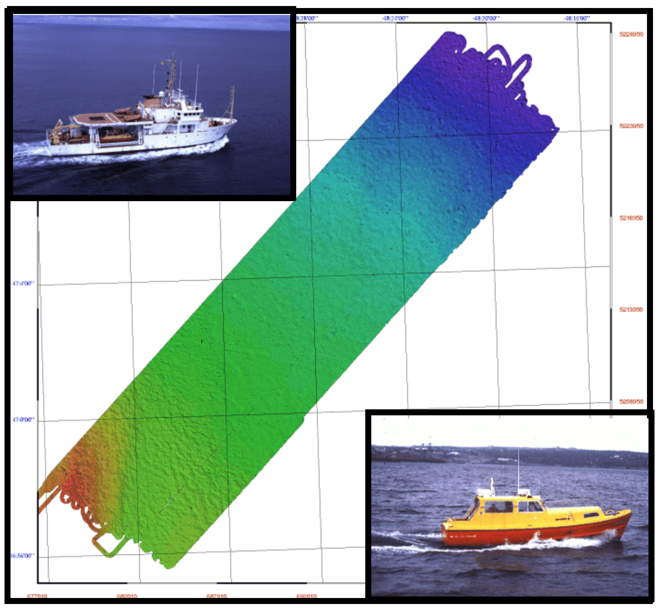
Natural Resources Canada / Ressources naturelles Canada

Establishment of the 98-024 Baseline Iceberg Scour Survey: CCGS Matthew 98-024



G.V. Sonnichsen

GEOLOGICAL SURVEY OF CANADA
OPEN FILE # 3821

Geological Survey of Canada (Atlantic)
P.O. Box 1006, Dartmouth, Nova Scotia
B2Y 4A2
sonic@agc.bio.ns.ca

Funding provided through the
Program for Energy, Research and Development (PERD)
Hydrocarbons Task, East Coast Offshore Geotechnics Program

Canada

TABLE OF CONTENTS

1.0 SURVEY INFORMATION

Dates:	June 26 to July 6, 1998
Vessel:	CCGS Matthew
DFO Survey No.:	98-024
Commanding Officer:	Capt. I. Rennie
Responsible Agency:	Geological Survey of Canada (Atlantic) GSC-A - Marine Environmental Geology (MEG)
Senior Scientist:	Gary Sonnichsen

Survey Personnel

GSCA Staff:	Ken Asprey	EM100/ Huntec DTS
	Tony Atkinson	EM100/ HDCS
	Austin Boyce	Simrad Sidescan
	Gary Sonnichsen	Senior Scientist
	Shawn. Rushton	St. Mary's Univ. COOP
Canadian Hydrographic Service	Glen Rodger	EM3000/ HDCS
Geomatics Canada	Brian Donahue	Navigation/ EM100
Geoforce ltd.	Martin Uyesugi	Huntec DTS
Seabed Exploration Association	Kevin DesRoches	HDCS processor

2.0 INTRODUCTION

The Geological Survey of Canada (Atlantic) (GSC-A) conducted a swath bathymetry, sidescan sonar and subbottom profiler survey over approximately 9 x 32 km of seabed on Grand Bank (Figure 1) from June 30 to July 6, 1998 CCGS Matthew (DFO Cruise 98-024).

Survey objectives were:

1) to map the distribution, dimensions and character of seabed ice scour features and surficial sediments between 100 and 140 m water depth on northeastern Grand Bank;
2) to establish a base line survey to be resurveyed to determine future changes in the existing population and, more importantly, to identify any additional scours created in the time between surveys.

The survey was carried out in support of GSC's long term research on the characteristics of the Grand Bank iceberg scour population and the processes and frequency of iceberg scouring. The survey was conducted under the Program for Energy Research and Development (PERD) Project 532208 GRAND BANKS ICE SCOUR. The project is focused on developing a regional characterization of the distribution and severity of seabed iceberg scouring, understanding the controlling environmental parameters, and refining estimated rates of occurrence. The research provides the knowledge base on seabed conditions and geohazards necessary for federal agencies and offshore regulators (Canada-Newfoundland Offshore Petroleum Board - CNOPB) who must approve development plans for new bottom-founded structures and pipelines off eastern Canada.

GSCA’s seabed scour research efforts in the 1990's have focused on establishing repetitive seabed mapping sites on NE Grand Bank in order to better quantify rates of scour recurrence on the Grand Banks. The low frequency of new scouring events demands a long record of resurvey in order to have statistically meaningful results. For each repetitive seabed mapping site, an initial sidescan and subbottom survey maps the distribution, dimensions and character of seabed ice scour features and surficial sediments, thus establishing a base map of initial conditions. Future repetitive surveys then record changes to the surficial seabed sediments and the existing scour population and, more importantly, would identify any additional scours created in the time between surveys. Repetitive mapping also provides valuable observations of the frequency and magnitude of seabed reworking by storm waves and currents. Understanding the dynamics of the Grand Banks seabed will better constrain estimates for the residence time for scours on the seabed before they are erased. To date, 5 transects or seabed areas have been resurveyed; areal limits vary from 15 to 280 km^2 and time between surveys from 1 to 11 years.

The 1998 Matthew program represents the first comprehensive attempt to use both sidescan sonar and swath bathymetric systems to establish a repetitive mapping transect. Integration of the 98-024 sidescan and swath bathymetric data sets will provide complete, comprehensive data on scour geometry and dimensions, especially depth which, historically, has been very difficult to quantify from sidescan and single beam subbottom profiler data.

This report provides a brief summary of survey operations and equipment (Appendices 1 to 6) and a preliminary discussion and interpretation of the results of the seabed surveys. Maps of shaded relief, colour-shaded seabed relief and acoustic backscatter derived from the Simrad EM multibeam bathymetry are presented in DesRoches and Sonnichsen (1999, in prep.). Maps and databases of the existing population of seabed iceberg scours are presented in Hart and Sonnichsen (1999, in prep.).

3.0 SYSTEMS OVERVIEW AND OPERATION

3.1. Navigation

The primary navigation system for Matthew 98-028 was the Global Positioning System (GPS) with corrections (differential) applied in real time to eliminate or minimize errors in the raw GPS signal generated by the Selective Availability policy of the US Dept. of Defense.

MOT-broadcast differential corrections were acquired from Cape Race over VHF radio to CHS' proprietary HPC navigation package. dGPS positions were logged by three systems in different formats; 1) the EM100 aboard Matthew: 2) the EM3000 aboard the CHS hydrographic launch PLOVER, and 3) a PC running GSC-A's proprietary AGCNav software.

3.1.1 EM100 navigation

Differentially corrected GPS positions were transmitted directly to the Simrad EM100 from CHS's HPC navigation system where they were stored in internal Simrad EM100 database format. During processing of the EM100 soundings, navigation data were imported into Universal Systems Ltd.'s (USL's) CARIS Hydrographic Information Processing System (HIPS) to edit obvious incorrect values or omissions. This is a necessary first step to cleaning the EM100 soundings.

3.1.2 EM3000 navigation

PLOVER was configured to receive and differentially correct GPS positions and transmit them directly to the Simrad EM3000 Merlin software where they were stored in internal EM3000 format. The EM3000 data were processed and cleaned aboard ship to remove spurious navigation errors. The cleaned navigation data were exported from HDCS using a program called *printfNav*- the resulting navigation data are archived within the GSCA Exploration Database (ED) at 10 second intervals as Expedition 98024PLOVER.

3.1.3 AGCNav navigation

AGCNav logs dGPS navigation data and broadcasts real time positions, course, speed, and survey line information to the bridge and a slave PC in the aft lab for back-up storage. AGCNav logged the raw 'differentially corrected' navigation data at 1 second intervals for the entire survey. Navigation was very stable throughout the program with continuous dGPS coverage. There was no operational downtime due to navigation.

Preliminary cleaning of the AGCNAV data files was conducted onboard. Smoothed and median-filtered navigation at 10 second intervals for the periods when either EM100, sidescan or Huntec DTS data were collected is stored in GSCA's internal Exploration Database (ED) as Expedition 98024. All data are fixed to the North American Datum of 1983 (NAD83). Figures 1 and 2 illustrate the track plot for the 98-024 CCGS Matthew survey .

3.2 Swath Bathymetric Systems

A multibeam swath bathymetric system is capable of providing highly accurate (+ 5 m horizontal, + 10's of cm vertical) high density bathymetric soundings over large seabed areas. The size of the covered area is a function of the swath angle and water depth; it can be up to 7X water depth, depending on the system.

The EM100 is one of the first generation of swath systems purchased by the Canadian Hydrographic Service (CHS). It is somewhat limited in terms of its spatial resolution and in terms of its effective swath. It has 32 beams (16 on the port side and 16 on the starboard side), radiating from the centre of the transducer in either a NARROW or WIDE mode beam setting. The NARROW mode has a swath angle of 40° and the WIDE mode has a swath angle of 80°. The EM100 was operated exclusively in WIDE mode providing a quite limited swath of approximately 1.4 X water depth, and spatial resolution of ~5 to 8 m depending on the beam. Vertical resolution was roughly +/- 20 cm. Matthew ran her survey lines 140 m apart to ensure that there was 100% seabed coverage.

The EM3000 is the most recent and advanced swath bathymetric system acquired by the Canadian Hydrographic Service (CHS). It is designed as a high resolution shallow water system. The system is capable of collecting up to 128 beams per transmission; the beams are spread over a total angular range of 120°. It is theoretically capable of swath coverage up to 5 times the water depth. One of the four systems purchased is permanently installed in the PLOVER a CHS hydrographic launch. The relatively deep water of the outer Grand Banks pushed the limits of the EM3000 system which operates at a higher acoustic frequency and often lost bottom lock because of signal attenuation. The EM3000 was operated from the PLOVER for 25.5 hours during the program. On the Grand Banks, the Plover ran lines at 200 m offset in order to ensure that there was 100% overlap of the more consistent inner beams.

3.2.1 Corrections to Swath Bathymetry Soundings

Multibeam bathymetric systems record raw, uncorrected two-way travel times for each received beam signal. This data must then undergo a series of corrections to compensate for changing sound velocities through the water column, the gyro, heave, pitch and roll of the ship, changing water depths due to tides and inaccurate navigation positions. For a brief overview of the corrections, refer to Sonnichsen and Lussier (1996).

3.2.1.2 Sound Velocity Corrections

An SVP (sound velocity profiler) was deployed to measure the velocity of sound through the water column at successive depths to the seabed. The speed of sound in seawater will vary primarily with changes to temperature and salinity which occur as a result of solar heating at the surface and the varying properties of vertically changing water masses. On northeastern Grand Bank, the water mass is relatively homogenous through mixing as a result of wave, tide and current activity. SVP’s were conducted at the beginning and end of the first line surveyed. Judging by the similarity of the two profiles, there were no significant changes in water mass characteristics across the survey area; this reduced the requirement for frequent updates to the sound velocity profile input to the EM100 or the EM3000. SVP profiles were conducted about once a day over the course of the survey.

3.2.1.2 Tidal Corrections

Corrections for tides were obtained from a file of the predicted vertical displacements for June for the Hibernia area of northeastern Grand Bank. Predictions for June, 1998 were provided by Charlie O'Reilly of Canadian Hydrographic Service's (CHS) Tidal Section.

