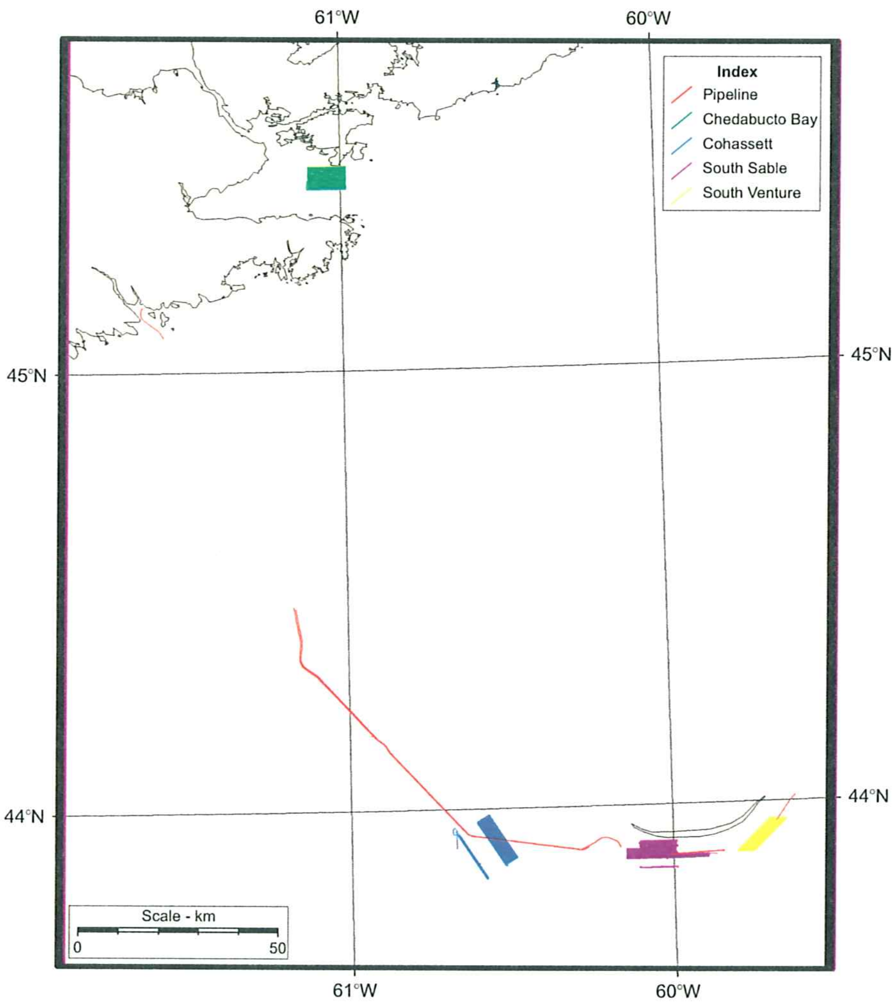
Multibeam Surveys Of Sable Island Bank, Scotian Shelf: Report on Creed Cruise 2000-100

Michael Li, Darrel Beaver, Ned King
and Peter Pledge



Geological Survey of Canada
Open File 4090
October 2001

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CRUISE SUMMARY SHEET

Ship	CSS Frederick G. Creed
Cruise Number	Creed 2000-100
Duration	27 May - 4 June, 2000
Survey Areas	Sable Island Bank, Scotian Shelf and eastern Chedabucto Bay, Nova Scotia
Scientific Staff	Michael Li (senior scientist) Darrel Beaver (system manager) Edward King (scientist) Peter Pledge (system specialist) (all GSCA personnel)
Ship's Personnel	Roger Harvey (captain) Jean La Brie (chief engineer) Phillippe Cahn (first officer) Mario Fournier (second engineer) Maurice Jean (chef)
Results	252 survey lines (2066 line km) completed 10 sound velocity profiles obtained

BACKGROUND AND OBJECTIVES

Sable Island Bank (SIB) is one of several topographic highs on the outer edge of the Scotian Shelf. During the post-glacial transgression, aeolian and marine processes reworked the glacial and glacial-marine Pleistocene deposits on the bank into a series of shoreface-connected sand ridges (Amos and King, 1984; Hoogendoorn and Dalrymple, 1986). Understanding the morphodynamics and migration of the sand ridges will link the hydrodynamic/sediment transport processes with the formation of the stratigraphy and evolution of SIB. The migration of sand ridges and the mobile layer thickness caused by this are also hazardous to the design and safety of offshore platforms and pipelines.

Though recent field measurements and model predictions (Amos and Judge, 1991; Li et al., 1997) have shown strong eastward net sediment transport, there are controversial opinions on the stability and migration rates of these sand ridges (Hoogendoorn and Dalrymple, 1986; Dalrymple and Hoogendoorn, 1997; and Ingersoll and Ryan, 1997). Geological Survey of Canada - Atlantic (GSCA) has worked jointly with Mobil and Sable Offshore Energy Project (SOEP) to understand the dynamics and stability of the shoreface-connected sand ridges as well as other types of bedforms that are superimposed on these sand ridges. From 1996 to 1998, we conducted new or repetitive multibeam surveys at South Sable, PanCanadian's Cohasset site, West Bar and along the SOEP pipeline route (e.g., Li et al., 1999). The main objective of the Creed 2000-100 cruise was to further extend and expand our multibeam coverage on Sable Island Bank, Scotian Shelf. More specifically, the objectives are (see Fig. 1):

(1) Conduct a repeat survey at the South Sable repetitive site to map the migration and morphological changes of sand ridges since 1998;
(2) Conduct a repeat survey at the Cohasset repetitive site to map the migration and morphological changes of sand ridges since 1998;
(3) Conduct a new survey at Southeast Sable (South Venture) site to understand the morphology and stability of sand ridges and detect other geohazards;
(4) Conduct a new survey at East Bar to understand the morphology and stability of sand ridges and detect other geohazards;
(5) Conduct a new survey at Southwest Sable to fill the gap between Cohasset and South Sable mosaics;
(6) Collect survey lines along SOEP gas pipelines to detect potential seabed scours along the pipelines.

Due to storms, the new survey at Southeast Sable (South Venture) was completed only 50%. Instead, surveys were conducted so that the South Sable mosaic was extended to both the east and the west. After a port call at Canso, NS, a northwesterly storm prevented us from returning to Sable Island Bank. As an alternative, a survey was conducted in eastern Chedabucto Bay for understanding the glacial and sea level history in this area. The details of the track lines of the areas surveyed on Creed 2000-100 cruise are shown in Fig. 2. These areas are Cohasset repetitive (Fig. 2a), South Sable repetitive and extension (Fig. 2b), South Venture (Fig. 2c), gas pipeline

Fig. 1 Location map showing the survey areas and track lines for Creed 2000-100 cruise. The details of track lines of each survey areas are shown in Fig. 2.

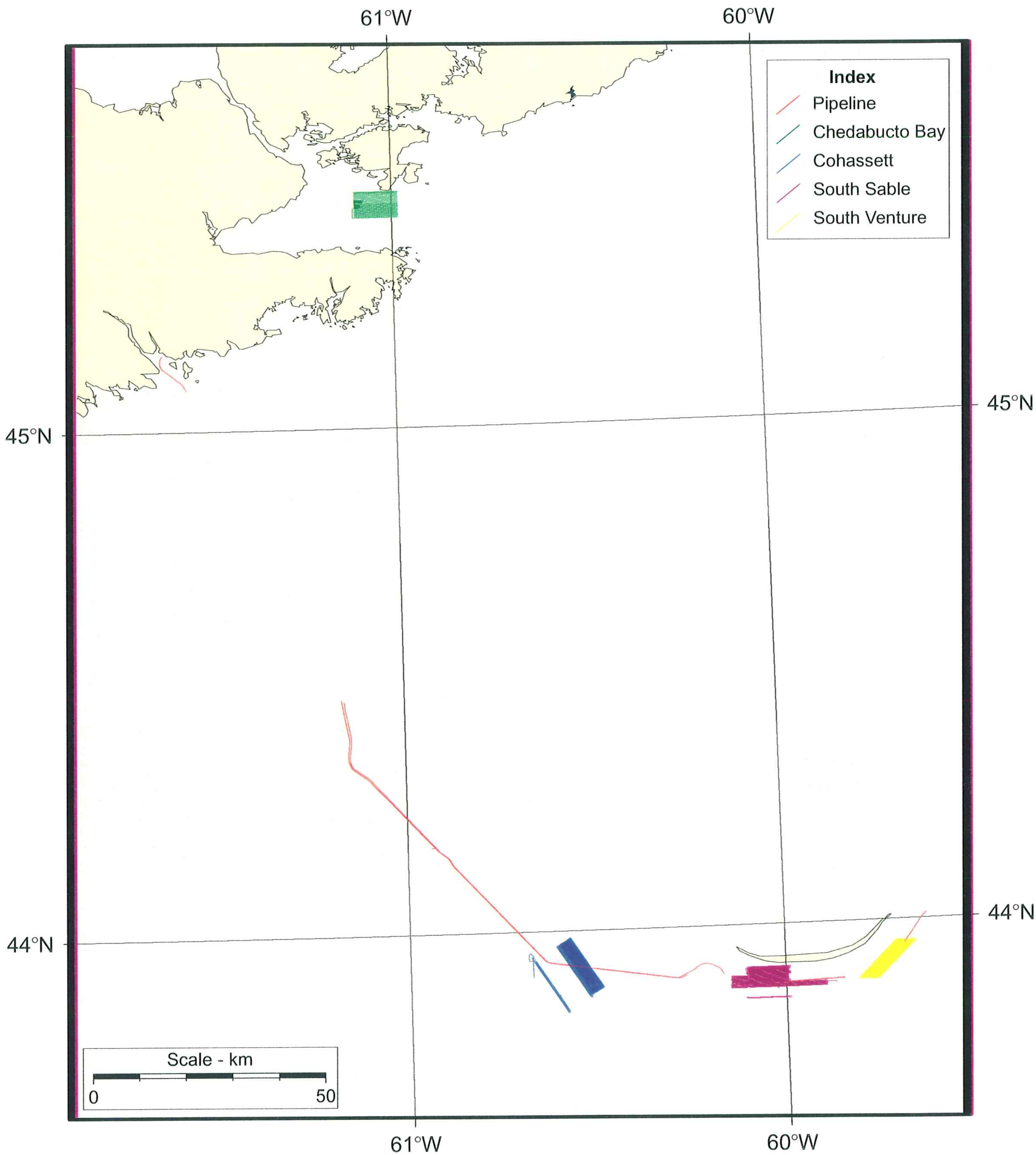

61°W
60°W
Index
Pipeline
Chedabucto Bay
Cohassett
South Sable
South Venture
45°N
44°N
Scale - km
0
50

Fig. 1

Fig. 2 Track lines of the areas surveyed on Creed 2000-100 cruise: (a) Cohasset repetitive, (b) South Sable repetitive and extension, (c) South Venture, (d) gas pipelines and (e) eastern Chedabucto Bay. P1, P2, P4, P5, and P6 in (d) respectively represent surveyed pipelines 1, 2, 4, 5, and 6.

