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Canadian Meteorological and Oceanographic Society

La Société canadienne de météorologie et d'océanographie

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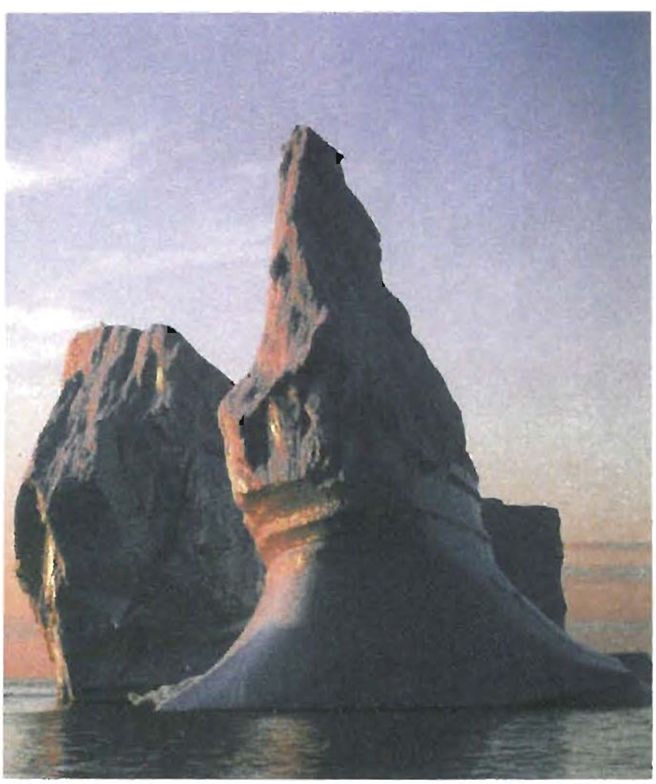
TOWING of ICEBERGS

REMORQUAGE D'ICEBERGS



....from the President's Desk

CMOS friends and colleagues:

I was very impressed with the extraordinary efforts made by the Vancouver Local Arrangements and Science Program Committees to host the Annual Congress this past June. This team laboured behind the scenes (sometimes all night) to ensure that those who attended enjoyed and benefited from the oral presentations, exhibits and posters. At the last CMOS Executive meeting in late June, it was noted that there should have been an evaluation form, so that attendees could tell the organizers what they did and didn't like. This will be rectified next year. Meanwhile, if you would like to tell the organizers anything, please send an email to president@cmos.ca and I will make sure to forward it to the appropriate people.

There are some new initiatives which the CMOS Executive will launch this year. An AD HOC Vision Committee is being formed to discuss how we are doing in implementing the vision as presented in *CMOS in 2003/2004 and its Future* http://www.cmos.ca/VisionPapere.pdf and to formulate new plans.

In addition, the AD HOC Finance Committee is being reinstated to advise the Executive and Council about the future financial viability of the Society by taking a long view on things like projected revenue and expenses, in the light of current trends and the strategic vision. It will devise a strategic financial plan. Out of that should come recommendations on the evolution of membership fees, subscription fees, revenue from meetings, donations and contributions, investment policy, investment in infrastructure and contingency plans for loss of government subsidies. The committee will also have responsibility for review of budget proposals in the shorter term but in the light of the strategic plan for finances. If you are interested in submitting ideas to these committees or in being part of the discussion, please contact me at president@cmos.ca.

We will be initiating a new feature in each CMOS Bulletin to highlight the achievements and contributions of our dedicated volunteers. If you would like to write a feature article, please contact Paul-André Bolduc at bulletin@cmos.ca.

I trust that you are having a good summer despite the humidity, floods, fog and thunderstorms which have plagued various parts of the country.

Susan Woodbury, ACM, FCMOS
President, Présidente

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Articles

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CMOS exists for the advancement of meteorology and oceanography in Canada

Le but de la SCMO est de stimuler l'intérêt pour la météorologie et l'océanographie au Canada.

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"at the service of its members / au service de ses membres"

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Cover page: The composite picture shown on the cover illustrates attempts to tow icebergs beginning in the '70s off the East Coast of Canada. A partnership between the petroleum industry and The Memorial University of Newfoundland resulted in a few successes, but not without a few mishaps associated with such a dangerous enterprise. To learn more, please read the interesting article written by Alan Ruffman on **page 99** of this issue. Photos are courtesy of Ice Engineering C-CORE, St-John's, NFLD

Page couverture: La photo composite de la page couverture illustre bien les tentatives de remorquage des icebergs qui se sont déroulées sur la côte est du Canada dans le début des années 70. Une participation conjointe de l'industrie pétrolière et de l'université Mémorial de Terre-Neuve ont permis quelques réalisations sans toutefois écarter complètement tous les dangers d'une telle entreprise hasardeuse. Pour en savoir plus, prière de lire l'intéressant article d'Alan Ruffman en **page 99** du présent numéro. Les photos sont la courtoisie de Ice Engineering, C-CORE, St.-John's, Terre-Neuve.

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The First Known Attempts Off Eastern Canada 'to Tow, or Cant' Icebergs: a seed to the understanding of iceberg scour processes at the seafloor

by Alan Ruffman, P.Geo.
President, Geomarine Associates Ltd.[1]

It is generally considered that the first attempts to tow, or to divert, icebergs was done by the modern operators of the offshore oil and gas exploration wells, especially off Labrador. Tenneco Oil & Minerals Ltd. was the operator of the first exploration well off Labrador, Leif P-38, then Leif L-38, and finally E-38, a new field wildcat well, drilled on the northeast part of Hamilton Bank in 1971 from an anchored drillship, *TYPHOON*. The *TYPHOON* was self-propelled, but was not dynamically positioned so had to be anchored on a drillsite.

The *TYPHOON*, owned by Storm Drilling Company of Houston, Texas, was mobilized out of St. John's, Newfoundland, on June 21, 1971. The Tenneco *et al.* Leif P-48 well was spudded on July 6, 1971 and encountered severe drilling problems in boulders in trying to drill the 36 inch (914 mm) surface casing hole. The drilling platform was shifted 60 ft to the west four times by winching in on its stern anchors with the same negative drilling result. Defeat was conceded on July 27, 1971 as an iceberg neared the drillship, and the drillship was moved about 3,000 feet south to a new location Tenneco *et al.* Leif E-38 where the pattern of eight anchors was reset (Daneliuk and Bell, 1972). In this paper when referring to the Leif drilling operations, I use British Units used by the oil industry of 1971 and in all the reports on file.

The Leif E-38 Hole #1 (called L-38 in Verlet and Duval (1972)) was spudded on July 31, 1971 in 550 feet (168 m) of water (Kelly Bushing (K.B.) to sea level was 40 ft). Boulders were again a problem, but one joint of 30 inch casing was run and cemented at 620 KB -- barely 40 ft below the sea floor. The 26 inch hole was drilled to 1,118 ft KB, and a 20 inch casing was run on August 9, 1971 and cemented at 1,063 ft KB. On completion of the cement job it was found that the back pressure value in the casing string did not hold, then that the 20 inch running tool could not be released. The 45 hours of fishing attempts were unsuccessful, and the hole was abandoned early on August 13, 1971 with a 'blind back off' to break a joint of the drillpipe above the running tool. This left 500 ft of drillpipe lying across the L-38 wellhead housing and guidebase and on the nearby ocean floor along with the bumper sub, four wellhead guide lines, two T.V. lines, two diver lines and a further 14 joints of drillpipe in the hole (Verlet and Duval, 1972; Daneliuk and Bell, 1972).

The *TYPHOON* was again moved on its stern anchors 75 ft to the west (later found to be 90 ft by Verlet and Duval (1972)), and a new hole #2, officially designated Leif E-38, was spudded at 2330 August 13, 1971 at 54° 17' 29.87" N, 55° 05' 52.17" W on Hamilton Bank in 550 ft water depth. This time, the seventh try by *TYPHOON*, things went better in the drilling department. Boulders had cost the *TYPHOON*, Tenneco and its partners twenty-one lost drilling days (Murray and McMillan, 1982; McMillan, 1990). The 30-inch surface casing was successfully drilled and set at 627 KB (37 ft subsea floor), and a string of 13 3/8 inch casing was run and cemented at 1,097 ft KB. Blowout preventers were then installed on the seafloor, and the hole was drilled to 3,150 ft KB. The hole was successfully logged with a string of 9 5/8 inch casing then run and cemented in place. Drilling resumed to 3,557 ft KB when a storm hit on September 25, 1971. *TYPHOON* was not to get a chance to ever log the 3,250 to 3,557 ft interval. Preparations were made to ride out the storm with *TYPHOON* intractably tethered to its eight 25- or 30-ton anchors. Nature, however, had other plans than more drilling.

> The permittee Tenneco Oil & Minerals Ltd. *et al.* comprised Tenneco and its partners, Eastcan Exploration Ltd., A.G.I.P. Canada Ltd., Amerada Hess Corporation, and Sun Oil Company, all with Calgary offices for their Canadian subsidiaries in 1971. The Leif E-38 well was drilled in Unit E, Section 38, of Grid Area 54-20-55-00. The support vessels, or work boats, used in 1971 were *M/V CAY W* and *M/V SAN JACINTO*, both registered in Freeport, Texas, and the *M/V SMIT-LLOYD 7* from Rotterdam, The Netherlands.

The next day on September 26, 1971 an iceberg was observed to approach the immobile drilling platform, and to appear to drift by. Then it appears that the tide changed and the current drift of iceberg Y12 drastically changed. The iceberg entered the anchor pattern of the drill rig and apparently headed directly for a collision with the drilling platform in the early evening. Daneliuk and Bell's (1972) 'Summary' in the 'Well History Report' tells the story all too briefly:

[1] Halifax, Nova Scotia, Canada.

> The seas were too rough for work boats to tow and alter the course of the oncoming iceberg. The well was shut-in. The riser, kill and choke lines were disconnected. The guide and anchor lines were dropped, and the ship was moved off location. [p. 1]

The rather clinical words of the 'Well History Report' disguise the apparent certain panic which ensued as the iceberg was seen to begin to approach the drillship. Appendix III of the Marine Environmental Services Limited 1972 Iceberg Towing Manual contains a 'Log of Previous Towing Experiences' that perhaps comes closer to better recording the ultimate drama of that September 26, 1971 night:

> "The day started quietly with moderate radar visibility, strong winds and fairly large waves. Several bergs, up to three at once, approached on radar. These were brought out from the coast by the West and N.W. winds. One berg (Y12) steadily approached the ship. Snow fell at noon -- gale force winds -- very high gusts. After several hours of drifting south-east, to pass the ship on the starboard side, the current slacked off and when the wind increased, the berg tried to pass, N.E., to port of the ship. At 1800, the current gained strength and pushed the berg back towards the ship. The drilling superintendent was informed, as requested, at 1.5 N.M. range. He called in the *S.L. 7* (9 miles away) [*SMIT-LLOYD 7*] and the "*Cay W*". The weather was still rough but an attempt to tow the berg was decided upon at 1700. By 2100, the line [sic = berg] ([after] 4 attempts at heaving, then at [sic = after] towing line out from *Typhoon* to *S.L. 7*) was in tow by *S.L. 7*, but the drilling superintendent decided there was not enough time, as the berg, at 0.47 miles, was within the anchor pattern. Spring buoys were slipped and anchor lines cut, and the ship moved off location." [p. A49]

In fact, cutting torches were used to cut at least the two stern anchor cables, and the seafloor was left littered with a considerable collection of dropped, or abandoned, debris as the *TYPHOON* was moved very, very precipitously off location. Abandoned were the eight 15-ton main anchors, four 15-ton and four 10-ton piggyback anchors, 6 spring buoys each with a 3-in chain guide dangling below it and each attached to 3,500 ft of anchor cable and two stern anchor cables of 3,400-ft length. Also left was the blowout preventer (BOP) stack (with the shear rams closed to shut-in and temporarily suspend the well), five guide lines (one of which was entangled in 6 lengths (200 ft) of 20-in casing), two T.V. lines and eight diver lines, all 600 ft long, 500 ft of the choke line and a 60-ft piece of the kill line and a 300-ft length of hose and cable attached to the Yellow POD on the BOP stack -- all strewn across the ocean floor (Verlet and Duval, 1972).

TYPHOON and its rig supply vessels rode out the storm, then attempted over a 24 hour period to move back into position as the storm appeared to be abating. It was not to be; the Labrador summer drilling season was over, and the storm re-intensified. By now it was September 30, 1971, and the well was declared as "temporarily suspended" and *TYPHOON* set sail for St. John's at 0200, its drilling season over; it was demobilized in St. John's on October 2, 1971 and released on October 8th. No company ever again attempted to use an anchored drilling platform off Labrador, or anywhere in iceberg-infested waters, with all subsequent holes drilled from dynamically-positioned drillships. Tenneco Oil & Minerals, Ltd. relinquished its interests off Labrador later in 1971, and Eastcan Exploration Ltd., one of the Tenneco partners and a subsidiary of Total Energy of France, became the operator of what was then known as the Eastcan Exploration Group.

As for the assessment and the cleanup of the Leif E-38 site, that remained until the next year in 1972 when Eastcan Exploration Ltd. hired the *NEWFOUNDLAND HAWK* and the *HUDSON HANDLER* as the mother ship of the *PISCES I* submersible, and did a major sidescan sonar, video and photo survey of the Leif E-38 and L-38 debris sites including five dives of the *PISCES* submersible (Dives Nos. 671 to 675) (Verlet and Duval, 1972; Biscarrat *et al.*, 1972). Cleanup and removal of the debris occurred in 1973 using heavy lift equipment. The Leif E-38 well was finally plugged and abandoned in late July 1973 during a week-long operation by the dynamically-positioned drillship *PELICAN*. The errant 1971 Hamilton Bank iceberg had cost $1.3 million in extra costs, and the Leif E-38 well never was reentered and never reached its projected TD.