3.2.2 Swath Data Processing

3.2.2.1 EM 100

The EM100 data and the above-mentioned corrections were imported into Universal Systems Ltd. (USL), CARIS Hydrographic Information Processing System (HIPS) for depth processing, direct visualization and editing. Here the differentially corrected navigation is viewed and corrected for obvious spurious or missing positions. Once the navigation data is cleaned and the corrections are available, the raw returns from each beam of the EM100 are corrected and merged with the cleaned navigation. The result is a collection of depths that are georeferenced to the seabed. It is then possible to view and edit ("clean") these depths and reject any that are considered to be inaccurate by the operator. At this stage, the data are transferred to an HP work station where GSC-A's modified *grass 4.1* routines are used to bin and grid the data values and convert them to georeferenced raster maps of seabed topography. This was done as soon as possible onboard Matthew in order to confirm data quality and coverage. If necessary, data were returned to HIPS for additional cleaning and editing. EM 100 data cleaning was done by Kevin DesRoches of SEA under contract during Matthew 98-024 (Appendix 7). An amplitude measure of seabed backscatter is recorded by HDCS as part of the raw signal returned by the EM100 beams. The backscatter data will be processed under contract by Seabed Exploration Associates (SEA) using the latest version of HIPS and CARIS. Results will be compared to seabed mosaics prepared in-house using the Simrad sidescan data.

3.2.2.2 EM 3000

Efforts to clean the EM3000 sounding data aboard Matthew were unsuccessful because the ship's version of HIPS was not current with the Simrad EM3000 datagrams. The EM3000 soundings will be cleaned post-survey under contract to Seabed Exploration Associates (SEA) using the latest version of HIPS and CARIS..

3.2.3 GSC-A Ocean Mapping seabed relief map production

The following is a brief summary of the steps taken aboard Matthew, and back at GSCA, to produce georeferenced color-shaded relief seabed maps of the EM100 bathymetry data.

Cleaned, georeferenced depth files were binned into 7x7m grid cells and an approximate average (note: at present, a running average of all values that fall in the cell is calculated rather than a true mean) depth of each cell is calculated using UNIX-based, USACERL grass4.1 Geographic Information System software. At GSC-A, a simplified Graphical User Interface (GUI) interface is used (AGCMENU), which is greatly enhanced with in-house swath bathymetric processing routines, additional menus and utility software.

Occasionally a 7x7 m cell would not contain any soundings and would show as a small gap in the data coverage. The data gaps were filled by calculating the average of the depth in each of 8 surrounding cells and applying it to the empty cell. This was repeated twice to fill small isolated gaps in the coverage. The soundings were colour-classified according to depth of the seabed below sea level. A shaded relief image was created using a 45° sun elevation and a sun azimuth of 44° (to best enhance seabed and mute minor pitch errors evident throughout the data). The colour -classified rasters and shaded relief rasters were merged together to produce a final colour-shaded relief raster image and exported from Grass in a TIFF format. Final map production was done in ArcView 3.1 for Windows 95 (Figure 3) . At the scale of Figure 3, only major morphological features and the larger scour features can be seen.

3.3 Sidescan Sonar

The Simrad Mesotech 992 dual frequency (120 and 330 kHz) sidescan was operated with a range of 300 m (600 m total swath). The 120 kHz and 330 kHz channels (port and starboard) were digitized to Exabyte tape using AGC-DIG, a GSC-A developed 4 channel digital acquisition system. Hard copy records were collected on two graphic recorders. A 10 inch Alden 9315 thermal printer recorded the 120 kHz data in two channel print mode with auto-annotation. The 330kHz due to its higher frequency allows somewhat higher resolution of seabed features at the expense of range. A fully programmable EPC 1086 recorder was optimized to display the full effective range of the 330 kHz channels. For this survey a delay of 27 msec (roughly 20 m at 1463 m/sec sound velocity through water) was imposed. Each channel displayed 150 m range for a combined swath of 300 m. Scale lines were printed at 30 m (41 msecs). Figure 4 is a lay-back corrected georeferenced mosaic of the sidescan sonar data. At the scale of Figure 4 only major backscatter variations can be seen; scour features do not show up at this coarse resolution.

3.4 Huntec DTS Subbottom Profiler

Previous surveys of the Grand Banks using the Huntec Deep Tow System (DTS) boomer profiler have failed to achieve significant penetration into the acoustically hard, over-consolidated seabed sediments. For 98-024, the Huntec DTS was operated with a 20 tip sparker element and a longer 24 element Geoforce streamer. This configuration provided much better penetration (60 msec or more) with a corresponding trade-off in reduced vertical resolution. For details on configuration and settings and operational difficulties see Appendix 6.

3.5 Quester Tangent QTCView Seabed Classification System

The QTView system analyses the acoustic returns from the ship's 30 kHz sounder in order to provide a remote numerical classification of the seabed. Conventionally, the user trains the QTView system by analysing the echos recorded over a known bottom type and building up a catalogue of echo bottom types (e.g., "SAND", "GRAVEL", "MUD"). Usually a seabed type is selected based on sediment texture data or visual evidence. All subsequent echos are compared to the established catalogue and tagged as a specific seabed type. This is a relatively new system that has not been widely accepted by the marine geological community; however fishermen, some naval organizations, and some fisheries biologists have describe very good success and repeatability in mapping distinct seabed types. GSCA is currently evaluating the system and comparing results from QTView with more conventional seabed mapping technologies sch as sidescan sonar and subbottom profilers. During 98-024, a new prototype QTView system was used which recorded a more complete and unprocessed classification of each echo trace and allows the opportunity to repeatedly classify the echo returns to test a variety of seabed classifications. The objective in 98-024 was to define seabed types from sidescan backscatter imagery, EM backscatter imagery and from textural and visual observations of the seabed. The goal was to overcome the reliance of having a known catalogue of seabed types prior to starting a survey, often in an area of unknown bottom type.

The QTView system was operated throughout much of 98-024 resulting in approximately 90 hours of data in a total of 20 files (Figure 5). Most of the data were collected along lines while EM100 and geophysical data were collected; some data were collected while the vessel was stationary, either during SVP casts or while the PLOVER was being deployed/retrieved. This represents a significant data set for evaluation of the merits of QTView because of the volume of data collected over a relatively dense grid in combination with sidescan sonar Huntec DTS and swath bathymetric data. Unfortunately, sediment and photographic ground truth were not possible to collect with the limited staff and sampling equipment aboard CCGS MATTHEW; plans are to collect that data in a subsequent expedition.

4.0 RESULTS

Expedition 98-024 successfully surveyed a seabed area of 280 km^2 with a water depth range of 90 to 135 metres (Figure 3). The survey is oriented at 45 degrees, orthogonal to the seabed slope and to the dominant drift track of icebergs drifting south under the influence of winds, waves and the Labrador Current. Huntec subbottom data suggest the seabed sediments are thin (typically less than 1 metre) and patchy over an over-consolidated regional unconformity which has eroded and truncated undifferentiated Unit 1 sandy silts and clays (Sonnichsen and Cumming, 1996). A hummocky seabed in the northeast portion of the surveyed area is tentatively considered to indicate an irregular relief on the unconformity surface; an alternative explanation would be that the seabed relief is evidence of older, degraded iceberg pitting events.

No sediment ground truth sampling was undertaken during the Matthew 98-024 survey; video and sediment sampling will be undertaken on a subsequent survey. Based on surficial geological maps for the area (Sea Inc., 1997), overlying unconsolidated sediments in the western map area are predominantly Grand Banks Sand and Gravel -Sand Facies but Grand Banks Sand and Gravel -Gravel Facies overlies the sand in the northwest of the survey area. In the eastern survey area below approximately 110 metres, we would expect poorly sorted sands and gravels of the Adolphus Sand Formation (SEA Inc, 1997).

The sidescan, EM100, EM1000 and the QTCView system all mapped similar complex patterns of high and low backscattter which most often are related to the crests and troughs of very low amplitude but large-scale sand ridges and sand wave fields, and starved sand waves (Figure 4). Based on sampling results elsewhere, we would suggest the high backscatter in the northwest is associated with an area of gravel lag. moderate backscatter occurs in the troughs of the bedforms due to subtle winnowing effects and a slight increase in the amount of surface cobbles, pebbles and shell hash. Low backscatter areas indicate areas of homogenous sand with only minor coarse clasts (likely drop stones) and shell hash, often associated with the crests of bedforms. Numerous isolated circular high back-scatter patches approximately 100 m in diameter show up on the sidescan mosaic (Figure 4) in the northeast of the survey area. It is unclear at this time whether the high backscatter indicates that harder or coarser subsurface materials are exposed or they indicate some surface pattern of seabed roughness or coarse sediment composition.

The seabed scour population is presently being mapped and catalogued using a combination of the raw sidescan records and processed mosaic and the shaded relief multibeam imagery: both vector maps of the scour distribution and a database of measured scour geometries and attributes will be produced (Strattech, 1999, in prep.) The combination of sidescan sonar and multibeam data provide very accurate and detailed information on the density and characteristics of seabed scours. The sidescan is useful for fine details on larger scours and essential in order to identify narrow, shallow (less than approx. 0.4 metres depth) scours that are not resolved in the coarser resolution multibeam images.

The area has a large population of seabed scours, both pits and furrows. The greatest density are evident in the northwest (Figure 5) which is the shallowest seabed and has the coarsest sediments. Preliminary analysis of the furrows suggest that most, if not all, have depths greater than 1 m below seabed. Furrows in excess of 7 km can be seen in the EM100 seabed relief images. Scour orientations are predominantly north and south. Pits ranging from approximately 1 m deep and 50 m across up to a maximum depth of 8 metres and 80 m across are evident (Figure 6). Pits appear to occur as often in isolation as at the terminal end of furrows. The pits often occur in close association with 1 or 2 other pits suggesting the iceberg is repeatedly impacting the bottom or grounding more than once.

The database of drifting icebergs initiated and maintained by HMDC (pers. comm., Ken Dyer,1997) will give valuable insight into the flux and size distribution of icebergs transiting across the 98-024 seabed site and other previously established GSCA repetitive mapping sites. That information will determine when and perhaps where to re-survey in order to determine whether new scour events have occurred.

5.0 ACKNOWLEDGMENTS

A special thank you to Captain Rennie and the crew of CCGS MATTHEW for their large and essential role in making Expedition 98-024 a successful and enjoyable program. Also the Program Support Subdivision for their assistance before, during and after the program. Thanks to Glen Rodgers of CHS for his hydrographic support aboard PLOVER and throughout the program. Thanks to Shawn Rushton, who provided support at all stages of the 98-024 program and throughout his COOP employment.

This report is a contribution to Task 5 Hydrocarbons of the Program for Energy, Research and Development (PERD) and was funded under Project 532209 East Coast Offshore Geotechnics.