Cohassett

Creed2000-100 Survey Tracklines

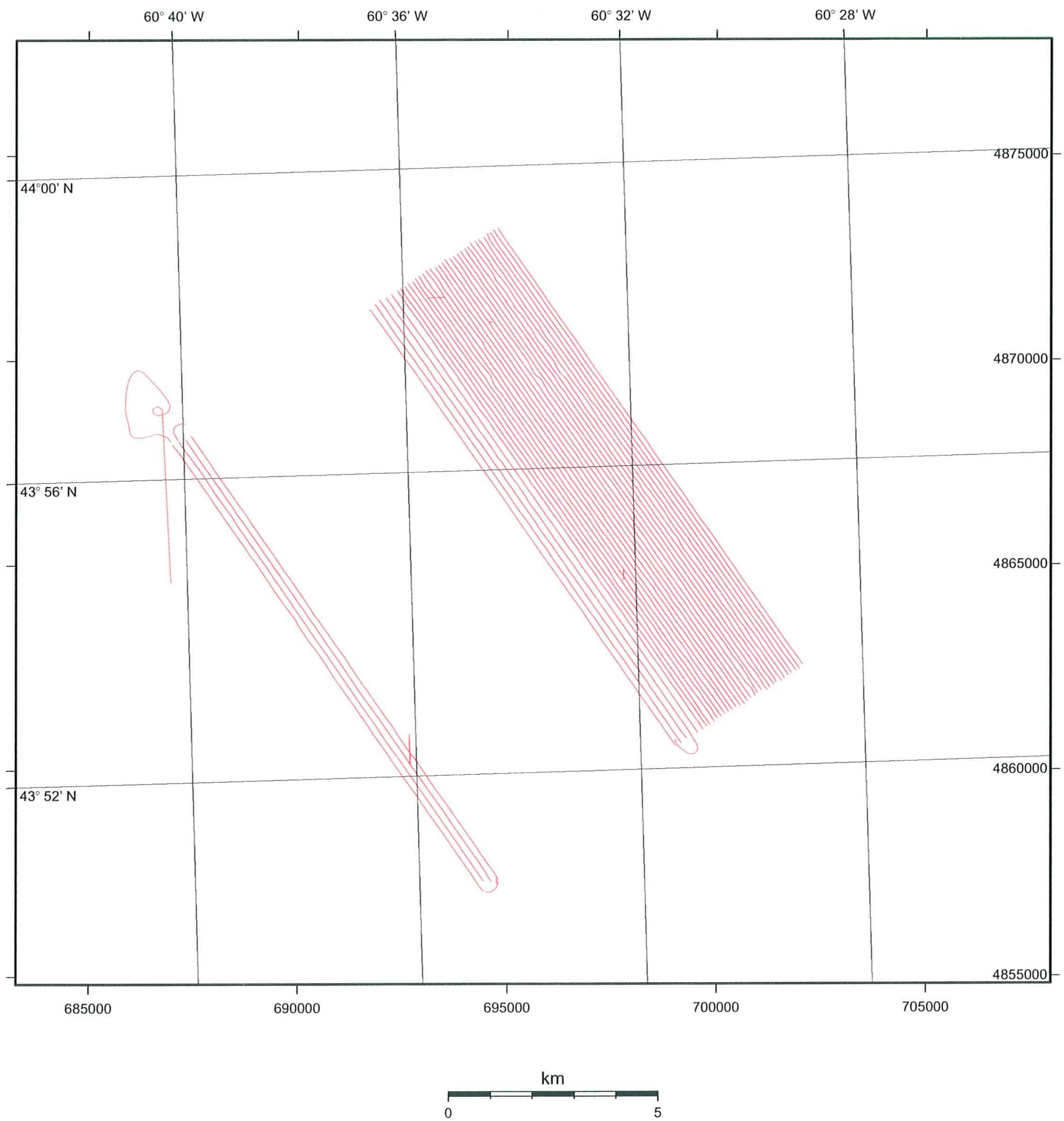


Fig. 2a

South Sable

Creed2000-100 Survey Tracklines

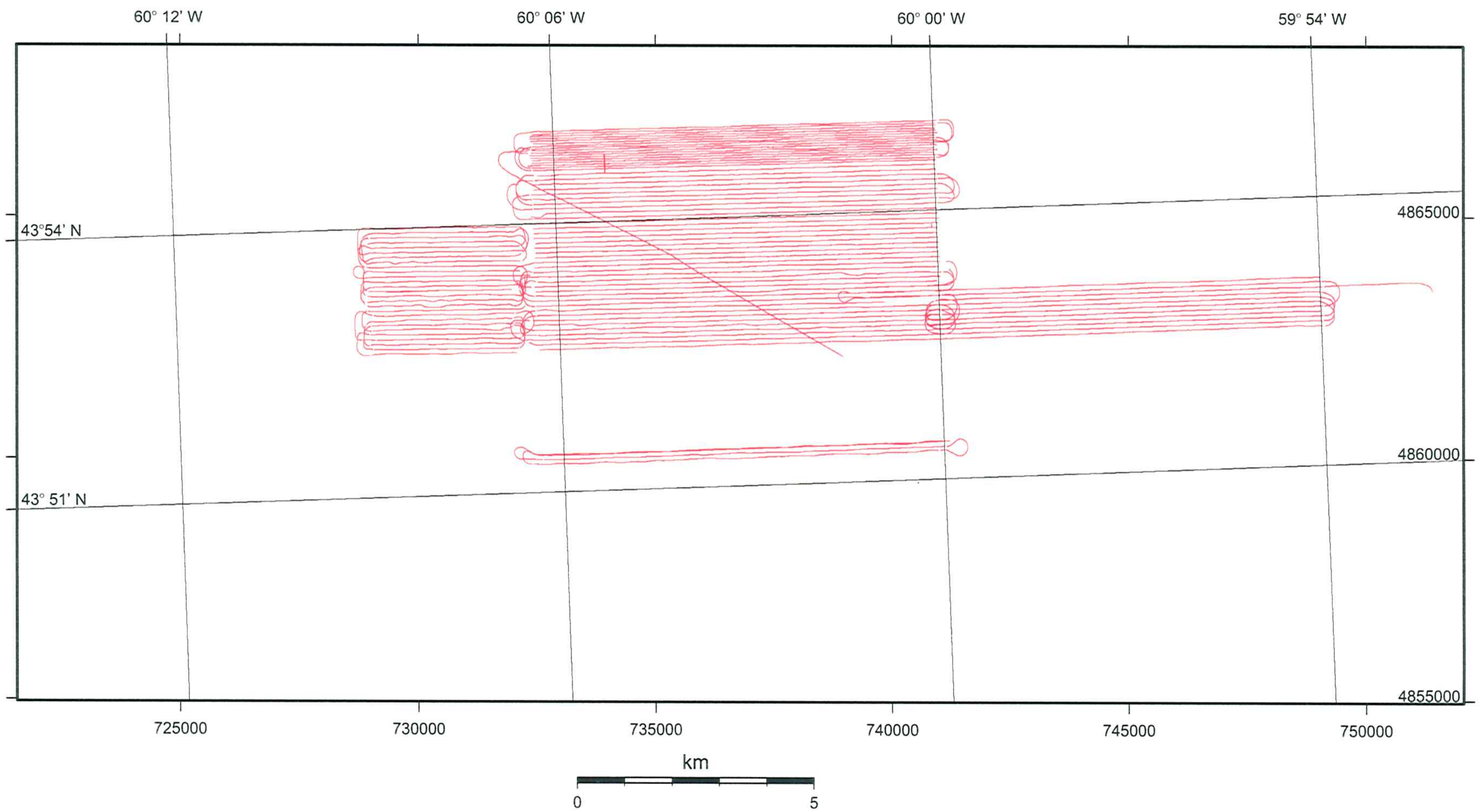
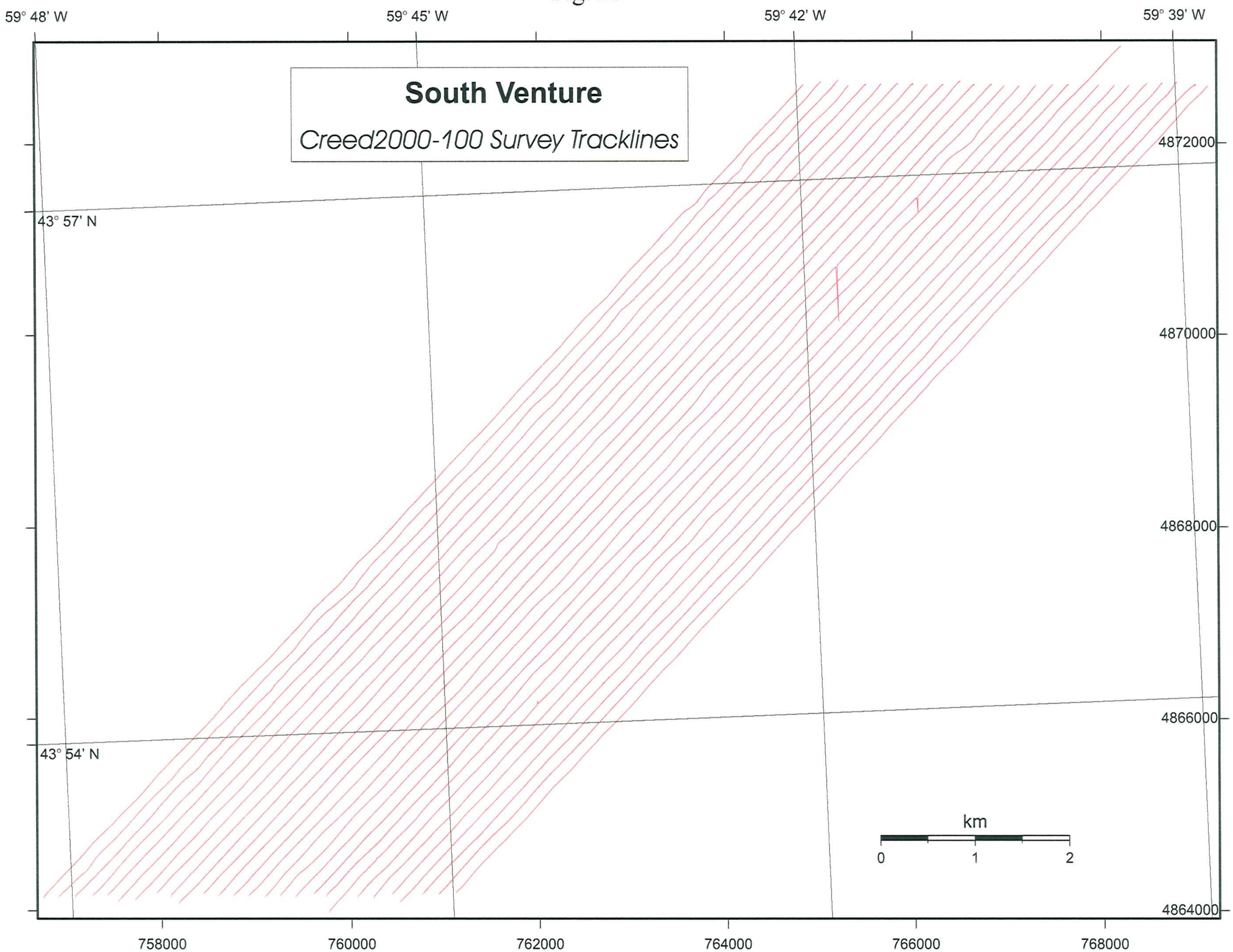


Fig. 2b

Fig. 2c


South Venture
Creed2000-100 Survey Tracklines
59° 48' W
59° 45' W
59° 42' W
59° 39' W
43° 57' N
43° 54' N
4872000
4870000
4868000
4866000
4864000
758000
760000
762000
764000
766000
768000
km
0
1
2

Pipeline Surveys 1, 2, 4, 5, & 6

Creed2000-100 Survey Tracklines

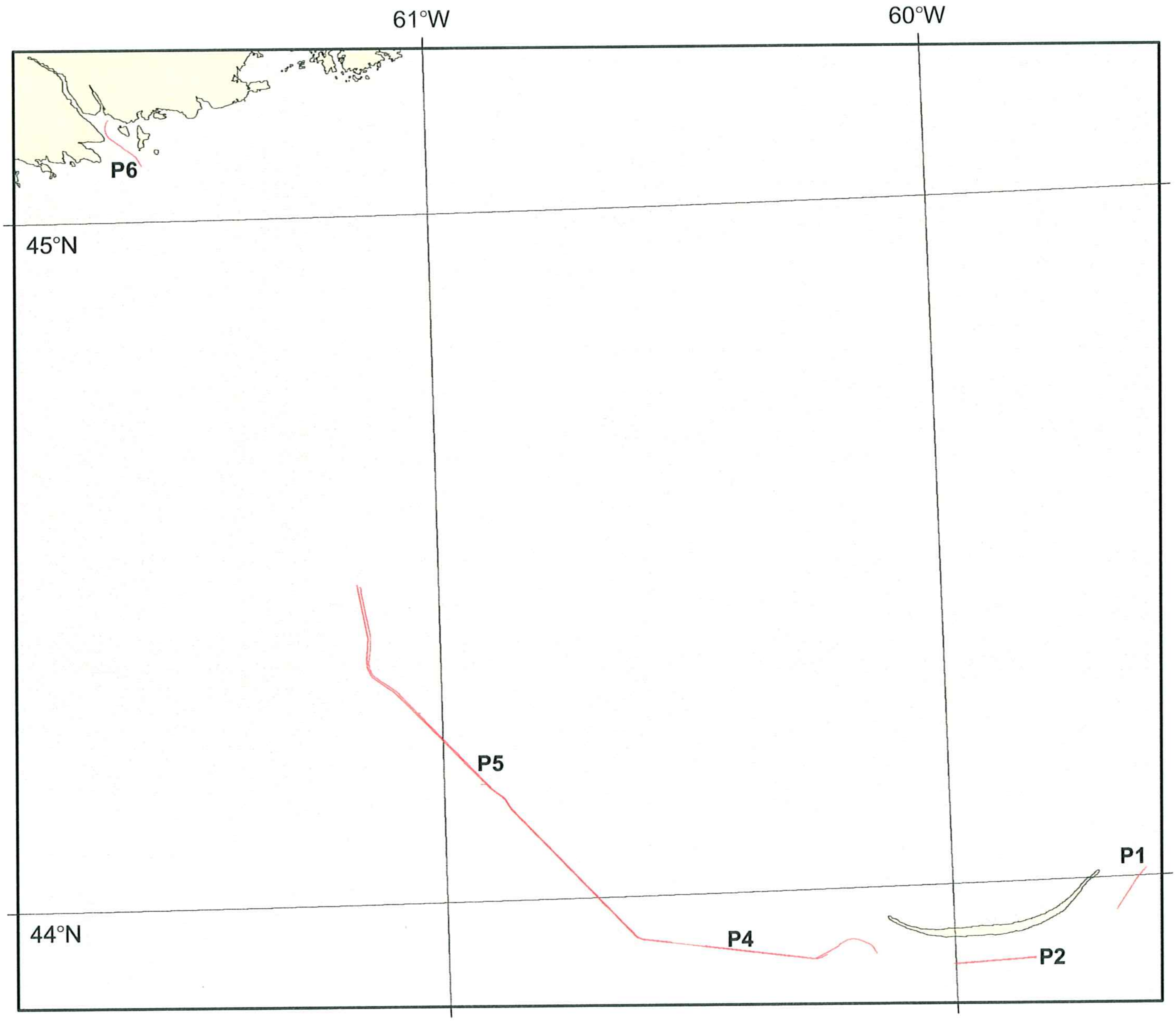


Fig. 2d

Chedabucto Bay

Creed2000-100 Survey Tracklines

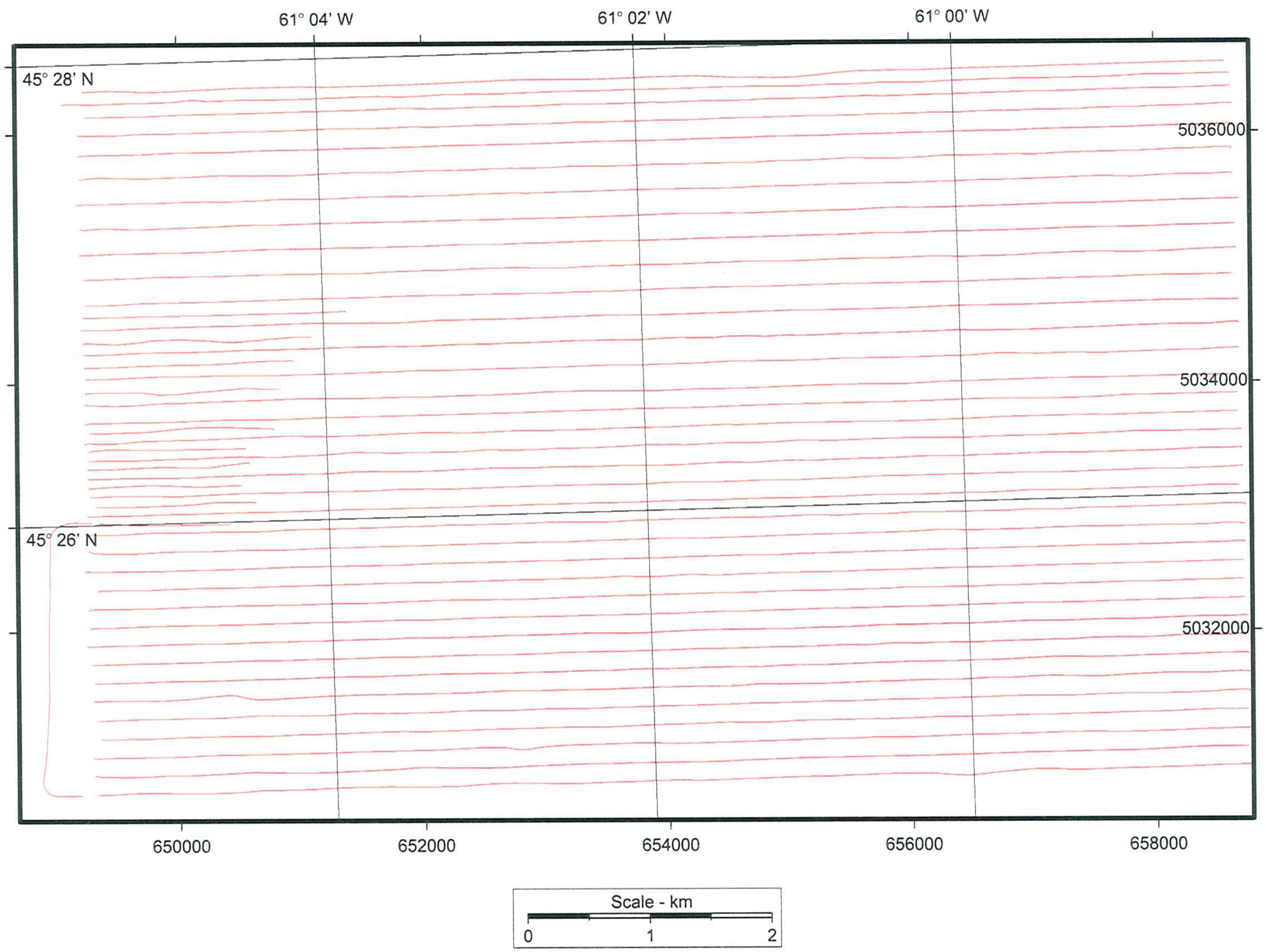


Fig. 2e

surveys (Fig. 2d), and eastern Chedabucto Bay (Fig. 2e).

CRUISE ORGANIZATION AND OPERATION PLATFORM

CCGS Creed was mobilized on 27th of May and a patch test was done in the Bedford Basin. Creed departed from BIO for Sable Island Bank around 5 pm. Because of the fuel and supply limits of Creed, the plan was to divide the cruise into three parts: each part consisting of about 2 days of surveying and 1 day for port call for refueling and supplies. Creed left BIO on the afternoon of May 27, made port calls at Country Harbor and Canso respectively on May 30 and June 2, and arrived at North Sydney for cruise switch.

To take full advantage of the ship time at survey areas, the four scientific staff were paired up and each team worked in a 6 hours on/6 hours off, 24 hour rotation when Creed was conducting surveys. Before each departure from port, the mean draft of Creed was obtained by averaging the ship's fore and aft drafts. A value of 0.57 m (the distance of the transducers above the ship's bottom) was subtracted from the mean draft and this corrected draft was entered into the Simrad system. This initial draft was reduced by 3 cm every 4 hours during survey to account for fuel and water consumption. The area to be surveyed was selected based on survey priority and weather conditions. Once the survey area was selected, the survey lines and navigation files were generated using the Geographic Information System software (GRASS). A disk with the navigation files was then inserted into the AGCNAV computer on the bridge and used for line running and starting/stopping lines in the correct order. At the start of each survey area or where water stratification was suspected, a sound velocity profile (SVP) was measured using the Moving Vessel Sound Velocity Profiler (MVSVP). This was usually done by the scientific crew with the assistance from the ship's engineer (see Appendix A of Li et al., 1999 for instructions of MVSVP operation). After the recovery of MVSVP, the profile data were downloaded into the Simrad system to be used in the multibeam data collection. The plots and data of SVPs collected in this cruise are given in Appendix 1.

When running surveys, one member of the scientific staff operated the EM1000 system from the bridge. This involved actively setting the line numbers, monitoring the data as it was being collected, and updating the logbook at fixed intervals (details described in Appendix B). The other scientific staff worked in the main-deck lab to clean and process the data using the HIPS (Hydrographic Information Processing System) software (see Appendix C of Li et al., 1999 for details of data cleaning). The two staff usually switched positions every three hours to give each other a break. If time allowed, the cleaned and tide-merged depth data were imported into the Geographic Information System software GRASS for gridding and gap filling. Colored and shaded-relief raster maps were then produced (This was done mostly by Darrel Beaver). All raw data, CHS-format HDCS data and HIPS data were backed up on Exabyte tapes and CDs. A list of CD's, tapes as well as disks archived for this cruise is given in Appendix 2. More technical information on the system power-on procedures, POS/MV instructions, Simrad instructions, lab hardware configuration as well as data backup can be found in Li et al. (1999).

TECHNICAL OPERATIONS

Vessel Description

The CSS Frederick G. Creed is a 20 meter long, 10 m wide, SWATH (Small Water Area Twin Hull) survey and sounding vessel. Creed has a gross tonnage of 150 tonnes and can accommodate 5 crew and 4 scientific staff. She is equipped with a Simrad EM1000 multibeam bathymetry system. Creed can perform surveys at speeds of 12-20 knots (19-36 km/hr), in water depths of 5-800 meters. The typical survey speed was 12 knots on this cruise.

The EM1000 System

The Simrad EM-1000 system is a 95 kHz multibeam echosounder mounted in the starboard pontoon of Creed. The system has 64 transducers which are arrayed over an arc of 150 degrees. These 64 beams produce depth sounding and echo intensity over a swath of the seabed up to 7.5 times the water depth. More details on the power-on and operation of the system can be found in Appendix D of Li et al. (1999).

Laboratory Setup

Two labs are required in typical Creed surveys: the bridge lab for Simrad system operation and data collection, and the main-deck lab for data cleaning/processing and measuring sound velocity profiles. The main components of the bridge lab included the Mermaid Sun workstation for the display and storage of bathymetry and backscatter data, the Simrad control computer for operational control of the Simrad system, the quality control/AGCNAV computer for navigation display, and the POSMV/SVP laptop computer for loading and configuring the SVP data. A Regulus navigation system with bridge lab monitor and helm display was also installed to familiarize the crew with the Regulus package. The main-deck laboratory consisted of the following key units: a CDROM burner/computer, the AGCNAV laptop computer, the Hewlett Packard workstation (DI01) for data cleaning and processing, a remote display monitor of the Regulus navigation system, the MVSVP computer and its control unit, and the MVSVP itself located on the stern deck. The labs were set up similarly to that of Creed 98-100 cruise, and described in detail in Li et al. (1999).