Tenneco Oil & Minerals Ltd.'s 1971 program to defend their anchored drilling platform from icebergs had been preceded by a minor experimental iceberg towing program as early as 1970 (Duval *et al.*, 1970; Ainslie and Jewett, 1970), conducted by the French Compagnie Française des Pétroles (CFP), and a major program earlier in 1971 by Eastcan Exploration Ltd., one of the partners with Tenneco on the oil and gas acreage off Labrador. In late April 1970 CFP with Marine Exploration Ltd. as consultants, had contracted the *ARCTIC EXPLORER*, a 300 HP wooden coastal trading vessel that was "completely unsuitable for serious towing" for a single experimental tow off southwest Greenland (Marine Environmental Services Limited (MAREX) 1972; Appendix III, Log of Previous Towing Experiences). This single screw vessel used a 60 mm diameter polypropylene mixture berthing warp shackled to a 35 mm towing wire (MAREX, 1972; Appendix I).

The experiment claimed to have moved a 135,000 ton iceberg, of an 80 m waterline length and a 19 m height above sea level, a distance of 61.2 m at speeds of 0.076 to 0.037 m/s with an estimated operational bollard pull of 1.4 tons (Appendix 1). The wind strength was not recorded, and there was no measurement of the current strength and direction (Appendix 1; MAREX, 1972). It is difficult to know how CFP could possibly have known the true effect of the towing effort over its 17 minute duration in the absence of the knowledge of the ambient current, or of the tidal current, in the area, both of which would have been tending to also move the iceberg. Regardless, the CFP 1970 experiment does qualify as the first attempt by the petroleum industry to tow an iceberg.

The 1971 Eastcan Exploration Ltd. iceberg towing program was again off southwest Greenland close to Tovqussaq Bank at 64°06'N, 52°13'W using the *LADY OF ESSEX* as a mothership and the Danish tug *SIGYN* as a towing vessel. Five icebergs were towed in six attempts from May 30 to June 5, 1971 (Appendix I; MAREX, 1972). The first iceberg towed was a grounded iceberg, and the attempted tow did not budge it (Appendix I). One of the attempts saw the towing hawser slide up to the peak of the berg and apparently turn the iceberg over; the towing line was rehooked up to then try to tow the rolled iceberg. Icebergs from 10,000 to 200,000 tons, from 20 to 87 m waterline length, and iceberg heights of 9 to 20 m were measured as having been towed at speeds of 0.24 to 1.46 kts (0.124 m/s to 0.752 m/s) over periods of 2.0 to 7.5 hours with operational bollard pulls of 10.0 to 13.0 tons (Appendix I; MAREX, 1972). The learning from these four successful towing efforts was presumably communicated to Tenneco Oil & Minerals Ltd. that was to try its first iceberg tow on June 29, 1971, some 3.5 weeks later on the Leif wells off Labrador.

As Eastcan's 1971 southwest Greenland program was underway, a second 1971 iceberg towing program was being mobilized in St. John's by the relatively new Faculty of Engineering and Applied Science at Memorial University of Newfoundland (MUN). Angus A. Bruneau had been recruited in July 1968 to set up the new Faculty of Engineering. He hired John H. Allen in the fall of 1969, and Allen was chief scientist on the first iceberg cruise of the Faculty of Engineering run on board the M.V. *BEINIR* chartered from the local College of Fisheries in the summer of 1970; the cruise report from this first MUN iceberg cruise has so far not been located, and may well be lost to history. What Bruneau recalls about that cruise is that it observed two icebergs moving in different directions at the same time such that their paths crossed. The icebergs were clearly of different drafts, and were being moved by varying cross-sections of the current. This said to Bruneau that "the study of icebergs will be an interesting intellectual activity" (Bruneau, personal communication, March 21, 2005).

Angus Bruneau recalls the birth of the idea to try to tow an iceberg quite clearly (personal communication, November 19, 2004 and March 21, 2005). It came in a conversation with William E. (Bill) Markham of Ice Forecasting Central, then in Halifax, Nova Scotia, when one or the other asked, "Can one tow an iceberg?" In the Fall of 1970 Angus Bruneau and the new Faculty of Engineering and Applied Science at MUN had hosted a dinner for the CEOs of the Calgary oil companies. The affair at the Palliser Hotel in Calgary attracted a few key CEOs, including Bob F. Abernathy of Amoco Canada Petroleum Company Ltd. -- the first company to drill an offshore well on the Grand Banks under its former name PanAmerican Petroleum; the Tors Cove No. 1 wildcat well spudded on June 7, 1966 with no care and no plan for iceberg management, or indeed no plan for ice management. Angus pitched his new engineering faculty and its embryonic coop program for students, and he pitched the university's growing interest in the ocean.

Abernathy invited Bruneau to visit Amoco's offices early the next morning, and he encouraged him to think about icebergs and to develop a proposal relevant to the offshore oil industry. The conversation with Bill Markham of Ice Central followed. The key negotiations then took place in the old Laurentian Hotel in Montréal where Angus Bruneau met with Percy M. Crosbie, the C.E.O. of Chimo Shipping of St. John's, along with Chimo's marine manager, Neils Jorgenson, who had successfully landed an oil exploration drilling rig on Sable Island where others had failed. Bruneau returned to Calgary to meet a select group of participants that Abernathy had assembled. Bruneau put forward what was at that point a two-ship, $350,000 proposal to tow icebergs with the second vessel being used as a stable platform from which to measure wind and currents and from which to track the iceberg movements (Bruneau, personal communication, March 21, 2005). At that meeting the oil company executives also formed the Eastcoast Petroleum Operators Association (E.P.O.A.); Bob F. Abernathy was chair and Denny E. Duff was the vice chair.

Eastcan Exploration Ltd. was skeptical of the proposed Memorial University iceberg towing experiment in what came to be known as the Iceberg Dynamics Project. Regardless of one member's reticence, the E.P.O.A. commissioned the project for the summer of 1971 as E.P.O.A. Project No. 2, but with a budget that was to be held to $300,000 (personal communication, Angus A. Bruneau, November 19, 2004). B.F. Abernathy (1971), in a December 6-7, 1971 presentation to the 'Canadian Seminar on Icebergs', as the Chair of the E.P.O.A., noted that the Amoco Canada Petroleum Company Ltd. was the operator of E.P.O.A. Project No. 2, and Imperial Oil Limited, Mobil Oil Canada Ltd. and Canadian Superior Oil Limited were the other funding participants with a cost of $215,000. At the same seminar in answering a question on the cost of the 1971 program Robert Dempster responded, "Two ships were proposed but due to budget restraints only one ship was used." Angus Bruneau later noted in the same session that, "Approximately $215,000 was spent on the cruise ..." (Bruneau and Dempster, 1971; p. 127). When I asked Angus Bruneau about the reduced cost, he noted that their discovery of the availability of a photo-plot radar system allowed Memorial University to reduce the experiment to a one-ship operation. He also suspects that the time of a lot of the salaried MUN personnel did not get charged to the project to reach the lower direct cost (personal communication, March 21, 2005).

Eastcan could not have been too skeptical because very shortly they carried out their own two-ship iceberg towing project off southwest Greenland from May 30 to June 5, 1971 before the Memorial University experiment even began! Abernathy (1971) also reported that the E.P.O.A. had bought into Eastcan Exploration Ltd.'s (actually la

Compagnie Française des Pétroles' (CFP), an owner of Eastcan) already-completed 1969 study as E.P.O.A. Project No. 3. This project comprised four reports, the fourth of which was entitled, '*The towing of icebergs to protect offshore drilling platforms*'. Eastcan was operator for this study, and Tenneco Oil & Minerals Ltd. along with AGIP Canada Ltd. were the participant members of the E.P.O.A.

It was Jean Duval *et al.* (1970), then of Compagnie Française des Pétroles, who first announced the oil industry's initial experiment to tow an iceberg in the October issue of *Petroleum Engineer International* with no details:

> During a recent Arctic offshore reconnaissance by a CFP/MAREX team a small iceberg was successfully towed in order to confirm the calculations of the 1969 study. Measurements were made of towing force, iceberg size, acceleration and maximum speed. [p. 18]

It was in his December 1970 report to the 'Canadian Seminar on Icebergs' that B.F. Abernathy presented the first brief technical information on la Compagnie Française des Pétroles' April 1970 attempt to tow an iceberg (Abernathy, 1971, p. 97 under E.P.O.A. Project No. 3; barely two-and-a-half lines of text with few details). Angus Bruneau does not recall either CFP, or its successor, Eastcan Exploration Ltd., ever providing Memorial University any iceberg towing data or experience from either the April 1970 initial towing effort by the *ARCTIC EXPLORER*, or from their two-ship effort in May-June of 1971 off southwest Greenland using the *LADY OF ESSEX* and tug *SIGYN*. In fact Bruneau did not even know that Eastcan had run its May 30 to June 5, 1971 five-iceberg towing experiment off southwest Greenland until March 2005 when he returned to St. John's to find my February 22, 2005 letter written to him to explore some further questions! (personal communication, March 21, 2005) Such was the academic-industrial divide in the early 1970s, even in an engineering faculty!

The Memorial University May 24 to June 19, 1971 iceberg towing cruise on board the *PERCY M. CROSBIE* of Chimo Shipping of St. John's attempted seven tows, one off Cape St. John off northeast Newfoundland and six off the Grey Islands (Groais and Bell Islands) east of the North Peninsula of Newfoundland (Appendix I; Bruneau and Dempster, 1972a). Icebergs ranged from a mass of 292,000 tons for iceberg No. 7E, dubbed 'Annette', to iceberg No. 9A, called 'Whalesback', that was estimated to have a mass of 85,000 tons. The maximum waterline lengths ranged from 85 to 114 m, while the iceberg heights above sea level ranged from 8 to 34 m. Bollard pulls ranged from 8 to 26 tons (Appendix 1; Bruneau and Dempster, 1972a; b; Bruneau *et al.*, 1974?; Dempster and Bruneau, 1973). On a fourteen-minute video the Memorial University Faculty of Engineering (c. 1972) narrator gave the tow line tension range as 26,000 to 35,000 lb (13 to 17.5 ton). Unlike an iceberg towing operation designed to defend an oil rig, Memorial University had the luxury of choosing its icebergs so as to avoid those that appeared difficult to tow or potentially unstable; it could also choose the best weather to some degree.

Even so, one tow of iceberg No. 13A, or 'Mary Ellen', was interrupted when the iceberg calved and rolled, throwing off the towing wire. The next day the same berg was put under tow again, and appeared to rock dangerously on several occasions during the six-hour tow (Appendix I). The *PERCY M. CROSBIE* returned to port in St. John's on June 16, 1971 after being at sea for 18.5 days of a 27-day engagement (Appendix 1).

While the *PERCY M. CROSBIE* had been at sea, Memorial University's second iceberg cruise had taken place from June 2-12, 1971 on board the Bedford Institute of Oceanography C.S.S. *DAWSON* cruise 71-021. Dr. John H. Allen was Chief Scientist on the cruise that worked mainly on Ritu Bank east of the Grey Islands off northeast Newfoundland. Erik Banke of the Bedford Institute of Oceanography was responsible for an experiment to try to determine the drag coefficients of the bottom surfaces of ice floes by towing them and measuring bollard pulls (Allen, 1971). No ice floes could be found in the working area, so a 0.5 hr tow of a 'small growler' was carried out on June 11, 1971 using a launch from the *DAWSON* and a load cell. Positions were difficult to determine, but Banke confidently stated in the *DAWSON* 71-021 cruise report (Allen, 1971) that, "It is apparent that ice-flow towing could be extremely useful in 'direct' determination of bottom drag" (p. 31). Peter Benedict, as an engineering participant on this cruise, was to later write a paper on a proposed new harness system for towing small domed icebergs, or growlers (1978). The two Memorial University cruises finished just shortly before Tenneco Oil & Minerals Ltd. *et al.* mobilized its three rig supply boats *SMIT-LLOYD 7*, *CAY W* and *SAN JACINTO* to provide iceberg protection for the real thing -- the drilling of the Leif wells from the drillship *TYPHOON*.

The Tenneco *et al.* 1971 drilling operation involved almost three months on Hamilton Bank (Duval, 1971; Marine Exploration Limited (MAREX), 1971, [1972]; Marine Environmental Services Limited (MAREX), 1972). Five iceberg tow attempts were carried out, and on one occasion the removal of a bergy bit was achieved by butting it out of the mooring buoy pattern using one of the rig supply vessels. The five icebergs towed ranged from "small" to 500,000 tons, with waterline lengths from "not recorded" to 90 m and iceberg heights of "not recorded" to 18 m, with operational bollard pulls of 10 to 40 tons using two-ship tows on three occasions and a single ship tow on the other two occasions (Appendix 1). Three of the five icebergs rolled with the line fouling the propeller on one occasion and the line parting on two occasions. Only one of the five tows could be deemed a successful tow over 1.25 hrs. Only once did Tenneco record the full set of specifications for an iceberg (Appendix 1).

There were three dispatches of the Tenneco towing vessel when a tow did not result. Early in the drilling season when one of the towboats was mobilized and no tow resulted on July 27, 1971, it was decided to abandon the P-48 site, not only in part because the well was not progressing because of a problem with boulders -- a problem at six of the seven sites when *TYPHOON* attempted to spud the various Leif wells -- but also because an iceberg was approaching the rig (Marine Exploration Limited, [1972], Section 6, p. 35). The last of these "no tow" occasions was on September 26, 1971 when in very rough weather a tow could not be successfully rigged up for some four hours, and a decision was made to precipitously abandon the final E-38 site. Thus errant icebergs drove *TYPHOON* off its drilling location on two occasions.