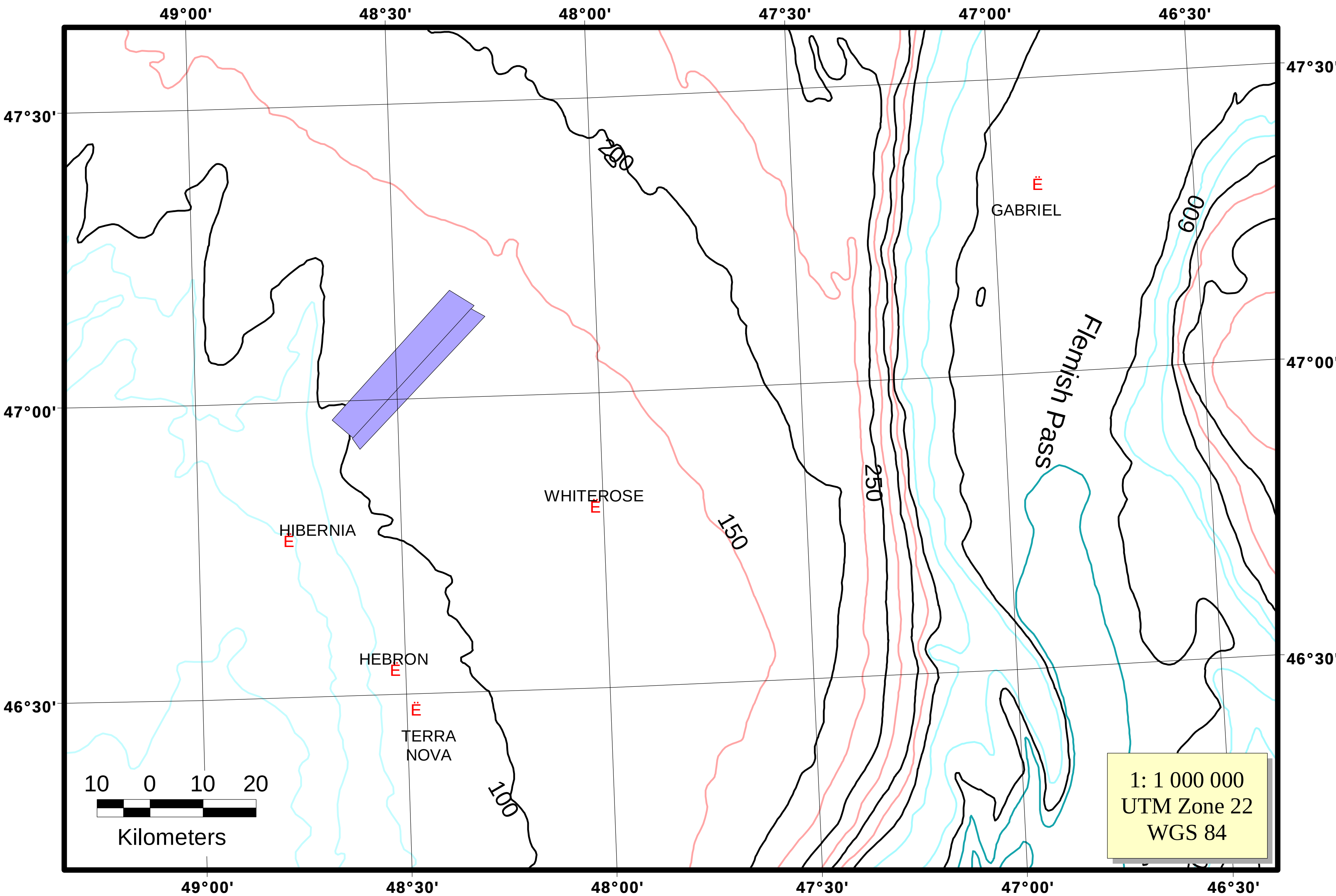


Figure 1: Location of the 98-024 Base Line Iceberg Scour Survey conducted from CCGS Matthew and CHS Launch Plover. EM 100 and EM 3000 multibeam data, Simrad sidescan sonar and Huntec DTS subbottom profiler data were collected.

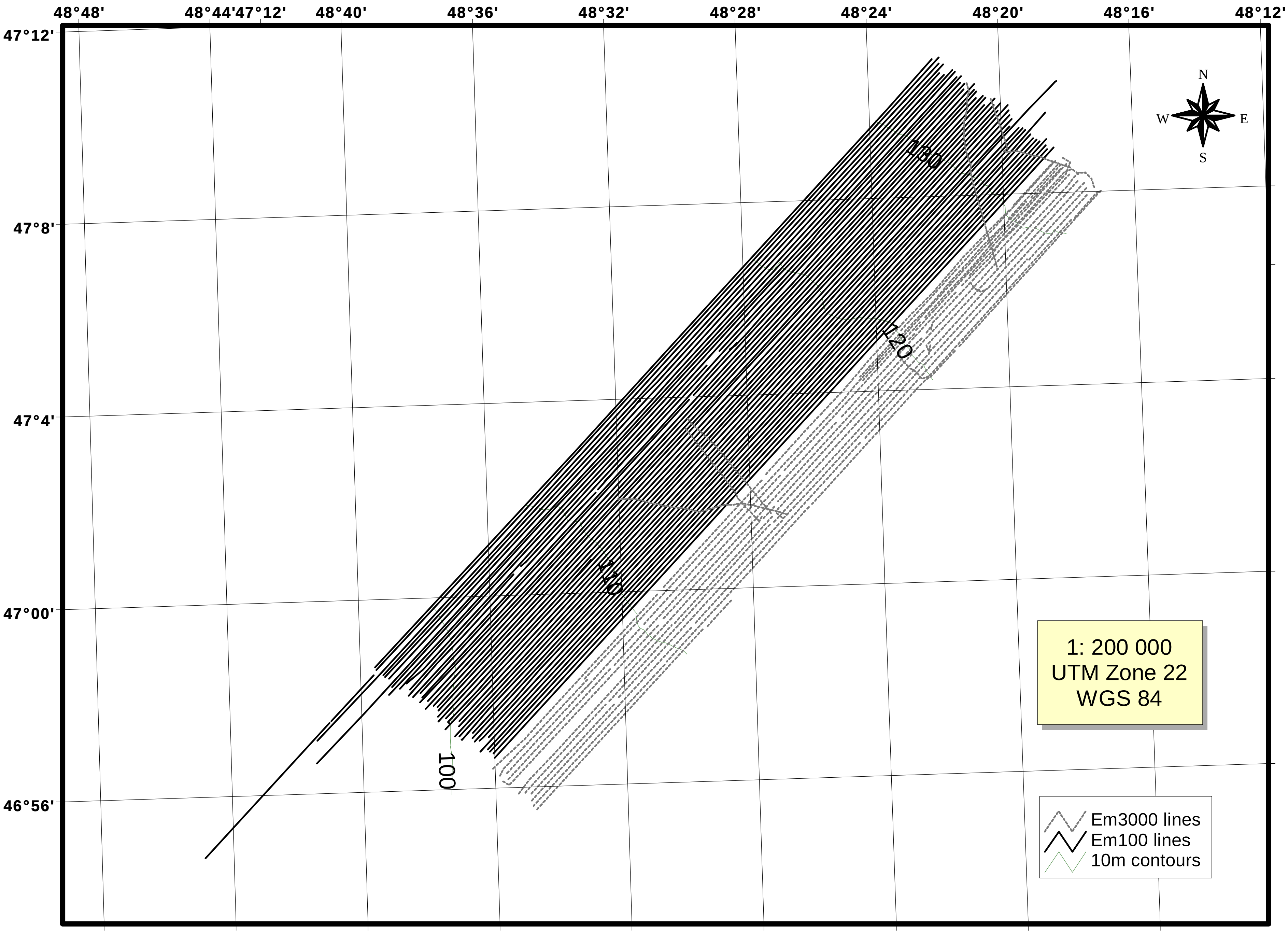


Figure 2: CCGS Matthew (EM100) and CHS Launch Plover (EM3000) survey tracks from Matthew 98-024

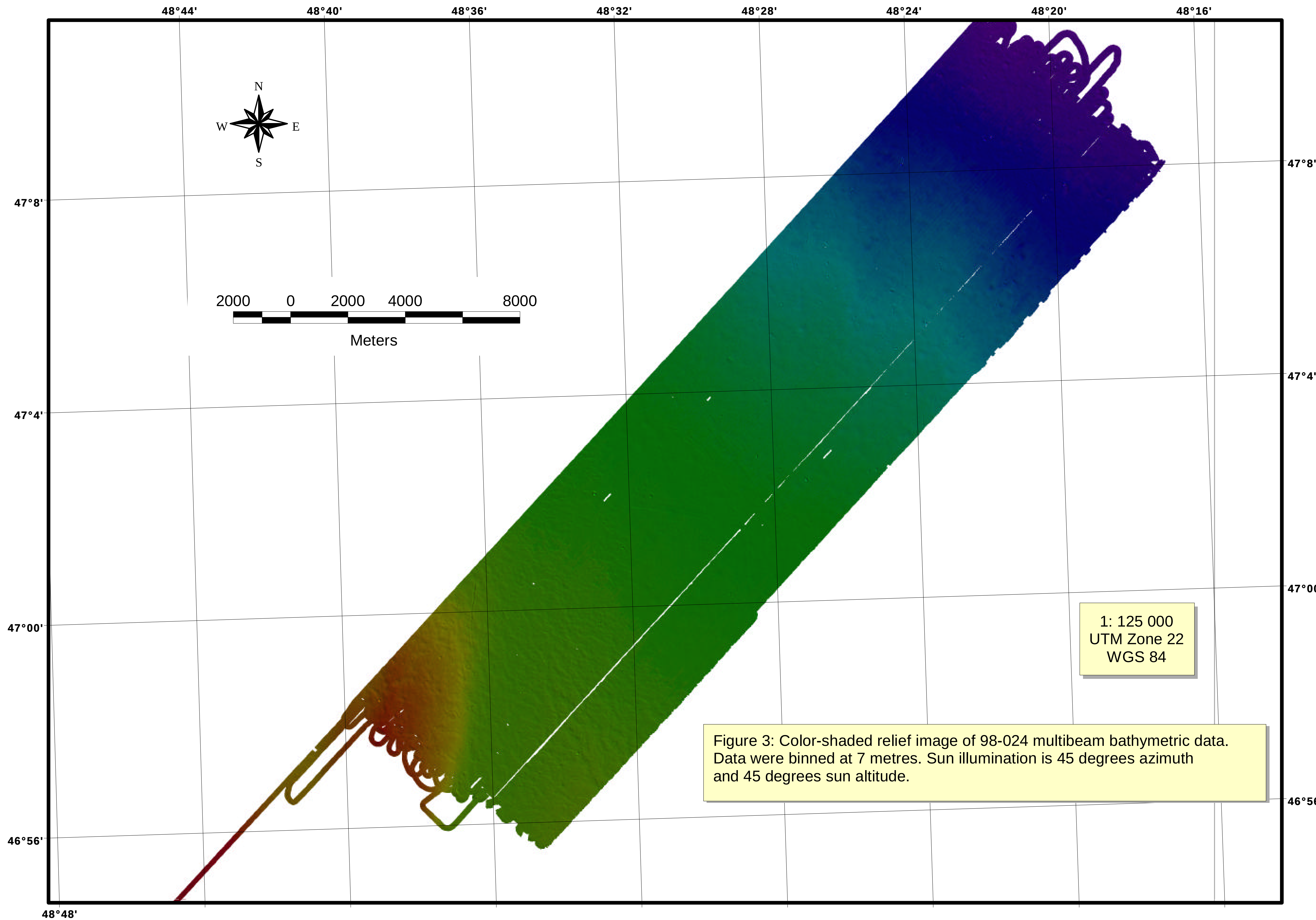


Figure 3: Color-shaded relief image of 98-024 multibeam bathymetric data. Data were binned at 7 metres. Sun illumination is 45 degrees azimuth and 45 degrees sun altitude.

