small part of site.

Site: <u>White Rose Flank</u>

Centre Co-ordinate: 46°48'N; 48°08'W

Survey Year: 1981

Grid Size (km): 14.5 x 15.9

Water Depth (m): 110-127

Line Spacing(m)/Orientation: 400/E-W
400/N-S

Data Quality: Good

Report Status: Released

Geologic Conditions: Fine to medium grained sand with minor gravel patches.

Iceberg Scour Presentations: Approximately 75 scours mapped but no parameters given.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 80-010

Site: <u>Bonanza M-71</u>

Centre Co-ordinate: 47°30'48"N; 48°11'55"W

Survey Year: 1982

Grid Size (km): 10 x 11

Water Depth (m): 181-211

Line Spacing (m)/Orientation: 400/WNW-ESE
3000-6000/NNW-SSE

Data Quality: Fair

Report Status: Released

Geologic Conditions: Fine to medium sand with a minor coarse.

Iceberg Scour Presentations: 22 iceberg scours observed on S.S. and/or profiler with length, depth, and orientation indicated when possible.

Field Systems: Sounder, ORE 100 kHz Sidescan, NSRF V-Fin, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: None

Comments: Scours are interpreted to be relict.

Site: <u>Linnet E-63</u>

Centre Co-ordinate: 48°12'30"N; 50°25'26"W

Survey Year: 1982

Grid Size (km): 15.8 x 14

Water Depth (m): 119-204

Line Spacing(m)/Orientation: 4000/N-S
400/E-W

Data Quality: Good

Report Status: Released

Geologic Conditions: Fine to medium sands with occasional gravel patchs.

Iceberg Scour Presentations: 35 scours mapped, but no parameters given.

Field Systems: Sounder, ORE 100 kHz Sidescan, V-Fin Profiler, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: None

Comments: Scours appear partially infilled.

Site: West Flying Foam L-23 | Centre Co-ordinate: 47°02'44"W; 48°40'17"W

Survey Year: 1982 | Grid Size (km): 17 x 8.5

Water Depth (m): 91-103 | Line Spacing(m)/Orientation: 400/N-S
2500/E-W

Data Quality: Good | Report Status: Released

Geologic Conditions: Medium sand with some gravel patches.

Iceberg Scour Presentations: No scours were identified.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, grabs, Photos.

Overlapping Data Sets: None

Comments: Numerous trawl marks observed.

Site: Dominion | Centre Co-ordinate: 47°23'N; 48°22'W

Survey Year: 1983 | Grid Size (km): 6.5 x 8

Water Depth (m): 156-166 | Line Spacing(m)/Orientation: 400/ENE
2000/NNW

Data Quality: Fair | Report Status: Proprietary

Geologic Conditions: Fine uniformly graded sand.

Iceberg Scour Presentations: Some scours and numerous pits mapped; widths and depths given where possible.

Field Systems: Sounder, 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs and Photos

Overlapping Data Sets: 80-010

Site: Mara

Centre Co-ordinate: 46°46'N; 48°38'W

Survey Year: 1983

Grid Size (km): 15 x 15.6

Water Depth (m): 80-100

Line Spacing(m)/Orientation: 400/NNE
2000/ESE

Data Quality: Good

Report Status: Proprietary

Geologic Conditions: Sand to gravel with sand ribbons and sand waves.

Iceberg Scour Presentations: Numerous scours and pits mapped showing width and depth where possible.

Field Systems: Sounder, 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs and Photos.

Overlapping Data Sets: 4000 Series ('80), 8000 Series ('80), C-CORE/Cormorant ('84), 80-010, 83-033, 81-012

Site: Titus

Centre Co-ordinate: 48°34'N; 50°44'W

Survey Year: 1983

Grid Size (km): 7.5 x 9

Water Depth (m): 160-206

Line Spacing (m)/Orientation: 400/NW-SE
2000/NE-SW

Data Quality: Fair to Good

Report Status: Released

Geologic Conditions: Fine grained sand to sandy gravel.

Iceberg Scour Presentations: Six scours were mapped from sidescan; numerous pits mapped from profiler and sidescan; depth, width, length and orientation given.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: None

Comments: Site is "peppered" with pits and scours as identified from profiler.

Site: Voyager

Centre Co-ordinate: 46°27'N; 48°22'W

Survey Year: 1983

Grid Size (km): 6.2 x 15

Water Depth (m): 92-103

Line Spacing (m)/Orientation: 400/NE-SW
3400/NW-SE

Data Quality: Fair Report Status: Released

Geologic Conditions: Sand to gravel 0.5 to 1.5 m.

Iceberg Scour Presentations: Three scours mapped indicating width, depth, length and orientation.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 80-010

Site: Avondale A-46 Centre Co-ordinate: 46°35'08"N; 48°36'18.2"W

Survey Year: 1987 Report Status: Proprietary

(No other information released)

Site: GBS Site Bathymetric Survey Centre Co-ordinate: 46°45'50"N; 48°45'35"W

Survey Year: 1987 Report Status: Proprietary

(No other information released)

Site: GBS Bathymetric and Geotechnical Site Survey Centre Co-ordinate: 46°45'50"N; 48°45'35"W

Report Status: Proprietary

(No other information released)

OPERATOR: PETRO CANADA INC.

Site: Port au Port
Centre Co-ordinate: 46°14'N; 48°45'W
Survey Year: 1981
Grid Size (km): 17x 7
Water Depth (m): 67-87
Line Spacing (m)/Orientation: 1000/NE-SW
500/NW-SE
Data Quality: Fair to Good
Report Status: Released
Geologic Conditions: Sand to gravel (.5 to 3m thick). Sandwaves, ribbons, and megaripples.
Iceberg Scour Presentations: One scour identified and mapped; parameters of 30 m wide and 1 m deep stated in report but not on map.
Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs, Photos.
Overlapping Data Sets: None

Site: Terra Nova K-08
Centre Co-ordinate: 46°27'30"N; 48°31'W
Survey Year: 1981
Grid Size (km): 3 x 2.5
Water Depth (m): 92-94
Line Spacing (m)/Orientation: 500/N-S
250-500/E-W
Data Quality: Fair
Report Status: Released
Geologic Conditions: Gravelly sand with a few sand patches.
Iceberg Scour Presentations: 11 scours mapped; no parameters given.
Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS High Resolution Seismic, Grabs, Photos.
Overlapping Data Sets: None
Comments: Closer line spacing at centre of site.

Site: Terra Nova South K-18
Centre Co-ordinate: 46°22'N; 48°31'W
Survey Year: 1981
Grid Size (km): 9 x 5
Water Depth (m): 91-94
Line Spacing(m)/Orientation: 1000/N-S
500/E-W

Data Quality: Fair to Good   Report Status: Released

Geologic Conditions: Gravelly sand to sandy gravel with patches of sand and gravel or cobbles.

Iceberg Scour Presentations: Three scours mapped but no parameters given.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS, High Resolution Seismic, Grabs, Photos.

Availability of Field Data:

Overlapping Data Sets: 77-011

Comments: Sidescan data collected on all E-W lines but only on three N-S lines.

Site: North Ben Nevis   Centre Co-ordinate: 46°38'25.89"N; 48°25'09.69"W

Survey Year: 1984   Grid Size (km): 10 x 5

Water Depth (m): 99-103   Line Spacing (m)/Orientation: 500/NW-SE 1000/NE-SW

Data Quality: Good   Report Status: Proprietary

Geologic Conditions: Medium to fine grained sand ribbons on a lag gravel surface.

Iceberg Scour Presentations: Poorly defined features interpreted as possible relict scours were identified but not mapped.

Field Systems: Sounder, ORE 100 kHz Sidescan, NSRF V-Fin, High Resolution Seismic Grabs, Photos.

Overlapping Data Sets: 80-010, 8000 Series, Ben Nevis (Mobil'79), North Ben Nevis (Husky '84)

Site: North Trinity   Centre Co-ordinate: 46°30'23.5'N 48°25'35.0'W

Survey Year: 1984   Grid Size (km): 6 x 3

Water Depth (m): 96-101   Line Spacing(m)/Orientation: 1000/N-S 500/E-W

Data Quality: Good   Report Status: Proprietary

Geologic Conditions: Coarse to fine grained sand ribbons on a gravel lag surface.

Iceberg Scour Presentations: No scours observed.

Field Systems: Sounder, ORE 100 kHz Sidescan, NSRF V-Fin, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 80-010, 8000 Series.

Site: St. George

Centre Co-ordinate: 45°44'54.64"N; 48°22'57.91"W

Survey Year: 1984

Grid Size (km): 5 x 3; 4.4 x 3

Water Depth (m): 102-122

Line Spacing (m)/Orientation: 1000/NW-SE; 500/NE-SW; 1000/NW-SE; 500/NE-SW

Data Quality: Good

Report Status: Proprietary

Geologic Conditions: Coarse to fine grained sand ribbons on a gravel lag surface.

Iceberg Scour Presentations: No scours observed.

Field Systems: Sounder, ORE 100 kHz Sidescan, NSRF V-Fin, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: None

Comments: Data collected as two separate grids; grid 2 extends to the SW of original.

Site: Terra Nova 1984

Centre Co-ordinate: 46°27'23"N; 48°28'12"W

Survey Year: 1984

Grid Size (km): 12.75 x 4

Water Depth (m): 92-99

Line Spacing(m)/Orientation: 500/N-S
1000/E-W

Data Quality: Good

Report Status: Proprietary

Geologic Conditions: Coarse to fine grained sand ribbons on a gravel lag surface.

Iceberg Scour Presentations: "Numerous" scours observed but none mapped; no parameters given.

Field Systems: Sounder, ORE 100 kHz Sidescan, NSRF V-Fin, High Resolution Seismic.

Overlapping Data Sets: None

Site: Terra Nova Infill K-07 — Centre Co-ordinate: 46°25'46.94"N 48°33'45.19"W

Survey Year: 1984 — Grid Size (km): 3 variable size blocks

Water Depth (m): 85-95 — Line Spacing (m)/Orientation: 500-1000/variable

Data Quality: Good — Report Status: Released

Geologic Conditions: Coarse to fine grained sand ribbons on a lag gravel surface.

Iceberg Scour Presentations: Scours were identified but not mapped due to their discontinuous nature.

Field Systems: Sounder, ORE 100 kHz Sidescan, NSRF V-Fin, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 77-011, C-CORE/Cormorant (1984)

Comments: Survey grid consists of 3 blocks.

Site: Gambo — Centre Co-ordinate: 46°19'29.53"N; 48°43'07.73"W

Survey Year: 1985 — Grid Size (km): 3 x 15.75

Water Depth (m): 65-86 — Line Spacing (m)/Orientation: 500/NE-SW 1000/NW-SE

Data Quality: Good — Report Status: Proprietary

Geologic Conditions: Coarse to fine grained sand on a lag gravel surface.

Iceberg Scour Presentations: No scours observed.

Field Systems: Sounder, ORE 100 kHz Sidescan, NSRF V-Fin, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 77-011

Comments: Irregular rectangle shape.

Site: Lancaster — Centre Co-ordinate: 47°16'56.9"N; 47°06'56.4"W

Survey Year: 1986 — Grid Size (km): 19 x 10.5 (approx.)

Water Depth (m): 500-990 — Line Spacing (m)/Orientation: 510/ENE-WSW 2000/ESE-WNW

Data Quality: Good   Report Status: Proprietary

Geologic Conditions: Fine sediment, hummocky slide originated sediments to west.

Iceberg Scour Presentations: No scours observed.

Field Systems: Sounder, ORE Sub-Bottom Profiler, High Resolution Seismic.

Overlapping Data Sets: 84-035

Comments: Irregular rectangle shape.