In summary, during the first four field programs to tow icebergs by, or for, the petroleum industry in 1970-1971, 18 icebergs were "towed". Their estimated masses ranged from "small" and from 85,000 to 500,000 tons, maximum waterline lengths were from 20 to 114 m, iceberg heights varied from "small" and from 8 to 61 m, with the towing vessels using bollard pulls from 1.4 to 40 tons. The durations of the tows were from "a few minutes" and from 0.25 to 7.25 hours. In the 1971 more serious towing efforts, five of the 17 towing efforts resulted in icebergs rolling, and in two cases breaking up or "foundering down"; a propeller was fouled immobilising the rig supply boat on one occasion when an iceberg rolled while Tenneco was defending the Leif wells (Appendix 1 and Table 1 below).

No. of Tows	Duration of Tows (hr)	Masses of Icebergs (ton)	Waterline Length of Icebergs (m)	Operational Height of Icebergs (m)	Bollard Pulls (ton)	Comments
late April 1970 Compagnie Française des Pétroles off southwest Greenland						
1	0.28	135,00080	19	1.4		very brief, no current data
May-June 1971 Eastcan Exploration Ltd. off southwest Greenland						
5	1.6-7.25	10,000-200,000	20-87	9-20	10-13	one iceberg rolled
June 1971 Memorial Univ. of Newfoundland, E.P.O.A. Project No. 2, northeast Nfld.						
7	2.4-6.75	85,000-292,000	85-114	8-34	8-26	one iceberg rolled and calved
June 1971 Memorial Univ. of Nfld. and Bedford Inst. of Ocean., northeast Nfld.						
1	0.5	n/a small growler	4	≈ 1.5	n/a	towed with ship's launch
July-September 1971 Tenneco Oil & Minerals Ltd. *et al.*, Leif wells, Hamilton Bank						
5	0.25-1.9	"small"-500,000	"not recorded" 44-91	"not recorded" 12-61	10-40	3 icebergs rolled, one twice, 2 bergs broke up
August 1972 Memorial Univ. of Nfld. and Bedford Inst. of Ocean., off Saglek, Lab.						
3	2.0	"small" 680-1,032	5.2-15.5	2.1-2.6	1.1-2.6	2 bergy bits rolled over 2 tows of 2 hr 3.4 to 3.8 n mi

Table 1: Review of 1970-1972 Petroleum Industry-University Iceberg Towing Field Programs

It is worth noting that Memorial University's success with its E.P.O.A. Project No. 2, Iceberg Dynamics Project, gave Angus Bruneau the confidence in late 1971 or January 1972 to write an unsolicited negotiated grant proposal for an Ocean Engineering group at Memorial to the National Research Council. He was chastised for not having talked to the Council in advance during the proposal preparation, but it then turned around and granted Memorial $500,000, their largest such negotiated grant to that date. Bruneau's proposal to establish C-CORE (Centre for Cold Oceans Resources Engineering) was to shortly follow and win approval of the Memorial University board (Bruneau, personal communication, March 21, 2005).

Memorial only tried towing glacial ice on one other occasion. Its third iceberg cruise, *DAWSON* 72-022, August 7-26, 1972, worked off Saglek Bay, northern Labrador. J.W. Gorman of the Bedford Institute of Oceanography attempted three tows of bergy bits on August 12th, 13th and 16th, again to measure drag coefficients. The first attempt was abandoned as the sling kept coming off as the ice rolled. The second and the last tow each lasted two hours with final tow being terminated as the sling slipped over the top of the bergy bit. Average tow speeds of 1.48 and 1.67 knots were achieved over 3.4 and 3.7 n mi respectively.

By the time of the *DAWSON* cruise of the next year, the Ocean Engineering Group had been formed at Memorial. The cruise experimented with measuring the underwater shape of icebergs using sonar techniques, but no tows were contemplated. While Ocean Engineering and C-CORE quickly moved on from iceberg towing, these two groups have remained viable for the past 34 years and have ensured that Memorial University has remained a significant actor in the marine engineering field in Canada.

When drilling returned to the Labrador Banks in 1973 with the drilling of Eastcan *et al.* M-48 wildcat exploration well closeby to the aborted Leif E-38 well of 1971 using the D/V *PELICAN*, each dynamically-positioned drillship situated in iceberg-infested waters was accompanied by specially-equipped rig supply vessels that were available to attempt to control icebergs. The vessels were equipped with towing hawsers instrumented with tension meters to allow the tow captains to monitor the towline and to prevent breakages. Icebergs up to about 1,000,000 tons were not actually 'towed' so much as 'steered', or slightly diverted, from their mainly current-controlled path. Iceberg management has become more sophisticated, with iceberg drift tracks now being predicted on the drilling platform using both the ocean and tidal currents' forces on the iceberg's keel and the wind's forces on the iceberg's sail, along with improved current and wind prediction algorithms. We still don't 'tow' icebergs, but we have become better at nudging them to minimize the risk to the drilling rigs. In addition, the orange 'caution' zones have been expanded in size so that potential remedial action is taken sooner.

But was the east coast Canadian oil industry the first to have a go at towing icebergs? It appears not.

It was in late 1924 that George W. Gray interviewed Captain William George Squares deCarteret, formerly of the cable repair vessel *MINIA*, by then a veteran of marine telegraph cable repairs of 'thirty-five years' experience' and then the marine superintendent of the Western Union cable depot in Halifax, Nova Scotia. Gray quoted an anonymous 'cable expert' as saying, "He has made more than four hundred repairs, and he knows the Atlantic bottom better than most of us landlubbers know our little strip of turf." No wonder that Gray titled his 1925 article *'The Bottom of the Ocean Is "Main Street" to Him'*.

Captain deCarteret, through Gray, gives a very readable account of the problems that a cable repair ship has to contend with, including fields of pack ice that may cover an area where a repair is needed and including icebergs. W.G.S. deCarteret is quoted:

> Every now and then an iceberg sits on a cable and grinds it against a rocky bottom until the cable is flattened out like a piece of tape. The first berg I tried to handle was one that had settled on a cable off Newfoundland. We threw a rope over a point which projected above the water, and proceeded to try to tow the iceberg out to sea. At the first bit of strain, however, the iceberg foundered, turned turtle with a mighty splash that sent out waves like the sinking of a great ship. Incidentally the cable was freed, and we were able to get to it. [Gray, 1925; p. 131, col. 2]

Other information has recently come to light that lets us put at least an approximate date on at least one of Captain deCarteret's attempts to tow an iceberg. Three members of the Titanic International Society, Inc. recently visited the U.S. National Archives and Records Administration in downtown Washington, D.C. in the Fall of 2003 to try to locate the records of Senator William Alden Smith's 1912 U.S. Senate investigation into the sinking of the *TITANIC*. This effort was not successful, but serendipity intervened, and the team came onto other documents dealing with the recovery of the bodies of *TITANIC* victims. In one case the three-person Titanic International team located data on an up-to-now-unknown vessel that had recovered a *TITANIC* victim's body and buried it at sea from the *SS OTTAWA* as late as June 6, 1912 (Haas [*et al.*], 2003; Ruffman, 2004). They also located other data in the U.S. Hydrographic Office's correspondence files on the *MINIA*, one of the four Canadian vessels that were chartered by the White Star Line to engage in the search ([Haas [*et al.*], 2003).

I have seen photographs of transatlantic cables damaged by iceberg scouring referred to as 'iceberg crush'. The iceberg generally does not spontaneously 'sit on a cable' or 'settle' on a cable as deCarteret suggests, but rather the drifting and somewhat metastable iceberg grounds, then has been moved by the currents and wind so as to drag its keel across the ocean floor making a broad 'iceberg scour' and crushing any telegraph cable it may encounter.

On May 4, 1912 Lieutenant Commander W.L. Littlefield, an Acting Hydrographer, and Captain John J. Knapp, Hydrographer, detailed to assist the U.S. Senate inquiry, telegraphed to Captain Frederick Harold Larnder of the Cable Ship *MACKAY-BENNETT*, the first vessel sent to recover bodies, and to Captain W.G.S. deCarteret of the second vessel, Cable Ship *MINIA*, also sent out from Halifax. The two U.S. Navy Hydrographers made a request for "a detailed account of your experience in locating bodies and wreckage. ... also what ice you encountered and whether you were able to observe the drift of any particular field [of pack ice] or berg ...".

Only Captain deCarteret of the Anglo-American Telegraph Co. Ltd. is known to have responded to the May 4th request. Captain W.G.S. deCarteret replied with a detailed three-page single-spaced typed letter on May 8, 1912, noting the drift of the bodies, drift of the icebergs, water temperatures, the location of the Gulf Stream, and noting that, "All bodies recovered in the cold water were frozen and had to be thawed in the sun before embalming; but one [Body No. 16] found on the edge of the [Gulf] stream [further to the east] was soft, and decomposition had set in." [deCarteret, 1912; p. 3 of May 8, 1912 letter]

Of more interest are Captain deCarteret's comments on the icebergs' constant movements and his experience in attempting to 'tow or cant them'. He stated on May 8, 1912:

> In my cable work during the early months of the year between Jan 15th and March 31st, [1912,] East and N.E. of Newfoundland, I have had to force a passage through heavy Arctic field ice for over 150 miles; and on two or three occasions have actually repaired a cable in a large lake of clear water, with heavy ice all around the horizon, which closed in just as the repair was completed. It has been necessary to attach hawsers to icebergs and tow or cant them so they would not ground on a cable and crush it; and I have known them to ground on the Banks of Newfoundland in 42 fms and crush a cable; but I have never known them to remain in or near the same spot for even 12 hrs unless they were near the shore on rocks or shoals. Therefore it is apparent that positions of icebergs given to a Captain are merely in the nature of a warning that they are around. [deCarteret, 1912; p. 2]

I believe that we can take Captain deCarteret's letter to the U.S. Navy Hydrographer in the U.S. Navy Hydrographic Office as sufficient evidence that the *MINIA*'s efforts to 'tow or cant' an iceberg predate the iceberg towing work of Eastcan Exploration Ltd., of Memorial University of Newfoundland, of Tenneco Oil & Minerals, Ltd., and of other east coast oil and gas exploration operations in the 1970s by some 58 years -- still a Canadian first, however.

Very, very little work has been done on the original records of the early cable repair ships such as *MINIA* and *MACKAY-BENNETT*, and indeed many, if not most, of the records may now be lost. It is clear that 'iceberg crush' on a cable was well known to the early cable companies. Photographs of such damage survive, and from Captain deCarteret's words above he had realised that icebergs grounded on the Grand Banks, and that if the grounded iceberg keel encountered a cable it did significant damage and necessitated a repair. Indeed, *MINIA* had been active on just such a repair just off the east coast of the Avalon Peninsula of Newfoundland immediately prior to its return to Halifax in mid-April 1912 when it was contracted as the second vessel to go to the *TITANIC* loss area to try to recover the bodies of victims (Ruffman, 1999).

It appears to me that Captain deCarteret had also recognised as early as 1912 that the icebergs that ground on the Grand Banks are often metastable, and that in effect such bergs at times can be 'canted', or tilted, to reduce their pressure on the seafloor and on a cable. This realisation was not put to paper in any formal sense, as far as I know, until Geomarine Associates Ltd. carried out three wellsite surveys on the Labrador Banks (Fig. 1) for Eastcan Exploration Ltd. in July-August 1975 (Geomarine Associates Ltd. [Ruffman], 1975). The Bjarni H-81 wellsite survey on Makkovik Bank (Fig. 1) documented a 2.4 km long, 40-60 m wide iceberg scour passing downhill into a shallow, linear, NW-SE trending, 13 m deep, topographic low, then back upslope out of the low (Geomarine Associates Ltd. [Ruffman *et al.*], 1976a). This February 1976 Bjarni wellsite survey interpretation was just not accepted by the operator Eastcan Exploration Ltd. at the time.

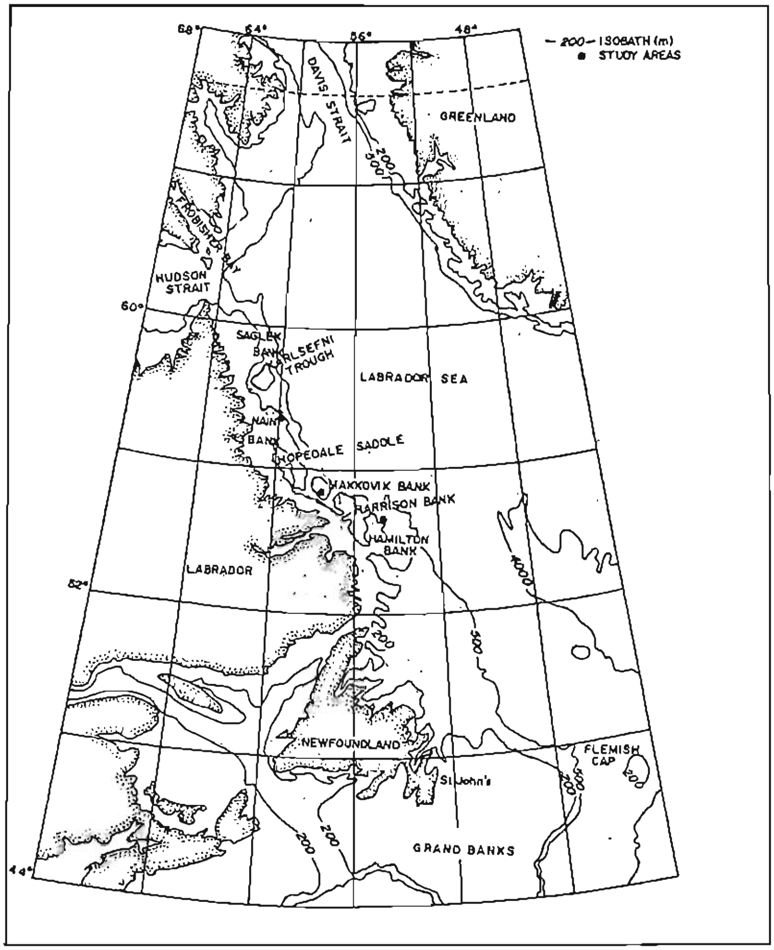

Figure 1: Location map of the three 1975 Eastcan Exploration Ltd. wellsite surveys modified from Woodworth-Lynas, Bass and Bobbitt (1986) showing the 200 m and 500 m bathymetric contours off Labrador. The northernmost black dot is the Snorri J-90 survey on Nain Bank, the middle dot is the Bjarni H-81 survey on Makkovik Bank, and the southernmost dot is the Gudrid H-55 survey on the northwest edge of Hamilton Bank on the edge of Cartwright Saddle.