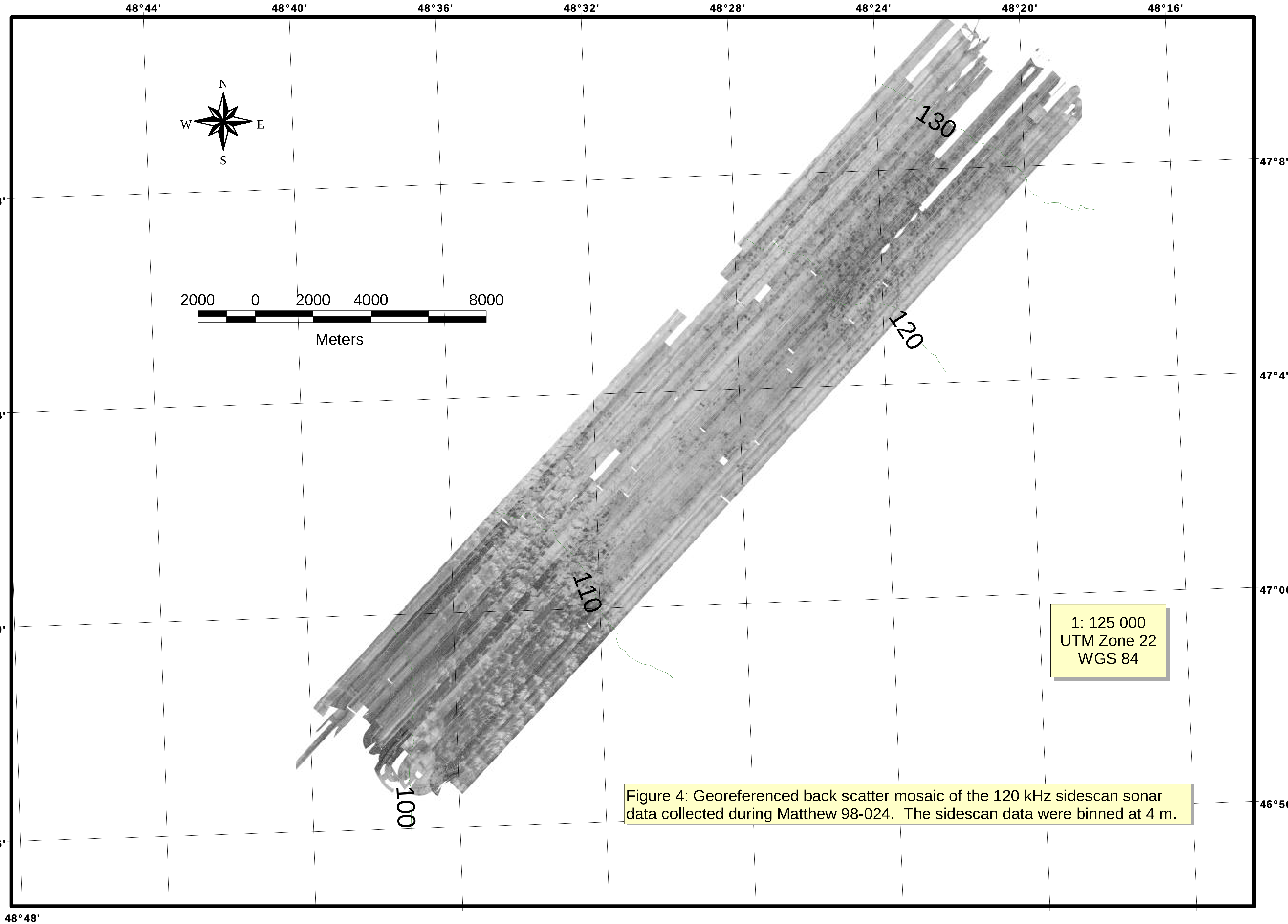


Figure 4: Georeferenced back scatter mosaic of the 120 kHz sidescan sonar data collected during Matthew 98-024. The sidescan data were binned at 4 m.

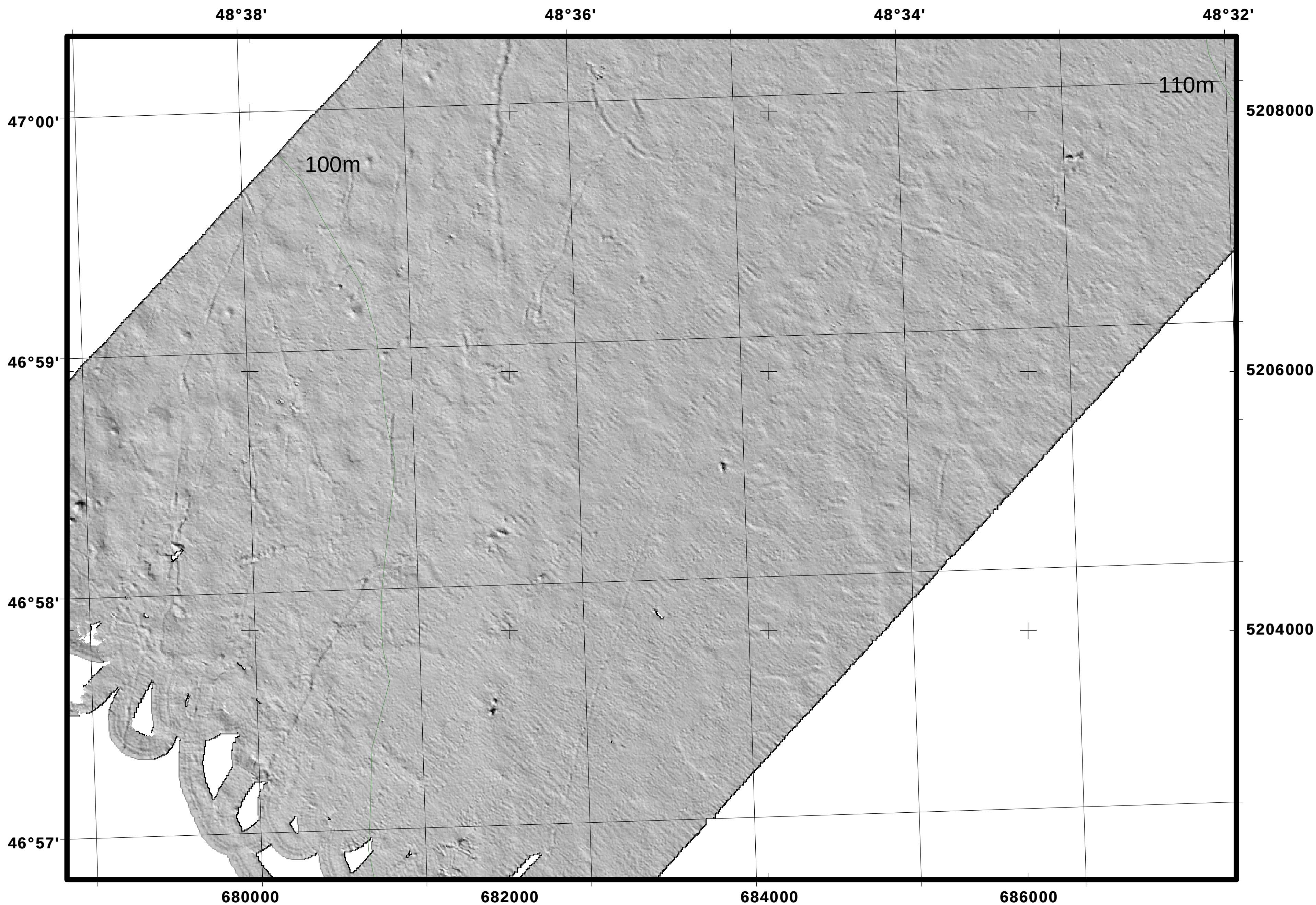


Figure 5: Shaded relief image of the EM100 multibeam data. Iceberg furrows and pits are most common here in the southwest where the seabed is shallower and the sediments are coarser. Sun illumination is from the NE. Vertical exaggeration is 10 X

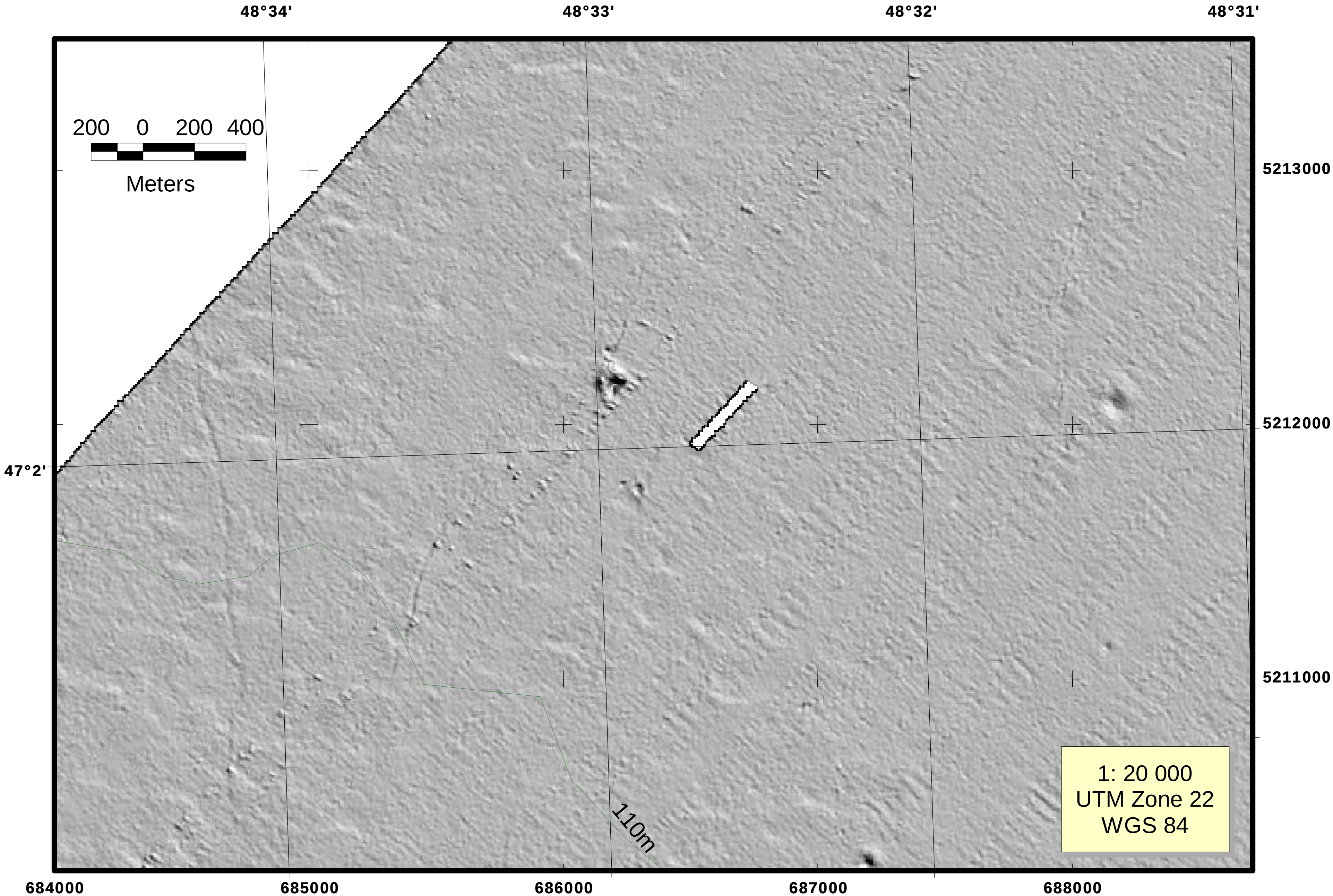


Figure 6: Shaded relief image of a large iceberg pit identified from the EM100 multibeam data. The pit is 8 m deep and approx. 80 m across. Berms are visible on three sides of the pit. The subtle furrow to the north is likely the lead in scour for the pit.