Navigation and Planning of Survey Lines

The Creed navigation system is comprised of two Magnavox 12 channel Differential Global Positioning Systems (DGPS). The corrected GPS signals from the Canadian Coast Guard station at Western Head, NS, are received via the MBX Beacon receiver located on the ship's bridge. This information is passed to the POSMV system which uses a gyro accelerometer package to provide sub-meter accuracy real-time positions to the SIMRAD sounders. The navigation data is also distributed to the PC based navigation display system.

Survey lines are generated using the Survey Builder in the GRASS software package AGCMENU prior to starting to survey in each area. The spacing between survey lines is generally four or five times water depth. The operator displays a geo-referenced raster image of the local Hydrographic chart, and interactively builds the proposed survey on the display. In the case of the Cohasset and South Sable repetitive surveys, the planned tracks were designed to overly the 1998 tracks as closely as possible to take advantage of near-nadir beam accuracies for future comparisons. These were then converted to survey files and AGCNAV navigation files. The navigation files are then run on the AGCNAV navigation computer. This provides the bridge officer with a real-time display of the ship relative to the current survey line.

Data Logging, Cleaning and Management

The Simrad EM1000 system is controlled by a series of PC computers running a real-time operating system. As the data are acquired, the corrections for the sound velocity are applied to the data. The data is stored on the Mermaid SUN workstation. The SIMRAD "packets" are acquired by the SUN via the Creed's Ethernet. The "packets" are assembled into a single Simrad raw data file for each survey line (.all files). Each of these files is comprised of the SIMRAD depth datagrams, backscatter datagrams, ships position, roll, heave, pitch, and a series of quality factor data.

The EM1000 raw data (bathymetry and navigation data) were transferred to the HP workstation DI01 in the main-deck lab via the ship's Ethernet link. After logging in on DI01, the Hydrographic Information Processing System software package (HIPS, Universal Systems Ltd., 1995) was started and used to convert the raw Simrad data to HDCS format. The HDCS data files were then opened, and the navigation data and the observed depth data were cleaned separately. The cleaned data were then merged with the tide data (see predicted tides in Appendix 3). The conversion of raw Simrad data to HDCS format, navigation data correction and depth data cleaning have been described in detail by Li et al. (1999). Finally, the processed HDCS data were imported into the GRASS software package AGCMENU which was used to grid and gap-fill the data. Color-classified maps, shaded-relief maps and the combined color-relief maps were generated as the end products. All raw data, HDCS data, and GRASS data were backed up on Exabyte tapes and CDs.

CRUISE ITINERARY

All time is in UTC (coordinated universal time) which is Atlantic Daylight Saving time + 3 hours.

Day 148, May 27, Saturday

Mobilization and patch test in Bedford Basin. Left BIO for Sable Island Bank at 22:15.

Day 149, May 28, Sunday

Creed arrived northwest of Northern Spur around 8:00. SVP 148.003 (see data and figure in Appendix 1) was collected before surveying pipeline 5. We started surveying pipeline 5 (southeastward) at 8:20 and completed pipeline 5 at 11:37. The survey line numbers for pipeline 5 SE were from 100 to 127.

We started surveying pipeline 4 (eastward) at 12:19. We were asked to steer around the Thebaud platform to comply with the 2 mile safety zone. Pipeline 4 E was completed at 13:37. The survey line numbers for pipeline 4 E were 200 and 201.

SVP 149.006 was collected in 30 m depth at 14:16 before starting the repetitive survey at South Sable. South Sable repetitive survey was started at 14:27. At midnight, lines 300 to 331 were completed.

Day 150, May 29, Monday

We continued the repetitive survey at South Sable. At 6:55 (survey line 355), the line spacing was changed from 100 m to 50 m due to concerns of lines overlapping. South Sable repetitive survey was completed at 15:00. The line numbers completed on Day 150 for South Sable repetitive survey are from 332 to377.

Creed then steamed to the south to do 3 lines in the deeper water of the South Sable repetitive survey area. SVP 150.003 was obtained at 15:44 and the line spacing was increased to 100 m again. The South Sable deep water survey lines were completed at 17:27. These are lines 400 to 406.

Creed then sailed back to South Sable repetitive area to survey pipeline 2. Two lines were surveyed: pipeline 2 eastward, line 408 at 17:38 and pipeline 2 westward, line 410 at 18:17.

Due to rough conditions at Cohasset caused by a northeaster storm, a decision was made to do surveys in the sheltered areas: east and west extensions from the South Sable repetitive site. South Sable Extension West survey was started at 19:11 and completed at midnight (23:56). The survey line numbers for South Sable West were from 500 to 536.

Day 151, May 30, Tuesday

The sea conditions at Cohasset did not improve and thus we continued surveying at South Sable area. South Sable East extension was started at 00:34. A sound velocity profile SVP151.002 was obtained at 03:37. South Sable Extension East survey was completed at 05:45 and the survey lines were from 600 to 615.

Creed was running low on fuel and we decided to go to Country Harbour for refueling and survey the pipeline route on our way to the harbour. The pipeline 4 westward survey was started at 06:48 and completed at 07:51. The survey line numbers for pipeline 4 westward were 700-703. As Creed approach pipeline 5 northwest section, SVP 151.003 was collected. We began surveying pipeline 5 northwest at 08:00 and finished the survey at 11:42. The survey line numbers for pipeline 5 northwest were from 704 to 711. As we entered Country Harbour, Pipeline 6 northwest inside of the Harbour was surveyed from 15:03 to 15:33. The survey line number was 750.

Creed docked at Country Harbour at16:30. Refueling and maintenance were conducted. Peter and Darrell assisted Brooke Ocean to test their free-fall Cone Penetrometer in the Harbour from 18:30 to 21:00. Creed left Country Harbour for Sable at 21:40.

Day 152, May 31, Wednesday

Creed arrived at the Cohasset site at 07:00. SVP 152.002 was obtained and Cohasset deep-water lines were surveyed from 07:23 to 10:00. The line numbers were 800 to 807 with 150 m spacings.

Cohasset repetitive survey was started at 10:17. Line spacing was reduced from 150 m to 100 m for survey line 817 at 14:33. Cohasset repetitive survey continued over night.

Day 153, June 1, Thursday

Cohasset repetitive survey was finished at about 07:54. The survey lines for this survey area were from 808 to 844.

Creed then steamed to the South Venture area. A velocity profile SVP 153.002 was collected. The South Venture survey started at 10:58 with 120 m line spacing. A second velocity profile, SVP 153.006 was obtained at 20:26 and the South Venture survey continued over night.

Day 154, June 2, Friday

The survey at South Venture continued and was completed at 03:40. The collected survey lines for South Venture survey were from 900 to 926.

Pipeline 1 (northeastward), that connects Venture and South Venture was surveyed from 03:49 to 04:13 (Line number 950). It was time again for Creed to make a port call. Because the dock at Country Harbour (now is owned by a private company) was occupied, the captain decided to use Canso for refueling and supplies. Creed broke off surveys on Sable at 04:13 and arrived at Canso at around 13:30.

By late afternoon, refueling and supplies were done. However, a storm was forecast for Sable Island Bank and it would be too rough to conduct surveys. A decision was made that we would do a survey in the eastern Chedabucto Bay to help understanding the glacial and sea level history in this area. Creed left Canso at about 22:00 and arrived at eastern Chedabucto Bay at about 23:00. SVP 154.001 was collected at 23:00 and surveying began at 23:15. The line spacing was set at 100 m.

Day 155, June 3, Saturday

Eastern Chedabucto Bay survey continued over night. Due to significant depth variation, the spacing of survey lines was adjusted several times and they ranged from 100 m to 200 m. The originally planned survey lines from 1000 to1035 were completed at 16:06. Some gaps were found in the data and intermediate patch lines were run. These lines were from 1051 to1060 with 100 m spacings. Creed broke off the survey at 19:00 pm and sailed for North Sydney. Creed arrived at North Sydney around midnight and the scientific staff returned to BIO the next day using a rental car.

In summary, we surveyed 5 areas (including pipelines) in Creed 2000-100 cruise. These areas are Cohasset repetitive, South Sable repetitive and extensions, South Venture, gas pipeline surveys and eastern Chedabucto Bay. A total of 252 survey lines were run and 10 sound velocity profiles were measured. Table 1 is a list of the dates, the survey areas, and their survey line numbers.

PRELIMINARY RESULTS

Shaded relief images and color-coded shaded relief images were used in this section to derive general information of depth range, morphology, bedform pattern and other geological features. The GRASS Query and ChickenTrack functions were used on gridded .ave or .fill files to obtain data on bedform height, wavelength and profile geometry. The preliminary results for each survey area are described below.

The Cohasset Area

The Cohasset repetitive area that was surveyed in 1998 (Area 5 in Fig. 1 of Li et al., 1999) was re-surveyed in this cruise. In addition, 4 survey lines were also collected in a deeper water area to the southwest of the Cohasset repetitive area (Fig. 2a). The colored bathymetry and shaded relief images of the new surveys in the Cohasset area are shown in Fig. 3.

The bathymetry and bedforms of the Cohasset repetitive survey area have been described in detail in Li et al. (1999) and are not repeated here. Qualitative comparisons of bedform patterns between this survey (Fig. 3) and surveys of 1996-98 as compiled in Li et al. (1999, Fig. 7) suggest that sand waves and sand ridges of various scales are stable. Advanced analyses have not been performed to quantify the migration of these large-scale features.

South Sable Repetitive and Extension

The South Sable area includes the South Sable repetitive survey, the west and east extension surveys and four survey lines in deeper water to the south of the South Sable repetitive survey area (Fig. 2b). The colored bathymetry and shaded relief images of the new surveys in the Cohasset area are shown in Fig. 4.

Table 1 A list of the dates, the survey areas and survey line numbers

Date Day of year	Calender	Survey Area	Survey Line Number
149	May 28	pipeline 5 SE	100 - 127; 28 survey lines
149	May 28	pipeline 4 E	200, 201; 2 survey lines
149 - 150	May 28 - May 29	South Sable repetitive	300 - 377; 52 survey lines
150	May 29	South Sable deep lines	400 - 406; 4 survey lines
150	May 29	Pipeline 2	408, 410; 2 survey lines
150	May 29	South Sable west	500 - 536; 28 survey lines
151	May 30	South Sable east	600 - 615; 11 survey lines
151	May 30	Pipeline 4 W	700 - 703; 4 survey lines
151	May 30	Pipeline 5 NW	704 - 711; 8 survey lines
151	May 30	Pipeline 6 NW	750
152	May 31	Cohasset deep lines	800 - 807; 4 survey lines
152	May 31	Cohasset repetitive	808 - 844; 34 survey lines
153 - 154	June 1- June 2	South Venture	900 - 926; 27 survey lines
154	June 2	Pipeline 1 NE	950
155	June 3	Eastern Chedabucto Bay	1000 - 1035; 1051 - 1060 46 survey lines

Fig. 3 Images of (a) the colored bathymetry and (b) shaded relief of the Cohasset area.