The company personnel, mainly from Total Energy in Paris, could not conceive how an iceberg could scour down into a 'protected' topographic low. There had been some echosounder 'tare-like' problems during the 1975 survey. Eastcan Exploration Ltd. required the survey contractors, Geomarine Associates Ltd., to reconstruct and to reinterpret the Bjarni 1:20,000 wellsite survey bathymetry map (Geomarine Associates Ltd. [Meagher and Ruffman], 1976) perhaps in the hope that the linear topographic low would flatten out. When the 1975 Snorri J-90 wellsite survey on Nain Bank (Fig. 1) was interpreted by July of 1976, iceberg scours were again found to clearly apparently scour upslope or downslope (Geomarine Associates Ltd. [Ruffman *et al.*], 1976b).

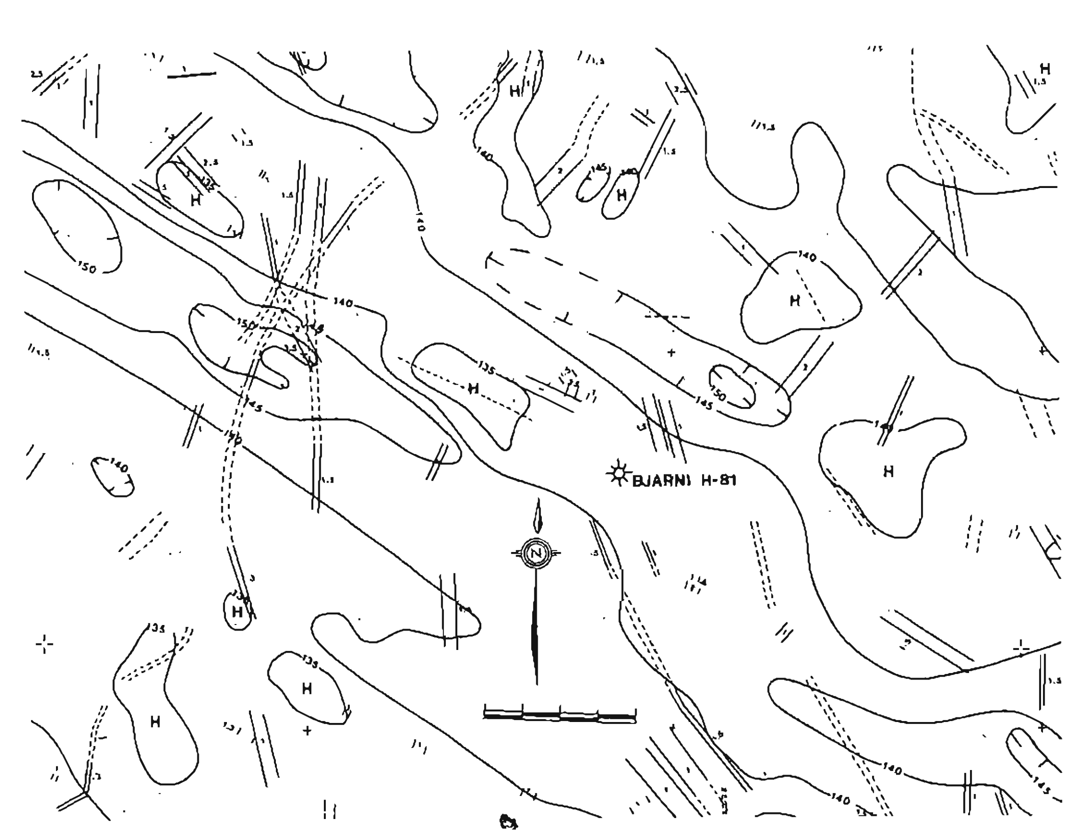

Figure 2: A portion of the September 1976 revised UTM bathymetry map from the Bjarni H-81 wellsite survey on Makkovik Bank carried out in August 1975 showing a 5 m contour interval with the sidescan-sonar-mapped iceberg scours overlaid as found in Enclosure 5 of Geomarine Associates Ltd. [Meagher and Ruffman] (1976). The iceberg scour depths below the seafloor in metres are labelled in the small numbers beside, or inside, the scours; they range from 0.5 to 3 m on this portion of the map. Scours with solid margins were observed on both the echosounder and on the sidescan sonar; dashed boundaries were observed only on the sidescan data. The scale bar is 800 m long. The hachure mark 700 m northeast of the wellsite is UTM 456,000 E, 6,152,000 N. The geographic position of the larger hachure mark in the southwest near the map's margin is 55°30'N, 57°45'W.

The painstakingly-redone Bjarni bathymetry map at a 5 m contour interval was completed in September 1976. It did not change the topography of the site survey, or the factthat sometime prior to the 1975 Bjarni wellsite survey a somewhat metastable iceberg had grounded on Makkovik Bank in about 137 m water depth, then had tilted a bit, or 'canted', in the direction of its drift and dragged its keel over the ocean floor of the bank (Fig. 2). It then righted a bit as its keel scoured down into the NW-SE trending shallow linear topographic low of some thirteen metres depth and across the bottom of the low. It then again 'canted' in the direction of drift as it scoured up and out of the linear low to a depth of 135 m and eventually passed off our postage-stamp-sized wellsite survey map perhaps after rolling and lessening its draft to float freely. The compiled 1:20,000 sidescan sonar map of the long, linear iceberg scours clearly showed one iceberg scour traversing the linear topographic low from one side to the other and continuously scouring over a seafloor elevation change of 15 m (Geomarine Associates Ltd. [Ruffman *et al.*], 1976a and [Meagher and Ruffman], 1976; Fig. 2).

On the Snorri J-90 wellsite survey (Fig. 1), the equally-as-carefully constructed 1:10,000 map of the bathymetry at a two-metre contour interval and the mosaic of iceberg scours overlaid on the bathymetry also showed clear evidence of icebergs that had first grounded in about 156 m of water depth on Nain Bank and scoured south or southeastward uphill to at least 146 m water depth over a change of 10 m (Geomarine Associates Ltd. [Ruffman *et al.*], 1976b). In fact, we could not actually tell the direction that the scouring iceberg had moved; the icebergs could well have been scouring downhill over an elevation change of 10 m, however the dominant direction of the Labrador Current is generally southward in this area which suggests that the icebergs were scouring upslope to make the iceberg scours mapped in 1975.

At both the Snorri and the Bjarni locations, the upslope or downslope iceberg scours interpreted on the sidescan sonar records of the day (1975) showed no obvious changes in width over their 10 m or 15 m elevation changes, respectively, that we could relate to the iceberg keel penetrating more, or less, deeply into the seafloor. Eastcan Exploration Ltd. never commissioned a bathymetry map to be made of the 1975 Gudrid H-55 wellsite survey area on Hamilton Bank (Fig. 1); had they done such a map, upslope and downslope iceberg scouring would have undoubtedly been seen (Geomarine Associates Ltd. [Ruffman *et al.*], 1976c).

The Snorri J-90 wellsite survey report of July 1976 included several diagrams of a floating iceberg to diagrammatically illustrate the process by which an iceberg had tilted, or 'canted', and been able to scour downslope, into a low, then upslope to leave the bathymetric low. In the wellsite survey report we gave our client three options for a process to explain the irrefutable seafloor evidence on the two sites where we saw upslope and downslope iceberg scour. We noted in the Snorri report (pp. 32-41; Geomarine Associates Ltd. [Ruffman *et al.*], 1976b):

To scour across [bathymetric] contours as we have observed in two sites, an iceberg must:

1. [ground and] come to a stop,
[then] 2. dig a progressively deeper scour as it proceeds "up-hill" (i.e., into shallower water),
[then] 3. break off a piece of the keel and stop scouring so deeply, or cease scouring altogether,
[or] 4. lift out of the water,
[or] 5. tilt and drag its scouring portion at a slightly shallower depth as the bottom rises,
[or] 6. a combination of all, or a number, of the above.

Chari and Allen (1972, 1973 and circa 1975) and Chari (1975) deal with the problem of iceberg scouring of seafloor sediments. They suggest that:

Any upward rise of the berg during the grounding process has to be discounted as even a small rise would result in a conversion of the kinetic energy into potential energy bringing the berg rapidly to a stop (Chari and Allen, circa 1975).

and in another paper:

In spite of its huge mass, because of the low velocity the entire kinetic energy of an iceberg will be transformed into potential energy for as small an elevation as an inch. If the berg were to move up the slope, it will come to a stop after a very short travel (Chari and Allen, 1972).

Chari and Allen appear to have used the equation:

potential energy	kinetic energy

$$mgh = \tfrac{1}{2} mv^2$$

and assumed the mass is equal [on both sides of the equation] hence:

$$h = \underline{\tfrac{1}{2} v^2/g}$$

Taking $v = 1$ kt $= 6080$ ft / 3600 sec $= 1.689$ ft/sec
and $g = 32$ ft/sec^2
then $h = 0.04457$ ft

The calculation of Chari and Allen (1972, circa 1975) would suggest no scouring can occur across [bathymetric] contours. However, they have forgotten that the iceberg is floating and that to lift it one metre out of the water does not require that the whole mass be lifted but rather that only a slab 1 metre thick and the area of the berg's horizontal cross section be actually lifted (Fig. 15 [in the original Snorri wellsite survey report; Fig. 3 here. We use this paper's figure numbers henceforth]). The analogy is that of a swimmer being able to partially lift a very heavy floating log out of the water, where on land, the same person would not be able to budge the same log. Thus [in] the equation:

$$mgh = \tfrac{1}{2} mv^2$$

The masses are not equal.

$$m_s g h_s = \tfrac{1}{2} m_b v_b^2$$

where m_s = mass of the slab lifted above sea level
m_b = mass of whole berg
[h_s = the thickness of the slab of the berg lifted above sea level]
and m_s = horizontal cross sectional area of berg at sea level x h_s x ρ_s = $A_s h_s$ [x density of the slab which we take as close to 1]
Hence: $h_s^2 = \tfrac{1}{2} m_b v_b^2 / A_s g$

For a typical large tabular berg, 14.7 x 10^6 tons of a 1400 ft x 700 ft size at the waterline, the kinetic energy at 1 kt is 6.5 x 10^5 ton ft^2/s^2. Using this size in the equation above were

$A_s = 1400 \times 700$ ft^2:
$h_s =$ 4.90 ft or 1.5 m (Fig. 3)

Thus, up to 1.5 metres of lift are possible. However, even the above corrected calculation ignores the fact that there may be a continuous source of kinetic energy acting on the berg through the wind (least effect), current (medium effect) or wind stress on dense pack ice (greatest effect). This constant source of energy would let a berg ride up even higher on a rising bottom.

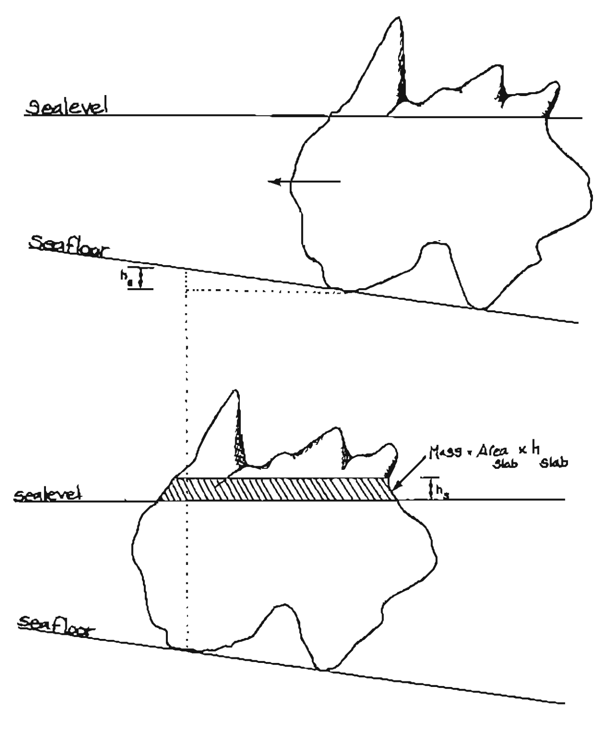

Figure 3: A cartoon from the 1976 Geomarine Associates Snorri J-90 wellsite survey report illustrating the conversion of an iceberg's kinetic energy to potential energy as the iceberg grounds and scours up, or rides up, a gently sloping seafloor so as to lift a slab of thickness h_s out of the sea.