Site: South Brook F-30   Centre Co-ordinate: 46°19'N 48°34'W

Survey Year: 1988   Grid Size (km): 3 x 10

Water Depth (m): 85-92   Line Spacing (m)/Orientation: 500/EW
1000/NS

Data Quality: Good   Report Status: Proprietary

Geologic Conditions: Fine sand to sandy gravel

Iceberg Scour Presentations: Five scours and numerous pits mapped. Depths and widths given.

Field Systems: Sounder 100 kHz Sidescan sonar, NSRF V-Fin Profiler, High Resolution Seismic, gral samples and seabed photographs.

Overlapping Data Sets: Overlaps southern extreme of Terra Nova South and Terra Nova Infill.

Site: Trinity   Centre Co-ordinate: 46°27.7'N
48°24.7'W

Survey Year: 1988   Grid Size (km): 5.8 x 5.8

Water Depth (m): 95.5-98   Line Spacing (m)/Orientation: 500/EW
1000/NS

Data Quality: Good   Report Status: Proprietary

Geologic Conditions: Sand ribbons underlain by a lag gravel surface

Iceberg Scour Presentations: One iceberg scour and a few pits mapped. Depths and widths given.

Field Systems: Sounder, 100 kHz sidescan sonar, NSRF V-Fin Profiler, High Resolution Seismic, gral samples and seabed photographs.

Overlapping Data Sets: Terra Nova 1984, 80-010

Site: Brigus E-38

Survey Year: 1988

Water Depth (m): 64-70

Centre Co-ordinate: 46°17'N
48°51'W

Grid Size (km): 11.5 x 12

Line Spacing (m)/Orientation: 500/NW-SE
1000/NE-SW

Data Quality: Fair to Good

Report Status: Proprietary

Geologic Conditions: Sand to sandy gravel with scattered boulders

Iceberg Scour Presentations: Two scours mapped with widths and depth given

Field Systems: Sounder 100 kHz Sidescan sonar, NSRF V-Fin Profiler, High Resolution Seismic, gral samples and seabed photographs.

Overlapping Data Sets: Gambo, Port au Port J.97, C-CORE Cormorant, 80-010

OPERATOR: SHELL

Site: Conche

Survey Year: 1980

Water Depth (m): 1300-1490

Centre Co-ordinate: 50°51'11"N; 49°34'19"W

Grid Size (km): 4 x 4

Line Spacing (m)/Orientation:
500-1000/NNE-SSW; 500-1000/WNW-ESE

Data Quality: Uncertain

Report Status: Released

Geologic Conditions: Sandy to gravelly muds.

Iceberg Scour Presentations: None (see field systems)

Field Systems: Sounder High Resolution Seismic, Cores, Grabs, Photos.

Overlapping Data Sets: None

Comments: Englee and Conche are separate sites joined by a tie line.

Site: Englee

Survey Year: 1980

Water Depth (m): 1440-1660

Centre Co-ordinate: 50°46'26"N; 49°33'39"W

Grid Size (km): 4 x 4

Line Spacing (m)/Orientation:
500-1000/NNE-SSW; 500-1000/WNW-ESE

Data Quality: Uncertain

Report Status: Released

Geologic Conditions: Sandy to gravelly muds.

Iceberg Scour Presentations: None (see field systems)

Field Systems: Sounder, High Resolution Seismic, Current Meters, Cores, Samples.

Overlapping Data Sets: None

Comments: Englee and Conche are separate sites joined by a tie line.

OPERATOR: TEXACO

Site: South Voyager

Survey Year: 1988

Water Depth (m): 97-109

Centre Co-ordinate: 46°27'N; 48°14'W

Grid Size (km): 11 x 14 km

Line Spacing (m)/Orientation: 500/E-W
3000-5000/NNW-SSE
500/NNW-SSE
2500-WNW-ESE

Data Quality: Good

Report Status: Proprietary

Geologic Conditions: Sand patches on gravel, overall thickness 2-5 m.

Iceberg Scour Presentations: A number of scours mapped

Field Systems: Sounder, Klein 100 kHz Sidescan Sonar, NSRF V-Fin Profiler, High Resolution Seismic, Grabs, Photos.

Overlapping Data Sets: 80-010

Comments: Most scours defined, with the exception of two well defined continuous features in the southern region.

OPERATOR: CANTERRA

Site: South Voisey

Centre Co-ordinate: 56°02'6"N; 58°30'5"W

Survey Year: 1982

Grid Size (km): 4 x 12

Water Depth (m): 448-499

Line Spacing(m)/Orientation: 250/NW-SE
1000/NE-SW

Data Quality: Good

Report Status: Released

Geologic Conditions: Silty clay 5-15 m thick.

Iceberg Scour Presentations: Report does not identify any scours.

Field Systems: Dual ORE 100 kHz Sidescan, 3.5 kHz Profiler, NSRF V-fin, High Resolution Seismic, Cores, Photos.

Overlapping Data Sets: 82-054, 82-054

Comments: A few "pock marks" identified.

Site: Hopedale South L-39

Centre Co-ordinate: 55°48'33'N; 58°50'49"W

Survey Year: 1983

Grid Size (km): 6 x 5.5

Water Depth (m): 560-594

Line Spacing(m)/Orientation: 500/NW-SE
500/NE-SW

Data Quality: Good

Report Status: Released

Geologic Conditions: Silty clay with minor portions of sand.

Iceberg Scour Presentations: No scours identified.

Field Systems: ORE 100 kHz Sidescan, NSRF V-Fin, High Resolution Seismic, Samples, Photos.

Overlapping Data Sets: None

Comments: "Pock marks" and otter board marks identified.

OPERATOR: CHEVRON

Site: HOPEDALE E-33
Centre Co-ordinate: 55°52'25"N; 58°50'52"W
Survey Year: 1978
Grid Size (km): 6.8 x 5.2
Water Depth(m): 55-57
Line Spacing (m)/Orientation: 1000/NW-SE
1000/NE-SW
Data Quality: Good
Report Status: Released

Geologic Conditions: 30-40 m of silt and clay thinning northward.
Iceberg Scour Presentation: None
Field Systems: Sounder, Sub-bottom profiler, Camera, Cores.
Overlapping Data Sets:
Comments: Line spacing varies from 250 m to 1000 m from centre of site.

Site: South Labrador N-79
Centre Co-ordinate: 55°48'50"N; 58°26'37"W
Survey Year: 1979
Grid Size (km): 10 x 4.5
Water Depth (m): 420-547
Line Spacing(m)/Orientation: 250-1000/NW-SE
250-1000/NE-SW
Data Quality: Good
Report Status: Released
Geologic Conditions: Saturated silty clay; 4-12 m thick underlain by gravel and sand sized material.
Iceberg Scour Presentations: None
Field Systems: High Resolution Seismic, Echo Sounder, 3.5 kHz Profiler.
Overlapping Data Sets: 82-054
Comments: No sidescan data and no scours identified based on profiler data. Line spacing varies with proximity to well location.

OPERATOR: ESSO

Site: Davis Strait C-5
Centre Co-ordinate: 60°41'27"N; 60°57'33"W
Survey Year: 1979
Grid Size (km): 5 x 5
Water Depth (m): 1060-1330
Line Spacing (m)/Orientation:
Data Quality: Good
Report Status: Released
Geologic Conditions: Sandy Silt

Iceberg Scour Presentation: None

Field System: Sound, High Resolution Seismic, Samples, Cores, Photos.

Overlapping Data Sets: None

Comments: No sidescan or sub-bottom profiles. This site and Davis Strait are combined as North Labrador Structure

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Site: Davis Strait

Centre Co-ordinate: 60°59'24"N; 61°56'25"W

Survey Year: 1979

Grid Size (km): "See Comments:

Water Depth (m): 1000 m

Line Orientation: NE-SW

Data Quality: Good

Report Status: Released

Geologic Conditions: Sandy silt with some boulders and cobbles in northern area.

Iceberg Scour Presentation: None

Field Systems: Sounder, High Resolution Seismic, Samples, Cores and Photos

Overlapping Data Sets: None

Comments: Consists of a single line extending from 60°54'55"N; 62°19'42"W to 61°05'43"N; 61°33'09"W. No sidescan or sub-bottom profiler. This site and Davis Strait C-5 are combined as North Labrador Structure.

OPERATOR: HUDSON'S BAY OIL AND GAS

Site: Adlavik M-03

Centre Co-ordinate: 55°42'45"N; 57°01'30"W

Survey Year: 1980

Grid Size (km): 2 x 3

Water Depth (m): 480-750

Line Spacing(m)/Orientation: 250/NE-SW
250/NW-SE

Data Quality: Fair to Good

Report Status: Released

Geologic Conditions: Sands with gravels to silts and clays.

Iceberg Scour Presentations: No scours identified.

Field Systems: Sounder, ORE 100 kHz Sidescan, High Resolution Seismic, Cores, Grabs, Photos.

Overlapping Data Sets: None

Comments: Otter board marks observed.

OPERATOR: PETRO CANADA INC.

Site: DB

Centre Co-ordinate: 54°40'19"N; 54°54'36"W

Survey Year: 1980

Grid Size (km): 6 x 2.5

Water Depth (m): 182-200

Line Spacing(m)/Orientation: 125/NE-SW
500/NW-SE

Data Quality: Good

Report Status: Released

Geologic Conditions: Muddy sand to gravel.

Iceberg Scour Presentations: Site is 60 percent scoured. Mozaic prepared but no individual scour parameters given.

Field Systems: Sounder, ORE 100 kHz Sidescan, Seismic, Camera, Grabs.

Overlapping Data Sets: None

Site: East HB

Centre Co-ordinate: 55°15'48"N; 55°36'54"W

Survey Year: 1980

Grid Size (km): 2 x 4.5

Water Depth (m): 152-162

Line Spacing(m)/Orientation: 250/N-S
450-1000/E-W

Data Quality: Good

Report Status: Released

Geologic Conditions: Sand to gravel

Iceberg Scour Presentations: 80 percent scoured; corrected mozaic prepared; no individual scour parameters given.

Field Systems: Sounder, ORE 100 kHz Sidescan, Seismic, Camera, Grabs.

Overlapping Data Sets: None

Comments: Scouring more evident in gravel areas. Scours have been traced and a mozaic overlay prepared.

Site: North Bjarni F-06

Centre Co-ordinate: 55°35'30"N; 57°45'49"

Survey Year: 1980

Grid Size (km): 2 x 2

Water Depth (m): 150-158

Line Spacing(m)/Orientation: 250/NE-SW
500/NW-SE

Data Quality: Good

Report Status: Released

Geologic Conditions: Muddy sand to sandy gravel.

Iceberg Scour Presentations: Mosaic prepared and better defined scours traced; no individual parameters.

Field Systems: Sounder, ORE 100 kHz Sidescan, Seismic, Camera, Grabs.

Overlapping Data Sets: 82-054

Comments: No evidence of seabed mobility; overlay exists for mosaic.

Site: Rut

Centre Co-ordinate: 59°10'17"N; 62°16'46"W

Survey Year: 1980

Grid Size (km): 2 x 2

Water Depth (m): 123-130

Line Spacing(m)/Orientation: 250/NE-SW
500/NW-SE

Data Quality: Good

Report Status: Released

Geologic Conditions: Muddy Sand (uniform).

Iceberg Scour Presentations: Site is 100 percent scoured. Corrected mozaic prepared but no individual scour parameters given.

Field Systems: Sounder, ORE 100 kHz Sidescan, Seismic, Camera, Grabs.

Overlapping Data Sets: 82-054.

Comments: Report contains some general orientation information. Scours have been traced and a mozaic overlay prepared.

Site: Helgi

Centre Co-ordinate: 54°58'N; 55°54'W

Survey Year: 1981

Grid Size (km): 4.5 x 3

Water Depth (m): 281-308

Line Spacing(m)/Orientation: 500 NE-SW
500 NW-SE

Data Quality: Good

Report Status: Released

Geologic Conditions: Sandy gravel to gravelly sand; 8-12 m of marine sediment (silty sand with some gravel).