Cohassett

Creed2000-100 Multibeam Bathymetry

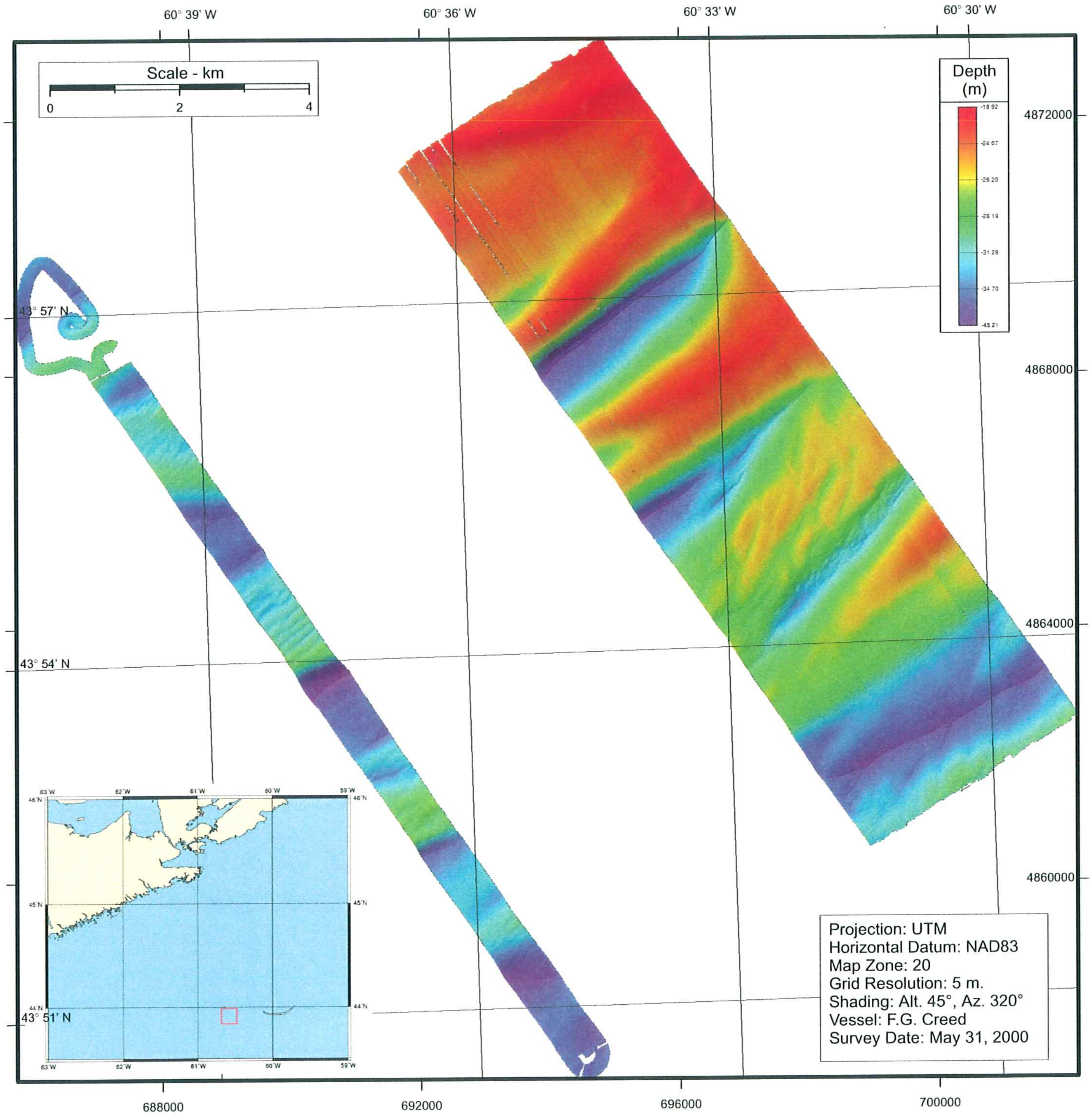


Fig. 3a

TEK Map Consulting

Cohassett

Creed2000-100 Multibeam Bathymetry

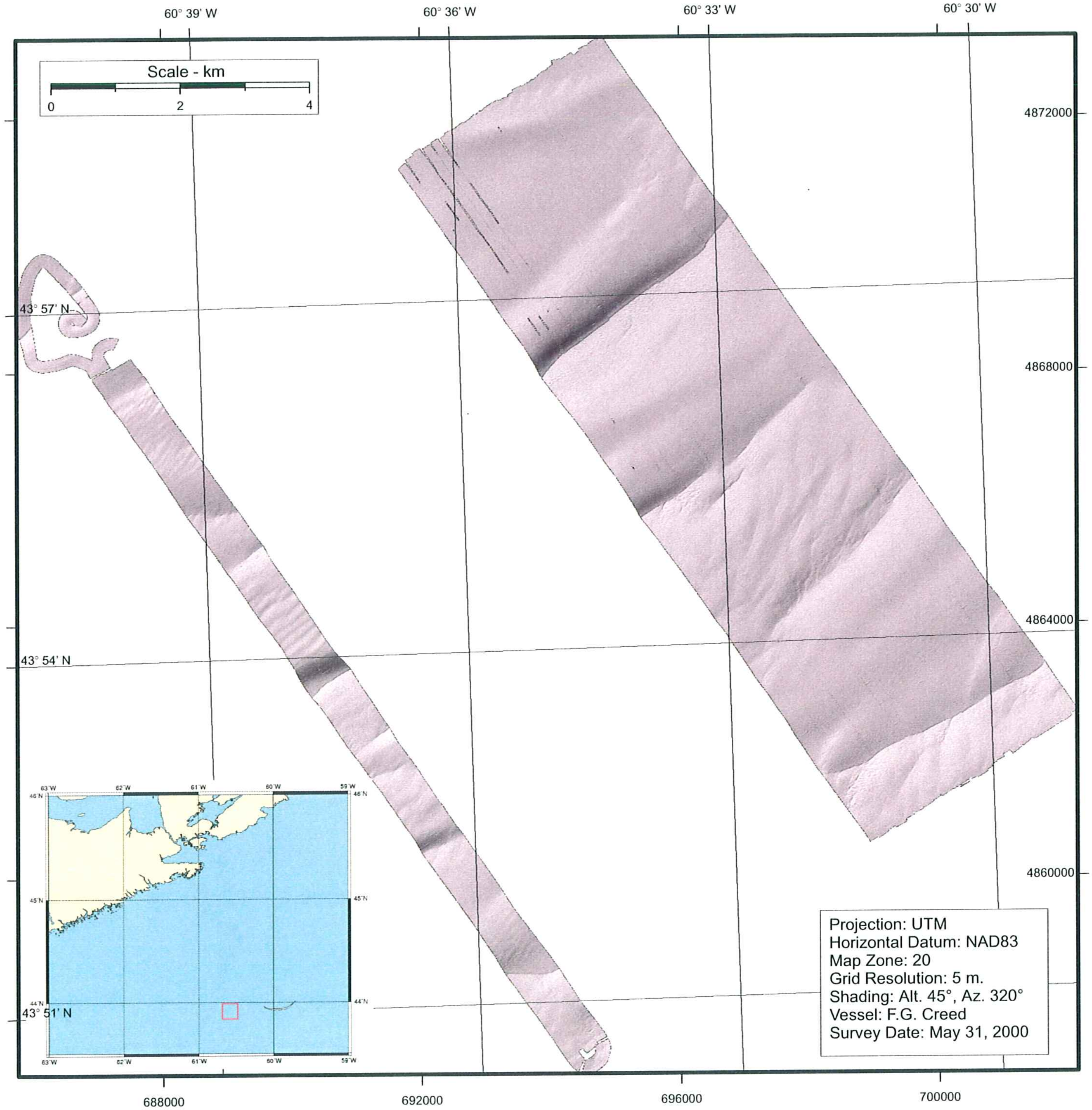
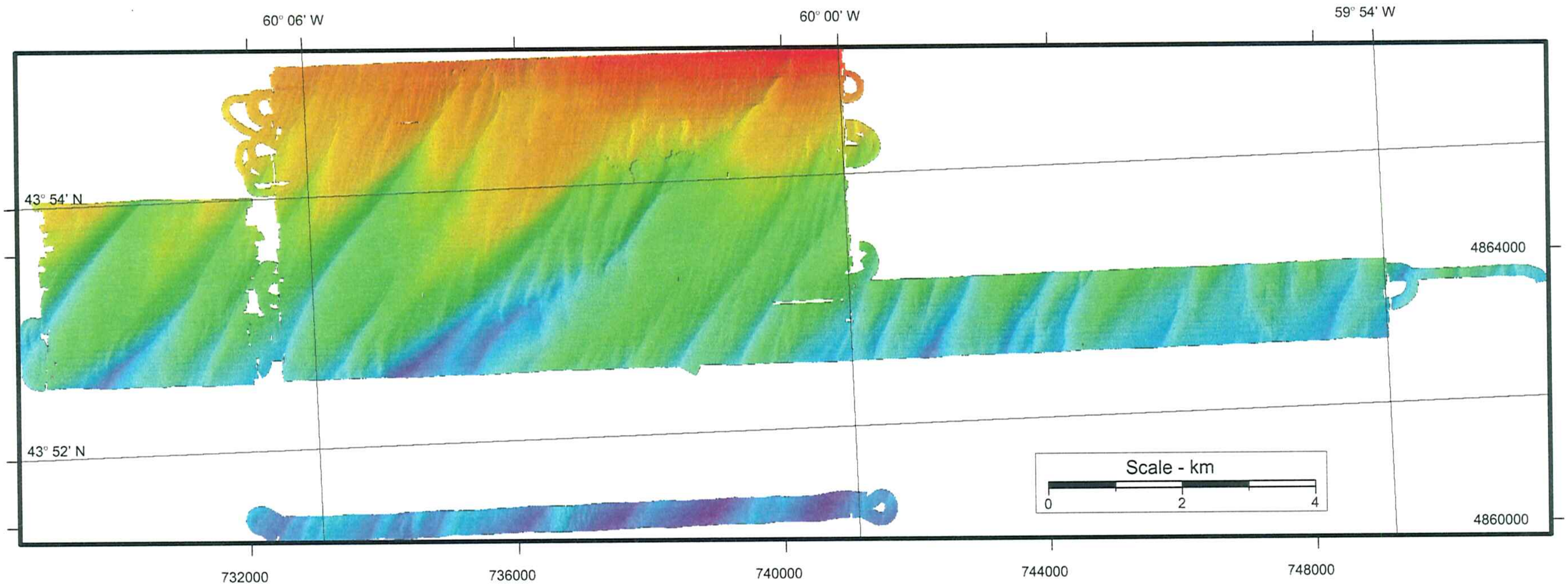


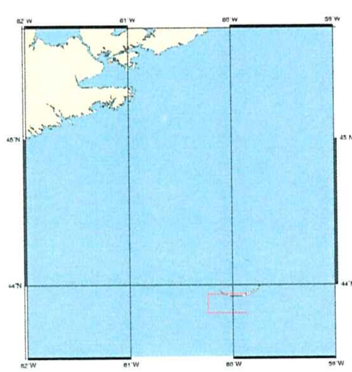
Fig. 3b

Fig. 4 Images of (a) the colored bathymetry and (b) the shaded relief of the South Sable area.

South Sable

Creed2000-100 Multibeam Bathymetry





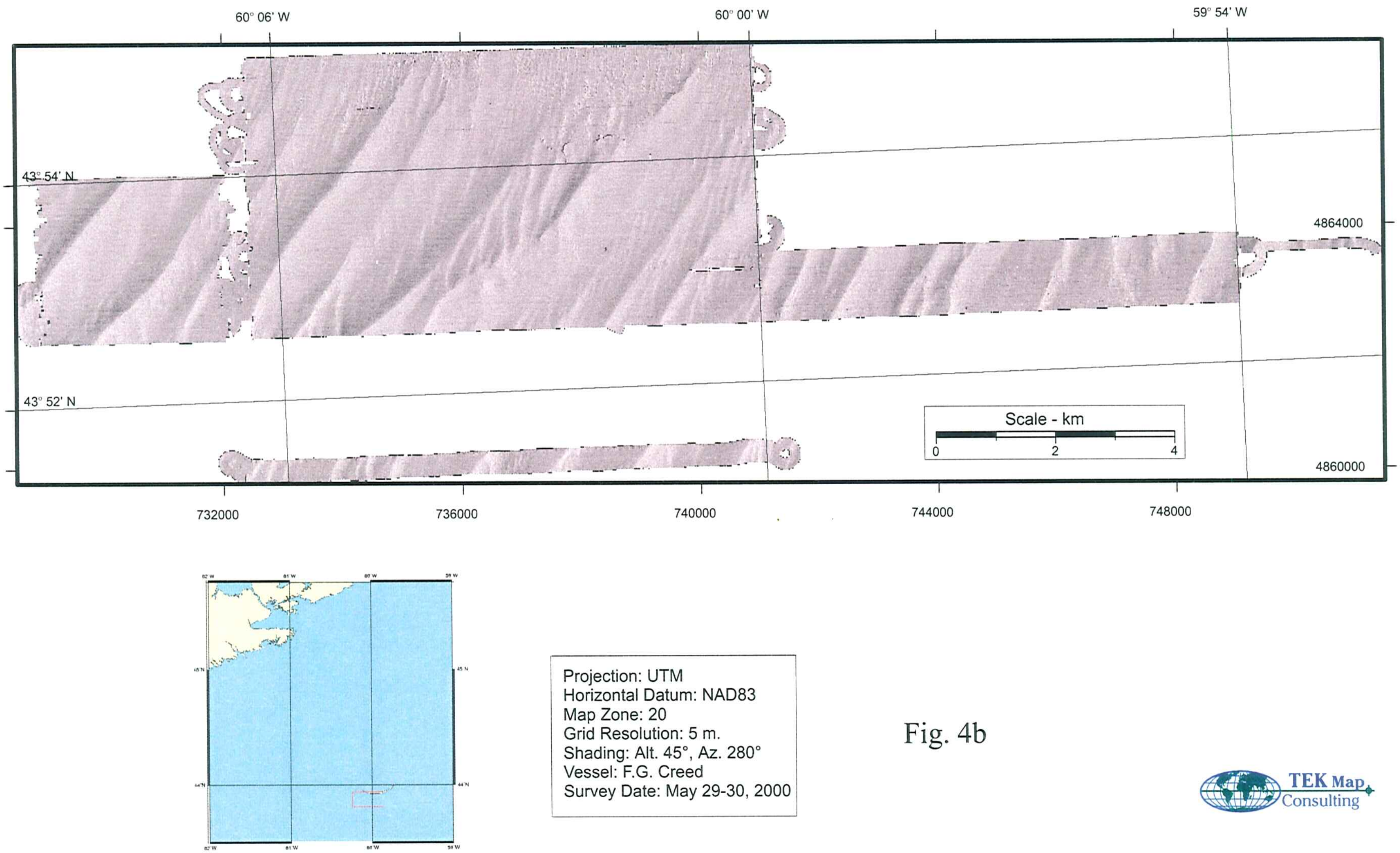
Projection: UTM
Horizontal Datum: NAD83
Map Zone: 20
Grid Resolution: 5 m.
Shading: Alt. 45°, Az. 280°
Vessel: F.G. Creed
Survey Date: May 29-30, 2000

Fig. 4a

TEK Map Consulting

South Sable

Creed2000-100 Multibeam Bathymetry



Projection: UTM
Horizontal Datum: NAD83
Map Zone: 20
Grid Resolution: 5 m.
Shading: Alt. 45°, Az. 280°
Vessel: F.G. Creed
Survey Date: May 29-30, 2000

Fig. 4b

TEK Map Consulting

The bathymetry and bedforms of the South Sable repetitive area and its west extension have been described in Li et al. (1999) and are not repeated here. Comparisons of bedform patterns between this survey (Fig. 4) and surveys of 1996-98 (Fig. 6 in Li et al., 1999) again suggest that sand waves and sand ridges seem to be stable. The water depth in the east extension area ranges from 25 m to 40 m. There are 8 NE-SW trending sand ridges. The wavelengths of these sand ridges range from 450 m to 1.5 km with an average of 760 m. The heights of these ridges range from 2 m to 5 m and the average height is 3.6 m. The profiles of these ridges are asymmetrical: the steep sides are facing the east on the western part but facing west on the eastern part of the survey area. The depth in the deep water survey ranges from 30 to 40 m. The morphology generally shows the extension of the sand ridges from the shallow-water nearshore area. There are seven NE-SW trending sand ridges and their average wavelength is 1.3 km.

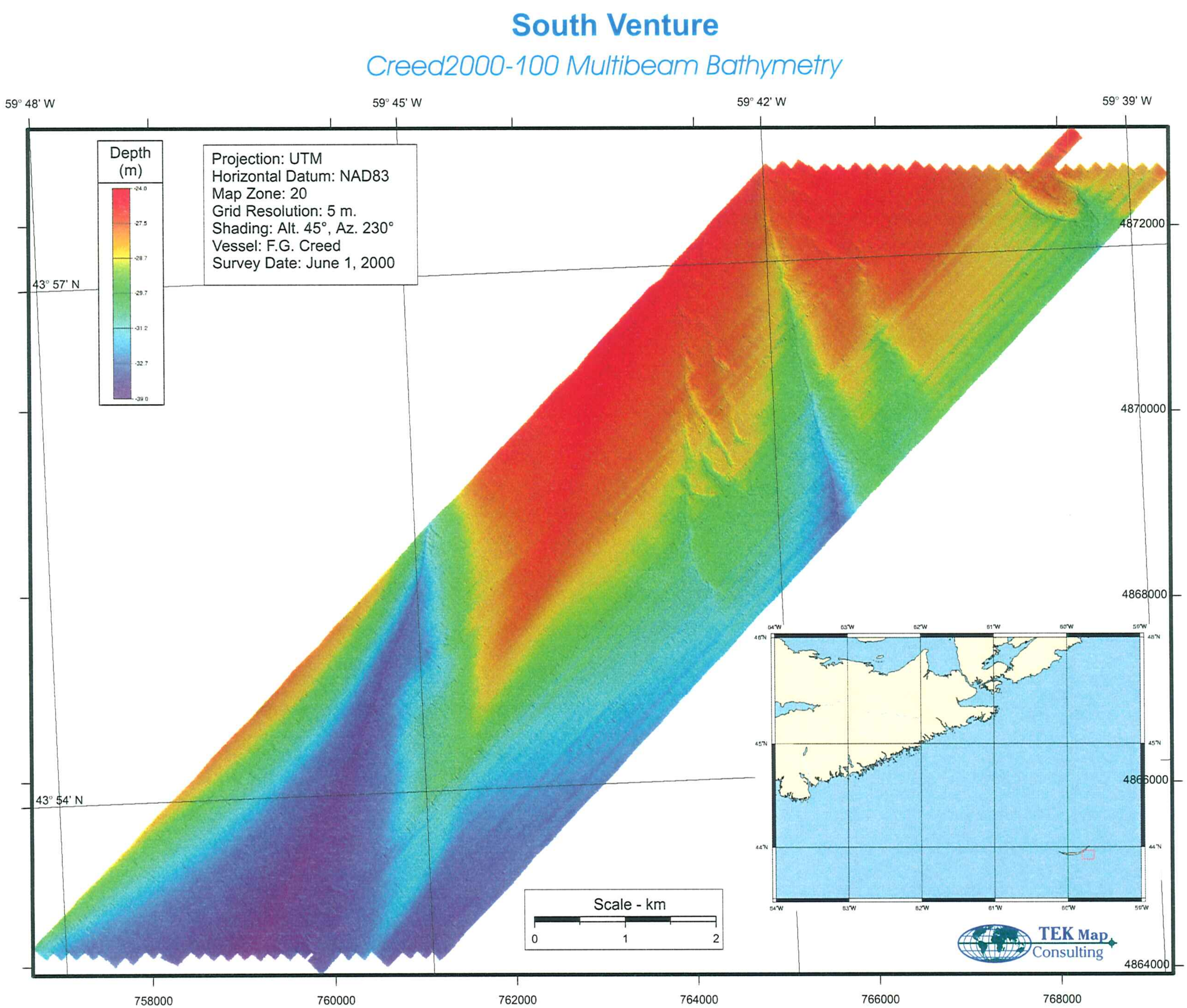
South Venture

A new survey at South Venture (Fig. 1 and Fig. 2c) was conducted on this cruise in order to expand our coverage of sand ridges to the southeast of Sable Island. Fig. 5 shows (a) the colored bathymetry and (b) the shaded relief of the South Venture newly collected from this cruise. Due to weather conditions, only 50% of the planned survey lines were completed at South Venture. Nevertheless the results in Fig. 5 show that the shallowest water of about 25 m occurs in the northeast corner and the water depth increases to about 40 m to the southwest. Three sand ridges dominate the South Venture area: their wave lengths are 1.5 km and 2.9 km respectively. The height of the large ridges is about 7 m and that of the smaller ridges is around 3-4 m. The profiles of the ridges are nearly symmetrical. The smaller bedforms superimposed on top of the ridges, however, are asymmetrical to the east on the western flank of the ridges and generally to the west on the eastern flanks. The sand ridge troughs are oriented roughly north-south to the southeast of Sable Island and the orientation rotates to northeast-southwest trending to the south of the Island. Except for the occurrence of possible sand ribbons in the northeast corner and the central part of the image, and faint lineations (possibly megaripples) in the troughs, the seabed at South Venture area is generally featureless (Fig. 5).

Surveys of SOEI Pipelines

The Sable Offshore Energy Inc. gas pipeline was mostly buried on the shallow Sable Island Bank. However it was simply lain on the seabed surface in the deeper water of Emerald Basin. It is suspected that energetic sediment transport on Sable Island Bank during winter storms may cause scours and exposure around the pipeline. By consulting with SOEI, surveys along sections of the SOEI pipelines were planned in this cruise. These include Pipeline 1 at South Venture, Pipeline 2 to the south of Sable Island, Pipeline 4 between Thebaud and Cohasset, Pipeline 5 on Northern Spur, and Pipeline 6 at the land fall inside Country Harbor (Fig. 2d). The colored bathymetry images of the surveyed pipelines are shown in Fig. 6. These images delineate that the pipeline route crosses sand ridges and other interesting bedforms and geological features, but they failed to detect the pipeline and/or occurrence of scours around the pipeline.

Fig. 5 Images of (a) the colored bathymetry and (b) the shaded relief of the South Venture area.