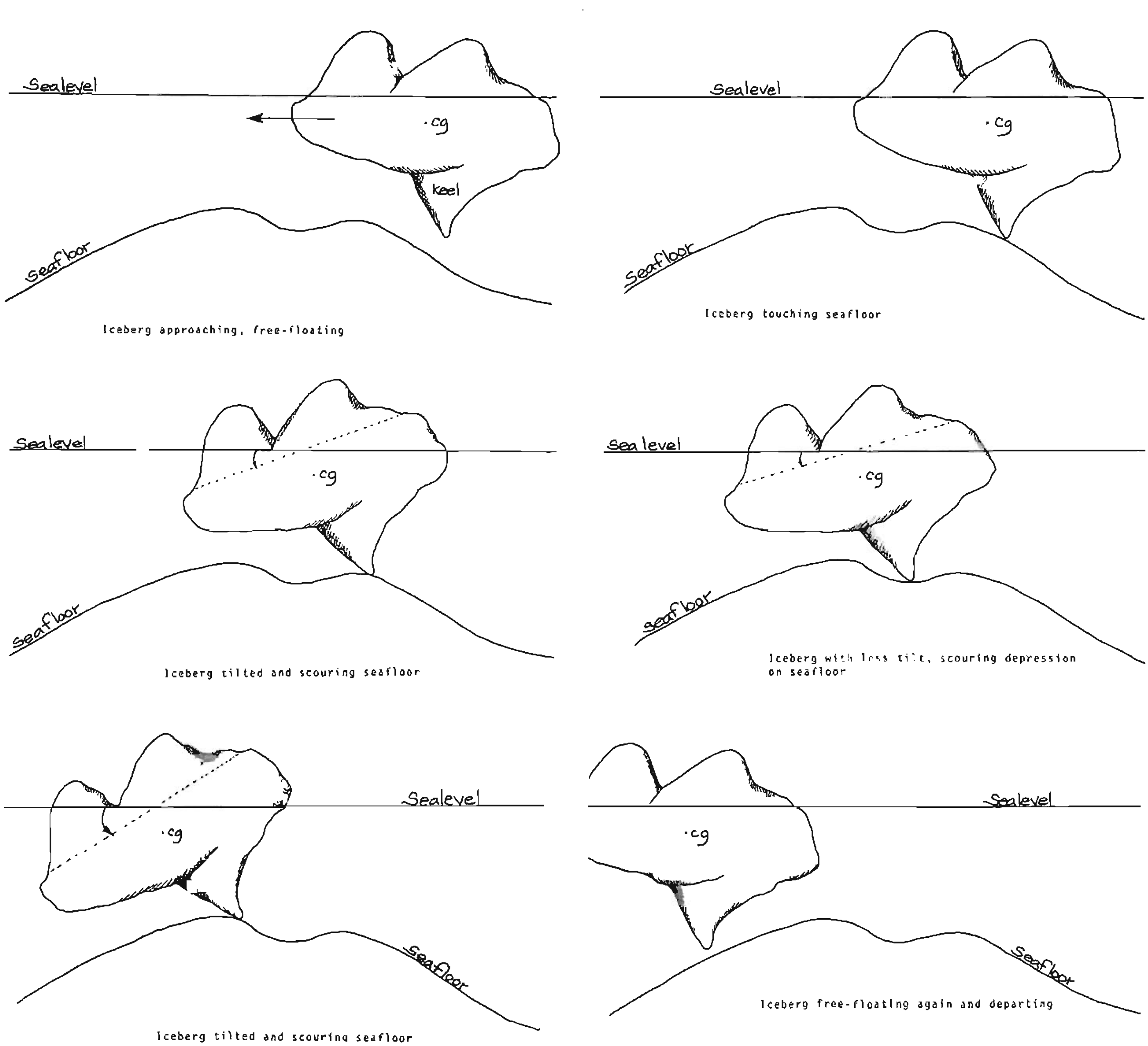

Figure 4: A cartoon collage of six figures taken from the 1976 Geomarine Associates Ltd. Snorri J-90 wellsite survey report showing an iceberg with a pronounced keel drifting into a topographic high on the seafloor, then rotating, or tilting, forward around its centre of gravity (cg) to drag its keel up and over the high, down into a minor topographic low and out again to finally float free all the time adjusting its angle of tilt, or 'cant', so as to keep its keel continuously scouring on the ocean floor.

However, we see scours apparently coming down one side of a low, across it and up the opposite wall. This leads to a third case different from the two above, i.e., that of converting kinetic energy of the iceberg into an initial tilting of the berg then into a partial lifting of a portion of the iceberg as it "drags its tail" or keel about on the ocean floor (Fig. 4). This process could occur with rounded, pyramidal, pinnacled and ridged and with horned and winged bergs, but would not occur with the blocky or tabular icebergs. The ability to scour in depressions will therefore be lowest off Greenland and Baffin Island [where tabular icebergs are most common] and will increase as the bergs progress south, melt, roll and develop a variety of shapes - hence, the potential to have keels. One would also expect the width and shape of the iceberg scours to progressively change to the south.

In the Snorri area, the median width of measured scours _ 0.9 m [in depth] was about 30 m and depths between 1-2 metres, thus the scouring face of the keel is generally about 30-60 m².

An iceberg that impinges on the bottom (Fig. 4) and tilts will tilt about its centre of gravity [cg]. Its ability to tilt will be defined by the spatial relationship between the centre of gravity and centre of buoyancy hence the iceberg's shape (Fig. 4). If the relationship is such that the friction of the bottom can exercise sufficient torque to tilt the berg without fracturing the keel (Fig. 4) then the berg can proceed without grounding [to a stop] and make a scour over a [topographic] high [on the seafloor]. As the berg scours over the high, the continuous input of energy from wind, current, or pack ice, must be sufficient to constantly overcome the energy losses in scouring or else the berg will stall and eventually ground [to a stop].

If a depression is encountered by a scouring berg, then it will tend to straighten up (Fig. 4) but will continue to scour the bottom with the keel. When eventually the berg reaches deeper water, it will regain its equilibrium position and continue to float freely (Fig. 4).

We have tried in a simplistic way to illustrate the tilting phenomena in Fig. 5. Here the berg has rotated a few degrees about its centre of gravity. What the figure illustrates is that the volume of ice submerged in the tilting is almost the same as (in fact slightly less than) the volume of ice lifted out of the water. The analogy is a "deadhead" found in any logging lake or port. The last stage before a deadhead log sinks is one wherein the log floats vertically with little of the log above water. Practical experience of log salvage companies indicates that it takes very little energy for a diver to push the lower submerged end of the log about. Similarly, relatively little energy is required to tilt the berg. A metastable berg that had a long period of roll would presumably be even easier to tilt and would be an even more efficient berg for scouring in depressions.

Thus we demonstrated in the Snorri wellsite survey report of July 1976 that much more scouring over elevated relief, or 'overscouring', was possible in a seafloor iceberg scour than the 0.013 m indicated by Chari and Allen (1972, 1973, circa 1975), or Chari (1975), or the 1.5 m indicated by our slab calculation above. We had demonstrated at least 10 m of 'overscouring' on the Snorri J-90 wellsite survey and at least 15 m of overscouring on the Bjarni H-81 wellsite survey, both carried out in 1975. We concluded in July 1976 in our Snorri report to Eastcan Exploration Ltd. "Thus if our suggestion of a berg's ability to tilt is correct, depressions cannot be considered safe from iceberg scouring in the southern parts of the so-called "iceberg alley". The findings may be different for northern areas because of differences in berg shape and stability". (p. 41, Geomarine Associates Ltd. [Ruffman *et al.*], 1976b)

The Bjarni and Snorri iceberg scour data led me to introduce the term iceberg 'harrowing', rather than iceberg 'ploughing' or 'scouring', in talks given in 1979 and 1982 (Ruffman, 1979; 1982; later 1985). The term 'harrowing' has not stuck. However the work of Chris Woodworth-Lynas and others at the Centre for Cold Ocean Resources Engineering (C-CORE) at Memorial University of Newfoundland has more than solidified the realization and acceptance that icebergs can, and do, scour upslope and downslope over considerable seafloor elevation changes. Woodworth-Lynas (1983) showed that iceberg scours could be grouped and separated into families by their crosscutting relationships perhaps reflecting changing ocean current and tidal currents over time. Bass and Woodworth-Lynas (1986; 1988) looked at iceberg crater marks, crater chains, upslope and downslope scouring.

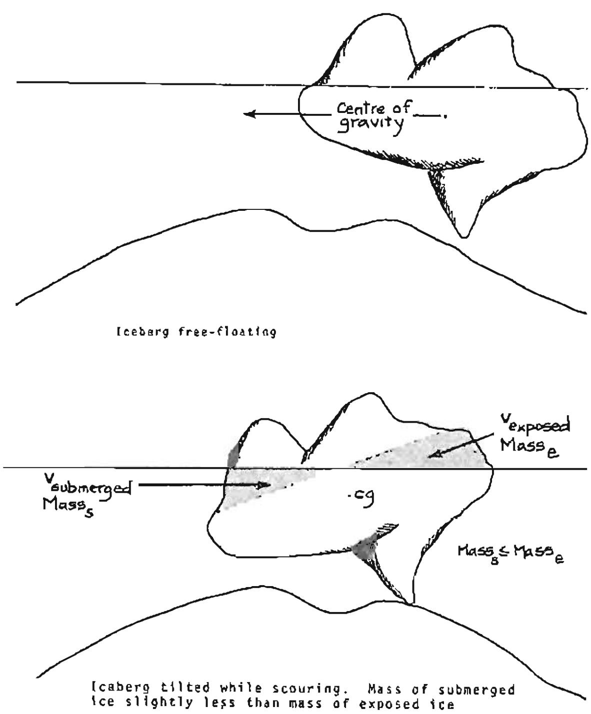

Figure 5: A cartoon from the 1976 Snorri wellsite survey report illustrating that when an iceberg grounds and slightly tilts forward around its centre of gravity to drag its keel over a topographic high on the sea floor, the mass of the submerged wedge of the iceberg is only slightly less than the mass of the wedge of the iceberg that is lifted out of the water.

Woodworth-Lynas, Simms and Rendell (1984a; b; 1985) dealt with iceberg groundings and scouring on the Labrador Shelf, while Woodworth-Lynas, Bass and Bobbitt in 1986 did a major inventory of upslope and downslope iceberg scouring mainly on the south Baffin Island and Labrador shelves using oil company wellsite survey data, radar tracking of icebergs from dynamically-positioned oil rigs while drilling exploration wells and, in one case, data from a specific 1985 iceberg scour survey program sponsored by the Environmental Studies Revolving Funds (DIGS - Dynamics of Iceberg Grounding and Scouring Experiment; Hodgson *et al.*, 1988). Woodworth-Lynas *et al.* (1986) went onshore on King William Island in Canada's Northwest Territories and looked at a relict ice scour that had overscoured over about a 5 m elevation change. This palaeo scour has been raised above sea level by post-glacial isostatic rebound.

Chris Woodworth-Lynas then gathered much of the work on ice and iceberg scour together in his Ph.D. studies at the University of Wales (1993), including the trenching of relict iceberg scours from the floor of the former glacial Lake Agassiz (Woodworth-Lynas and Guigné, 1990). A review paper by Woodworth-Lynas *et al.* (1991) appeared in *Continental Shelf Research*, with more work in the Strait of Belle Isle gathered during contract surveys looking for electrical transmission cable routes that would minimize the hazard presented by the scouring icebergs that are regularly flushed in and out of the channel by the diurnal tidal currents (Woodworth-Lynas *et al.*, 1992).

As it now stands, an iceberg 'overscouring' range of at least 20 to 30 metres has been seen in certain circumstances. An overscouring range of 35 m was recorded by radar tracking of scouring icebergs from the Rut H-11 drillship on Saglek Bank in 1981, and a range of 45 m was recorded from the drillship on the Bjarni H-81 well on Makkovik Bank in 1973 (Woodworth-Lynas *et al.*, 1984a; b; 1985). However, neither of these proposed long iceberg scours suggested by the radar-tracking of an iceberg from an oil rig were verified by sidescan sonar surveys. Woodworth-Lynas, Bass and Bobbitt (1986) have then gone on to discuss the 'theoretical modelling of upslope, [and] downslope scour' (pp. 71 onward) including the case of 'tilt' (pp. 87-97).

At least with respect to tilting of the iceberg during iceberg scouring, it now appears that Chris Woodworth-Lynas *et al.* and I must concede, in part, that initial realisation to Captain W.G.S. deCarteret of the Cable Ship *MINIA* in 1912. And certainly we must give credit to the *MINIA* and to its Captain deCarteret as being the first known vessel to try to 'tow or cant' an iceberg.

And to Charles R. Darwin?

Early on in his studies, Chris Woodworth-Lynas found a wonderful paper and quote by Darwin (1855) drawn from his Antarctic experience, that yet again shows the insight, or perhaps it was the intuition, of this renowned scientist (Woodworth-Lynas *et al.*, 1986; Woodworth-Lynas, 1993):

> ... in an iceberg 1000 feet [300 m] thick, as the whole floats, there will of course be no pressure on a surface exactly level with its bottom, and if driven over a prominence standing up at the bottom of the sea some 50 or 100 feet above the base line of the berg, only the weight of as much ice as is forced up above the natural level of the floating mass, will press on the prominence. It may therefore, I think, be concluded that an iceberg could be driven over great inequalities of surface easier than could a glacier. [Darwin, 1855; p. 97]

Darwin never saw the ocean floor of which he hypothesized. Indeed, no-one could even map the detailed shape of the ocean floor until the echosounder came along in the 1930s, some 75 years later. And no-one saw and recognised actual iceberg 'scours' until sidescan sonar mapping tools were put in use in the early 1970s to acoustically image the seafloor, some 120 years after Darwin's voyages.

Nevertheless, numerous nineteenth century scientists recognised that icebergs impacted on the floor of the ocean and hypothesized on the role of ice and iceberg scours as a geological erosional process. These early writers were not particularly concerned with the physics of the scouring iceberg, or with the engineering concerns that a scouring iceberg posed to anthropogenic cables or structures placed on the ocean floor. Rather, these early scientists saw the seafloor scouring of icebergs as an erosional process which over time would tend to level and flatten topographic highs on the bottom of the sea.