Iceberg Scour Presentations: Scouring moderate. Scours mapped to scale (depths not given on chart).

Field Systems: Sounder, Dual ORE 100 kHz Sidescan, 3.5 kHz Profiler, High Resolution Seismic, Samples, Cores, Photos.

Overlapping Data Sets: None

Comments: Sidescan data set incomplete.

Site: NK — Centre Co-ordinate: 56°04'48"N; 58°12'W

Survey Year: 1981 — Grid Size (km): 8 x 3

Water Depth (m): 434-450 — Line Spacing(m)/Orientation: 490 NW-SE
375 NE-SW

Data Quality: Fair to Poor — Report Status: Released

Geologic Conditions: Silty sand with local occurrances of sand or gravel.

Iceberg Scour Presentations: Mapped, no parameters.

Field Systems: Sounder, ORE 100 kHz Sidescan, ORE 3.5 kHz Profiler, High Resolution Seismic, Samples, Cores and Photos.

Overlapping Data Sets: 82-054

Comments: Fish too high and displays excessive heave.

Site: SK — Centre Co-ordinate: 58°47'N; 60°30'W

Survey Year: 1981 — Grid Size (km): 12 x 3

Water Depth (m): 188-202 — Line Spacing(m)/Orientation: 600-1200 NE-SW
750/NW-SE

Data Quality: Good — Report Status: Released

Geologic Conditions: Sand with minor silt and gravel <.5 m thick underlain by glacial till.

Iceberg Scour Presentations: Extensively scoured. Prominent scours mapped.

Field Systems: Sounder, ORE 100 kHz Sidescan, Huntec DTS.

Overlapping Data Sets: None

Comments: None

Site: West DB

Survey Year: 1981

Water Depth (m): 168-190

Centre Co-ordinate: 54°46'18"N; 55°03'W

Grid Size (km): 4.5 x 3

Line Spacing(m)/Orientation: 420/NW-SE
420/NE-SW

Data Quality: 3.5 kHz - poor
S.S. - Good

Report Status: Released

Geologic Conditions: Fine to medium grained sand.

Iceberg Scour Presentations: Extensively scoured but only 50 percent mappable where possible scours have been mapped but no parameters given.

Field Systems: Sounder ORE 100 kHz Sidescan ORE 3.5 kHz Profiler, High Resolution Seismic, Samples and Photos.

Overlapping Data Sets: None

Comments: Excessive heave on 3.5 kHz sub-bottom profiler data.

OPERATOR: TOTAL EASTCAN EXPLORATION

Site: Bjarni

Survey Year: 1976

Water Depth (m): 130-165

Centre Co-ordinate: 55°30'30"N; 57°42'06"W

Grid Size (km): 12 x 12

Line Spacing(m)/Orientation: 1000/NW-SE
350/SW-NE

Data Quality: Good

Report Status: Released

Geologic Conditions: Sand to sandy gravel with cobbles.

Iceberg Scour Presentations: Moderate to heavily scoured. Scours mapped with widths and depths given.

Field Systems: Sounder, ORE 100 kHz Sidescan, 3.5 kHz Profiler.

Overlapping Data Sets: 82-054, 80-031, 81-057, 79-019, Bjarni Survey Site.

Comments: Lots of statistical information; tables, graphs, etc.

Site: Gudrid — Centre Co-ordinate: 54°54'30"N' 55°52'32"W

Survey Year: 1976 — Grid Size (km): 12.5 x 6.5

Water Depth (m): 305-490 — Line Spacing(m)/Orientation: 250/NW-SE

Data Quality: Fair to Good — Report Status: Released

Geologic Conditions: Stratified mud to sand and sandy gravel.

Iceberg Scour Presentations: Minimal scouring - limited to Northern area. Scours mapped with widths and depth given.

Field Systems: Sounder, ORE 100 kHz Sidescan, 3.5 kHz Profiler.

Overlapping Data Sets: Helgi Site, 76-025.

Comments: Sounder data very poor and therefore not used. Only one line orientation.

Site: Snorri — Centre Co-ordinate: 57°19'44"N; 59°57'44"W

Survey Year: 1976 — Grid Size (km): 5.5 x 5.5

Water Depth (m): 128-160 — Line Spacing(m)/Orientation: 270/N-S
470/NE-SW

Data Quality: Excellent — Report Status: Released

Geologic Conditions: Sand to gravel.

Iceberg Scour Presentations: Heavily scoured; scours mapped showing maximum depth along scour and drawn to correct width and orientation.

Field Systems: Sounder, ORE 100 kHz Sidescan, 3.5 kHz Profiler, Camera, Grabs.

Overlapping Data Sets: 82-054

Comments: Contains a large amount of statistical information (full report on scours).

Site: Delta — Centre Co-ordinate: 59°03'30"N; 62°28'00"W

Survey Year: 1978 — Grid Size (km): 3.6 x 4.0

Water Depth (m): 127-135 — Line Spacing(m)/Orientation: 200/NW-SE
1000/NE-SW

Data Quality: Good — Report Status: Released

Geologic Conditions: Glacial deposits 90-145 m.

Iceberg Scour Presentations: Heavily scoured (17 km^2).

Field Systems: Sounder, 50 kHz Sidescan, High Resolution Seismic.

Overlapping Data Sets: None

Comments: Delta, SG, HB and South Gudrid are contained in a single report.

Site: <u>HB Prospect</u>

Centre Co-ordinate: 55°19'N; 56°39'W

Survey Year: 1978

Grid Size (km): 4.5 x 3.7

Water Depth (m): 146-208

Line Spacing(m)/Orientation: 225/NW-SE
1000/NE-SW

Data Quality: Good

Report Status: Released

Geologic Conditions: "Recent" sediment thickness 7-10.5 m.

Iceberg Scour Presentations: Heavily scoured (17/km^2) mapped for a 1 km^2 area only (no parameters).

Field Systems: Sounder, 50 kHz Sidescan, High Resolution Seismic.

Overlapping Data Sets: None

Comments: HB, Delta, DG and South Gudrid are contained in a single report.

Site: <u>SG Prospect</u>

Centre Co-ordinate: 58°53'N; 62°11'W

Survey Year: 1978

Grid Size (km): 3.6 x 4.0

Water Depth (m): 154-196

Line Spacing(m)/Orientation: 200/N-S
1000/E-W

Data Quality: Excellent

Report Status: Released

Geologic Conditions: Post Glacial Sediments 22-44 m.

Iceberg Scour Presentations: Heavily scoured (23/km^2) mapped for a 2 km^2 area only (no parameters).

Field Systems: Sounder, 50 kHz UDI Sidescan, High Resolution Seismic.

Overlapping Data Sets: None

Comments: Mean scour depth 2.4 m. SG, HB, Delta and South Gudrid are contained in a single report.

Site: South Gudrid

Centre Co-ordinate: 54°51'N; 55°45'W

Survey Year: 1978

Grid Size (km): 3.7 x 4.8

Water Depth (m): 259-287

Line Spacing(m)/Orientation: 100/NW-SE
1000/NE-SW

Data Quality: Good

Report Status: Released

Geologic Conditions: Post glacial sediments, 6.5 - 14.5 m.

Iceberg Scour Presentations: Heavily scoured (20/km^2) mapped for a 1 km^2 area only (no parameters).

Field Systems: Sounder, 50 kHz Sidescan, High Resolution Seismic.

Overlapping Data Sets: 80-031, 76-025

Comments: Scours have "soft" shapes and are shallow. South Gudrid, SG, HB and Delta are contained in a single report.

Site: North Leif

Centre Co-ordinate: 54°22'N; 55°10'W

Survey Year: 1979

Grid Size (km): 5.5 x 4.5

Water Depth (m): 143-172

Line Spacing(m)/Orientation: 200/NW-SE
1000/NE-SW

Data Quality: Good

Report Status: Released

Geologic Conditions: Medium grained sand with some gravel (32 m) underlain by glacial till.

Iceberg Scour Presentations: Moderate scouring (15/km^2) mapped showing widths and lengths (see comments).

Field Systems: Sounder, 50 kHz Sidescan, High Resolution Seismic, Single Channel, Grabs, Photos, Cores.

Overlapping Data Sets: 76-025.

Comments: Widths are indicated by line thickness per 25 m width.

Site: Ogmund

Centre Co-ordinate: 57°31'N' 60°26'W

Survey Year: 1979

Grid Size (km): 5 x 4

Water Depth (m): 145-160

Line Spacing(m)/Orientation: 200/N-S
1000/E-W

Data Quality: Good

Report Status: Released

Geologic Conditions: Sand with minor silt and gravel; 144 m of upper till, 37 m lower till.

Iceberg Scour Presentations: Heavily scoured, 30/km^2; 680 scours identified, widths and lengths given (see comments).

Field Systems: Sounder, 50 kHz Sidescan, High Resolution Seismic, Single Channel, Grabs, Photos, Cores.

Availability of Field Data:

Overlapping Data Sets: 82-054

Comments: Widths are indicated by lines thickness per 25 m width.

BAFFIN-DAVIS REGION

OPERATOR: AQUITAINE

Site: Ralegh
Centre Co-ordinate: 62°16'45"N; 62°25'06"W

Survey Year: 1979
Grid Size (km): 12 x 4

Water Depth (m):
Line Spacing(m)/Orientation: 200-1000/NE-SW
1000/NW-SE

Data Quality: See Comments
Report Status: Released

Geologic Conditions: Gravel bearing sand/silt/clay.

Iceberg Scour Presentations: Sounder data indicates a heavily scoured seabed.

Field Systems: Sounder, High Resolution Seismic.

Availability of Field Data:

Overlapping Data Sets: None

Comments: Primary grid is rectangular consisting of 4 sub-areas with tighter line spacing; NE area centred approx. 62°17'47"N, 62°21'57"W; SE area 62°15'53"N, 62°20'56"W; NW area 62°17'14.5"N, 62°29'10"W; SW area 62°14'54"N; 62°33'09.5"W

No sidescan or profiler data acquired.

Site: Hekja
Centre Co-ordinate: 62°11'N; 62°58'W

Survey Year: 1979
Grid Size (km): 5 x 3.7

Water Depth (m): 325-475
Line Spacing(m)/Orientation: 200/NE-SW
1000/NW-SE

Data Quality: See Comments
Report Status: Released

Geologic Conditions: Predominantly silt.

Iceberg Scour Presentations: None

Field Systems: Sounder High Resolution Seismic.

Availability of Field Data:

Overlapping Data Sets: None

Comments: Sounder data suggests a heavily scoured seabed. No sidescan or profiler data acquired.

Site: Hekja (Sidescan Sonar Survey) — Centre Co-ordinate: 62°11'N; 62°58'W

Survey Year: 1980 — Grid Size (km): 4 x 7

Water Depth (m): 325-475 — Line Spacing(m)/Orientation: 200/NW-SE

Data Quality: Good — Report Status: Released

Geologic Conditions: Predominantly silt.

Iceberg Scour Presentations: 281 scours mapped and statistical information derived but no parameters are given for individual scours.

Field Systems: Sounder, 100 kHz Sidescan.

Availability of Field Data:

Overlapping Data Sets: None

Comments: Numerous layback problems due to currents.

Site: Finnbogi — Centre Co-ordinate: 60°53'N; 63°58'W

Survey Year: 1981 — Grid Size (km): 7 x 3

Water Depth (m): 394-404 — Line Spacing(m)/Orientation: 220/N-S, 1000/E-W

Data Quality: Good — Report Status: Released

Geologic Conditions: Cobbly gravels in SE to cobbles and boulders in north and west.

Iceberg Scour Presentations: A few features believed to be scours were identified on the lone NSRF V-fin line.

Field Systems: Sounder, High Resolution Seismic, NSRF V-Fin (one line), Grabs, Cores, and Photos.

Availability of Field Data:

Overlapping Data Sets: None

Comments: No sidescan and only one line of NSRF V-fin.