South Venture
Creed2000-100 Multibeam Bathymetry
59° 48' W
59° 45' W
59° 42' W
59° 39' W
43° 57' N
43° 54' N
Depth (m)
-24.0
-27.5
-28.7
-29.7
-31.2
-32.7
-39.0
Projection: UTM
Horizontal Datum: NAD83
Map Zone: 20
Grid Resolution: 5 m.
Shading: Alt. 45°, Az. 230°
Vessel: F.G. Creed
Survey Date: June 1, 2000
4872000
4870000
4868000
4866000
4864000
758000
760000
762000
764000
766000
768000
Scale - km
0
1
2
TEK Map Consulting

Fig. 5a

South Venture

Creed2000-100 Multibeam Bathymetry

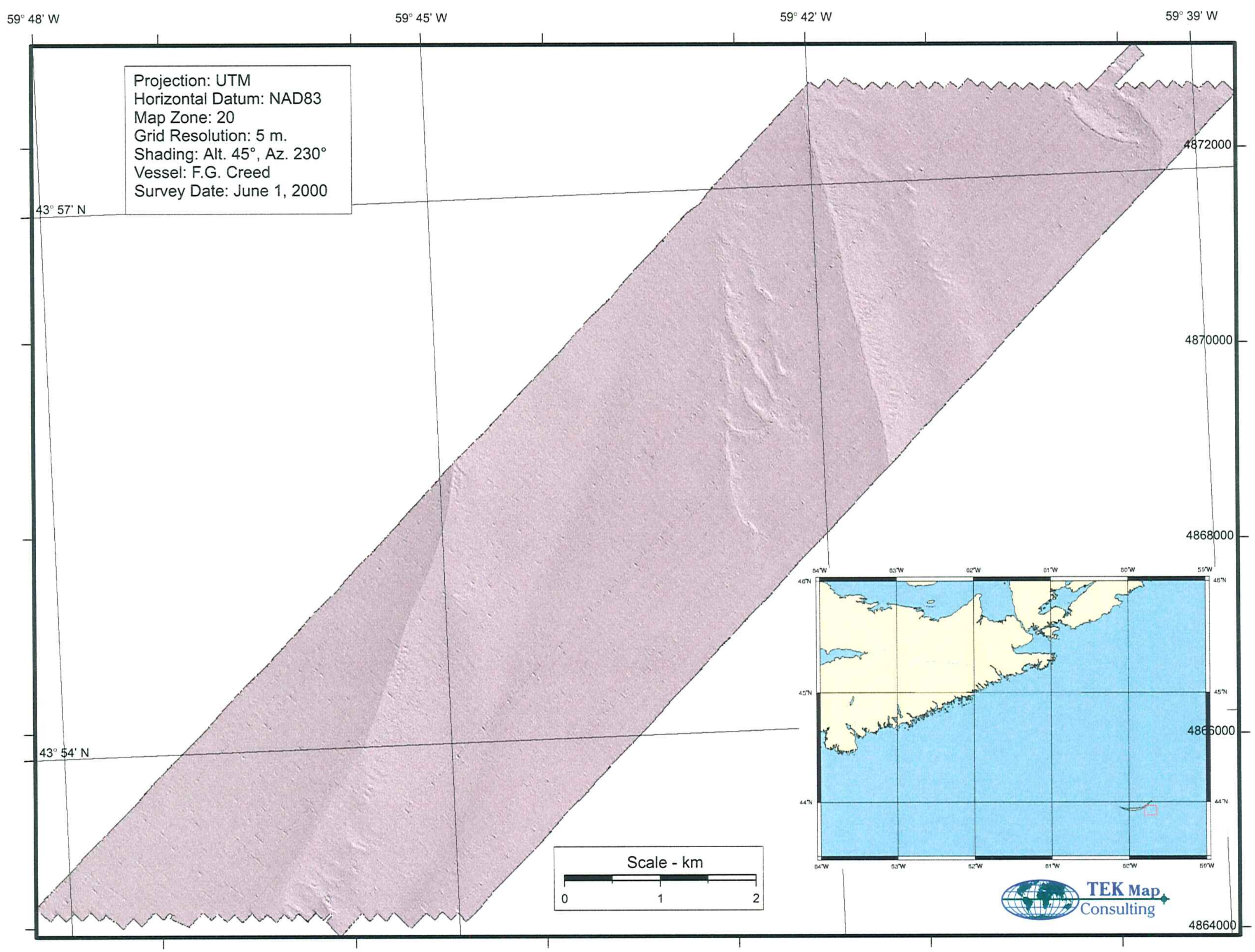
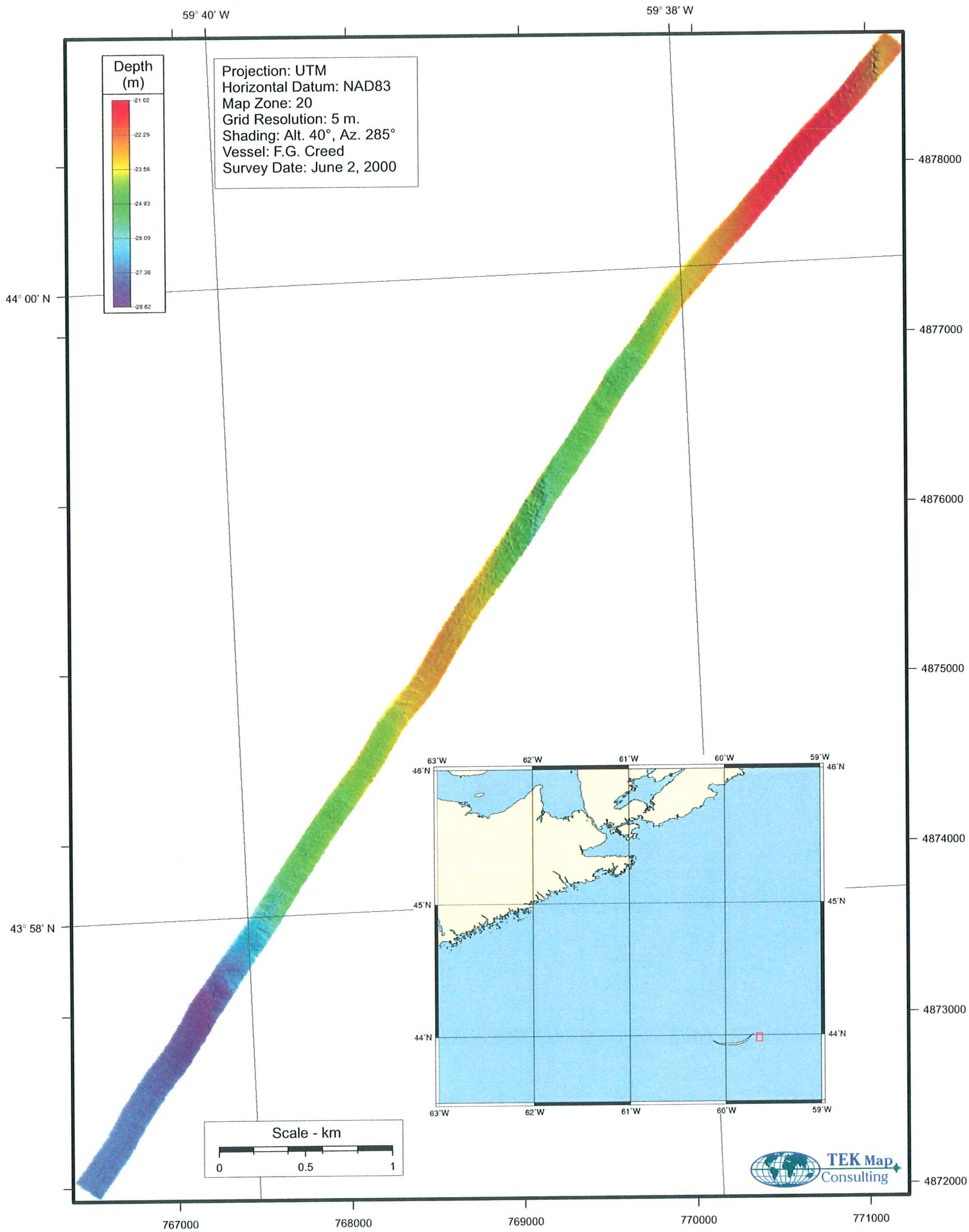


Fig. 5b

Fig. 6 Images of the colored bathymetry of the surveyed pipelines.

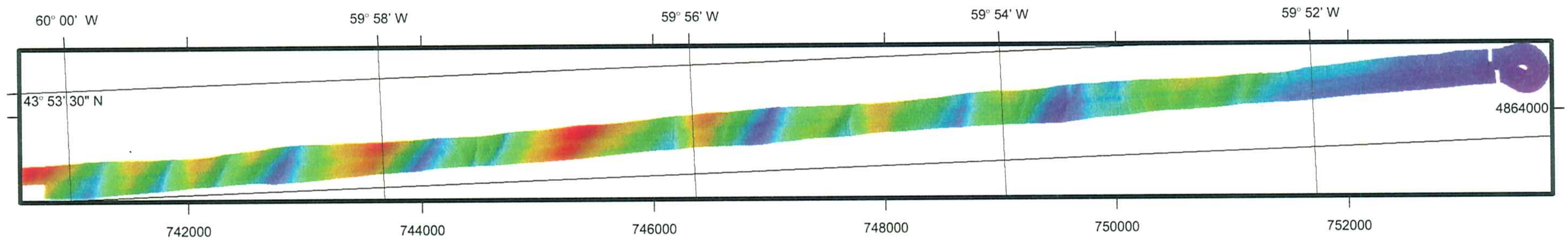
Pipeline - 1

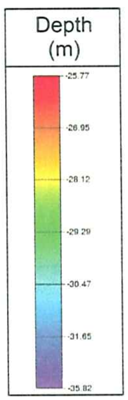
Creed2000-100 Multibeam Bathymetry



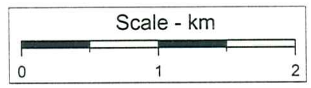
Pipeline - 2

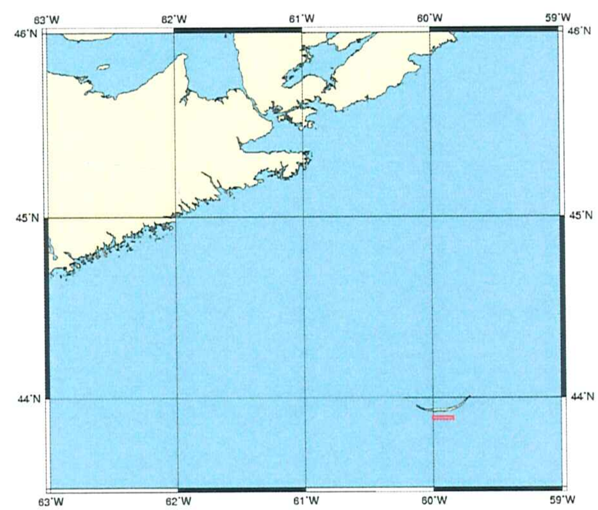
Creed2000-100 Multibeam Bathymetry





Projection: UTM
Horizontal Datum: NAD83
Map Zone: 20
Grid Resolution: 5 m.
Shading: Alt. 40°, Az. 315°
Vessel: F.G. Creed
Survey Date: June 2, 2000

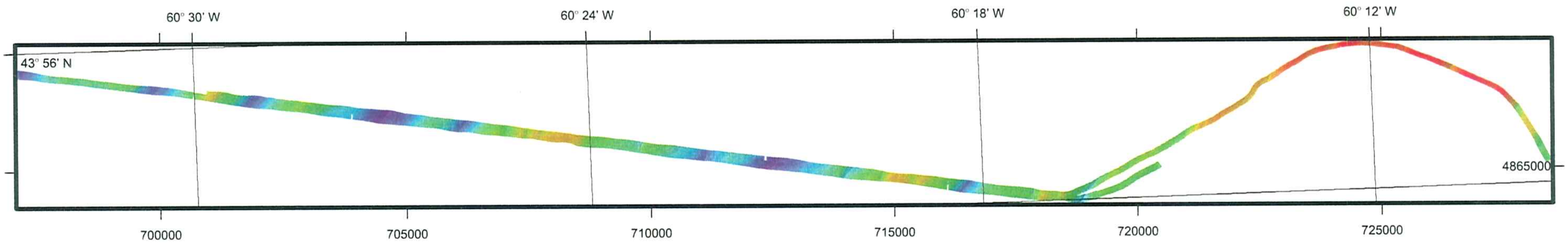


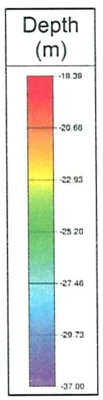


TEK Map Consulting

Pipeline - 4

Creed2000-100 Multibeam Bathymetry

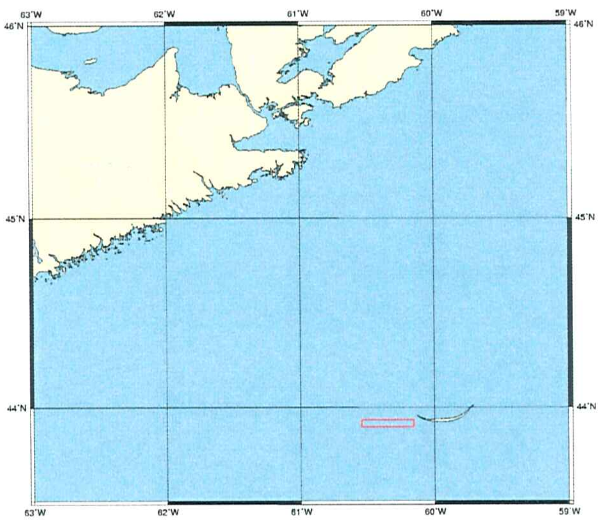




Scale - km

0 5

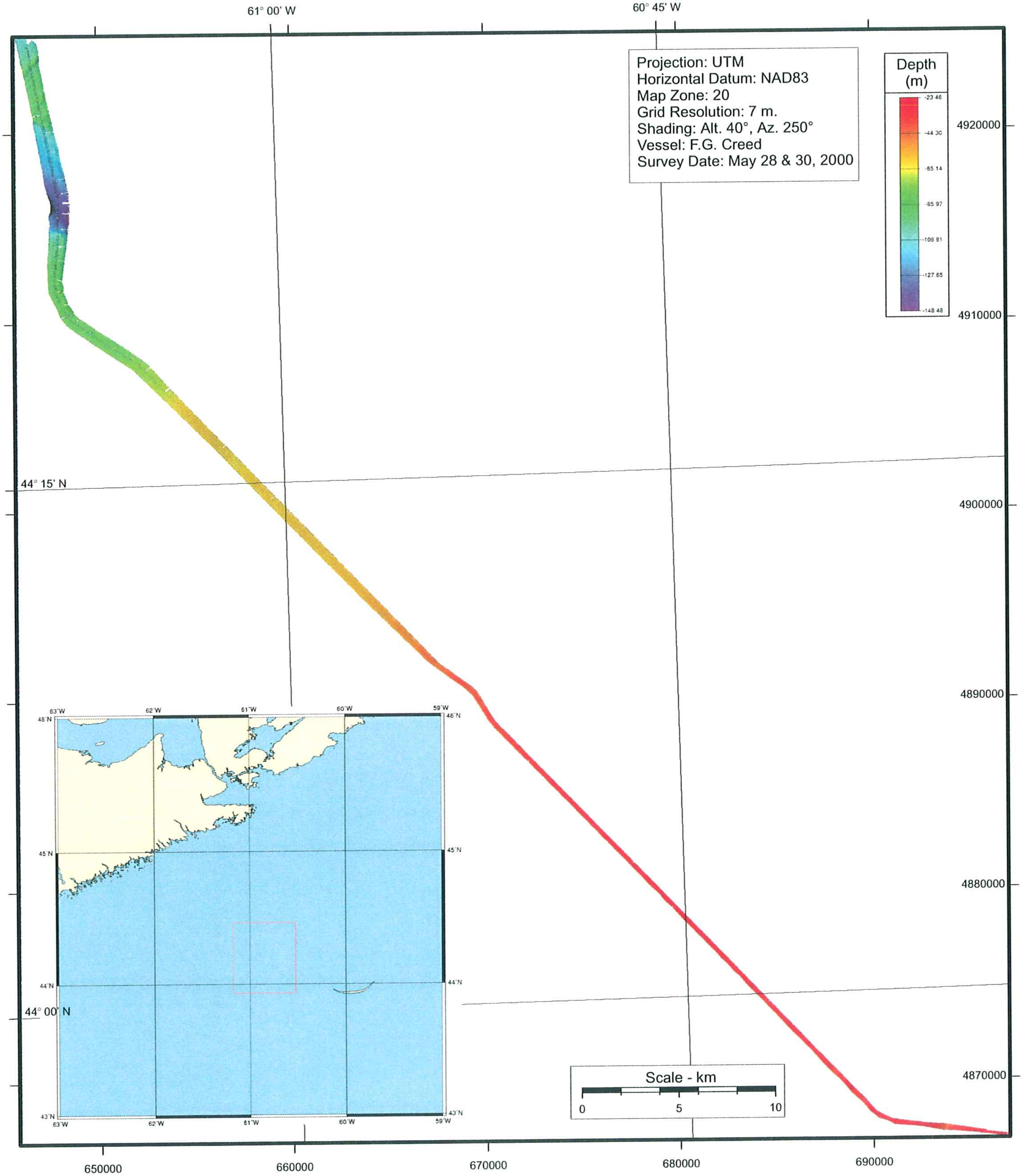
Projection: UTM
Horizontal Datum: NAD83
Map Zone: 20
Grid Resolution: 5 m.
Shading: Alt. 40°, Az. 330°
Vessel: F.G. Creed
Survey Date: May 28 & 30, 2000