APPENDIX 1   DATA COLLECTION TIMES 98-024

EM100 MULTIBEAM

START TIME DAY/HOUR/MIN/SEC	STOP TIME DAY/HOUR/MIN/SEC	REASON FOR STOPPAGE
181131300	181152300	SVP cast # 1002
181160600	181202000	pick up launch
181204100	182093500	deploy launch
182095300	182162900	SVP cast # 1003
182165500	182191700	pick up launch
182193200	183053300	heavy winds, unable to survey
183234900	184123500	SVP cast # 1004
184125900	185092800	deploy launch
185100400	185142700	launch, crew change
185143900	185201800	pick up launch
185203700	186093200	deploy launch
186095500	186100700	momentary problem with EM100
186100800	186200300	pick up launch
186202200	187193200	END OF SURVEY

EM3000 MULTIBEAM

START TIME DAY/HOUR/MIN/SEC	STOP TIME DAY/HOUR/MIN/SEC	REASON FOR STOPPAGE
182110711	182182653	end of day
185101755	185142700	launch crew change
185143900	185194325	end of day
186095635	186194614	end of day

HUNTEC DTS WITH SPARKER

START TIME DAY/HOUR/MIN	STOP TIME DAY/HOUR/MIN	LINES	PROBLEMS	REASON FOR STOPPAGE
1812220	1820752	1006,1008,1010		end of overnight geophysical surveys
1822148	1830520	1023,1025		end of overnight geophysical surveys
1842220	1850923	1043,1045,1047(partial)		end of overnight geophysical surveys
1852245	1860925	1067,1069,1071(partial)		end of overnight geophysical surveys
1862150	1871413	1083,1085,1087,1089	(1871313) ch.1 out of commission	END OF SURVEY

SIMRAD 992 SIDESCAN

START TIME DAY/HOUR/MIN/SEC	START TIME DAY/HOUR/MIN/SEC	REASON FOR STOPPAGE
1812236	1820752	end of overnight geophysical surveys
1822148	1830520	end of overnight geophysical surveys
1842220	1850923	retrieve gear to deploy PLOVER
1851004	1851109	end of overnight geophysical surveys
1852245	1860925	retrieve gear to deploy PLOVER
1861002	1861121	end of overnight geophysical surveys
1862150	1871413	END OF SURVEY

APPENDIX 2 LINE NUMBER START / STOPS

LINE NUMBER	START DAY/TIME	STOP DAY/TIME	EM100 DATA	HUNTEC DATA	SIDESCAN DATA
1001	181/1313	181/1523	X	-	-
1002	181/1606	181/1612	X	-	-
1003	181/1819	181/1612	X	-	-
1004	181/1819	181/1824	X	-	-
1005	181/1824	181/2020	X	-	-
1006	181/2041	181/2301	X	X	X
1007	181/2301	181/2308	X	X	X
1008	181/2308	182/0308	X	X	X
1009	182/0308	182/0321	X	X	X
1010	182/0321	182/0750	X	X	X
1011	182/0750	182/0824	X	-	-
1012	182/0824	182/0912	X	-	-
1013	182/0912	182/1045	X	-	-
1014	182/1045	182/1054	X	-	-
1015	182/1054	182/1302	X	-	-
1016	182/1302	182/1313	X	-	-
1017	182/1313	182/1416	X	-	-
1018	182/1416	182/1420	X	-	-
1019	182/1420	182/1629	X	-	-
1020	182/1655	182/1917	X	-	-
1021	182/1932	182/2135	X	-	-
1022	182/2135	182/2148	X	X	X
1023	182/2148	183/0144	X	X	X
1024	183/0144	183/0159	X	X	X
1025	183/0200	183/0512	X	X	X
1026	183/0512	183/0529	X	X	X
1027	183/0529	183/0533	X	X	X
1028	183/2349	184/0333	X	-	-
1029	184/0333	184/0341	X	-	-
1030	184/0341	184/0543	X	-	-
1031	184/0543	184/0554	X	-	-
1032	184/0554	184/1009	X	-	-
1033	184/1009	184/1019	X	-	-
1034	184/1019	184/1224	X	-	-
1035	184/1259	184/1546	X	-	-
1036	184/1546	184/1552	X	-	-
1037	184/1552	184/1741	X	-	-
1038	184/1741	184/1749	X	-	-
1039	184/1749	184/1949	X	-	-
1040	184/1949	184/1953	X	-	-
1041	184/1953	184/2155	X	-	-
1042	184/2155	184/2228	X	X	X
1043	184/2228	185/0158	X	X	X
1044	185/0158	185/0218	X	X	X
1045	185/0218	185/0612	X	X	X
1046	185/0612	185/0625	X	X	X

LINE NUMBER	START DAY/TIME	STOP DAY/TIME	EM100 DATA	HUNTEC DATA	SIDESCAN DATA
1047	185/0625	185/0928	X	X	X
1048	185/0928	185/1004	X	-	-
1049	185/1004	185/1109	X	-	-
1050	185/1109	185/1124	X	-	-
1051	185/1124	185/1319	X	-	-
1052	185/1319	185/1326	X	-	-
1053	185/1326	185/1427	X	-	-
1054	185/1439	185/1444	X	-	-
1055	185/1444	185/1543	X	-	-
1056	185/1543	185/1653	X	-	-
1057	185/1653	185/1701	X	-	-
1058	185/1701	185/1739	X	-	-
1059	185/1739	185/1744	X	-	-
1060	185/1744	185/1806	X	-	-
1061	185/1806	185/1820	X	-	-
1062	185/1820	185/2018	X	-	-
1063	185/2037	185/2133	X	-	-
1064	185/2133	185/2138	X	-	-
1065	185/2138	185/2230	X	-	-
1066	185/2230	185/2244	X	-	-
1067	185/2244	186/0256	X	X	X
1068	186/0256	186/0305	X	X	X
1069	186/0305	186/0649	X	X	X
1070	186/0649	186/0701	X	X	X
1071	186/0701	186/0932	X	-	X
1072	186/0955	186/1007	X	-	X
1073	186/1008	186/1121	X	-	X
1074	186/1121	186/1133	X	-	-
1075	186/1133	186/1328	X	-	-
1076	186/1430	186/1642	X	-	-
1077	186/1642	186/1646	X	-	-
1078	186/1646	186/1837	X	-	-
1079	186/1837	186/1848	X	-	-
1080	186/1848	186/2003	X	-	-
1081	186/2022	186/2100	X	-	-
1082	186/2100	186/2151	X	-	-
1083	186/2151	187/0112	X	X	X
1084	187/0113	187/0129	X	X	X
1085	187/0129	187/0541	X	X	X
1086	187/0541	187/0549	X	X	X
1087	187/0549	187/0911	X	X	X
1088	187/0911	187/0921	X	X	X
1089	187/0621	187/1428	X	X	X
1090	187/1428	187/1431	X	X	X
1091		S K	I P	P E	D
1092	187/1431	187/1646	X	-	-
1093	187/1646	187/1654	X	-	-
1094	187/1654	187/1855	X	-	-
1095	187/1855	187/1905	X	-	-
1096	187/1905	187/1932	X	-	-

APPENDIX 3 EM3000 Data PLOVER

LINE NUMBER	START DAY/TIME	STOP DAY/TIME
3001	1821108	1821137
3002	1821138	1821147
3004	1821156	1821225
3005	1821226	1821255
3006	1821256	1821325
3007	1821326	1821337
3008	1821339	1821407
3009	1821517	1821537
3010	1821540	1821609
3011	1821610	1821632
3012	1821633	1821648
3013	1821649	1821709
3014	1821710	1821738
3015	1821739	1821756
3016	1821757	1821827
3018	1851020	1851048
3019	1851049	1851106
3020	1851107	1851149
3021	1851150	1851157
3022	1851201	1851223
3023	1851224	1851245
3024	1851246	1851301
3025	1851303	1851333
3026	1851334	1851335
3027	1851336	1851405
3028	1851406	1851408
3029	1851409	1851424
3030	1851435	1851450
3031	1851451	1851518
3032	1851519	1851548
3033	1851549	1851617
3034	1851618	1851632
3035	1851633	1851702
3036	1851703	1851721
3037	1851722	1851751
3038	1851752	1851820
3039	1851821	1851836
3040	1851838	1851917
3041	1851918	1851937
3042	1851938	1851943
3043	1851944	1852007
3044	1860957	1861018
3046	1861019	1861048
3047	1861049	1861104
3048	1861108	1861137
3049	1861138	1861207
3050	1861208	1861237
3051	1861238	1861248
3052	1861251	1861322
3054	1861323	1861347
3055	1861350	1861408
3056	1861443	1861512
3057	1861513	1861520
3058	1861522	1861550
3059	1861551	1861556
3060	1861557	1861626
3061	1861627	1861628
3062	1861634	1861703
3063	1861704	1861713
3064	1861714	1861743
3065	1861744	1861813
3066	1861814	1861843
3067	1861844	1861911
3068	1861912	1861941
3069	1861942	1861946

APPENDIX 4 Quester Tangent QTCView Data

QT file	Start Daytime	to End Daytime
MA181A98.CAL	1811612	1811735
MA181B98.CAL	1811741	1812023
MA181C98.CAL	1812055	1812359
MA182A98.CAL	1820000	1820314
MA182B98.CAL	1820315	1820958
MA182C98.CAL	1821107	1821629
MA182D98.CAL	1822157	1830002
MA183A98.CAL	1830003	1830516
MA184A98.CAL	1841047	1842208
MA184B98.CAL	1842223	1850204
MA185A98.CAL	1850206	1850615
MA185B98.CAL	1850617	1851915
MA186A98.CAL	1852317	1860306
MA186B98.CAL	1860307	1860653
MA186C98.CAL	1860654	1860944
MA186D98.CAL	1861341	1862025
MA187A98.CAL	1862349	1870118
MA187B98.CAL	1870136	1870547
MA187C98.CAL	1870548	1870914
MA187D98.CAL	1870917	1871934

APPENDIX 5 DIGITAL SIDESCAN AND HUNTEC DATA

AGCDig Digital Tapes (Exabyte)

SIMRAD 992 SIDESCAN

Note:
SIMRAD 992 SSS, Ch 0-120-L, Ch 1-120-R (300 meter range); Ch 2-330-L, Ch 3-330-R (300 meter range); Ch 4 GPGGA nav.
140 microsecond sample rate, 2885 samples/shot

TAPE	START Day/Time	STOP Day/Time
1	181/2239	183/0540
2	184/2228	186/0827
3	186/0831	187/1413

HUNTEC DEEP TOWING SYSTEM SPARKER
Channel 1=External 24 element streamer
Channel 2= External 10 element streamer
40 microsecond sample rate 3000 samples/shot

TAPE	START Day/Time	STOP Day/Time	24channel streamer	10channel streamer
1	181/2246	183/0520	X	X
2	184/2210	186/0920	X	X
3	186/2150	187/1257	X	X
4	187/1313	187/1428	X	X

APPENDIX 6

TECHNICAL REPORT
DEEP TOW OPERATIONS
C.C.G.S. MATTHEW #98024
June 26 - July 7, 1998

Submitted by:

Geoforce Consultants Ltd.
P.O. Box 696
Dartmouth, Nova Scotia
B2Y 3Y9

Prepared for:

Natural Resources Canada - Atlantic Region
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia
B2Y 4A2

Distribution: G. Sonnichsen (EMG)
M. Gorveatte (EMG)
A. Boyce (for Curation)
Project File #C135-20

Dated: July 7, 1998

1.0 INTRODUCTION

This is a technical review of the Deep Tow Seismic (DTS) operations aboard the Canadian Coast Guard Ship Matthew, during Natural Resources Canada mission #MA98024. This marine geophysical and multi-beam hydrographic survey was located near the Hibernia field off Newfoundland, from June 26 to July 7, 1998. The field program was directed by Senior Scientist Mr. Gary Sonnichsen of MEG.