Site: South Hekja — Centre Co-ordinate: 62°07'30"N; 63°03'00"W

Survey Year: 1981 — Grid Size (km): 16 x 3.8

Water Depth (m): 350-380 — Line Spacing(m)/Orientation: 425/WNW-ESE, 1000/NNE-SSW

Data Quality: Good — Report Status: Released

Geologic Conditions:

Iceberg Scour Presentations: Large number of scours mapped but no individual scour parameters given.

Field Systems: Sounder, 100 kHz Sidescan.

Availability of Field Data:

Overlapping Data Sets: None

Comments: Data acquisition and interpretation done by separate contractors.

OPERATOR: CANTERRA

Site: Ralegh

Centre Co-ordinate: 62°17'58"N; 62°32'52"W

Survey Year: 1982

Grid Size (km): 4.1 x 2.1

Water Depth (m): 325-360

Line Spacing(m)/Orientation: 200/NE-SW
200/NW-SE

Data Quality: Good

Report Status: Released

Geologic Conditions: 0.2-5.0 m of sandy silt/clay.

Iceberg Scour Presentations: High density (24 per km^2). Scours mapped but uncertain if individual parameters identified.

Field Systems: ORE 100 kHz Sidescan, Huntec DTS, Sounder.

Availability of Field Data:

Overlapping Data Sets: None

Comments: Layback and cross-current complications with data.

CHARTS (REDUCTIONS)

FULL SCALE COPIES ARE AVAILABLE THROUGH

GEONAUTICS LIMITED UPON REQUEST

GEONAUTICS LIMITED

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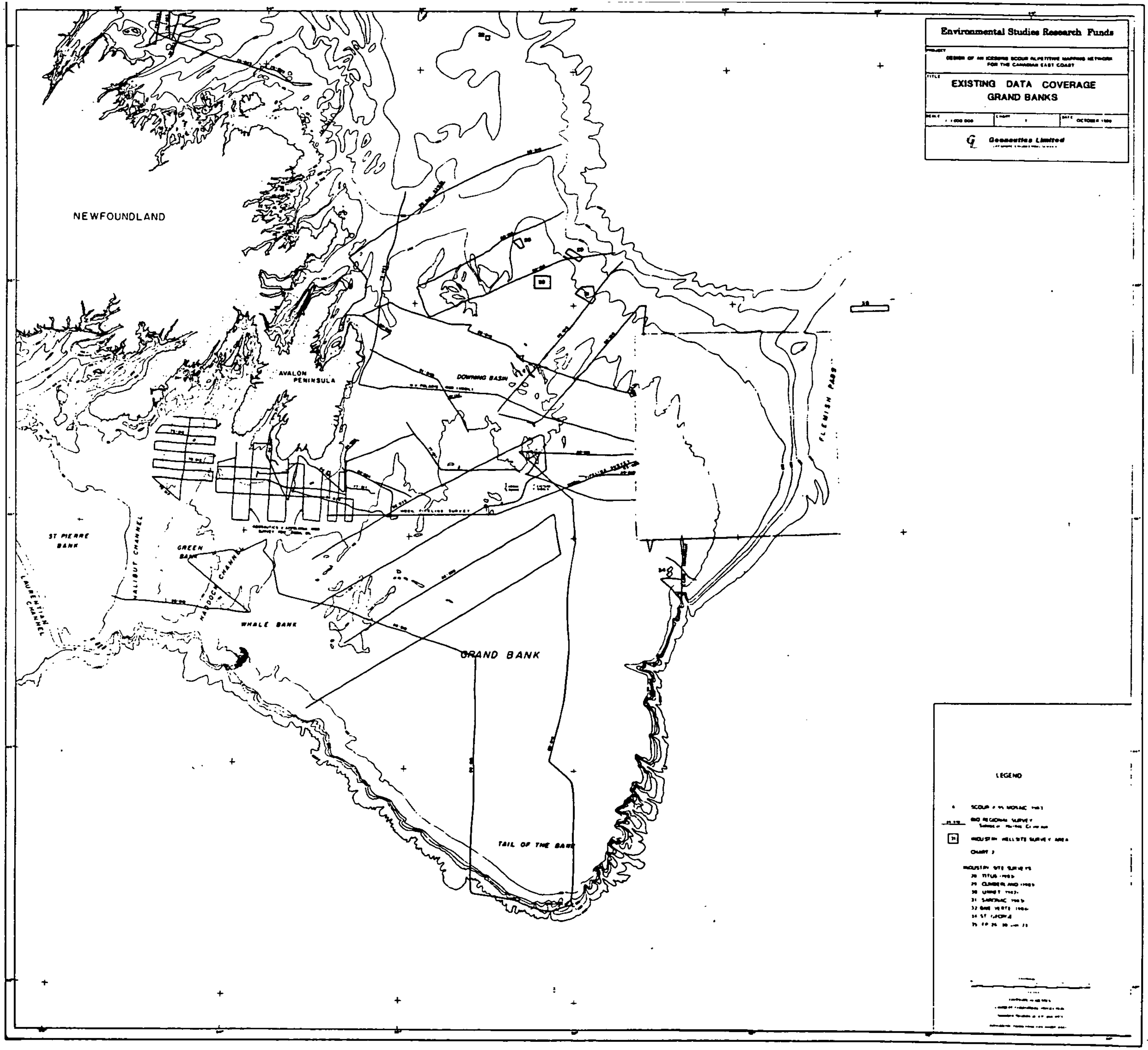
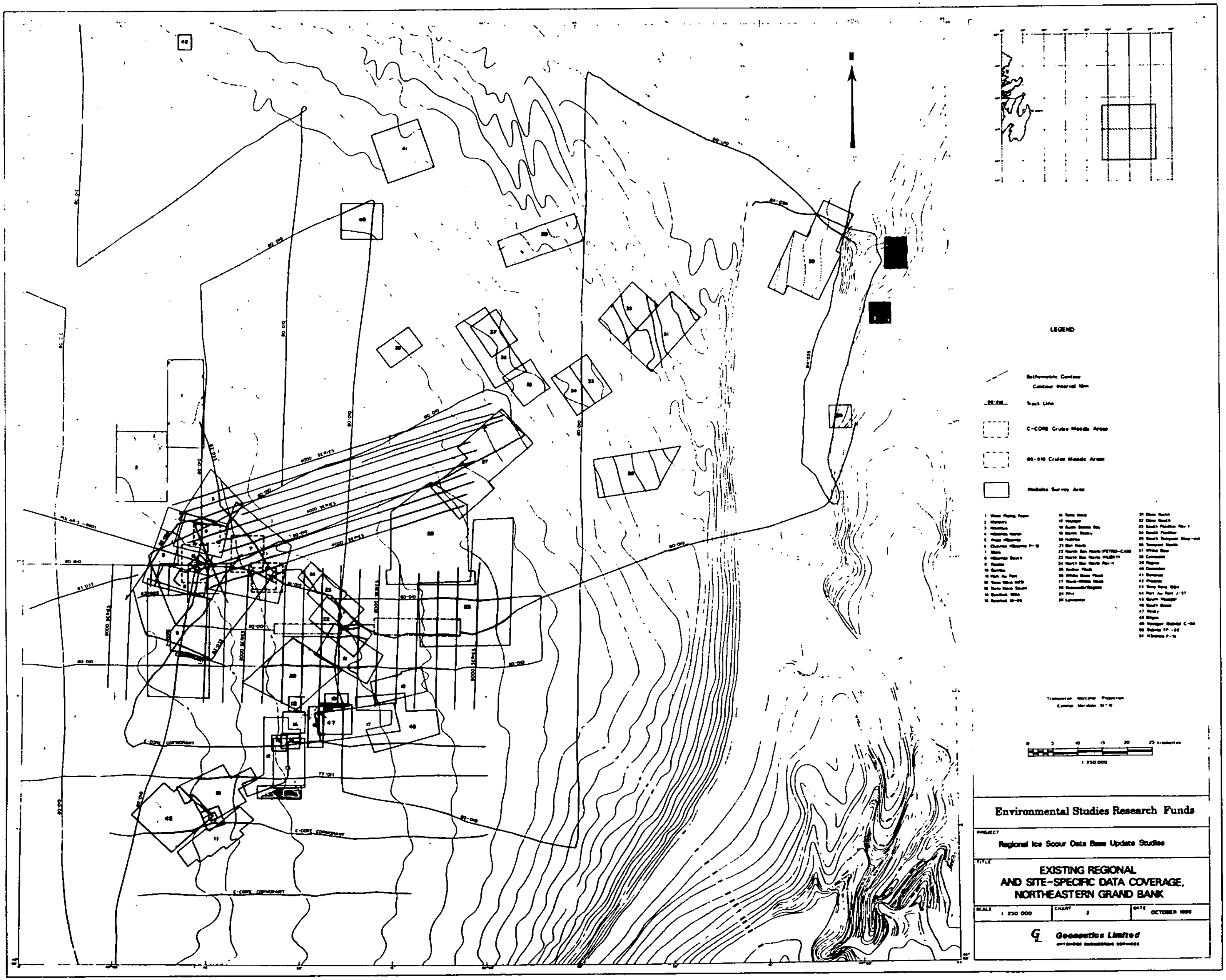
ST. JOHN'S, NF