TEK Map Consulting

Pipeline - 5

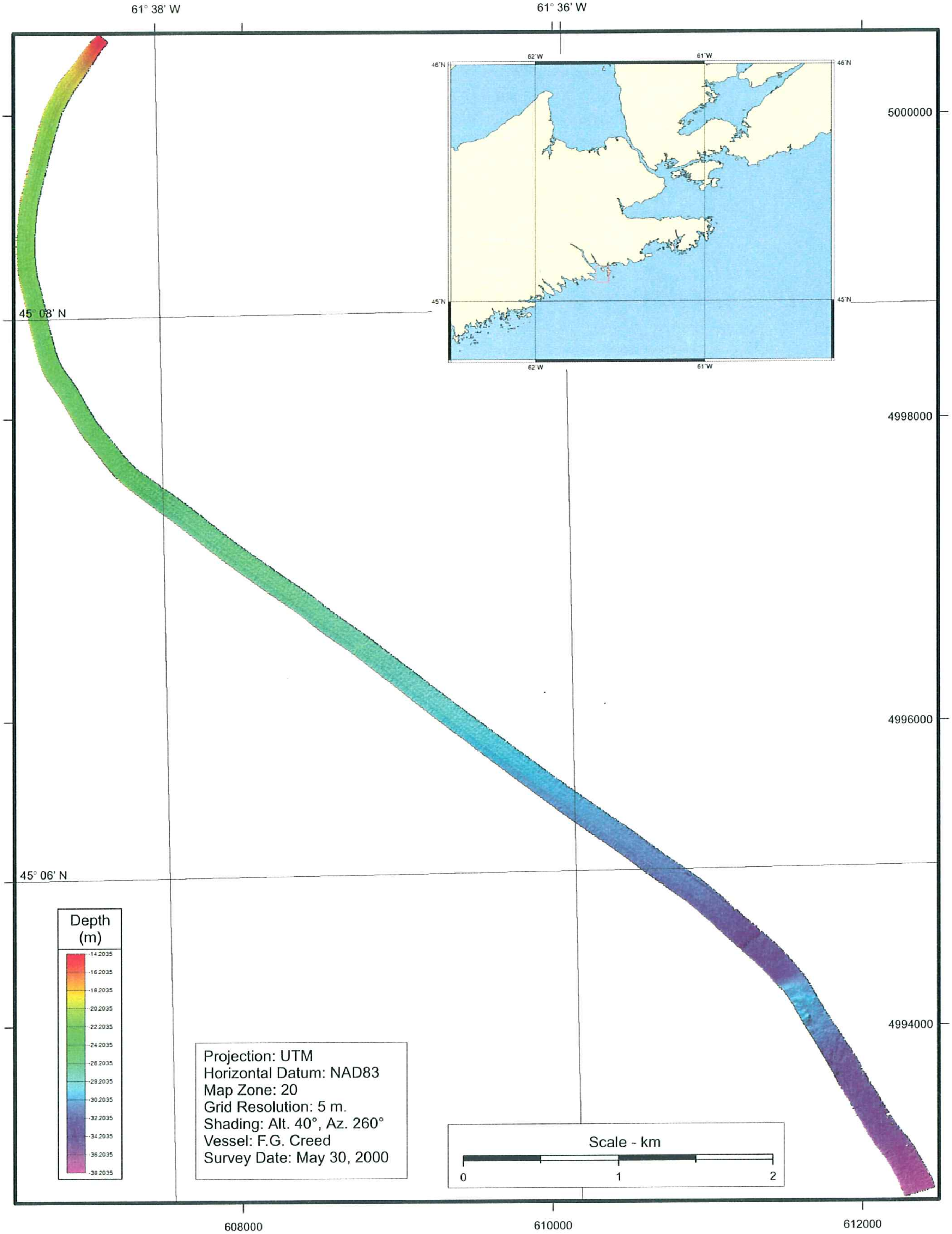
Creed2000-100 Multibeam Bathymetry



TEK Map Consulting

Pipeline - 6

Creed2000-100 Multibeam Bathymetry



TEK Map Consulting

Eastern Chedabucto Bay

Chedabucto Bay has been the site of considerable study already (e.g. Shaw et al., 1995) because it is thought to be a site of late (10-11 ka) glacial vestiges. Earlier reflection seismic and multibeam coverage in the inner bay had enabled recognition of numerous features associated with a low stand of sea level at about -38 m and remnants of coastal processes from the subsequent transgression. The objective was thus to survey the eastern Chedabucto Bay to expand the multibeam coverage to the outer bay. The detailed track plots of the eastern Chedabucto Bay are given in Fig. 2e. The colored bathymetry, with preliminary interpretations, and shaded relief images of the survey are shown in Fig. 7.

The area comprises a very steep southern face of Isle Madame. Bedrock outcrops dominate the seabed of the central area which is bounded by deep channels both to the south and north (Fig. 7a). The multibeam images depict WNW-ESE oriented mounds in the basin south of the topographic high. They are typically less than 500 m long, 150 to 200 m wide and with over 10 m relief. These are interpreted as drumlins, which is consistent with the findings of Shaw et al (1995) immediately to the west of our survey area. The deep channel north of the topographic high is largely floored with muds but occasional topographic highs protrude. Most of the bedrock crops are characterized as being rough and highly jointing. A circular outcrop pattern in the center of Fig. 7a suggests a planated dome structure. On the western end of the topographic high, there are several flat-topped, oval elevations. These are tentatively interpreted as erosional drumlins destroyed by marine transgression (John Shaw, pers. comm.). Similar remnants, termed 'drumlin scours', were mapped by Wang and Piper (1982) in the region down to -50 m depth.

More detailed description and interpretation of the seabed features based on the multibeam survey of eastern Chedabucto Bay is given in Appendix 4.

ACKNOWLEDGMENTS

We would like to thank the crew of Creed for their corporation and support during Creed 2000-100 cruise. Tide predictions were provided by Canadian Hydrographic Service at BIO. We would like thank Steve Perry for coming in on the weekend to solve a network problem. Bob Covill of TekMap generated the track plots and bathymetry maps. This report also benefitted from the reviews by John Shaw and Russ Parrott. The Sable sediment dynamics and seabed stability project is jointly founded by Sable Offshore Energy Inc. and the Program for Energy Research and Development (PERD) through the East Coast Offshore Geotechnics Project 12100E01.

Fig. 7 Images of (a) the colored bathymetry and (b) the shaded relief of Eastern Chedabucto Bay.

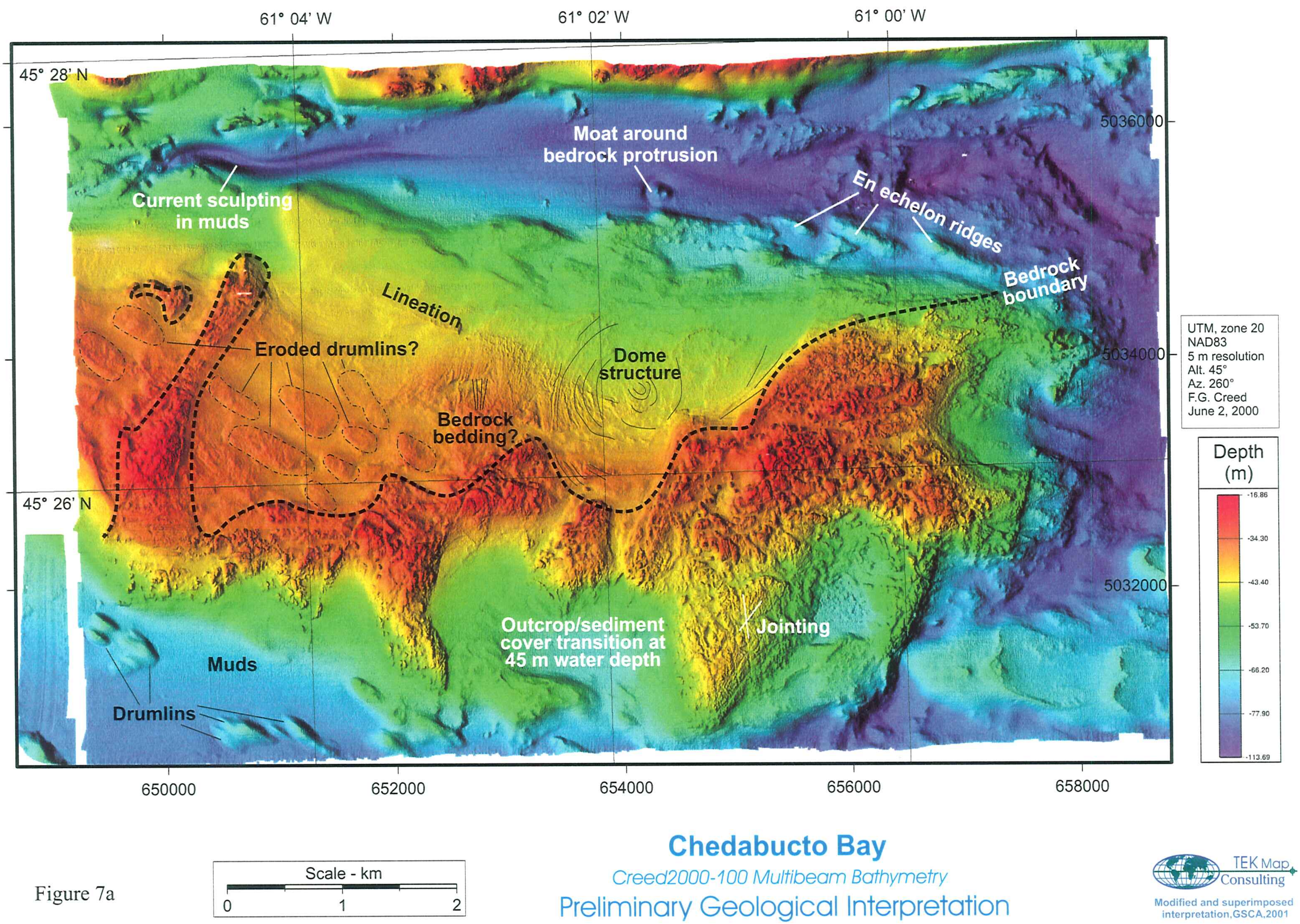
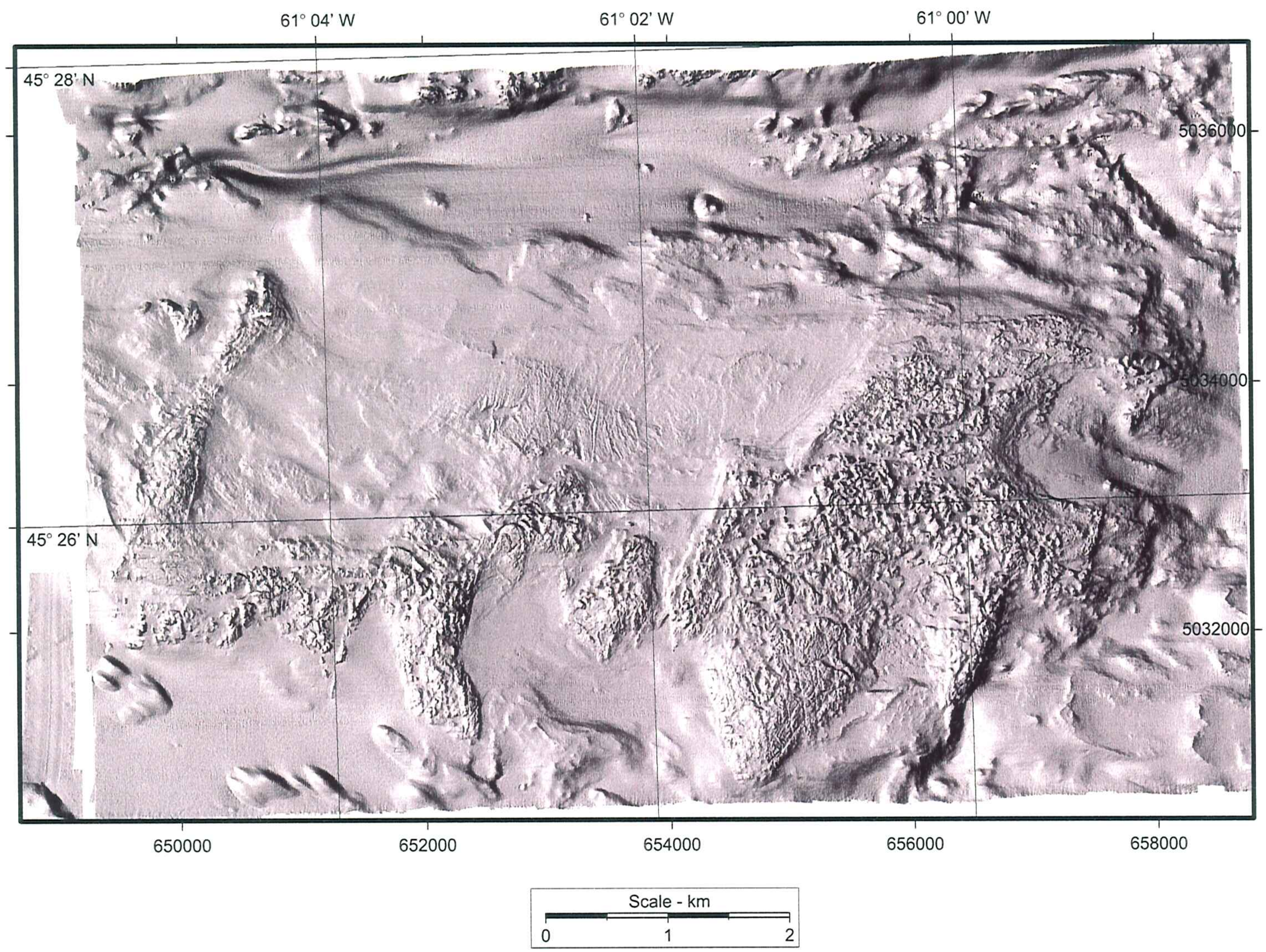

61° 04' W
61° 02' W
61° 00' W
45° 28' N
45° 26' N
5036000
5034000
5032000
650000
652000
654000
656000
658000
Moat around bedrock protrusion
Current sculpting in muds
En echelon ridges
Bedrock boundary
Lineation
Eroded drumlins?
Dome structure
Bedrock bedding?
Outcrop/sediment cover transition at 45 m water depth
Jointing
Muds
Drumlins
UTM, zone 20
NAD83
5 m resolution
Alt. 45°
Az. 260°
F.G. Creed
June 2, 2000
Depth (m)
-16.86
-34.30
-43.40
-53.70
-66.20
-77.90
-113.69
Scale - km
0
1
2
Chedabucto Bay
Creed2000-100 Multibeam Bathymetry
Preliminary Geological Interpretation
TEK Map Consulting
Modified and superimposed interpretation,GSCA,2001

Figure 7a

Chedabucto Bay

Creed2000-100 Multibeam Bathymetry



Projection: UTM
Horizontal Datum: NAD83
Map Zone: 20
Grid Resolution: 5 m.
Shading: Alt. 45°, Az. 260°
Vessel: F.G. Creed
Survey Date: June 2, 2000

TEK Map Consulting

Fig. 7b

REFERENCES

Amos, C.L. and King, E.L., 1984. Bedforms of the Canadian eastern seaboard: A comparison with global occurrences. Mar. Geol., 57: 167 - 208.

Amos, C.L. and Judge, J.T., 1991. Sediment transport on the eastern Canadian continental shelf. Cont. Shelf Res., 11: 1037-1068.

Dalrymple, R.W. and Hoodendoorn, E.L., 1997. Erosion and deposition on migrating shoreface-attached ridges, Sable Island, Eastern Canada. Geoscience Canada, 24: 25-36.

Hoogendoorn, E.L. and Dalrymple, R.W., 1986. Morphology, lateral migration and internal structures of shoreface-connected ridges, Sable Island Bank, Nova Scotia, Canada. Geology, 14: 400 - 403.

Ingersoll, R.W. and Ryan, B.A., 1997. Repetitive surveys to assess sand ridge movement offshore Sable Island. Proc. Oceans 97: 1377-1393.

Li, M.Z., Amos, C.L. and Heffler, D.E., 1997. Boundary layer dynamics and sediment transport under storm and non-storm conditions on the Scotian shelf. Marine Geology, 141: 157-181.

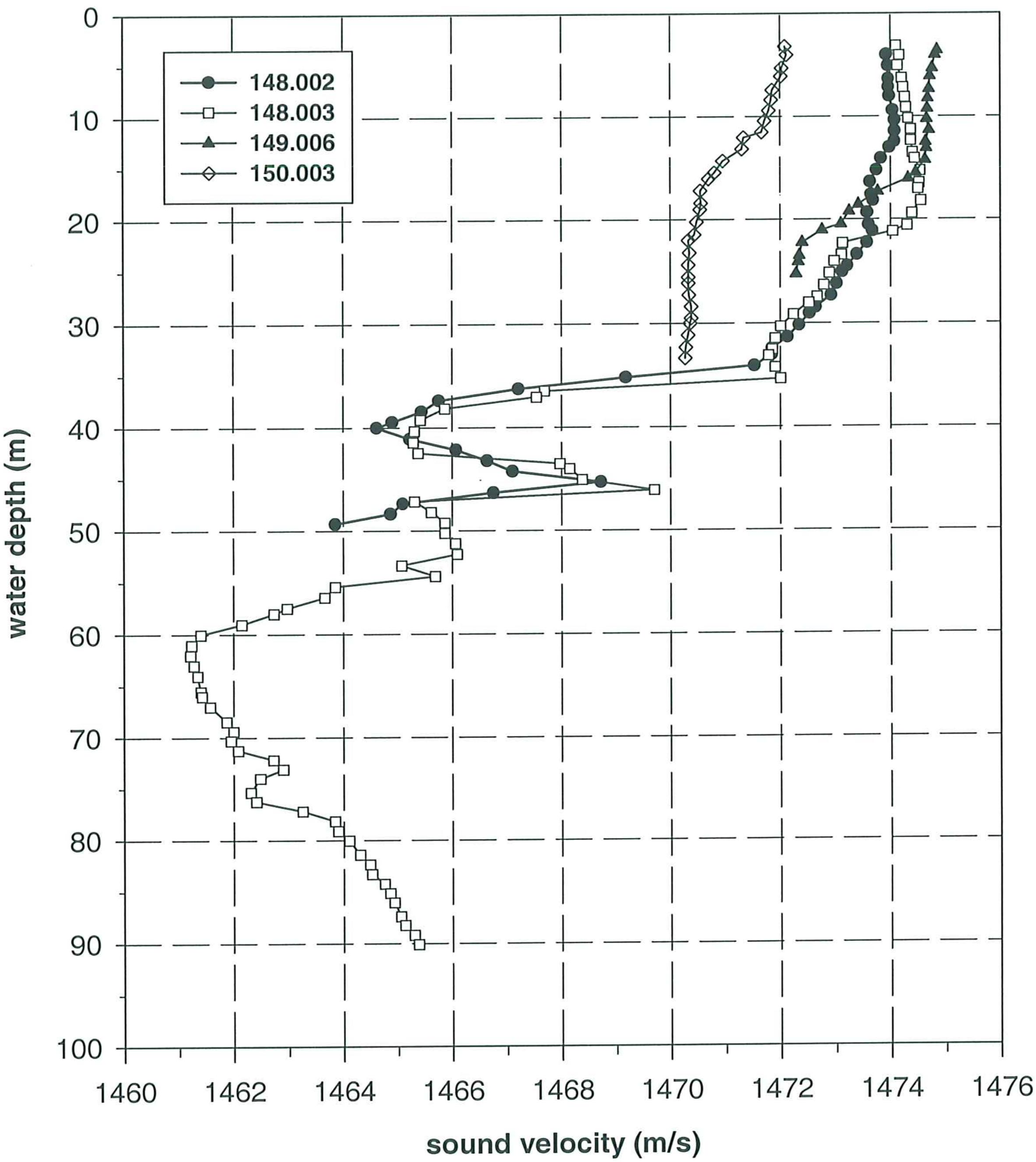
Li, M.Z., Currie, R., Beaver, D., Girouard, P. and Pledge, P., 1999. Multibeam Surveys of Sable Island Bank and the Gully Area of Scotian Shelf: Report on Creed Cruise 98-100. GSCA Internal Cruise Report, 44 p.