The DTS was part of the geophysical survey program, which consisted of the following equipment systems.

* Deep Tow Boomer/Sparker profiling system
* Simrad MS992 Dual frequency side scan sonar system
* AGC DIG Digital Logger (Simrad and DTS)

Overall, DTS operations went well with no major problems to report. Over 400 line kilometres of DTS data was collected with no equipment downtime. For details see Equipment Performance in section 2.2.

In general, the DTS data quality was very good. Traditionally the Hibernia area has been “acoustically hard” and penetration with the DTS boomer was often limited to 20 milliseconds or less. For this field program the DTS twenty tip sparker source was used with a longer 24 element Geoforce streamer. This configuration produced much better penetration (60 milliseconds or more) at the expense of some resolution. The acoustic interference between the DTS sparker and the Simrad side scan was quite noticeable at the start of the survey. To reduce this interference the DTS trigger was slaved to the Simrad which worked very well.

Geoforce Consultants Limited provided technician, Martin Uyesugi under the DTS standing offer contract (D.S.S. #23420-95-01HAL) to supervise the installation, operation and maintenance of the DTS system during the field program.

1.1 DAILY SUMMARY

A daily summary of operations follows. All times are UTC unless otherwise noted.

Date	JD	Event
24/06/98	175	Commence installation of DTS onboard vessel at BIO jetty. Hydraulic hoses on DTS winch replaced due to safety inspection.
25/06/98	176	PCU 220 VAC outlet installed in lab. Complete DTS installation.
26/06/98	177	Depart BIO jetty at 1900 hrs. In transit to Grand Banks, Newfoundland.
27/06/98	178	In transit to survey area. Deploy DTS in 50 fathoms of water for equipment test, sea conditions good. Test line # 1 1628 - 1728 Recover DTS at 1730 hours. ***Service Note:*** *Initially there was no 220 VAC power at the lab breaker box. Power to the panel had to be reset in engine room. The Chief Engineer said the thruster engines tripped non essential systems.* *The DTS system worked fine in sparker mode, however, there was strong acoustic interference on the Simrad side scan. The noise was worse on the outer edges of the side scan records due to the tvg ramp. To synchronize the interference, the DTS was slaved to the Simrad side scan.*
28/06/98	179	In transit to survey area. Anchored in Trepassy Bay due to weather.
29/06/98	180	Depart Trepassy Bay at 1800 hours.
30/06/98	181	Arrive at Hibernia at 1200 hours. Prepare for multi-beam survey. Deploy DTS at 2220 hours. Survey lines #1006 2246 - 2302 (join line in progress) #1008 2302 - 0000

1/07/98	182	Continue survey operations.		
		Survey lines	#1008	0000 - 0308
			#1009	0308 - 0322
			#1010	0322 - 0750
		Recover DTS at 0800 hours.		

Service Note: *The sparker acoustic interference on the Simrad side scan records was still evident in 100 metres of water. The DTS was slaved to the Simrad system using the Simrad trigger output to the AGC DIG. At 300 metre range this produced a trigger rate of approximately 0.41 seconds.*

		Deploy DTS at 2130 hours.		
		Survey lines	#1023	2156 - 0000 2/07/98
2/07/98	183	Continue survey operations.		
		Survey lines	#1023	0000 - 00145 (continuation)
			#1025	0158 - 0512
		Side scan hit bottom during turn, recover DTS at 0520 hours.		
		Captain halts survey operations due to sea conditions.		
3/07/98	184	On weather standby.		
		Running multi beam lines during rough weather.		
		Deploy DTS at 2210 hours.		
		Survey lines	#1043	2228 - 0000
4/07/98	185	Continue survey operations.		
			#1043	0000 - 0156 (continuation)
			#1045	0218 - 0611
			#1047	0628 - 0923
		Recover DTS at 0930 hours.		
		Deploy DTS at 2235 hours.		
		Survey lines	#1067	2245 - 0000

Service Note:

During daily maintenance, notice spurious readings on the fish depth signal. Disconnect the deck cable and the problem still persisted. Suspect problems in the BMC module. Install the BMC from the backup systems console which cured the problem.

Lost signal from external 10 element streamer shortly after deployment. Tee off signal from 24 element streamer and continue survey operations.

5/07/98	186	Continue survey operations.		
		Survey line	#1067	0000 - 0255 (continuation)
			#1069	0305 - 0649
			#1071	0700 - 0920
		Recover DTS at 0930 hours.		

Service Note:

Inspect tow fish and discover that the 10 element streamer connector had been pulled out at the ASU. Reconnect streamer and secure with tie raps. Test signal which appeared OK.

Deploy DTS at 2140 hours.		
Survey lines	#1083	2150 - 0000

6/07/98	187	Continue survey operations.		
			#1083	0000 - 0112 (continuation)
			#1085	0130 - 0540
			#1087	0550 - 0910
			#1089	0922 - 1415
		Recover DTS at 1415 hours.		

Service Note:

Picking up 60 hertz noise on the 10 element streamer at end of line #1087. By the end of the following line #1089, the noise was over riding the signal on the AGC DIG display. Curiously, the noise was not evident on the analog EPC record.

At the end of the final line the PCU stopped firing and tripped the lab circuit breaker. The DTS technician was called and found the PCU was loading down and very hot. It was thought that the sparker needed to be retipped. To force the sparker to discharge and complete the survey, the PCU output power was increased, allowing the sparker to discharge till the end of the line.

Disconnect DTS system.

7/07/98 188 Arrive St. John’s, Newfoundland at 1300 hours.
Pack and offload equipment from vessel.
Flight back to Halifax.
****** END OF MISSION ******

2.0 DESCRIPTION OF EQUIPMENT

a) Deep Tow Seismic System

Geoforce Consultants Ltd. of Dartmouth, Nova Scotia is contracted under a Standing Offer Contract with Natural Resources Canada to supervise the operation, maintenance and ongoing engineering development of NRCan owned Deep Tow Seismic systems. The DTS system, originally manufactured by Huntec (70) Limited, is a high resolution, sub-bottom profiler with the acoustic source, energy supply, motion sensor, and two receiving hydrophones housed in an underwater deep towed body. The AGC #2 Deep Tow system has a maximum power output of 540 joules (30 mfd storage capacitance) with an ED 10 F/C Boomer and optional multi tip sparker source. Normally an LC10 single element hydrophone mounts inside the tow fish beneath the boomer. A fifteen foot, ten element single channel hydrophone array is towed behind the fish. For this survey, a Geoforce GF24/24 twenty-four foot, 24 element streamer was installed on the tow fish and the internal hydrophone was disconnected.

The ED10 boomer is depth compensated and outputs a highly repeatable broadband pulse, capable of resolving 10 centimetres. Peak output intensity is 118 db relative to 1 micro bar at 1 metre, with a pulse duration of 110 microseconds. The sparker source has twenty, # 22 awg, solid core tips. Peak amplitude and pulse width for the sparker source are depth dependant.

The deck equipment consists of a Huntec Model 1000 Oceanographic winch, which includes a multi-way slip ring and a 305 metre, fourteen conductor, armoured tow cable. The winch is powered by a 440 VAC, 15 HP hydraulic pump unit. The tow cable is handled by a 36 inch diameter roller cluster rigged on the centre position of the aft A frame.

The lab instrumentation consists of the Huntec Systems Console and DC high voltage power supply (PCU). The Systems Console houses the Bottom Motion Compensator circuits, the +24 volt fish supply, and modules for signal processing and tape outputs. The Huntec Mk III PCU provides DC power to the boomer in switchable ranges from 2 to 6 kilovolts.

This survey was the first installation of the DTS system on C.C.G.S. Matthew. The AGC #2 system’s smaller winch and tow fish is more suited to installation on Matthew with its limited after deck space. Deck power (460 VAC) for the winch was available on the stern, however, a 220 VAC single phase outlet was installed in the lab for the Power Control Unit.

b) Graphic Display, Signal Processing and System Key

Seismic #1 and Seismic #2 signals were displayed on a single EPC 9800 (s/n 126). Seismic #1 (GF24/24 streamer) was processed by the Adaptive Signal Processor (ASP) module then passed thru a 3323R KrohnHite filter with a low pass setting of 3500 hertz. Seismic #1 was displayed on channel A of the EPC 9800 recorder. Seismic #2 (15/10 element streamer) was processed by a second ASP console and displayed on channel B on the EPC 9800 recorder. A TSS 312B annotator provided time marks on the hard copy records and provided EPC recorder print delay.

c) Data Recording

The DTS signals were recorded on the new AGC DIG (version 2.33) digital four channel logger with 8700 Exabyte tape drive.

AGC DIG Inputs	Description
Ch. #1	Seismic #1 - External GF24/24 element streamer
Ch. #2	Seismic #2 - External 10/15 element streamer
Trigger	DTS +5 volt master trigger

d) Equipment List

Unit Description	Serial Number
Tow Fish Body	1015
ED10F/C Boomer Source	2023
MK5-2 Attitude Sensor Unit	5012
S500 Energy Storage Unit	1019
Internal LC 10 Hydrophone	---
External 10/15P Benthos Streamer	---
External GF24/24 Geoforce Streamer	GF102
Huntec 1000 Oceanographic Winch and Power Pack	---
Roller Cluster 36" Dia.	---

Systems Console	105
EPC 9800 Graphic Recorder	126
MK 3 Power Control Unit	105
Second ASP Console	101
Krohnhite 3323 Filter	299
AGC DIG Data Logger	---

2.1 EQUIPMENT SETTINGS

The following equipment settings were used for the majority of DTS survey lines.

Parameter	Setting
Fire rate	0.41 seconds
PCU power setting	4 kilovolts (240 joules)
ESU power setting	30 microfarad (540 joules max.)
BMC (motion compensation)	Pressure Mode
Display Gain	Seismic #1- Fixed +20 Db. Seismic #2 - Adaptive TVG
Filter Setting	Seismic #1 - 700 - 3500 hertz Seismic #2 - 1000 - 6000 hertz
Processor Gain (System Console)	4 KV (both channels)
DTS source	sparker
AGC DIG delay	140 milliseconds
AGC DIG sample rate	40 microsecond
AGC DIG samples per channel / range	3000 / 195 metres
EPC sweep speed	125 msec.
EPC print polarity	positive

2.2 EQUIPMENT PERFORMANCE

Overview

Overall, DTS equipment performance was very good with no system downtime to report. The only equipment problem was an erratic readout on the BMC depth signal on day 185. A spare BMC module was installed to fix this problem. The Seismic #2 streamer was pulled out of its connector on the ASU. It is suspected that the side scan fish snagged the streamer tail line, pulling the connector out. The streamer was not damaged in this mishap.

Data Quality

In general, the DTS data quality was very good. The new Geoforce 24 element streamer and sparker provided good penetration into the hard compacted sands and till in the Hibernia study area. The 24 element, twenty four foot long Geoforce streamer provided much higher signal returns and could consistently map deeper layers than the standard 10 element fifteen foot streamer. A GF24/24 should be made a permanent addition to the NRCan DTS systems.

Matthew Survey Operations

The Matthew proved to be capable of joint side scan and Deep Tow operations. The installation was tight but did work. Due to the vessel's small size, adverse sea conditions did halt survey operations long before the limits of the survey equipment had been reached.