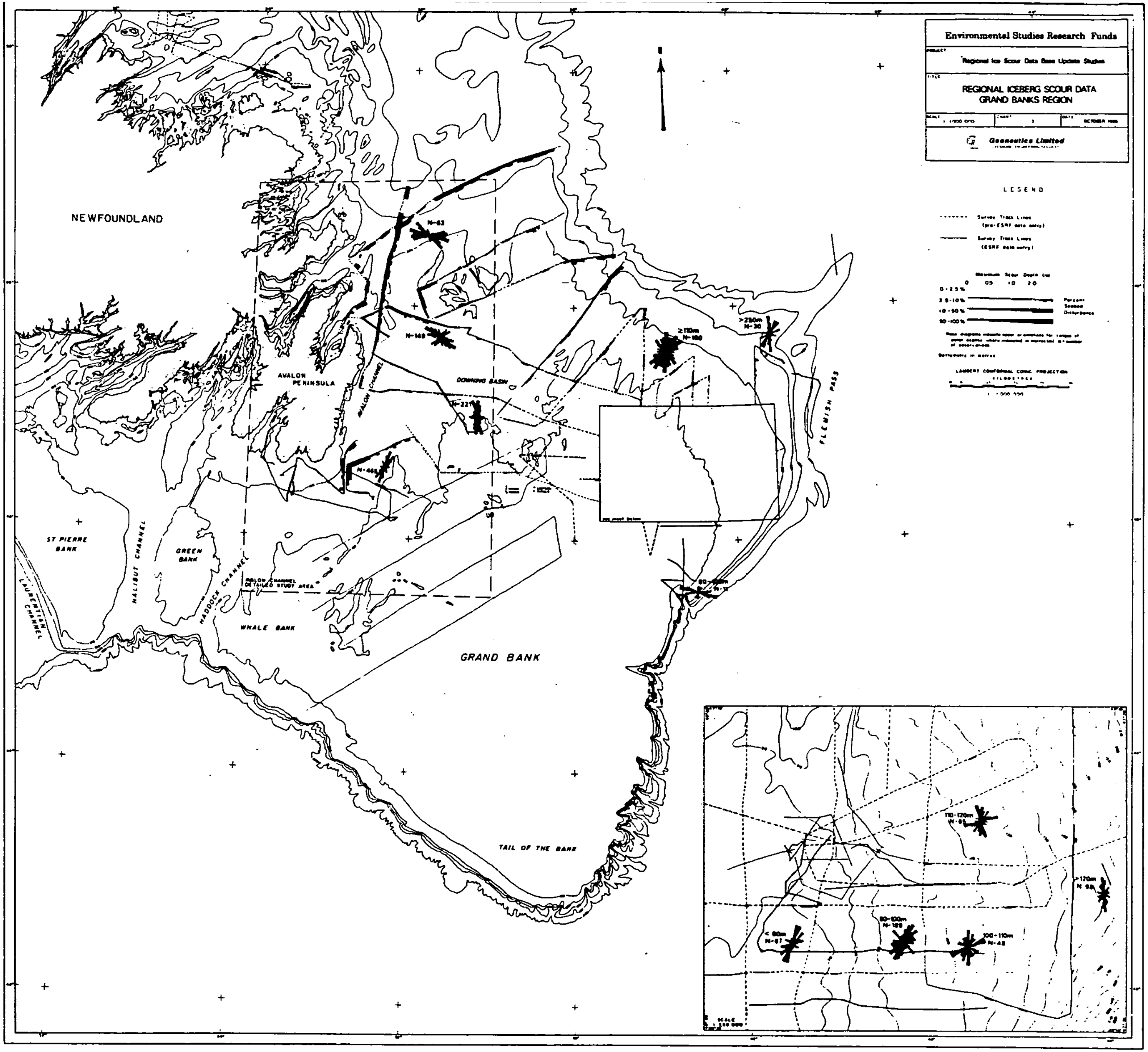
A1B 3M9

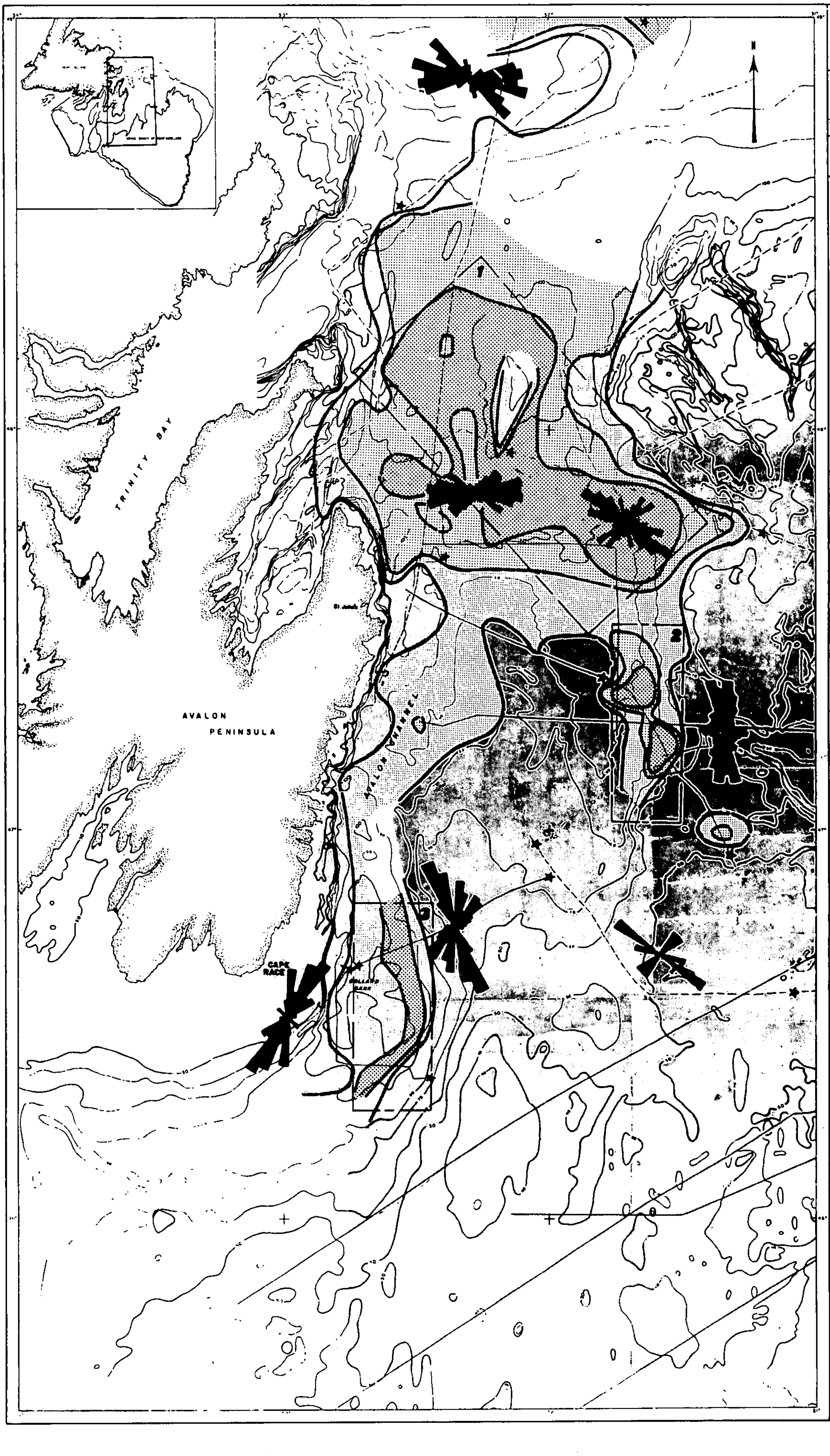
ATTN. MR. G.J. HODGSON

(709) 364-6015


Environmental Studies Research Funds
EXISTING DATA COVERAGE
GRAND BANKS
NEWFOUNDLAND
AVALON PENINSULA
DOWNING BASIN
FLEMISH PASS
ST PIERRE BANK
GREEN BANK
HALIBUT CHANNEL
HADDOCK CHANNEL
LAURENTIAN CHANNEL
WHALE BANK
GRAND BANK
TAIL OF THE BANK
LEGEND


LEGEND
Bathymetric Contour
Contour Interval 10m
Track Line
C-CORE Cruise Mosaic Areas
80-010 Cruise Mosaic Areas
Wellsite Survey Area
1 : 250 000
Environmental Studies Research Funds
PROJECT
Regional Ice Scour Data Base Update Studies
TITLE
EXISTING REGIONAL
AND SITE-SPECIFIC DATA COVERAGE,
NORTHEASTERN GRAND BANK
SCALE
1 : 250 000
CHART
DATE
Geonautics Limited


Environmental Studies Research Funds
Regional Ice Scour Data Base Update Studies
REGIONAL ICEBERG SCOUR DATA
GRAND BANKS REGION
Geonautics Limited
LEGEND
Survey Track Lines
(pre-ESRF data entry)
Survey Track Lines
(ESRF data entry)
0-2.5%
2.5-10%
10-50%
50-100%
Percent
Seabed
Disturbance
Bathymetry in metres
LAMBERT CONFORMAL CONIC PROJECTION
NEWFOUNDLAND
AVALON PENINSULA
AVALON CHANNEL
DOWNING BASIN
FLEMISH PASS
ST PIERRE BANK
HALIBUT CHANNEL
GREEN BANK
HADDOCK CHANNEL
LAURENTIAN CHANNEL
AVALON CHANNEL DETAILED STUDY AREA
WHALE BANK
GRAND BANK
TAIL OF THE BANK
N-63
N-149
N-221
N-445
≥110m
N-160
>250m
N-30
110-120m
>120m
< 90m
N-67
90-100m
N-129
100-110m
N-48
SCALE



Environmental Studies Research Funds

PROJECT
Regional Ice Scour Data Base Update Studies

TITLE
AVALON CHANNEL DETAILED STUDY
ICEBERG SCOUR DENSITY AND ORIENTATIONS

SCALE	CHART	DATE
1 : 350 000	4	OCTOBER

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OFFSHORE ENGINEERING SERVICES

LEGEND

SURVEY TRACKS

Survey Track Lines (ESRF data entry)

Survey Track Lines (pre-ESRF data)

SCOUR DENSITY BOUNDARY

Defined

Approximate

SCOUR DENSITY (scours / sq.km)

0 - 1.5
1.5 - 3.0
3.0 - 6.0
>6

Interval over which rose diagrams were compiled.

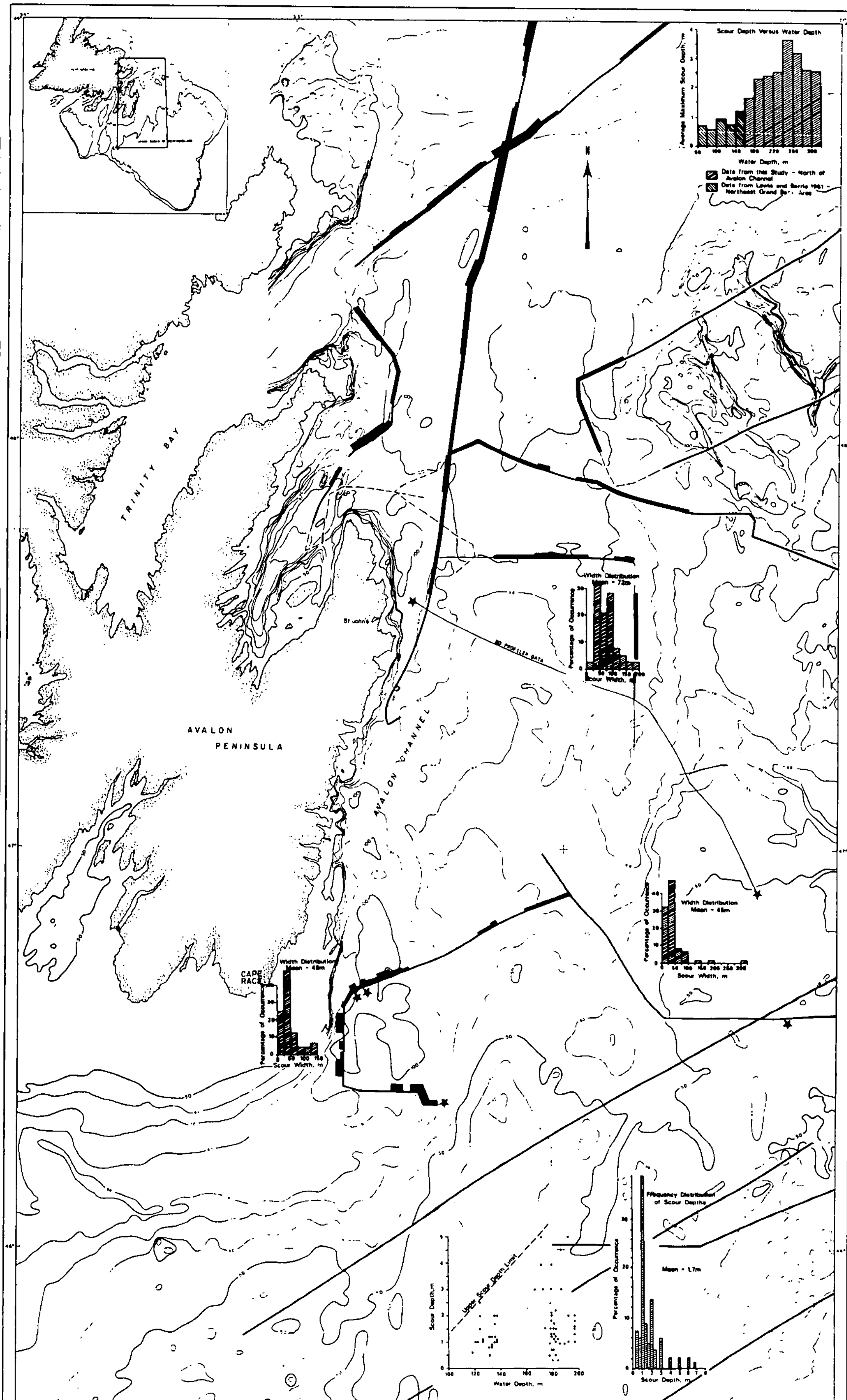
Area referred to in text

Bathymetric contour interval 10 fathoms (20 fathom where depths >200) from CHS charts 8011 and 8014