Woodworth-Lynas (1993) noted that Charles Lyell (1845; Vol. II, Chapter XXIII, pp. 144-146) and a Dr. Harding of Kentville, Nova Scotia (reported by Lyell, *op. cit.*; p. 147) had seen modern ice scour striations scribed in the soft Triassic sandstones at the base of Cape Blomidon, Nova Scotia, and ice scour marks developed on the tidal flats near Wolfville, Nova Scotia, respectively, both regularly revealed with the lowering of the large Bay of Fundy tides. He also notes that Archibald Geikie, with remarkable foresight as well, theorized the processes that should occur under an iceberg, and showed these in his original Figure 5 (Geikie, p. 84, 1865), which is the first known illustration of a scouring iceberg (see Woodworth-Lynas, 1993, pp. 3-5):

> When such current-driven masses grate along the sea-bottom they must tear up the ooze and break down and scratch the rocks. In the course of long ages a submerged hill or ridge may get its crest and sides much bruised, shorn, and striated, and the sea-bed generally may be similarly grooved and polished, the direction of the striation being more or less north and south according to the prevalent trend of the drifting ice. [Geikie, 1865; p. 84]

The pioneer Nova Scotia geologist John William Dawson (1868) made observations in the Strait of Belle Isle, between Newfoundland and Labrador, and around the shores of Belle Isle, and indicated that he believed that:

> ... the iceberg is the child of the glacier, and

> therefore the agency of the one is indirectly that of the other. Thus, in any view we must plough with both of these geological oxen ..." [Dawson, 1868; p. 36] and that icebergs are the "... huge polishers of the seafloor." [p. 34] and that they "smooth and level the higher parts of the sea bottom, and mark it with furrows and striae indicative of the direction of their own motion [p. 34].

Dawson described the keel of an overturned, previously-grounded, iceberg as "presenting a flat and scored surface covered with sand and earthy matter" (p. 34).

Elisha Kent Kane (1857), who was the doctor on board the *ADVANCE* of the U.S. Grinnell Expedition of 1850-1851 searching for Sir John Franklin, made an even more detailed observation of what appears to have been the bottom of a previously-grounded and scouring iceberg off West Greenland:

> Many of the bergs were covered with detritus. From one which had thawed down to the water's edge, I obtained some specimens of different rocks which were found adhering to its upper face. ... Some of them were marked with well-defined striae, without angular crossings, smooth, and occasionally polished even highly; others were cut in facets of more or less regularity. They varied in size from large blocks to mere pebbles, conglomerated in the ice with finely-powdered gneissoid material. The berg had evidently changed its equilibrium; and it seemed as if these rocks had been cemented in its former base, and had there been subjected to attrition during its rotary oscillations against the bottom of the sea. [Kane, 1857; Chapter XV, p. 113]
>
> The berg is beyond all doubt a most important agent in modifying the soundings upon the coast. The grounded bergs off Disco [Disko Island] are known to leave troughs, plowed by their projecting tongues, as they float and ground with the rise and fall of the tides. [Kane, 1857; Chapter XLVIII, p. 458]

Interestingly, during Canada's first *Ice Seminar* held in Calgary in 1969, icebergs received some attention as a hazard to navigation in that offshore hydrocarbons exploration in "Iceberg Alley" off Labrador was under consideration by Calgary-based firms. The papers in 1969 had no papers on iceberg scouring, and the term 'iceberg scouring' was not mentioned in the report of the meetings. J.E. Murray's (1969) key paper on '*The drift, deterioration and distribution of icebergs in the North Atlantic Ocean*' did not mention the potential problem of iceberg scouring of the ocean floor damaging bottom-mounted wellhead or pipeline facilities.

Even two years later, when the Halifax *Canadian Seminar on Icebergs* was held in December 1971, iceberg scouring of the sea bottom was just barely on the radar of the participants. Only two marine geologists were present, Bernie R. Pelletier and Alan C. Grant.

Pelletier (1971) reported on ice and ice pressure ridge keel scouring as first mapped in the summers of 1970 and 1971 in the shallow Beaufort Sea using the newly-developed sidescan sonar seafloor mapping technology. He did not mention iceberg or ice island scouring in this area. Several authors in the report of the 1971 meetings '*Proceedings of the Canadian Seminar on Icebergs*' refer to grounded icebergs, or to the influence of ocean bottom depth, or morphology, on the track of drifting icebergs. Olaf Løken *et al.* (1971, p. 132) and Løken (1971) noted that an offshore glacial moraine at 95 m water depth on the Baffin Island continental shelf east of Clyde River has the effect of grounding and stranding icebergs of a draft >95 m. Løken *et al.* did not discuss the resultant iceberg scour problem.

John Allen (1971) of the Faculty of Engineering and Applied Science at Memorial University of Newfoundland gave a talk at the 1971 Seminar noting in the published text that the "Results on grounding of bergs and their tracks or bottom scouring were inconclusive." and he noted that for an iceberg which was seen grounded between two shoals "... no track was discernable" (p. 111) on the *DAWSON* 71-021 cruise. He noted that [iceberg] "Tracks [or scours] were noted on the [ocean] bottom on Ritu Bank but their ages were not ... known." (p. 111), and he noted that "the shape of icebergs affects their stability a great deal and that grounding affects the shape" (p. 111). In response to a question asking for an "estimate [of] the incidence of bottom scouring?" Allen said "No, there is not enough known", and when asked "How old can "gouged trenches" be?" he replied "We don't know." (p. 111).

While Alan Grant (1971) in the leadoff paper in the 1971 iceberg seminar's proceedings does not mention iceberg scouring in his written words, he clearly mentioned such features in his oral presentation since in reply to a question about the distribution of modern marine sediments he replied "The shore side of the shelf is quite scoured ..." (p. 7). Another questioner asked "Could the [marginal] channel be used as a haven for lateral pipeline systems, etc.?" and Grant had the wisdom to reply "It would appear that normal bergs would not enter the channel since the surrounding shelf would act as a protection. However, there is the possibility of an oddly shaped berg rolling over, say, into the channel and doing damage. It is an area where further study is necessary." (p. 7).

M.J. Dunbar led the closing discussion to the 1971 meeting, and he did include "The age of [iceberg scour] gouge marks" as one of the 'problem areas' defined by the December 1971 *Seminar on Icebergs* (p. 161). The terms scour, gouge, ice scour and iceberg scour did not appear in the 1971 volume's *Glossary of ice terms (WMO-1968)* (pp. 163-171).

Even though hydrocarbons exploration drilling had begun on the Labrador Shelf in July 1971, with the Eastcan Exploration Ltd. Leif wells, there was really very little concern about, and even less scientific understanding of, the iceberg seafloor scouring process, or the problems it could cause for bottom-mounted facilities.

The issue of terminology did not begin to emerge until the oil and gas industry, first in northern Alaska, then in the Beaufort Sea of Canada, spawned concern and research about the effects of moving wind-driven pack ice and pressure ridge keels on seafloor infrastructure such as pipelines, wellheads, and on the sacrificial artificial islands that were created to drill exploration wells offshore in the Canadian Beaufort Sea. The Americans seemed to gravitate to the term 'gouging' while Canadians preferred the term 'scouring'.

When the first papers were written describing features on the seafloor of the Alaskan Arctic coast that resulted from the interaction of floating pack ice grounding on the bottom, the term 'microrelief' was used (Carsola, 1954; Rex, 1955) though the cause of the features was uncertain. Skinner (1971) writing of the same area attributed features on the seafloor to the grounding of ice islands and used the term 'ice island scouring', and Shearer *et al.* (1971) refer to 'ice scouring' on their Figure 2. Earlier work in Antarctic used the term 'gouging' (Wright and Priestley, 1922). Woodward (1948) used 'gouging' off Alaska, and the U.S. Department of Commerce (1964) used 'scouring' in the same area. Lewis (1978) discussed the large number of terms in use for relatively shallow Beaufort Sea features and preferred 'ice scours'. Barnes *et al.* (1978), writing of the north coast of Alaska, notes the terms 'ice scores, ice scours, ice gouges' and the verbs 'scraping, plowing, scouring and gouging', but preferred the 'gouging' of 'ice gouges' (Barnes *et al.*, 1984). Canadian papers dealing with the Beaufort Sea or Arctic Islands have followed the lead of Shearer *et al.* (1971) and Pelletier (1971) and used the terms 'scouring' and 'ice scours'; see also Pelletier and Shearer (1972) at the International Geological Congress in Montréal. A Canadian government consultant's study by Meagher *et al.* (1976) referred simply to 'ice scouring' in northwestern James Bay when referring to the signature left on the seafloor by wind-driven pack ice and pressure ridge keels.

It is not the purpose of this paper to resolve the plethora of terminology -- enough to say that the terms 'ice scouring' and 'ice scours' were born of an essentially shallow water situation and developed from features that were generally made by the grounding of sea ice and the keels of ice pressure ridges, not by icebergs, and only occasionally by pieces of ice islands that might resemble small icebergs.

The first publication of sidescan sonar images of iceberg scour marks was in Belderson *et al.* (1972) but the true origin of the features went unrecognized in this volume. In their Figure 73, the linear trends off Western Scotland were attributed to bedrock structures "which have perhaps been complicated and emphasized by ice scour" (pp. 82-83) referring, I expect, to glacial ice sheets at a time of lower sea level. On their Figure 86 (pp. 98-99), the iceberg scour marks on the western flank of Rockall Bank were simply referred to as "an anastomosing pattern of ridges up to about 4 m high, ...". However, it is in this volume that Belderson and Kenyon and their co-authors sow the seeds of the term "ploughing" which they use in their later papers -- a term which has to some degree misled, or at least diverted, our understanding of a significant amount of iceberg interaction with the seafloor.

Belderson *et al.* (1972) portrays one of the HUDSON '70 sidescan sonar records from the Beaufort Sea in 60 m depth and in their caption (pp. 94-95) refer to "... furrows ploughed into muddy sediment by drifting ice. ... The rims are often raised due to the shoving aside of sediment by the moving ice." Clearly the farming, or bulldozer, analogy was uppermost in the authors' minds. Reimnitz *et al.* (1972) actually used the term 'bulldozing' in their abstract. Belderson *et al.* (1973) quickly realized their error in the earlier pictorial text (Belderson *et al.* 1972) and produced a paper that entrenched the term 'plough marks', if not in usage, then in our concept of how an iceberg interacts with the ocean floor. They recorded 'iceberg plough marks' off W. Scotland, Rockall Bank and west of the Shetland Islands. This paper was rapidly followed by a second that reported on 'iceberg plough marks' off Norway (Belderson and Wilson, 1973). The term 'furrows' was used, along with 'furrow floors' and 'rims' and the authors assumed that the absence of iceberg scour marks in the topographic lows implied the marks had simply been buried by higher sedimentation.

R.H. Belderson and his colleagues gave us the farming term 'iceberg plough marks' and perhaps with it the traditional concept that an iceberg ploughs, or bulldozes, its way when it impinges on the bottom. Even using the marine term 'grounding' to describe an iceberg's collision with the bottom brings to mind a ploughing or bulldozing action plus ride-up. As Canadians began to map our own eastern continental shelf with sidescan sonar tools, iceberg scouring became apparent almost everywhere one looked north of the Grand Banks and the Strait of Belle Isle.

Harris and Jollymore (1974) referred to 'iceberg furrow marks' and came closest to escaping the assumptions of the ploughing model in referring to "linear large-scale furrows produced by bottom dragging icebergs ..." (p. 43). However, they again assumed a ploughing action: "The furrows are attributed to the ploughing action of bottom dragging icebergs" (p. 43). Later, Harris (1974) virtually abandons the term iceberg 'furrow' and uses only 'iceberg marks' but again hints at an alternative process to ploughing with his terms "... seafloor markings formed by icebergs that have dragged across the bottom" (p. 97) and "... Bergs that might otherwise drag bottom further in on the bank" (p. 100). Ian Harris and Paul Jollymore never continued their interest in icebergs in the literature which is a pity, since I believe their Belle Isle Bank data in their 1974 study contained the data by which one could have defined the iceberg 'harrowing' process and the tilting of icebergs.

Other Bedford Institute of Oceanography scientists in Dartmouth, Nova Scotia, identified iceberg scours. Van der Linden (1974) and Van der Linden *et al.* (1976) referred to 'ice gouges' and 'iceberg gouges', 'furrows and shoulders' and 'ice scours or scouring' on Hamilton Bank resulting from the seafloor being "gouged or ploughed by the keels of icebergs". Monahan and Macnab (1975) use 'scours and scouring'. King in 1976, used 'iceberg furrows' ... "presumably formed as ice ploughed the furrow. ... As the grounding ice moved ... the bulldozing action ..." (p. 1085). King interpreted the features in Laurentian Channel to be 'relict iceberg furrows'.

There was a boom in private Canadian offshore seabed surveying and consulting firms beginning in 1973 with the formation of Geomarine Associates Ltd., and expanding to include McElhanney Geosurveys Limited, Nordco Ltd., GeoTerrex Ltd., and the university-associated Centre for Cold Ocean Resources Engineering (C-CORE) at Memorial University of Newfoundland. These firms from their very beginnings used the term 'iceberg scour' and 'iceberg scours' as they mapped modern and palaeo iceberg scours from Georges Bank north to the eastern end of the North West Passage and from the West Greenland Shelf to central Hudson Bay, for the oil and gas industry on wellsite hazard surveys, on pipeline route surveys, on research contracts to the Atlantic Geoscience Centre of the Geological Survey of Canada, on reports for the Environmental Studies Revolving Funds (ESRF) and for the Panel on Energy Research and Development (PERD) projects.