The separation between the DTS and side scan tow positions on the aft "A" frame was minimal. It was always a concern that the two tow fish would tangle. By launching the side scan first then lowering it to survey depth, then DTS fish could then be deployed forward of the side scan. For the most part this procedure did work, with only one tangle of the DTS streamer with the side scan. The DTS tow fish depth was limited to approximately mid water depth to keep the bottom return between the surface return and first multiple. Ideally, it would have been nice if the tow fish could have been towed deeper, however doing so would have placed the DTS tow fish back with the side scan fish and increased the possibility of tangling.

In shallow water, the side scan and DTS are forced into similar tow depths and it will not be possible to maintain the separation between tow fish. This is a concern for the Forbe's PEI mission on Matthew later this year.

Status of Equipment

AGC #2 is in transit from St. John’s. BMC module and ten element streamer require service before Hudson cruise, otherwise the system is in good operational condition.

Parts Consumed

1 - sparker tip

3.0 RECOMMENDATIONS

1) The C.C.G.S. Matthew proved to be a good platform for DTS survey operations. The AGC #2 DTS system proved ideal for installation on the Matthew due to it’s smaller winch and tow fish. However, the Matthew has limitations in adverse sea conditions. Survey operations had to be suspended where a larger vessel like Hudson or Parizeau would continue to survey.

2) The defective BMC module (intermittent glitch on depth display readout) and 10 element streamer hydrophone (60 hertz noise) will have to be repaired before the next Hudson cruise.

3) This is the same streamer that experienced the same problem on the Hudson cruise this spring. It is the only “original” Benthos streamer remaining, the other streamers having all been overhauled by Geoforce last year. Prior to the Matthew cruise this streamer was disassembled, checked and the fluid changed, but no obvious problem was found. The mating hydrophone connectors have’nt been replaced in recent memory and the seal may be loose due to wear. It’s possible water is gradually seeping into contacts, causing noise pickup.

4) The long GF24/24 streamer has proved to be a valuable upgrade for the DTS systems. When used with the sparker source, the increased penetration in “ acoustically hard” bottoms is a big improvement in system capability. It is recommended the remaining Benthos streamer be overhauled into a 20 - 25 element streamer.

5) The AGC #3 system is slated for use on the Hudson in July, however, the repairs to the ED10 boomer (Antarctic program) have not yet been completed. Either the AGC #2 tow fish will have to be substituted or the boomer taken out of AGC #2 and installed in AGC #3 tow fish.

6) Towing configuration for Forbe’s mission should be discussed. There will be many towed vehicles to be accommodated in a very limited space.

APPENDIX 7

Processing Report- EM3000 Data
98024
CGS Matthew
JD 182, 185, 186

Purpose
The purpose of this document is to outline actions taken to process EM3000 data collected on the Candian Hydrographic Service launch "PUFFIN" during cruise 98024 of the CCGS Matthew, June 1998. The project called for the integration of the EM3000 data with a previously processed EM100 dataset that adjoined the study area to the northwest.

All processing was to be done in the office of SEA on NT machines using the processing package HIPS, with post-processing and final raster production to be done in CARIS. It was requested that all digital products could be ported to AGC-GRASS, which is the UNIX-based GIS package in use currently at the Atlantic Geoscience Centre. The raster products generated in CARIS were converted to ASCII (x-y-z) format using software written by SEA.

Introduction

Initial conversion of the EM3000 data on board the Matthew revealed a problem either in the Simrad datagram or in the HDCS converter used on the Matthew. The data conversion was found to have not properly applied the heave correction, although the data appeared fine in the Mermaid software on the Puffin.
Previous experience with EM3000 data at SEA showed no similar heave problems, therefore it was thought that the HDCS converter for the NT had been more recently upgraded than the UNIX and would therefore be more appropriate for the data.

To test this hypothesis, two copies of the data were loaded onto the NT machines, one of the raw unprocessed Simrad data files and one of the partially processed HDCS files which were converted from the Simrad on board the Matthew. The raw data were then converted using the NT converter and compared with the semi-processed HDCS files from the Matthew. A quick examination showed that the data were properly heave-corrected, so the Matthew files were discarded and the raw Simrad files were converted and used for this project.

Since the EM100 data were processed on board, no attempt to reprocess the data were made and the HDCS files were used.

Data Description

The data were collected over three days, julian days 182, 185, and 186 in a NE/SW trending band selected to abut a region of similarly-trending EM100 data collected on board the Matthew on the same cruise. Initial problems with the collection procedure limited the data collected on 182 to about half of the collection day (about 5 hours). These problems revealed themselves in the quality of the backscatter information, which improved greatly the next day. This will be discussed in greater detail below.

The bottom over which the data were collected is mainly flat and gently dipping to the NW, with depths ranging from 100 to 130m.

Processing Details

All processing was done with Universal Systems Ltd. HIPS software. The processing basically followed the pattern:

1) Editing for navigation problems
2) Editing for attitude (G/H/P/R) problems
3) Swath editing of observed depths
4) Merge with tide information
5) Subset editing of spatially referenced data
6) Repeat steps 3) through 5) as necessary

The first two steps are a simple matter of rejecting bad points and, in the case of navigation editing, interpolating a new sounding location where possible. This is possible in most cases.

Swath Editing

Generally speaking, there were few navigation or attitude sensor problems in the data. Swath editing, however, revealed some serious problems with the outer beams, probably a result of the extreme depths at which the system was used. It is likely that the return signal of the high frequency system was so attenuated by the travel distance in the water column that relatively minor changes in sound velocity were being interpreted as water bottom (fig. 1). SwathEditor, the HIPS tool for editing the swath data line by line, also has other filter capabilities available. These include filtering by maximum slope and minimum angle to remove spikes, and by maximum and minimum depth to remove outliers. However, these tools apply corrections swath by swath and are most useful for

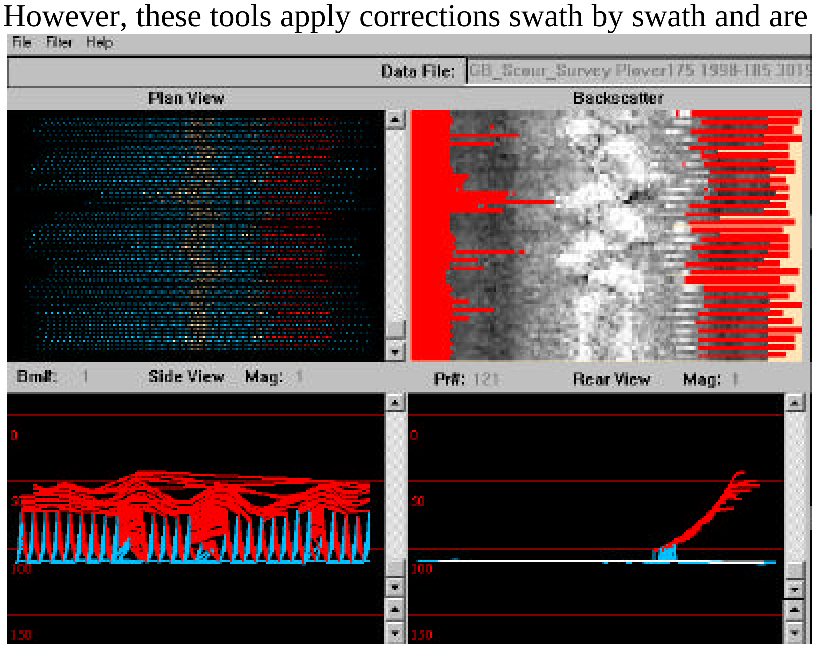


Figure 1 A screen capture of a SwathEdit session of one of the EM3000 lines showing the loss of bottom contact in the starboard side beams. The red points are those that have been rejected by the editing. The lower right window (the rear view) shows that most of the problem in this instance is in the outer beams.

filtering out spikes and are inappropriate in this case in where all or part of a swath is to be rejected. Therefore, editing this data consisted of first cutting the outer 15 beams on either side, and then visually scanning the data for obvious problems.

Subset Editing

The data were then edited using the Subset Editor in HIPS. The subset editor allows spatial editing of the processed depths from data from many lines and is useful for both removing outliers and detecting inter-line errors and inconsistencies.

Subset Editor bins the soundings in the area selected and provides a filtering tool based on the user-defined parameters calculated from the mean and standard deviation. The editor allows the operator to select filter parameters and reject, accept or undo any changes afterward. Filter parameters selected can vary, depending on factors such as amount of scatter in the data and degree of topographic variability. In general, to avoid removing too much data, a more variable topography requires larger filter factors, hence leaving a larger window of acceptable data points, and a more gentle terrain can be filtered a bit more vigorously.

The study area, although topographically gentle, had to be processed with care, as the features often were on the metre and sub-metre scale at over 100m water depth. Therefore it was necessary to test all of the filter subsets at least once with a variety of factors to determine whether scours or other small-scale features would be disrupted or destroyed by the filter before deciding on a filter to use. The factors used for the subset editing for this project are shown in the following table (as they appear in CARIS):

Base Definition	
St. Deviation Scale:	0.5

Level Definition	
St. Deviation Scale	0.2
Offset	0.0

Raster Production

The final step of data processing is the analysis of the digital terrain model that the data is used to generate. As this data set consisted of not only EM3000 data processed on this contract, but also EM100 data that was processed onboard ship, the DTM’s were created using all of the sounding data available. To check the data, a coarse DTM was created at 7m resolution and illuminated along track and across track. The across track illumination is useful for highlighting between-line errors, and the along track illumination picks out heave and other swath errors.

In this case, the across-track illumination revealed an inconsistency in the data sets that was not readily identified in either the swath or subset editing. It initially appeared as an apparent upward shift applied to the EM3000 data, or an equivalent depression of the EM100. However, on further examination it appeared that the EM3000 data had apparently suffered two upward shifts when compared with the EM100. All of the data up to and including line 3018 are apparently shifted vertically by 0.5m, and the lines after that line (3019 and on) suffer a further 0.5m shift.