Shaw, J., Forbes, D.L., Ceman, J.A., Asprey, K.A., Beaver, D.E., Wile, B, Frobel, D., and Jodrey, F. 1995. Cruise report 94138: Marine geological surveys in Chedabucto and St. Georges Bays. Nova Scotia, and Bay of Islands, Newfoundland. Geological Survey of Canada Open File 3230.

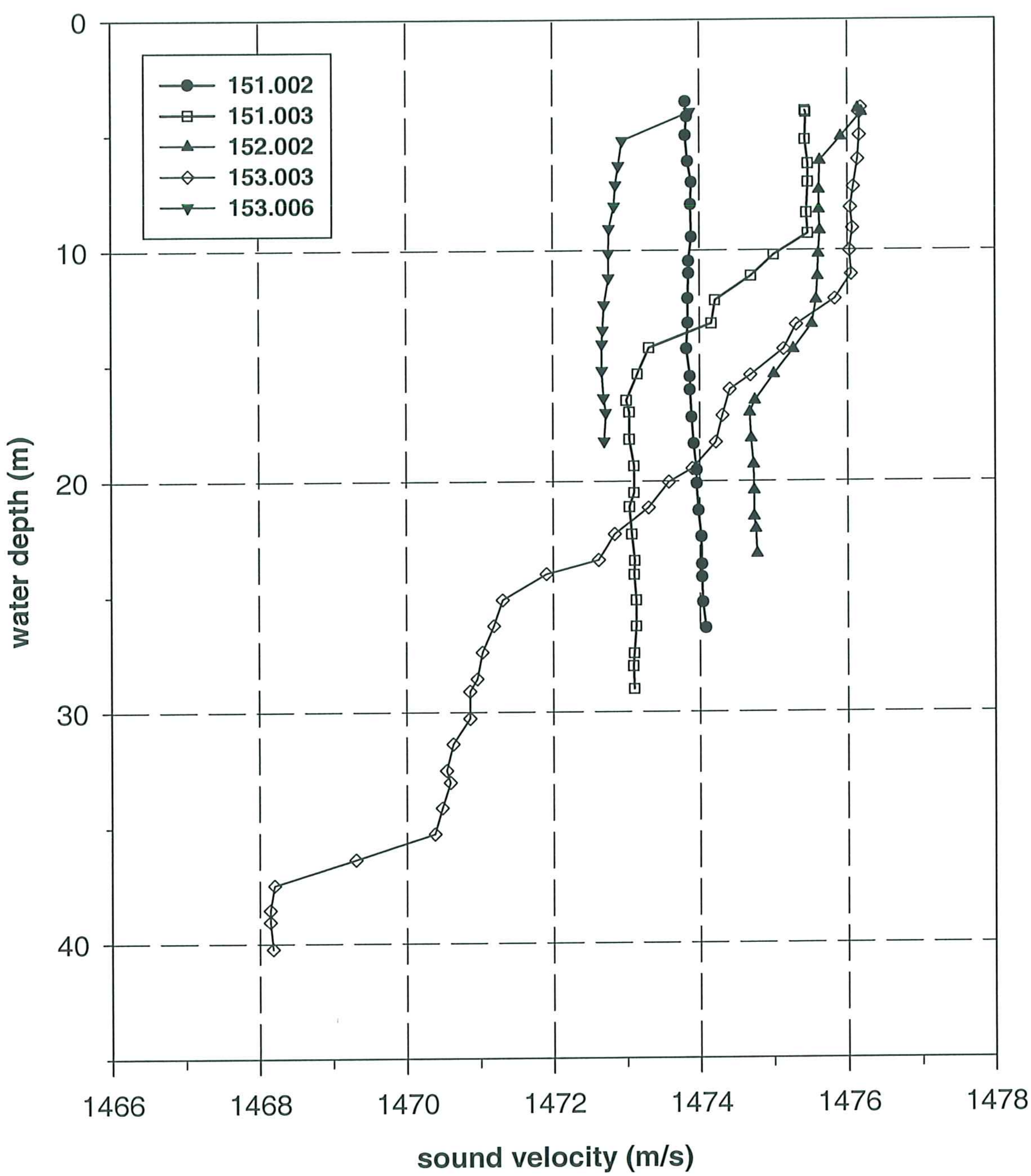
Universal Systems Ltd., 1995. CARIS Hydrographic Information Processing Systems (HIPS) - User's Guide. Document Number HIPSUSERS-Sep95-UNIX.

Wang, Y, and Piper, D.J.W. 1982. Dynamic geomorphology of the drumlin coast of southeast Cape Breton Island. Maritime Sediments and Atlantic Geology, 18, 1-27.

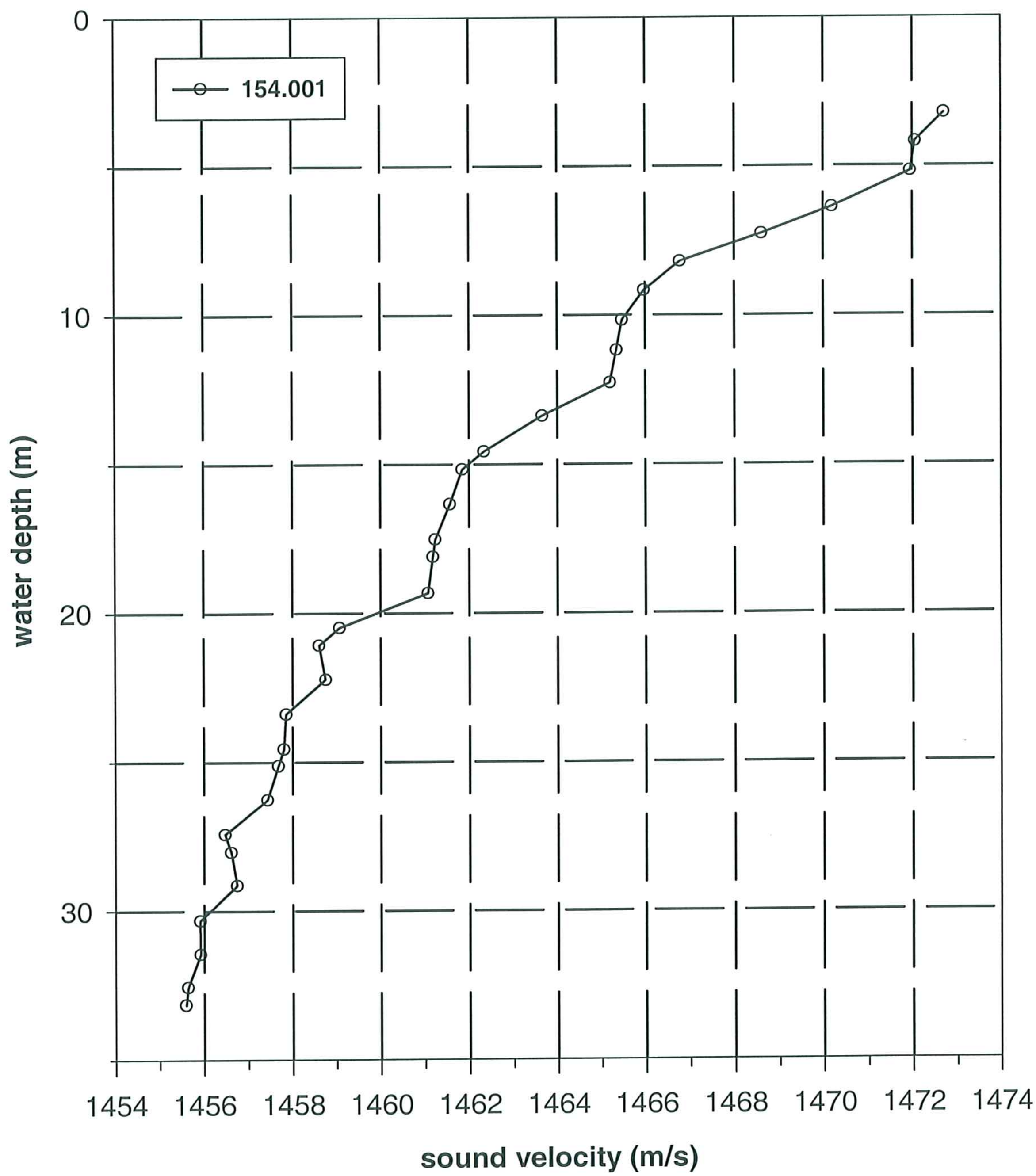
Appendix 1: The Sound velocity profile data collected on Creed 2000-100. Temperature was not measured and the values of 2.00 were just number fillers.



148.002
148.003
149.006
150.003
water depth (m)
sound velocity (m/s)
0
10
20
30
40
50
60
70
80
90
100
1460
1462
1464
1466
1468
1470
1472
1474
1476



151.002
151.003
152.002
153.003
153.006
water depth (m)
0
10
20
30
40
1466
1468
1470
1472
1474
1476
1478
sound velocity (m/s)


154.001
water depth (m)
0
10
20
30
1454
1456
1458
1460
1462
1464
1466
1468
1470
1472
1474
sound velocity (m/s)

SVP 148.002
Time: 03:00:18   Date: 05-28-2000
Position: 44 35.24839N 61 14.15619W
CALC,4020,05-28-2000,1,meters
AML SOUND VELOCITY PROFILER S/N:04020

DEPTH (M)	VELOCITY (M/S)	TEMP (C)
3.97	1473.93	2.00
4.00	1473.92	2.00
5.07	1473.95	2.00
6.35	1473.96	2.00
7.15	1473.96	2.00
8.04	1473.98	2.00
9.41	1474.04	2.00
10.39	1474.08	2.00
11.43	1474.08	2.00
12.47	1474.07	2.00
13.03	1473.98	2.00
14.10	1473.83	2.00
15.24	1473.74	2.00
16.40	1473.63	2.00
17.61	1473.65	2.00
18.20	1473.68	2.00
19.36	1473.58	2.00
20.53	1473.60	2.00
21.15	1473.67	2.00
22.26	1473.57	2.00
23.41	1473.39	2.00
24.51	1473.21	2.00
25.09	1473.12	2.00
26.21	1473.02	2.00
27.33	1472.92	2.00
28.49	1472.64	2.00
29.06	1472.53	2.00
30.20	1472.34	2.00
31.35	1472.13	2.00
32.44	1471.85	2.00
33.02	1471.85	2.00
34.11	1471.53	2.00
35.19	1469.18	2.00
36.26	1467.21	2.00
37.38	1465.76	2.00
38.44	1465.44	2.00
39.45	1464.90	2.00
40.00	1464.61	2.00
41.10	1465.22	2.00
42.17	1466.07	2.00
43.24	1466.64	2.00
44.27	1467.10	2.00
45.33	1468.72	2.00
46.35	1466.75	2.00
47.37	1465.09	2.00
48.37	1464.87	2.00
49.35	1463.85	2.00

SVP 148.003
Time: 03:02:52 Date: 05-28-2000
Position: 44 35.3418N, 61 13.67412W
CALC,4020,05-28-2000,1,meters
AML SOUND VELOCITY PROFILER S/N:04020

DEPTH (M)	VELOCITY (M/S)	TEMP (C)
3.12	1474.10	2.00
4.04	1474.16	2.00
5.04	1474.13	2.00
6.27	1474.20	2.00
7.17	1474.23	2.00
8.12	1474.26	2.00
9.13	1474.28	2.00
10.19	1474.32	2.00
11.25	1474.37	2.00
12.34	1474.37	2.00
13.49	1474.40	2.00
14.09	1474.44	2.00
15.29	1474.54	2.00
16.47	1474.52	2.00
17.02	1474.50	2.00
18.20	1474.55	2.00
19.39	1474.39	2.00
20.57	1474.30	2.00
21.16	1474.04	2.00
22.30	1473.13	2.00
23.41	1473.11	2.00
24.03	1472.98	2.00
25.16	1472.89	2.00
26.33	1472.79	2.00
27.46	1472.67	2.00
28.03	1472.52	2.00
29.16	1472.24	2.00
30.31	1472.01	2.00
31.45	1471.91	2.00
32.52	1471.86	2.00
33.11	1471.79	2.00
34.24	1471.91	2.00
35.36	1472.01	2.00
36.47	1467.69	2.00
37.06	1467.54	2.00
38.16	1465.87	2.00
39.25	1465.42	2.00
40.34	1465.31	2.00
41.43	1465.29	2.00
42.49	1465.38	2.00
43.54	1467.97	2.00
44.02	1468.15	2.00
45.09	1468.38	2.00
46.13	1469.70	2.00
47.18	1465.31	2.00
48.20	1465.62	2.00
49.24	1465.87	2.00

50.23	1465.87	2.00
51.26	1466.06	2.00
52.29	1466.09	2.00
53.37	1465.07	2.00
54.42	1465.69	2.00
55.42	1463.85	2.00
56.45	1463.66	2.00
57.50	1462.97	2.00
58.02	1462.73	2.00
59.05	1462.15	2.00
60.04	1461.40	2.00
61.05	1461.23	2.00
62.03	1461.21	2.00
63.02	1461.27	2.00
64.03	1461.34	2.00
65.52	1461.40	2.00
66.00	1461.42	2.00
67.00	1461.57	2.00
68.44	1461.87	2.00
69.39	1462.00	2.00
70.31	1461.95	2.00
71.27	1462.08	2.00
72.18	1462.72	2.00
73.11	1462.90	2.00
74.00	1462.48	2.00
75.34	1462.31	2.00
76.27	1462.41	2.00
77.19	1463.25	2.00
78.16	1463.84	2.00
79.12	1463.90	2.00
80.04	1464.10	2.00
81.43	1464.30	2.00
82.36	1464.48	2.00
83.31	1464.52	2.00
84.25	1464.75	2.00
85.15	1464.85	2.00
86.05	1464.93	2.00
87.39	1465.05	2.00
88.24	1465.13	2.00
89.19	1465.30	2.00
90.11	1465.38	2.00

SVP 149.006
Time: 10:09:46 Date: 05-28-2000
Position: 4351.91903,N,06006.47817,W
CALC,4020,05-28-2000,1,meters
AML SOUND VELOCITY PROFILER S/N:04020

DEPTH (M)	VELOCITY (M/S)	TEMP (C)
3.56	1474.85	2.00
4.01	1474.81	2.00
5.32	1474.76	2.00
6.08	1474.72	2.00
7.33	1474.70	2.00
8.23	1474.68	2.00
9.25	1474.67	2.00
10.26	1474.66	2.00
11.34	1474.70	2.00
12.52	1474.64	2.00
13.10	1474.65	2.00
14.26	1474.63	2.00
15.50	1474.46	2.00
16.07	1474.32	2.00
17.32	1473.77	2.00
18.58	1473.42	2.00
19.21	1473.25	2.00
20.44	1473.10	2.00
21.04	1472.76	2.00
22.23	1472.40	2.00
23.49	1472.35	2.00
24.10	1472.33	2.00
25.26	1472.29	2.00

SVP 150.003
Time: 11:24:42 Date: 05-29-2000
Position: 43 50.39044N, 59 57.17818W
CALC,4020,05-29-2000,1,meters
AML SOUND VELOCITY PROFILER S/N:04020

DEPTH (M)	VELOCITY (M/S)	TEMP (C)
3.20	1472.09	2.00
4.02	1472.12	2.00
5.30	1472.03	2.00
6.08	1472.02	2.00
7.43	1471.86	2.00
8.38	1471.84	2.00
9.41	1471.80	2.00
10.43	1471.72	2.00
11.51	1471.67	2.00
12.03	1471.34	2.00
13.16	1471.31	2.00
14.30	1470.96	2.00
15.47	1470.81	2.00
16.05	1470.70	2.00
17.21	1470.55	2.00
18.40	1470.56	2.00
19.03	1470.54	2.00
20.24	1470.48	2.00
21.46	1470.44	2.00
22.00	1470.33	2.00
23.21	1470.35	2.00
24.37	1470.33	2.00
25.58	1470.33	2.00
26.15	1470.33	2.00
27.30	1470.34	2.00
28.40	1470.38	2.00
29.50	1470.38	2.00
30.02	1470.36	2.00
31.16	1470.32	2.00
32.32	1470.28	2.00
33.37	1470.27	2.00