Rose diagrams indicate scour orientations

MERCATOR PROJECTION
1 : 350 000 at 46° N

KILOMETRES



Environmental Studies Research Funds

PROJECT

Regional Ice Scour Data Base Update Studies

TITLE

AVALON CHANNEL DETAILED STUDY

ICEBERG SCOUR DEPTHS AND WIDTHS

SCALE	CHART	DATE
1 : 350 000	5	OCTOBER 1986

Geonautics Limited

LEGEND

SURVEY TRACKS

- Survey Track Lines (ESRF data entry)
- Survey Track Lines (pre-ESRF data) Original data from BIO cruises

77-011	80-012
78-023	81-045
80-010	82-039

MAXIMUM SCOUR DEPTH (per 2 km sample length)

0-1m	1-2m
2-3m	>3m

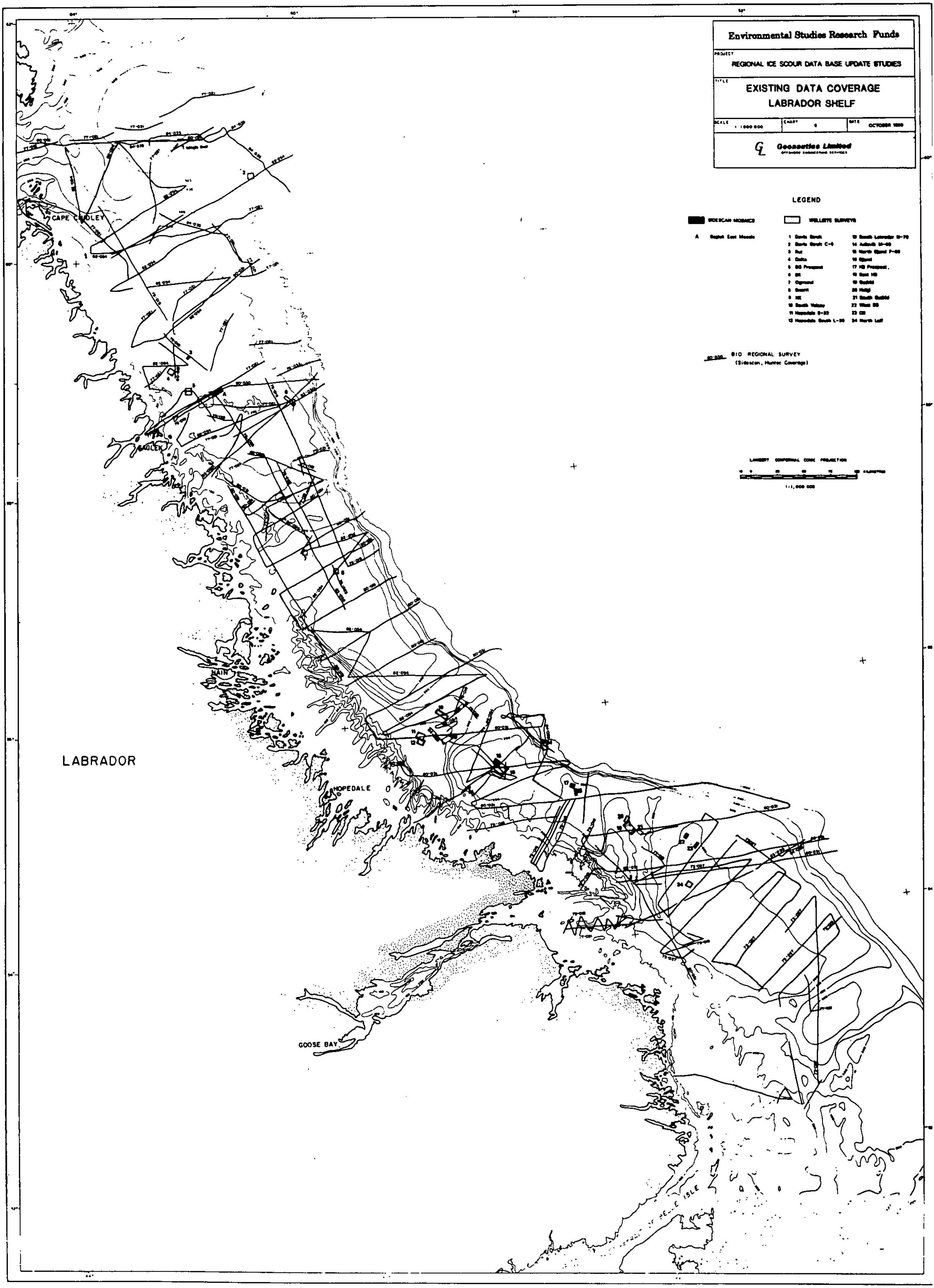
Interval over which Scour width distributions were compiled

Bathymetric contour interval 10 fathoms (20 fathom where depths >200) from CHS charts 8011 and 8014