It is difficult to speculate where this error originated, although some conclusions can be reached. As it does not offset all of the EM3000 data uniformly it is unlikely to be a

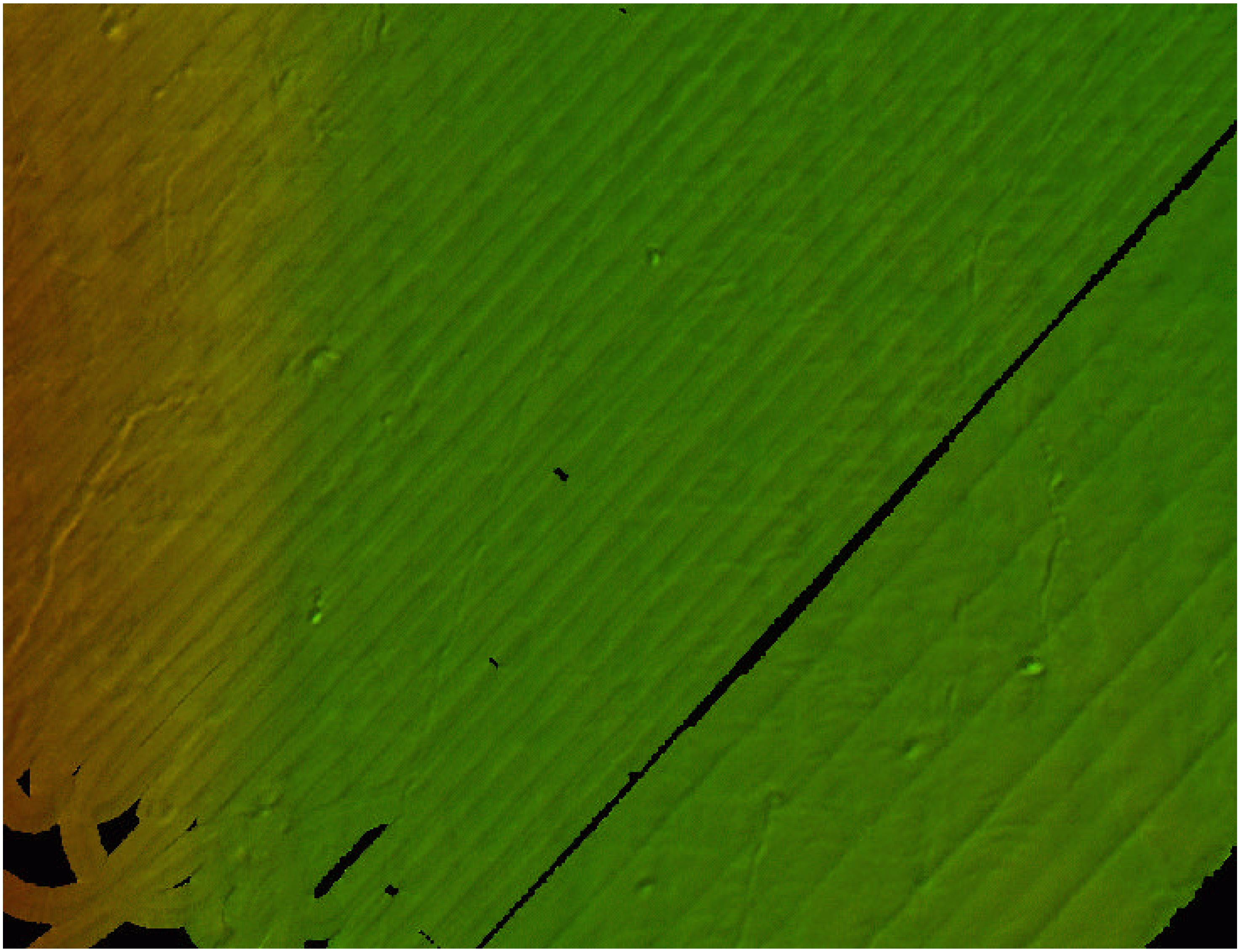


Figure 2 Detail of the southern portion of the 7m raster. The data in the southeast corner is EM3000 and in the northwest EM100. The extra resolution provided by the EM3000 data is not visible due to the coarseness of the gridding. Data are illuminated from the northwest corner to highlight between line errors.

problem with the vessel configuration file, unless a major change in the configuration of the vessel or the instruments on board occurred during the cruise. No such reconfiguration was reported, therefore it is assumed not to have happened. Another potential source of error is the tide file, but the one used was the same one that was applied to the EM100 data there is no concomitant error in that data. Therefore tides are probably not the cause of the shift.

There is, however a distinct change in the quality of the data collected within the EM3000 data, specifically before and after line 3018. At the beginning of line 3019, the data improves dramatically, more outer beams appear to make bottom contact and the backscatter becomes more coherent. There is no explanation as of yet as to why this happened, except perhaps the hydrographer collecting the data changed the settings at the start of line 3019 and maintained them from that point on. No record of this has been found, but it is a possibility.

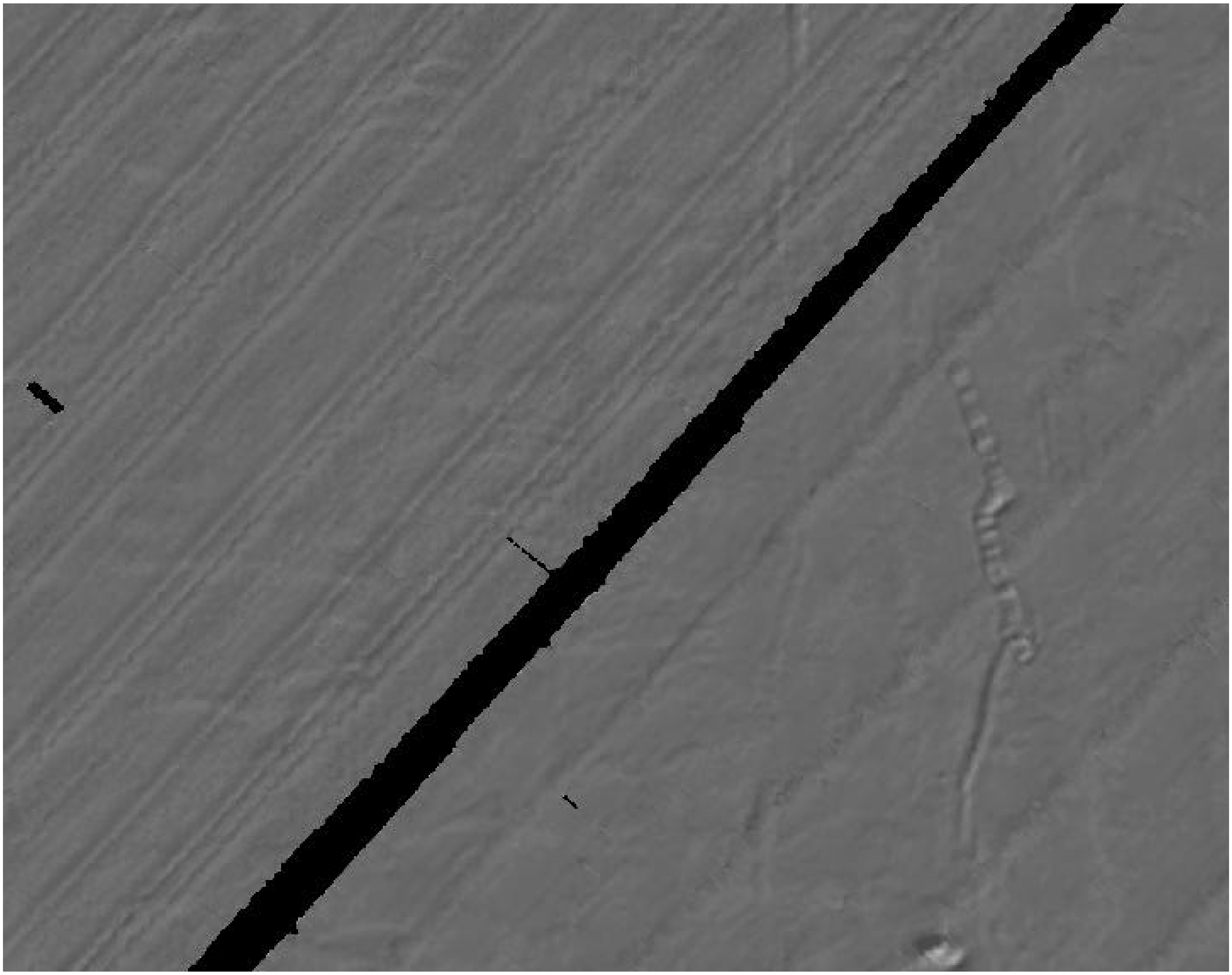


Figure 3 Detail of the southern portion of the 3m raster. Illumination is from the northwest. The improved resolution of the EM3000 data in the southeast is clearly visible. Approximate width of view is 2 km.

In any case, the goal of this study is to produce maps of bottom features and not navigable charts, therefore the EM3000 data were manipulated to produce a level raster image. To do this, the EM3000 data were normalized to the EM100 by editing the vessel configuration file. Removing the offset error was accomplished by artificially depressing the EM3000 data by 0.5 (for JD 182) and 1.0 m (for JD 185 and 186).

The final raster was generated at 7m resolution, as per the contract request. Further rasters were produced at 3m resolution (see figure 3) to show the improved resolution of the EM3000 system.

Backscatter

This dataset posed several challenges regarding backscatter processing. First, the data were collected using different tools, Simrad EM100 and EM3000 and each of these report backscatter information quite differently. Also, the way backscatter information is interpreted in SIPS makes it impossible to determine a quantitative measure for a given sounding. Unlike HIPS, SIPS does not provide output for each sounding, instead it produces a raster image at a user-defined resolution. The value given to each cell is an eight-bit composite of the values for all soundings in the cell neighbourhood.

Processing the backscatter involves producing a SIPS image from each individual line, producing a mosaic of all of the SIPS images, and finally assigning a colour palette to the map that accurately reflects the dynamic range of the data. This proved to be impossible for the entire data set, as the dynamic range of the EM100 data were appreciably different than the EM3000. Also the same inconsistency at line 3019 was found in the backscatter. Therefore the backscatter was handled as three separate data sets for processing purposes and combined as one only for the production of the final raster image.

The colourmap which is applied to the raster is selected from a single line from the dataset which best represents the full range in backscatter values. A poor selection of colourmap will result in the truncation of the map at one end of the spectrum or the other (or both). Thus, the range of colours that appear on the raster image are specifically chosen to maximize the dynamic range of the 8-bit spectrum and as such, will probably not bear a quantitative relationship to another dataset and certainly not to another sonar tool.

To produce images that would be useful for interpretation, given the differences in the EM100 and EM3000 datagrams and the limitations of SIPS, two approaches are possible. The first approach is to combine all of the sonar data together in one semi-quantitative scale and apply a single colour palette to the image. Attempts to do this with this data produced images in which the datasets inhabited the extreme ranges of the available spectrum (black and white) and provided little real detail.

The other approach is to attempt to optimize the colour palette for each individual dataset and thereby maximize the effective visual dynamic range that is available to each. This produces an image useful for interpretation at the expense of having a quantitative backscatter colour scale. This technique was used because, although they may appear to change in intensity as they cross from one dataset to another, bottom features can be easily interpreted in the image.

Figure 4 shows a blowup of the southwestern portion of the study to show the quality of the data.

The backscatter was also provided in ASCII format. A mosaic of each data set was produced and converted to ASCII using an in-house program.

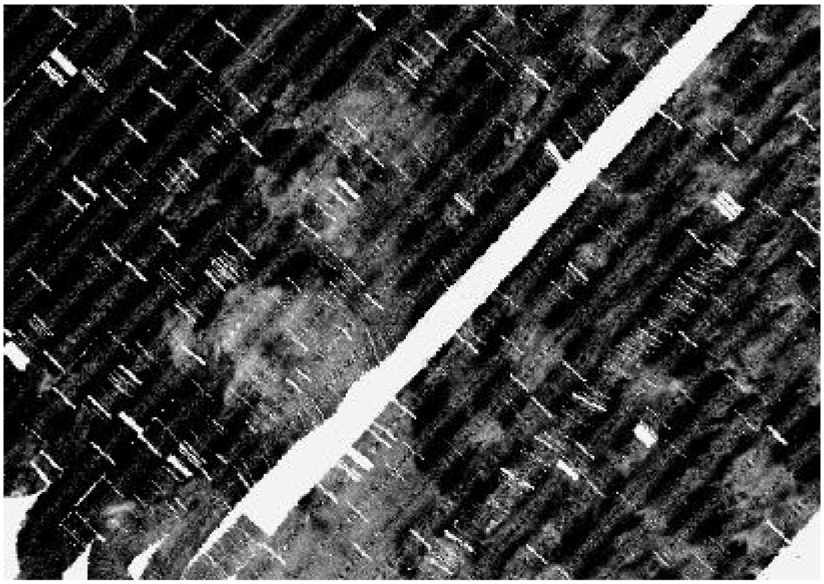


Figure 4 A detail from the combined backscatter raster. The data to the southeast of the white space is EM3000 and to the northwest EM100. Resolution of the image is 7m and the distance across the bottom of the image is approximately 3 km.