SVP 151.002
Time: 23:26:20 Date: 05-29-2000
Position: 43 52.72366,N, 59 53.13597,W
CALC,4020,05-29-2000,1,meters
AML SOUND VELOCITY PROFILER S/N:04020

DEPTH (M)	VELOCITY (M/S)	TEMP (C)
3.55	1473.81	2.00
4.20	1473.83	2.00
5.02	1473.81	2.00
6.15	1473.84	2.00
7.06	1473.89	2.00
8.01	1473.88	2.00
9.43	1473.89	2.00
10.47	1473.85	2.00
11.00	1473.85	2.00
12.09	1473.84	2.00
13.17	1473.84	2.00
14.28	1473.82	2.00
15.48	1473.87	2.00
16.06	1473.87	2.00
17.24	1473.89	2.00
18.38	1473.92	2.00
19.53	1473.96	2.00
20.11	1473.96	2.00
21.27	1473.98	2.00
22.40	1474.02	2.00
23.60	1474.03	2.00
24.15	1474.03	2.00
25.24	1474.04	2.00
26.37	1474.08	2.00

SVP 151.003
Time: 03:54:03 Date: 05-30-2000
Position: 43 55.54719,N, 060 32.88129,W
CALC,4020,05-30-2000,1,meters
AML SOUND VELOCITY PROFILER S/N:04020

DEPTH (M)	VELOCITY (M/S)	TEMP (C)
3.96	1475.43	2.00
4.03	1475.44	2.00
5.21	1475.43	2.00
6.26	1475.47	2.00
7.06	1475.47	2.00
8.39	1475.45	2.00
9.28	1475.47	2.00
10.21	1475.01	2.00
11.12	1474.70	2.00
12.17	1474.21	2.00
13.18	1474.16	2.00
14.24	1473.31	2.00
15.37	1473.15	2.00
16.51	1473.00	2.00
17.02	1473.04	2.00
18.19	1473.04	2.00
19.34	1473.10	2.00
20.50	1473.10	2.00
21.10	1473.04	2.00
22.29	1473.07	2.00
23.43	1473.11	2.00
24.04	1473.10	2.00
25.15	1473.13	2.00
26.29	1473.13	2.00
27.45	1473.10	2.00
28.01	1473.09	2.00
29.00	1473.10	2.00

SVP 152.002

Time: 03:01:39 Date: 05-31-2000
Position: 43 56.70187,N, 060 40.36822,W
CALC,4020,05-31-2000,1,meters
AML SOUND VELOCITY PROFILER S/N:04020

DEPTH (M)	VELOCITY (M/S)	TEMP (C)
3.89	1476.14	2.00
4.04	1476.19	2.00
5.10	1475.91	2.00
6.14	1475.63	2.00
7.40	1475.62	2.00
8.26	1475.62	2.00
9.17	1475.63	2.00
10.18	1475.61	2.00
11.15	1475.60	2.00
12.17	1475.58	2.00
13.23	1475.52	2.00
14.31	1475.27	2.00
15.40	1475.01	2.00
16.52	1474.75	2.00
17.05	1474.68	2.00
18.16	1474.70	2.00
19.29	1474.73	2.00
20.41	1474.74	2.00
21.54	1474.74	2.00
22.07	1474.76	2.00
23.15	1474.78	2.00

SVP 153.002
Time: 06:45:20 Date: 06-01-2000
GPS Position: 43 51.58723,N, 059 44.19100,W
CALC,4020,06-01-2000,1,meters
AML SOUND VELOCITY PROFILER S/N:04020

DEPTH (M)	VELOCITY (M/S)	TEMP (C)
3.83	1476.18	2.00
4.05	1476.16	2.00
5.03	1476.16	2.00
6.07	1476.14	2.00
7.27	1476.08	2.00
8.16	1476.04	2.00
9.06	1476.07	2.00
10.02	1476.03	2.00
11.06	1476.05	2.00
12.13	1475.83	2.00
13.24	1475.31	2.00
14.30	1475.14	2.00
15.43	1474.69	2.00
16.04	1474.41	2.00
17.17	1474.31	2.00
18.32	1474.22	2.00
19.46	1473.90	2.00
20.03	1473.58	2.00
21.15	1473.30	2.00
22.28	1472.84	2.00
23.40	1472.62	2.00
24.00	1471.91	2.00
25.13	1471.31	2.00
26.25	1471.19	2.00
27.39	1471.03	2.00
28.56	1470.96	2.00
29.10	1470.86	2.00
30.26	1470.86	2.00
31.37	1470.63	2.00
32.51	1470.54	2.00
33.03	1470.59	2.00
34.13	1470.48	2.00
35.26	1470.38	2.00
36.37	1469.31	2.00
37.47	1468.20	2.00
38.54	1468.14	2.00
39.05	1468.14	2.00
40.23	1468.18	2.00

SVP 153.006
Time: 16:11:13 Date: 06-01-2000
GPS Position: 43 57.98374,N, 059 39.43224,W
CALC,4020,06-01-2000,1,meters
AML SOUND VELOCITY PROFILER S/N:04020

DEPTH (M)	VELOCITY (M/S)	TEMP (C)
4.01	1473.87	2.00
5.24	1472.95	2.00
6.33	1472.90	2.00
7.16	1472.86	2.00
8.08	1472.84	2.00
9.06	1472.77	2.00
10.12	1472.76	2.00
11.20	1472.76	2.00
12.36	1472.70	2.00
13.47	1472.68	2.00
14.07	1472.67	2.00
15.22	1472.67	2.00
16.40	1472.69	2.00
17.05	1472.72	2.00
18.27	1472.70	2.00

SVP 154.001
Time: 18:55:49 Date: 06-02-2000
Position: 45 27.30647,N, 061 03.92396,W
CALC,4020,06-02-2000,1,meters
AML SOUND VELOCITY PROFILER S/N:04020

DEPTH (M)	VELOCITY (M/S)	TEMP (C)
3.23	1472.71	2.00
4.19	1472.06	2.00
5.18	1471.95	2.00
6.38	1470.19	2.00
7.27	1468.61	2.00
8.20	1466.78	2.00
9.17	1465.97	2.00
10.17	1465.48	2.00
11.19	1465.35	2.00
12.28	1465.20	2.00
13.39	1463.66	2.00
14.57	1462.34	2.00
15.18	1461.85	2.00
16.34	1461.57	2.00
17.53	1461.24	2.00
18.11	1461.19	2.00
19.33	1461.08	2.00
20.49	1459.07	2.00
21.08	1458.60	2.00
22.23	1458.75	2.00
23.39	1457.85	2.00
24.56	1457.80	2.00
25.12	1457.68	2.00
26.26	1457.43	2.00
27.42	1456.47	2.00
28.02	1456.61	2.00
29.14	1456.74	2.00
30.32	1455.91	2.00
31.45	1455.92	2.00
32.56	1455.63	2.00
33.15	1455.59	2.00

Appendix 2: A list of CD's, tapes and disks archived for Creed 2000-100 cruise

Appendix 2
Creed 2000-100 Archived Data

1. General Cruise Log Book

2. Compact Disks:

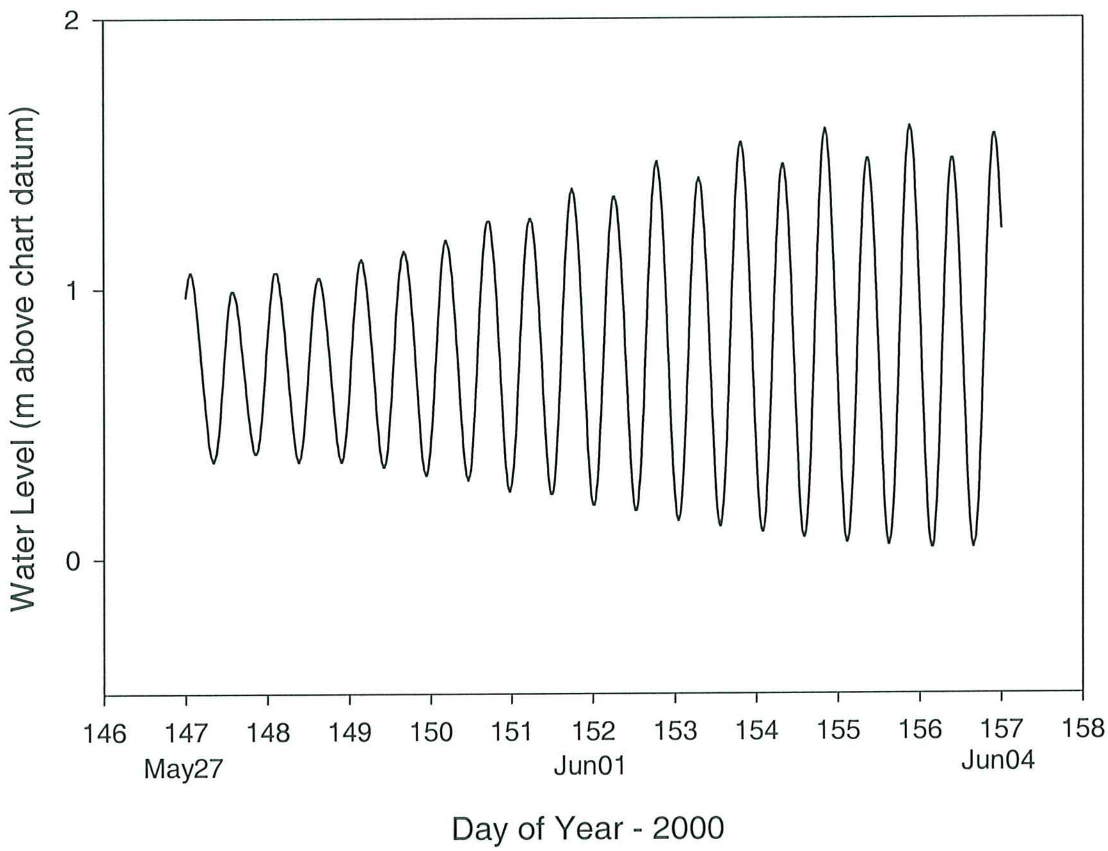
Cd Number	Day of Year	Contents
1	149	HDCS data/processed depth
2	150	HDCS data/processed depth
3	151	HDCS data/processed depth
4	152	HDCS data/processed depth
5	153	HDCS data/processed depth
6	154	HDCS data/processed depth
7	155	HDCS data/processed depth
8		Grass project

3. Exabyte Tapes:

Tape Number	Day of Year	Contents
1	149	raw data
2	150	raw data
3	150	HDCS data
4	152	raw data
5	152	HDCS data
6	153	raw data
7	153	HDCS data
8	154	raw data
9	154	HDCS data
10	155	raw data final
11	155	raw data final
12	150-155	HDCS data
13	150-155	HDCS data
14	148-155	total HDCS data
15	148-155	total HDCS data
16	148-155	total raw data
17		Grass project
18		Grass project

Appendix 3: Predicted tide

Predicted Tide From 26/5 to 4/6, 2000 for Sable Island Bank



Appendix 4: Description of eastern Chedabucto Bay survey

Chedabucto Bay Survey

Weather constraints at the end of the cruise restricted surveying to sites in the lee of southwesterlies, which, from our position in Canso, dictated a Chedabucto Bay site.

Inner Chedabucto Bay has been the site of considerable study already (Shaw et al., 1995; Forbes et al., 1995). The area is of general interest because it is thought to be a site of late (10-11 ka) glacial vestiges (e.g., Stea et al., 1992) which would have influenced deposits and sea level in the bay. Earlier reflection seismic and multibeam coverage in the inner bay had enabled recognition of numerous features associated with a lowstand at about -50 m and remnants of coastal processes from the subsequent transgression. They also recognized drumlins with a possible glacimarine and Holocene mud draping in the area. Our choice of coverage immediately south of Isle Madame was to investigate possible offshore equivalents of large drumlins/moraines (e.g., at Heath Head and Red Head).

A considerable area had already been covered (e.g., Shaw et al., 1995) in the inner bay so it was planned to cover the outer bay and then join with the existing data. Before completion, foreseeable weather conditions along the transit to Sydney necessitated an earlier cessation of operations in the bay so the joining of the multibeam coverage to the west was not realized. A total of approximately 57 sq. km coverage was obtained. Figure 7 shows the resulting images.

Figure 7a shows a preliminary interpretation of the image. The area comprises a very steep southern face of Isle Madam, generally with bedrock outcrop dominating the seabed. This is bounded to the south by a deep channel (locally over 75 m) separating the island from a topographic high which shallows to about 17 m. South of this the bathymetry drops again to depths in the 70 m range with depths reaching 100 m just south of the survey area. There is a strong water depth-dependant contrast with the basinal areas largely floored by smooth or gently contoured mud and the higher areas dominated by bedrock outcrop.

The bedrock is largely exposed to the seabed above about 45 m water depth but even in the shallower depths thin sediment pockets are present between local bedrock highs. The bedrock itself presents two contrasting morphological characters and is tentatively interpreted as belonging to two separate Groups. On Isle Madame, a late Devonian sedimentary sequence dominates but Hadrynian volcanics of the Fourchu Group are exposed in small windows. Extrapolation of boundaries from land is uncertain. The dominant bedrock character on the offshore topographic high is rough and highly jointed. It dominates the eastern, southern and extreme western parts of the topographic high. The other bedrock province is less undulating and depicts sub-parallel, curvilinear ridges and troughs thought to represent relief from differentially weathered/eroded sedimentary bedding. This bedrock type is present, often beneath a thin sediment cover, in a broad half-circle distribution on the topographic high. A circular outcrop pattern (Fig. 7a) is thought to reflect a planated dome structure. It is uncertain if these two provinces are offshore equivalents of the Isle Madame volcanics and sediments but their morphological characters are consistent with this correlation.

The multibeam image depicts WNW-ESE oriented mounds in the basin south of the topographic high. They are typically under 500 m long, 150 to 200 m wide and present over 10 relief at the seabed. The only existing seismic coverage is a single air gun traverse which crosses the SE corner of the image area oriented parallel to these mounds. It is of poor quality but indicates that these are features protruding up through ponded sediments. The multibeam image indicates they are entirely draped with sediment. These are interpreted as drumlins, which is consistent with the findings of Shaw et al. (1992) immediately to the west of our survey area. They have the same orientation as drumlins on land in the Canso area and on eastern Isle Madame (Stea et al., 1992) immediately down- and up-ice. Inference from Stea's ice flow phases would suggest their formation postdating the early-mid Wisconsinan ice flow pattern but predating the onshore flow as the Late Wisconsinan inner shelf ice divide developed. Preliminary inspection of the site does not indicate any features related to the postulated late glacial offshore ice dome (Stea et al., 1992).

The channel between Isle Madame and the topographic high is largely floored with muds but occasional topographic highs protrude, mainly at the eastern end. Some are clearly local bedrock knobs but some, on the southern channel flank, are long and linear and set in an en echelon pattern but it is unclear if this is a bedrock or glacial feature control. They do, perhaps coincidentally, have the same orientation as the drumlins. These local topographic highs and the more constricted part of the channel (NW corner of Fig. 7a) have clearly influenced local Holocene depositional pattern under the influence of currents, forming channels and moats, probably more through diminished or non-deposition than to erosion.

In the shallower area there is a clear decrease in sand and or/soft sediment thickness as bedrock structure becomes less subdued and jointing and bedding feature details are better expressed. This change occurs most markedly at the 45 m water depth. It is most clearly depicted along a linear feature in (or on top of) the sedimentary bedrock (Fig. 7a) in an otherwise relatively flat-lying area. This change is tentatively attributed to the latest sea-level lowstand with heightened beach zone washing and redistribution above and sub-littoral deposition below. The topographic high would have been an island at this time. It is in general agreement with finding of Shaw et al. (1992), to the east and Taylor et al. (1989) to the northeast. Another indication of this lowstand is the eight or ten flat-topped, oval shaped elevations lying on top of the sedimentary bedrock (Fig. 7a). They are of the same scale as drumlins in the basin and they exhibit a similar orientation. Their tops all lie at about 35 m water depth. These are tentatively interpreted as the gravel/cobble–topped erosional remnants of drumlins destroyed with marine transgression (John Shaw, pers. comm.). Such features are common above the lowstand level along much of the Atlantic coastline of Nova Scotia (Wang and Piper, 1982).

References

Forbes, D.L., Shaw, J., and Taylor, R.B. 1995. Differential preservation of coastal structures on parablacial shelves: Holocene deposits of southeastern Canada. Marine Geology, 124, 187-201.

Shaw, J., Beaver, D.E., Sile, B. and Asprey, K.A. 1992. A marine geological survey of Chedabucto Bay, Nova Scotia. Geological Survey of Canada internal report. 7 p. plus tables and figures

Shaw, J., Forbes, D.L., Ceman, J.A., Asprey, K.A., Beaver, D.E., Wile, B, Frobel, D., and Jodrey, F. 1995. Cruise report 94138: Marine geological survey s in Chedabucto and St. Georges Bays. Nova Scotia, and Bay of Islands, Newfoundland. Geological Survey of Canada Open File 3230.

Stea, R.R., Conley, H., and Brown, Y. compilers, 1992. Surficial geology of the Province of Nova Scotia: Nora Scotia Department of Natural resources, Map 92-1, scale 1:500 000.

Taylor, R.B., MacLean, B., and Beaver, D. 1989. Cruise report 88-018 Phase 13 (G) M.V. Navicula Southwest Cape Breton Island, Nova Scotia. Geological Survey of Canada internal report.

Wang, Y, and Piper, D.J.W. 1982. Dynamic geomorphology of the drumlin coast of southeast Cape Breton Island. Maritime Sediments and Atlantic Geology, 18, 1-27.