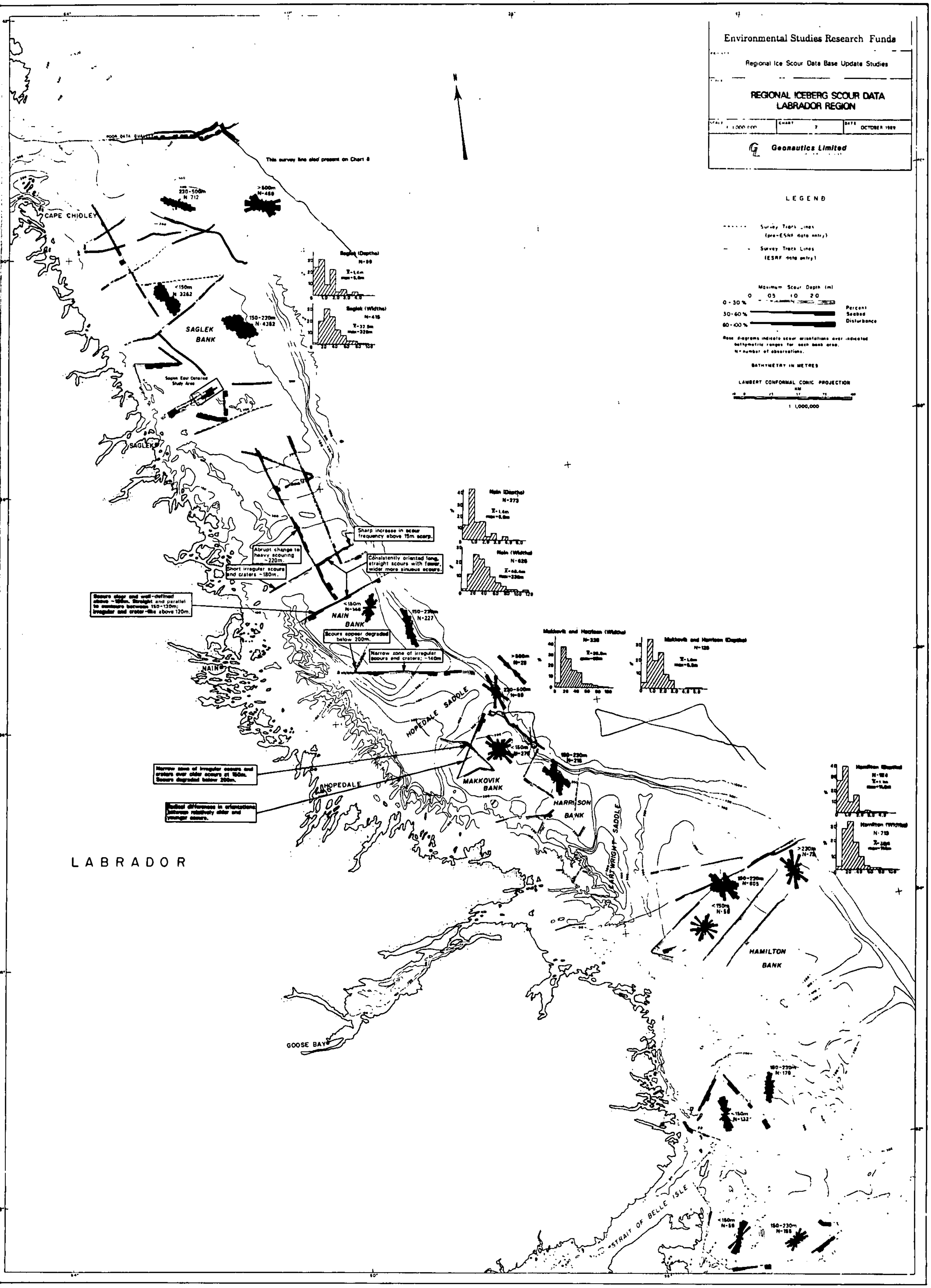
MERCATOR PROJECTION

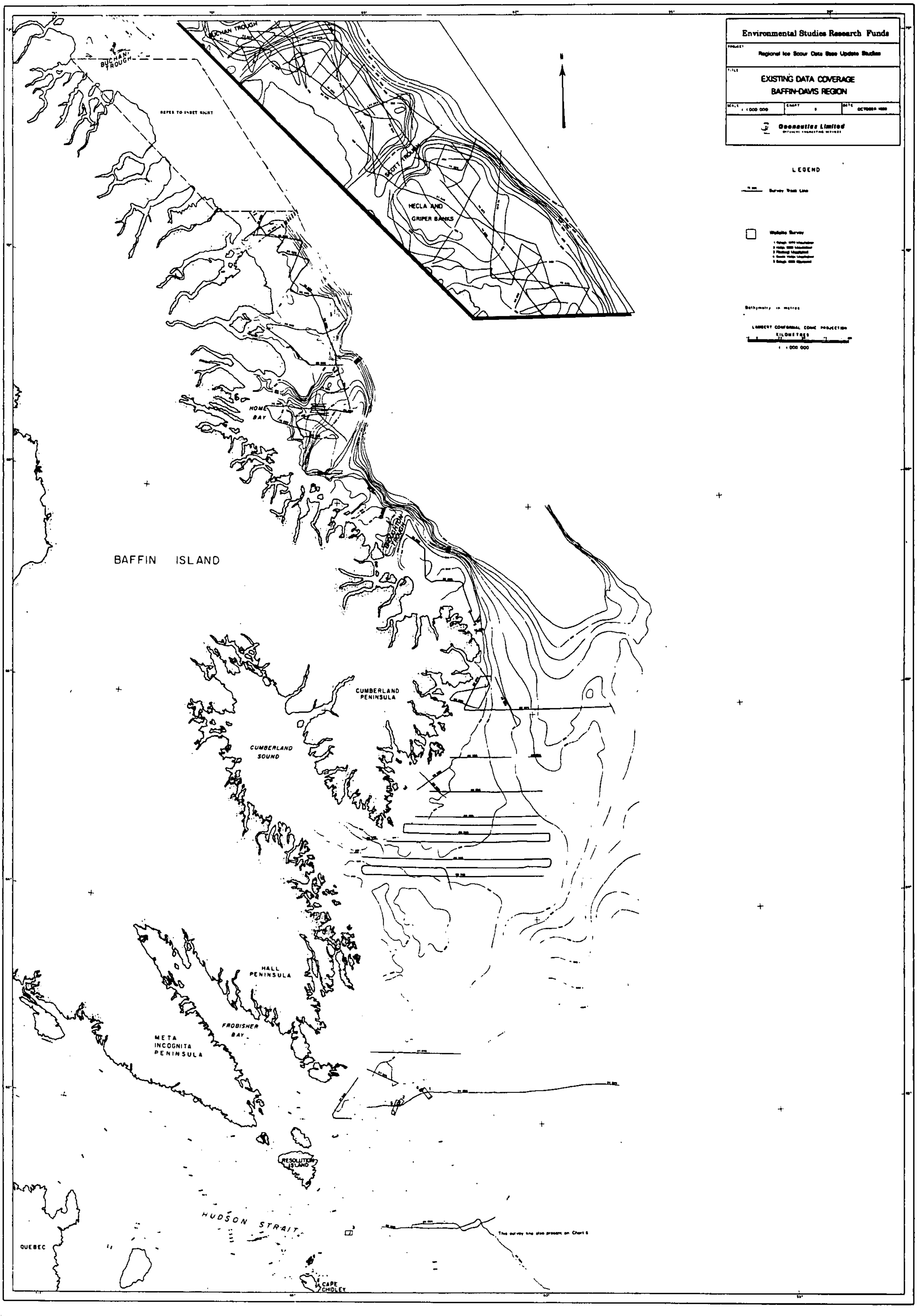
1:350 000 at 46°N

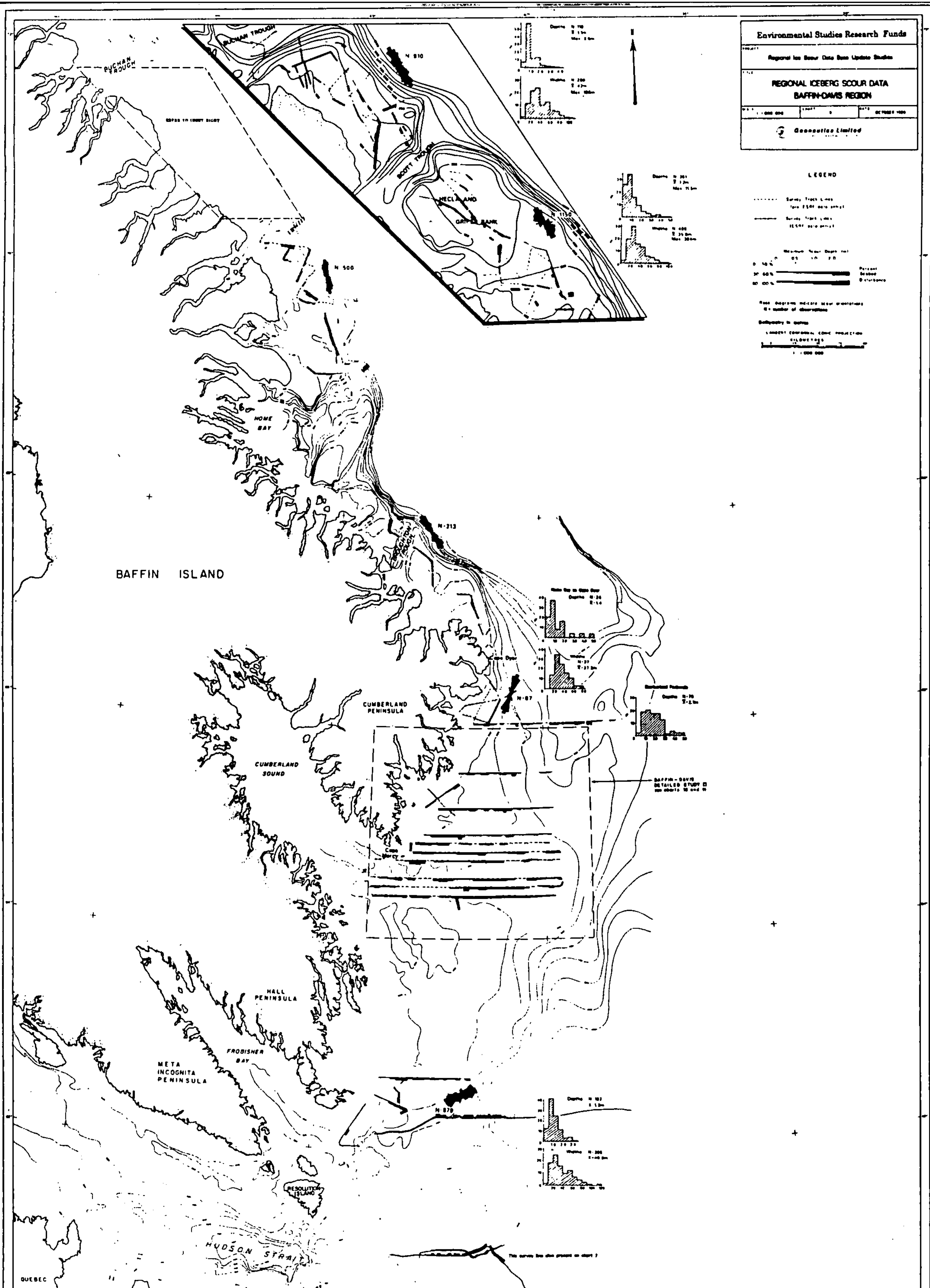
KILOMETRES

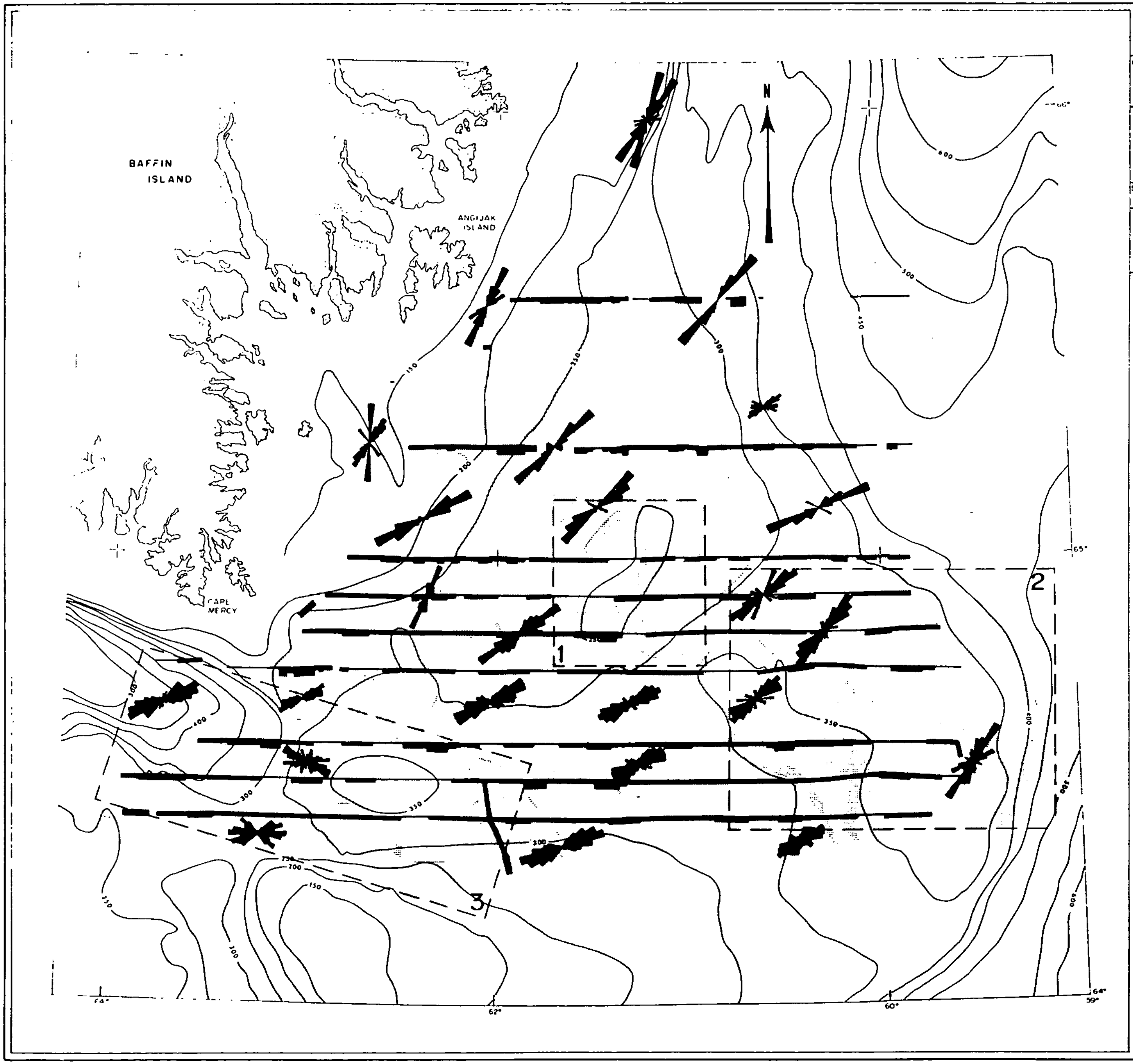


Environmental Studies Research Funds
PROJECT
REGIONAL ICE SCOUR DATA BASE UPDATE STUDIES
TITLE
EXISTING DATA COVERAGE
LABRADOR SHELF
SCALE
CHART
DATE
Geoacoustics Limited
LEGEND
BIO REGIONAL SURVEY
(Sidescan, Huntec Coverage)
CAPE CHIDLEY
SAGLEK
NAIN
HOPEDALE
LABRADOR
GOOSE BAY


Environmental Studies Research Funds
Regional Ice Scour Data Base Update Studies
REGIONAL ICEBERG SCOUR DATA
LABRADOR REGION
CHART 7
DATE OCTOBER 1989
Geonautics Limited
LEGEND
Survey Track Lines
Maximum Scour Depth (m)
0-30 %
30-60 %
60-100 %
Percent Seabed Disturbance
BATHYMETRY IN METRES
LAMBERT CONFORMAL CONIC PROJECTION
1 1,000,000
This survey line also present on Chart 8
CAPE CHIDLEY
230-500m
N 712
>500m
N-450
<150m
N 3262
150-230m
N-4382
SAGLEK BANK
Saglek East Detailed Study Area
SAGLEK
Saglek (Depths)
N-99
Saglek (Widths)
N-418
Sharp increase in scour frequency above 15m scarp.
Abrupt change to heavy scouring ~220m.
Short irregular scours and craters ~180m.
Consistently oriented long, straight scours with fewer, wider more sinuous scours.
Straight and parallel
irregular and crater-like above 120m.
<150m
N-144
NAIN BANK
150-230m
N-227
Scours appear degraded below 200m.
Narrow zone of irregular scours and craters; ~140m
NAIN
Nain (Depths)
N-273
Nain (Widths)
N-626
Makkovik and Harrison (Widths)
N-336
Makkovik and Harrison (Depths)
N-126
>500m
N-28
230-500m
N-88
HOPEDALE SADDLE
<150m
N-276
150-230m
N-216
MAKKOVIK BANK
HARRISON BANK
CARTWRIGHT SADDLE
HOPEDALE
Hamilton (Depths)
N-124
Hamilton (Widths)
N-719
>230m
N-72
150-230m
N-605
<150m
N-58
HAMILTON BANK
LABRADOR
GOOSE BAY
150-230m
N-176
<150m
N-132
STRAIT OF BELLE ISLE
<150m
N-59
150-230m
N-158


Environmental Studies Research Funds
Regional Ice Scour Data Base Update Studies
EXISTING DATA COVERAGE
BAFFIN-DAVIS REGION
LEGEND
Survey Track Line
Bathymetry in metres
LAMBERT CONFORMAL CONIC PROJECTION
KILOMETRES
BUCHAN TROUGH
SCOTT TROUGH
HECLA AND
GRIPER BANKS
HOME
BAY
BAFFIN ISLAND
CUMBERLAND
PENINSULA
CUMBERLAND
SOUND
HALL
PENINSULA
FROBISHER
BAY
META
INCOGNITA
PENINSULA
RESOLUTION
ISLAND
HUDSON STRAIT
QUEBEC
CAPE
CHIDLEY


Environmental Studies Research Funds
REGIONAL ICEBERG SCOUR DATA
BAFFIN-DAVIS REGION
LEGEND
BUCHAN TROUGH
SCOTT TROUGH
HECLA AND
GRIFFIN BANK
N 910
N 1150
N 500
N-213
N-87
N-878
HOME BAY
BAFFIN ISLAND
CUMBERLAND PENINSULA
CUMBERLAND SOUND
HALL PENINSULA
FROBISHER BAY
META INCOGNITA PENINSULA
RESOLUTION ISLAND
HUDSON STRAIT
QUEBEC
CAPE CHIDLEY