By the time of the April 25-27, 1979 National Research Council sponsored 'First Canadian Conference on Marine Geotechnical Engineering' in Calgary, Alberta, then the February 15-19, 1982 'Workshop on Ice Scouring' in Montebello, Québec, and finally the February 5-6, 1985 Workshop on Ice Scour Research, Ice Scour and Seabed Engineering, held in Calgary, Alberta, the transformation of the terminology was nearly complete; most speakers and most papers in the proceedings use the term 'ice scour' and 'iceberg scour'. All the major bibliographies compiled on icebergs (Howard, 1986) and that on ice scour (Goodwin *et al.*, 1985), along with Comfort and Graham's (1986) 'Evaluation of Sea Bottom Ice Scour Models', all ESRF reports, all used the terminology 'iceberg scour'. The major volume 'Geology of the Continental Margin of Eastern Canada', in 1990, one of the Decade of North American Geology (DNAG) volumes of the Geological Society of America, cemented the terminology 'ice scour' and 'iceberg scour' (Lewis and Woodworth-Lynas, 1990). Chris Woodworth-Lynas in all his papers and in his 1993 Ph.D. thesis 'The Geology of Ice Scour' uses the same general term 'scour' for both drifting pack ice and iceberg features made on the ocean floor, perhaps recognising that for now, when it comes to offshore development issues, and constraints to offshore development, iceberg scour is essentially a Canadian (and to a lesser degree an Alaskan and a Greenland) problem. Woodworth-Lynas and Guigné are now defining palaeo 'ice keel scours marks' on the surface of Mars (2003)!

Darwin's 1855 model did not involve tilting and 'canting' of the icebergs that he had observed, and in the end he didn't get it quite right. His model involved the iceberg riding up over a topographic high on the ocean floor and physically lifting a slice of the iceberg around its girth from just below sea level to just above sea level. The thickness of the lifted slice would have to be equal to the height of the topographic high overridden (and scoured) by the iceberg. Thus the iceberg had to have enough kinetic energy to convert this to gravitational potential energy as the thin slice of the iceberg at its girth was lifted out of the water. The analysis done by Geomarine Associates Ltd. in July 1976 above showed that even at the maximum observed drift rates of icebergs on the Labrador banks of about 1 kt (1.85 km/hr or 0.5 m/s), the usual icebergs of 1-3 million tonnes did not have enough kinetic energy to 'overscour' by more than a few metres uphill before such a berg would stop dead and not move until the current or wind reversed, or until it 'foundered down', or rolled, and reduced its draft.

Darwin in 1855 did not cite this problem in giving his suggestion of how an iceberg could scour over a topographic high, but went on to consider icebergs, or rather the large ice islands seen in the Antarctic, to have the 'plasticity' of mountain glaciers seen onshore, hence to be 'semi-viscid':

> In short, if in our mind's eye we look at an iceberg, not as a rigid body (as has hitherto been always my case) which would be deflected or broken up when driven against any submarine obstacle, but as a huge semi-viscid, or at least flexible mass floating on the water, I believe much of the difficulty will be removed which some have experienced in understanding how rectilinear grooves could be formed continuously running, as if regardless of the outline of the surface, up and down moderately steep inequalities, now existing as hills on the land. It should be borne in mind that the course of deeply-floating icebergs is determined by the currents of the sea, and not, as remarked by Scoresby, by the shifting winds; and as the currents of the sea are well known to be definite in their course, so will be the grooves formed by current-borne icebergs. It is indeed difficult to imagine any difference between the effect on the underlying surface, of a glacier propelled by its gravity, and that of a mountainous island of ice driven onwards by an oceanic current, except that the iceberg would perhaps have the power, from the causes above specified, of even more closely moulding itself, and, as it were, of *flowing* straight over submarine obstacles, than has a glacier on the dry land. [Darwin, 1855; pp. 97-98]

Darwin did not recognise that force of gravity that drives the "plasticity of glaciers" is not an operative factor in the sea since the iceberg is floating. Nor did Darwin recognise that tilting of an iceberg in the direction of drift will do the trick to allow it to scour up and over a topographic high on the ocean floor. The tilting and 'canting' model for metastable icebergs allows them to 'overscour' over a much wider range of bathymetry. This model in fact fits the observed upslope and downslope iceberg scours observed throughout the world's iceberg-infested waters.

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References

Abernathy, B[ob]. F. 1971. The Eastcoast Petroleum Operators Association. *in* Proceedings of the Canadian Seminar on Icebergs, 6 and 7 December, 1971. Canadian Forces Maritime Warfare School, Canadian Forces Base Halifax, Maritime Command Headquarters, Canada Department of National Defence, Halifax, Nova Scotia, pp. 84-99.

Ainslie, A.R. and P.E. Jewett. 1970. The Towing of Icebergs to Protect Offshore Drilling Platforms. Marine Exploration Ltd., Cowes, Isle of Wight, England, pp.

Allen, J[ohn]. H. 1971. Cruise Report C.S.S. Dawson [71-021]. Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, Newfoundland, 37 pp.; E[rik]. Banks[sic = Banke], subsection on 'Ice-floe Towing', pp. 30-31.

Allen, J[ohn]. 1971. An Analysis of the Effect of Bottom Scouring Icebergs. *In* Proceedings of the Canadian Seminar on Icebergs, 6 and 7 December, 1971. Canadian Forces Maritime Warfare School, Canadian Forces Base Halifax, Maritime Command Headquarters, Canada Department of National Defence, Halifax, Nova Scotia, pp. 110-111.

Allen, J[ohn]. 1972. Iceberg Study, Saglek, Labrador Including Cruise Report C.S.S. DAWSON [72-022], August 7-August 26, 1972, Initial Report. Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, Newfoundland, 92 pp.; J.W. Gorman subsection on 'Bergy-Bit Towing', pp. 68-83.

Barnes, P.W., D. McDowell and E. Reimnitz. 1978. Ice gouging characteristics: their changing patterns from 1975-1977, Beaufort Sea, Alaska. U.S. Geological Survey, Washington, D.C., Open File Report 78-730, 40 pp.

Barnes, P.W., D.M. Rearic and E. Reimnitz. 1984. Ice gouging characteristics and processes. *in* The Alaska Beaufort Sea - Ecosystems and Environments. Academic Press, Orlando, Florida, pp. 185-213.

Bass, Don and Chris Woodworth-Lynas. 1986. Iceberg Crater Chains and Scour Up- and Downslope. *In* C.F.M. Lewis, D.R. Parrott, P.G. Simpkin and J.T. Buckley, editors. Ice Scour and Seabed Engineering, Proceedings of a Workshop on Ice Scour Research. 322 pp., held at Gulf Canada Resources, February 5-6, 1985, Calgary, Alberta, Environmental Studies Revolving Funds, Canada Oil and Gas Lands Administration, Canada Department of Energy, Mines and Resources and Northern Affairs Program, Canada Department of Indian Affairs and Northern Development, Report No. 049, ISBN 0-090783-48-1, Ottawa, Ontario, December, pp. 122-128.

Bass, D.W. and C.M.T. Woodworth-Lynas. 1988. Iceberg crater marks on the sea floor, Labrador Shelf. Marine Geology, Vol. 79, pp. 243-260.

Belderson, R.H., N.H. Kenyon, A.H. Stride and A.R. Stubbs. 1972. Sonographs of the Seafloor, Elsevier, Amsterdam. 185 pp.

Belderson, R.H., N.H. Kenyon and J.B. Wilson. 1973. Iceberg plough marks in the northeast Atlantic. Palaeogeography, Palaeoclimatology, Palaeoecology. Vol. 13, No. 3, pp. 215-224.

Belderson, R.H. and J.B. Wilson. 1973. Iceberg plough marks in the vicinity of the Norwegian Trough. Norsk Geologisk Tiddskrift, Vol. 53, pp. 323-328.

Benedict, C. Peter. 1978. A Towing Concept for Small Icebergs. *in* A.A. Husseiny, Editor. Iceberg Utilization: Proceedings of the First International Conference and Workshops on Iceberg Utilization for Fresh Water Production, Weather Modification and Other Applications. October 2-6, 1977, Iowa State University, Ames, Iowa, Pergamon Press, New York City, Toronto, pp. 334-338.

Biscarrat, P.A., G. de Lombares, D.E.T. Bidgood, and A.C. Grant. [1972]. Offshore Labrador, Bottom Survey Report [by M/V NEWFOUNDLAND HAWK] August 1972. prepared for the Eastcan Exploration Group, Calgary, Alberta, 17 pp. plus 5 Appendices; A, Time Sequence of 1972 Bottom Survey Operations., 6 pp.; B, Theory and Interpretation of the Side Scan Sonar System., 5 pp.; C, Nova Scotia Research Foundation V-Fin Bottom Profiling System., Nova Scotia Research Foundation Report No. 73-1, January, 1973, 30 pp.; D, Toran Readings., 19 pp.; E, Grounding Effects of Spherical Shape Icebergs. 1 p., total 78 pp., variously paged; List of Enclosures Bottom Survey 1972 Volume II., 3 pp. comprising a list of enclosures of airgun lines A1 to A7, sidescan sonar lines S1 to S64, and V-Fin lines V-1 to V-7; total 78 enclosures; Geological Survey of Canada, Atlantic Geoscience Centre, Dartmouth, Nova Scotia, Open File Report 247(1975).

Bruneau, A. and R. Dempster. 1971. Iceberg Features, Motions and Towing Problems. *in* Proceedings of the Canadian Seminar on Icebergs, 6 and 7 December, 1971. Canadian Forces Maritime Warfare School, Canadian Forces Base Halifax, Maritime Command Headquarters, Canada Department of National Defence, Halifax, Nova Scotia, pp. 124-127.

Bruneau, A[ngus]. A. and R[obert]. T. Dempster. 1972a. Iceberg Dynamics Project Report. Volume I, Experimental Equipment and Problems, 68 pp., plus 15 figures on unnumbered pages, Appendix 1, Distribution of Equipment June 18, 1971 [to] End of Field Experiment, pp. [69]-[77]; Appendix II, Equipment Supply, p. [78]; Appendix III, Force Recording System Description and Operation, pp. [79]-[93]; Appendix IV, Strength of Equipment and Material Used, p. [94]; Volume II, Observations, Data and Analysis, 149 pp.; Volume III, Iceberg Towing Procedures, 58 pp.; Summary List of Contents - Volumes I, II, and III, pp. 59-72, 315 total pp.

in 3 volumes; Contract Report prepared by the Faculty of Engineering and Applied Sciences, Memorial University of Newfoundland, St. John's, Newfoundland, for Eastcoast Petroleum Operators Association, Project Operator, Amoco Canada Petroleum Company Ltd., Calgary, Alberta, Report submitted to Canada Department of Energy, Mines and Resources, Resource Management and Conservation Branch, Ottawa, Ontario, June 15, 1972, Project No. 8640-A4-5E, publicly released June 16, 1976, Eastcoast Petroleum Operators Association (E.P.O.A.), Project No. 2, sponsored by participant members Amoco Canada Petroleum Company Ltd., Canadian Superior Oil Ltd., Imperial Oil Limited and Mobil Oil Canada Ltd.

Bruneau, A.A. and R.T. Dempster. 1972b. Engineering and Economic Implications of Icebergs in the North Atlantic. Oceanology International 72, March 19-24, Brighton, England, Conference Papers, Structures Floating and Fixed, Wednesday, March 22, pp. 176-180.

Bruneau, A.A. and R.T. Dempster. 1973. Dangers Presented by Icebergs and Protection Against Them. *in* Jean Malaurie. Editor. Proceedings le Pétrole et le Gaz Arctiques: problèmes et perspectives/Arctic Oil and Gas: problems and possibilities. Fondation Française d'Études Nordiques, V° congrès international, May 2-5, Le Havre, France, pp. [348]-362; Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, Newfoundland, EAST Report No. 71, 10 pp.

Bruneau, A.A., R.T. Dempster and G.R. Peters. 1978. Iceberg Towing For Oil Rig Avoidance. Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, Newfoundland, EAST Report No. 265, 10 pp. unpaged; *In* A.A. Husseiny, Editor. Iceberg Utilization: Proceedings of the First International Conference and Workshops on Iceberg Utilization for Fresh Water Production, Weather Modification and Other Applications. October 2-6, 1977, Iowa State University, Ames, Iowa, Pergamon Press, New York City, Toronto, pp. 379-388.

Carsola, A.J. 1954. Microrelief on Arctic Sea-Floor. Bulletin American Association of Petroleum Geologists, Vol. 38, No. 7, pp. 1587-1601.

Chari, T.R. 1975. Some geotechnical aspects of iceberg grounding. Unpublished Ph.D. thesis, Memorial University of Newfoundland, St. John's, Newfoundland, 181 pp.

Chari, T.R. and J.H. Allen. 1972. Iceberg grounding - A preliminary theory. *In* R.G. Charlwood, D.S. Weaver and B. Tabbarok, Editors. Proceedings, Symposium on Applications of Solid Mechanics. June 26-27, University of Waterloo, Solid Mechanics Division, Waterloo, Ontario, pp. 81-95.

Chari, T.R. and J.H. Allen. 1973. Iceberg grounding problems in the North Atlantic. *In* T. Karlsson, Editor. Second International Conference on Port and Ocean Engineering under Arctic Conditions, University of Iceland, Department of Engineering and Science, Reyjkavik, Iceland, pp. 608-616.

Chari, T.R. and J.H. Allen. 1974. Resistance of sediments to iceberg scouring. Preprint, Oceans Engineering Group, Faculty of Engineering, Memorial University of Newfoundland, St. John's, Newfoundland, available through Oceans Engineering Information Centre, No. N00062, 12 pp.; New Frontiers in Geotechnical Engineering, Twenty-seventh Canadian Geotechnical Conference, Edmonton, Alberta, Preprints of Papers, pp. 1-12.

Comfort, G. and B. Graham. 1986. Evaluation of Sea Bottom Ice Scour Models. Artec Canada Limited, Calgary, Alberta, Environmental Studies Revolving Funds, Ottawa, Ontario, Report No. 037, June, 72 pp. plus Appendices A-C, pp. [73]-[140], 140 pp. total.