Environmental Studies Research Funds

PROJECT
Regional Ice Scour Data Base Update Studies

TITLE
BAFFIN-DAVIS REGION DETAILED STUDY II
ICEBERG SCOUR ORIENTATIONS AND DEPTHS

SCALE	CHART	DATE
1 500 000	10	OCTOBER 1989

Geonautics Limited
OFFSHORE ENGINEERING SERVICES

LEGEND

PERCENT SEABED DISTURBANCE

0-30% 30-60% 60-100%

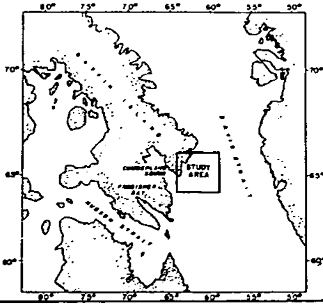
MAXIMUM SCOUR DEPTH (metres)

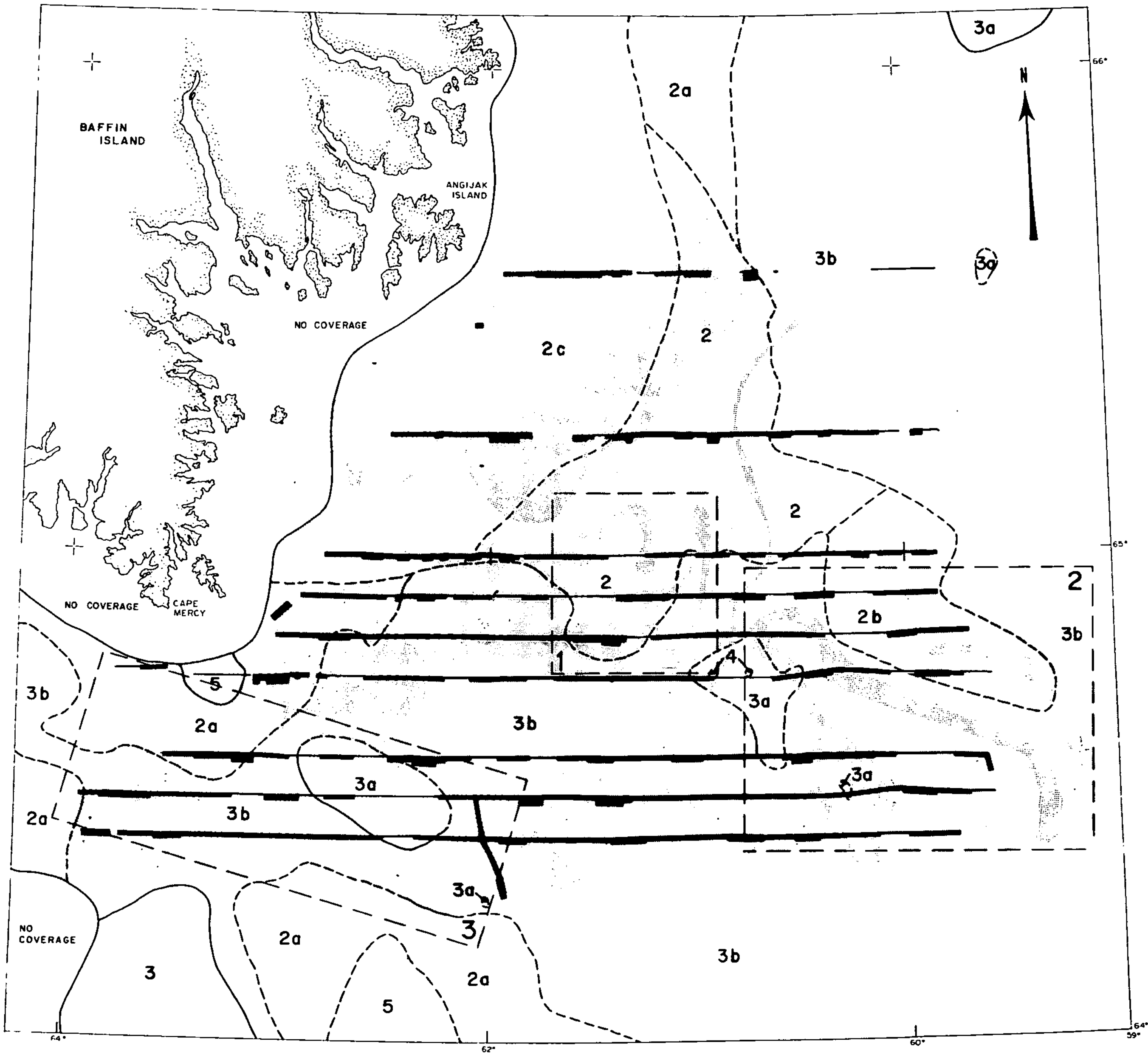
< 0.9m 1.0-1.9m 2.0-2.9 > 3.0

[2] Area referred to in text

Bathymetric contour interval 50m
Rose diagrams indicate scour orientations

LAMBERT CONFORMAL CONIC PROJECTION
1:500 000
KILOMETRES





Environmental Studies Research Funds

PROJECT
Regional Ice Scour Data Base Update Studies

TITLE
BAFFIN-DAVIS REGION DETAILED STUDY II
ICEBERG SCOUR DISTURBANCE, DEPTHS AND SURFICIAL GEOLOGY

SCALE	CHART	DATE
1 : 500 000	11	OCTOBER 1989

Geonautics Limited
OFFSHORE ENGINEERING SERVICES

LEGEND

SURFICIAL GEOLOGY (after Praeg et al)

5 Resolution Island Sand and Gravel

4 Tiniktartuq Silt and Clay

3 Davis Strait Silt
a) stratified
b) unstratified

2 Baffin Shelf Drift
a) defined
b) partially stratified
c) undefined

Geologic Boundary, defined / approximate

PERCENT SEABED DISTURBANCE

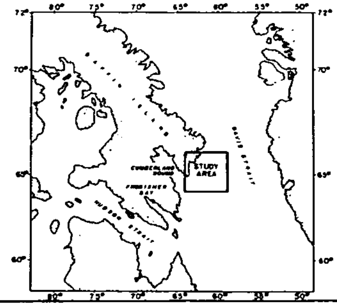
0-30%   30-60%   60-100%

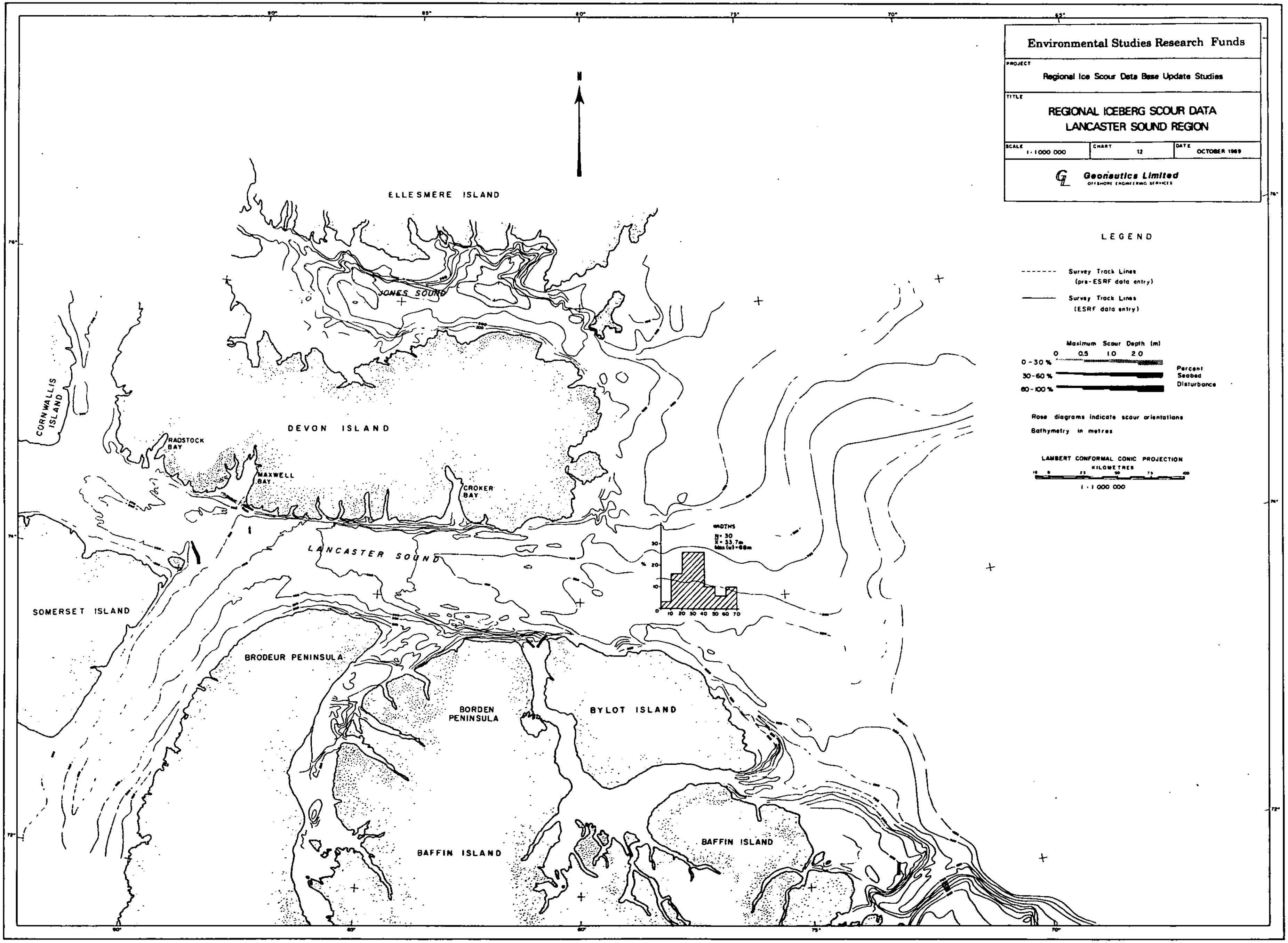
MAXIMUM SCOUR DEPTH (metres)

< 0.9m   1.0 - 1.9   2.0 - 2.9   > 3.0

2 Area referred to in text

LAMBERT CONFORMAL CONIC PROJECTION
1 : 500 000
KILOMETRES





Environmental Studies Research Funds
PROJECT
Regional Ice Scour Data Base Update Studies
TITLE
REGIONAL ICEBERG SCOUR DATA
LANCASTER SOUND REGION
SCALE 1:1 000 000
CHART 12
DATE OCTOBER 1989
Geonautics Limited
OFFSHORE ENGINEERING SERVICES
LEGEND
Survey Track Lines (pre-ESRF data entry)
Survey Track Lines (ESRF data entry)
Maximum Scour Depth (m)
0 0.5 1.0 2.0
0-30 %
30-60 %
60-100 %
Percent Seabed Disturbance
Rose diagrams indicate scour orientations
Bathymetry in metres
LAMBERT CONFORMAL CONIC PROJECTION
KILOMETRES
1:1 000 000
N
ELLESMERE ISLAND
JONES SOUND
CORNWALLIS ISLAND
DEVON ISLAND
RADSTOCK BAY
MAXWELL BAY
CROKER BAY
LANCASTER SOUND
SOMERSET ISLAND
BRODEUR PENINSULA
BORDEN PENINSULA
BYLOT ISLAND
BAFFIN ISLAND
BAFFIN ISLAND
WIDTHS
N = 30
X = 33.7m
%
0 10 20 30 40 50 60 70
90°
85°
80°
75°
70°
65°