Daneliuk, B.A. and J.A. Bell. 1972. Well History Report Tenneco *et al.* Leif E-38, 54°17'29".87 N. Lat, 55°05'52".17 W. Long. Tenneco Oil & Minerals, Ltd., Calgary, Alberta, report submitted to Canada Department of Energy, Mines and Resources, Resources Management and Conservation Branch, Dartmouth, Nova Scotia, January, 92 pp. plus 6 other figures; contains: N[orm]. J. McMillan. 1971. Description of 37 Sidewall Cores from Tenneco *et al.* Leif E-38. Tenneco Oil and Minerals Ltd., September, pp. 41-78; Canada-Newfoundland Offshore Petroleum Board, St. John's, Newfoundland and Labrador, formerly Resource Management Conservation Branch (RMCB), then Canada Oil and Gas Lands Administration (COGLA), Canada Department of Energy, Mines and Resources, Ottawa, Ontario, publicly released October 8, 1973.

Darwin, C.[harles R.] 1855. On the power of Icebergs to make rectilinear, uniformly-directed Grooves across a Submarine Undulatory Surface. Philosophical Magazine and Journal of Science, Vol. X, Fourth Series, No. LXIV, August, Paper XII, pp. 96-98.

Dawson, J[ohn]. W[illiam]. 1868. Comparisons of the Icebergs of Belle-Isle with the Glaciers of Mont Blanc, with Reference to the Boulder-Clay of Canada. The Canadian Naturalist and Geologist: A Bi-Monthly Journal of Natural Science, Vol. 3, New Series, pp. 33-44.

deCarteret, William G.S. 1912. C.S. MINIA, Halifax, N.S. May 8, 1912 [letter to] The Hydrographer, [U.S.] Hydrographic Office, Washington, D.C., U.S. National Archives and Records Administration, Washington, D.C., Record Group 37, Correspondence Files, Hydrographic Office Document No. 63846-805, Entry 39, Stack: 10W4 16-10-13, Box 111, 3 pp.; published in [Haas, Charles, Editor, Bob Bracken and Jack Eaton]. 2003. Exclusive! Memoir of a melancholy mission. Voyage, The Official Journal of the Titanic International Society, Inc., Freehold, New Jersey, No. 45, pp. 6-9.

Dunbar, M.J. 1971. Closing Discussion. *in* Proceedings of the Canadian Seminar on Icebergs, 6 and 7 December, 1971. Canadian Forces Maritime Warfare School, Canadian Forces Base Halifax, Maritime Command Headquarters, Canada Department of National Defence, Halifax, Nova Scotia, pp. 161-162.

Duval, J[ean]. [J.], A.R. Ainslie and D.J. Taylor. 1970. Arctic Offshore Problems Examined. Petroleum Engineer International, Vol. 42, No. 11, October, pp. 14, 16 and 18.

Duval, J[ean]. [J.] 1971. Iceberg Tracking from an Oil Exploration Platform in Labrador Waters. *in* Proceedings of the Canadian Seminar on Icebergs, 6 and 7 December, 1971. Canadian Forces Maritime Warfare School, Canadian Forces Base Halifax, Maritime Command Headquarters, Canada Department of National Defence, Halifax, Nova Scotia, pp. 80-83.

Eastcan Exploration Ltd. (formerly Compagnie Française des Petroles). 1969., later incorporated as E.P.O.A. report in 1971. Feasibility Study of Oil Operations in Iceberg Infested Waters. Part I Arctic Drilling Platforms; Part II Arctic Lifesaving Systems; Part III Maintaining a Drilling Platform On-station in Iceberg Infested Waters; Part IV The Towing of Icebergs to Protect Offshore Drilling Platforms. Contract Report prepared for the Eastcoast Petroleum Operators Association, Project Operator, Eastcan Exploration Ltd., Calgary, Alberta, Eastcoast Petroleum Operators Association (E.P.O.A.), Project No. 3, sponsored by participant members Eastcan Exploration Ltd., Gulf Oil of Canada Ltd., A.G.I.P. Canada Ltd., and Tenneco Oil & Minerals Ltd.

Geikie, Archibald. 1865. The scenery of Scotland Viewed in Connexion with its Physical Geology. Macmillan and Co., London and Cambridge, 360 pp.; Chapter IV, Action of Glaciers and Icebergs. pp. 77-90.

Geomarine Associates Ltd. [Ruffman, Alan]. 1975. Operations Report, Sea Bottom Survey, Labrador Shelf, July-August, 1975. Geomarine Associates Ltd., Halifax, Nova Scotia, Project 75-8, Report for Eastcan Exploration Ltd., operator for the Labrador Group, Calgary, Alberta, September 30, 71 pp., Canada-Newfoundland Offshore Petroleum Board (ex Canada Oil and Gas Lands Administration), Library, St. John's, Newfoundland and Labrador, release date ≈December 1982.

Geomarine Associates Ltd. [Ruffman, Alan, Monique Long and Lauchie Meagher.] 1976a. Bjarni [H-81, Makkovik Bank] Wellsite, Bathymetry and Iceberg Scours. Geomarine Associates Ltd., Halifax, Nova Scotia, Project 75-8, Report for Eastcan Exploration Ltd., operator for the Labrador Group, Calgary, Alberta, February, 135 pp., 7 plates, 10 appendices, plus 7 maps, scale 1:20,000, Canada-Newfoundland Offshore Petroleum Board (ex Canada Oil and Gas Lands Administration), Library, St. John's, Newfoundland and Labrador, Vol. 4, release date ≈December 1982.

Geomarine Associates Ltd. [Ruffman, Alan, Monique Long and Lauchie Meagher.] 1976b. Snorri [J-90, Nain Bank] Wellsite, Bathymetry and Iceberg Scours. Geomarine Associates Ltd., Halifax, Nova Scotia, Project 75-8, Report for Eastcan Exploration Ltd., operator for the Labrador Group, Calgary, Alberta, July, 127 pp., 9 plates, 19 appendices, plus 8 maps, scale 1:10,000, Canada-Newfoundland Offshore Petroleum Board (ex Canada Oil and Gas Lands Administration), Library, St. John's, Newfoundland and Labrador, Vol. 2, release date ≈December 1982.

Geomarine Associates Ltd. [Ruffman, Alan, Monique Long and Lauchie Meagher.] 1976c. Gudrid [H-55, Hamilton Bank] Wellsite, Iceberg Scours. Geomarine Associates Ltd., Halifax, Nova Scotia, Project 75-8, Report for Eastcan Exploration Ltd., operator for the Labrador Group, Calgary, Alberta, July, 114 pp., 6 plates, 12 appendices, plus 4 maps, scale 1:20,000, Canada-Newfoundland Offshore Petroleum Board (ex Canada Oil and Gas Lands Administration), Library, St. John's, Newfoundland and Labrador, Vol. 5, release date ≈December 1982.

Geomarine Associates Ltd. [Meagher, Lauchie and Alan Ruffman.] 1976. Bjarni [H-81, Makkovik Bank] Wellsite, Revised Bathymetry. Geomarine Associates Ltd., Halifax, Nova Scotia, Project 75-8, Report for Eastcan Exploration Ltd., operator for the Labrador Group, Calgary, Alberta, September, 32 pp., 5 enclosures, appendix, plus 5 maps, scale 1:20,000, Canada-Newfoundland Offshore Petroleum Board (ex Canada Oil and Gas Lands Administration), Library, St. John's, Newfoundland and Labrador, Vol. 6, release date ≈December 1982.

Goodwin, C. Ross, Jean C. Finley, Lynne M. Howard, Compilers and Editors. 1985. Ice Scour Bibliography. The Arctic Institute of North America, The University of Calgary, Calgary, Alberta, Environmental Studies Revolving Funds, Ottawa, Ontario, Report No. 010, July, 99 pp.

Grant, A[lan]. C. 1971. Comments on Surficial Aspects of the Labrador Shelf Region. *In* Proceedings of the Canadian Seminar on Icebergs, 6 and 7 December, 1971. Canadian Forces Maritime Warfare School, Canadian Forces Base Halifax, Maritime Command Headquarters, Canada Department of National Defence, Halifax, Nova Scotia, pp. 3-15.

Gray, George W. 1925. The Bottom of the Ocean Is "Main Street" to Him. Captain W.G.S. deCarteret, veteran skipper in the transatlantic cable service, has made more than 400 repairs on the lines that join Europe and America - He tells the romance of laying cables and the strenuous jobs of mending them - Adventures of men engaged in this unusual work. The American Magazine, New York City, New York, Vol. XCIX, No. 1, January, pp. [48]-49, 130-132.

Haas, Charles, Editor[, Bob Bracken and Jack Eaton]. 2003. Exclusive! TIS discovers document recording steward's 1912 recovery. Voyage, The Official Journal of the Titanic International Society, Inc., Freehold, New Jersey, No. 45, pp. 3-5.

[Haas, Charles, Editor, Bob Bracken and Jack Eaton]. 2003. Exclusive! Memoir of a melancholy mission. Voyage, The Official Journal of the Titanic International Society, Inc., Freehold, New Jersey, No. 45, pp. 6-9.

Harris, Ian McK. and Paul G. Jollymore. 1974. Iceberg Furrow Marks on the Continental Shelf Northeast of Belle Isle, Newfoundland. Canadian Journal of Earth Sciences, Vol. 11, No. 1, pp. 43-52.

Harris, Ian McK. 1974. Iceberg Marks on the Labrador Shelf. *in* W.J.M. van der Linden and J.A. Wade, editors. Offshore Geology of Eastern Canada, Volume 1. Geological Survey of Canada, Paper 74-30, Vol. 1, pp. 97-101, plus enclosed profile sheet.

Heyda, Charles M. and Edward S. Szymanski. 1983. Gazetteer of Greenland, Names Approved by the United States Board on Geographic Names. Defense Mapping Agency, Washington, D.C., Second Edition, December, Stock No. Gazgngreenland, 271 pp.

Hodgson, G.J., J.H. Lever, C.M.T. Woodworth-Lynas and C.F.M. Lewis, editors. 1988. The Dynamics of Iceberg Grounding and Scouring (DIGS) Experiment and Repetitive Mapping of the Eastern Canadian Continental Shelf, Volume 1 - The Field Experiment. Geomatics Ltd., St. John's, Newfoundland, Environmental Studies Revolving Funds (ESRF) Canada Oil and Gas Lands Administration, Canada Department of Energy, Mines and Resources and Northern Affairs Program, Canada Department of Indian Affairs and Northern Development Report No. 094, ISBN 0-920783-83-7, Ottawa, June, 316 pp.

Howard, Lynne M. 1986. Icebergs: A Bibliography Relevant to Eastern Canadian Waters. The Arctic Institute of North America, The University of Calgary, Calgary, Alberta, Environmental Studies Revolving Funds, Ottawa, Ontario, Report No. 030, May, 277 pp.

Kane, Elisha Kent. 1857. The United States Grinnell Expedition in Search of Sir John Franklin [1850-1851]. A Personal Narrative. Phillips, Sampson and Co., Boston; Sheldon, Blakeman & Co., New York; Childs & Peterson, Philadelphia; Trübner & Co., London, New Edition, 552 pp. Canadian Institute for Historical Microproductions (CIHM), Microfiche Series, F1001 C1155 Nos. 42583 and 90758.

King, L.H. 1976. Relict iceberg furrows on the Laurentian Channel and Western Grand Banks. Canadian Journal of Earth Sciences, Vol. 13, No. 8, pp. 1082-1092.

Lewis, C.F.M. 1978. The frequency and magnitude of drift-ice grounding from ice-scour tracks in the Canadian Beaufort Sea. *in* Proceedings of the fourth International Conference on Port and Ocean Engineering under Arctic Conditions (POAC), September 26-30, 1977, Memorial University of Newfoundland, St. John's, Newfoundland, pp. 568-579.

Lewis, C.F.M. and C.M.T. Woodworth-Lynas. 1990. Ice Scour. pp. 785-793, *in* C.F.M. Lewis and M.J. Keen, editors. 1990. Constraints to Development. Chapter 14, pp. 743-823. *in* M.J. Keen and G.L. Williams, editors. 1990. Geology of the Continental Margin of Eastern Canada. Geological Survey of Canada, Geology of Canada Series, No. 2, 855 pp. plus map case; also Geological Society of America, The Geology of North America, The Decade of North American Geology (DNAG) project, Vol. I-1.

Løken, O[lav]. H., C.S.L. Ommanney, G. Holdsworth and U.C. Arnold. 1971. Iceberg Studies in the Glaciology Subdivision. *in* Proceedings of the Canadian Seminar on Icebergs, 6 and 7 December, 1971. Canadian Forces Maritime Warfare School, Canadian Forces Base Halifax, Maritime Command Headquarters, Canada Department of National Defence, Halifax, Nova Scotia, pp. 128-134.

Løken, Olav H. 1973. Bathymetric observations along the east coast of Baffin Island: submarine moraines and iceberg distribution. *In* Peter J. Hood, N.J. McMillan and B.R. Pelletier, editors, Earth Science Symposium on Offshore Eastern Canada; Proceedings of a Symposium sponsored by the National Advisory Committee on Research in the Geological Sciences and the National Research Council Associate Committee on Geodesy and Geophysics, February 22-24, 1971, Ottawa, Ontario, Geological Survey of Canada, Paper No. 71-23, pp. 509-519.

Lyell, Charles 1845. Travels in North America, in the Years 1841-2 with Geological Observations on United States, Canada, and Nova Scotia. Wiley and Putnam, New York City, New York; John Murray, London, England, Vol. I, 251 pp. and Vol. II, 231 pp.; reprinted by Arno Press, New York, 1978, Canadian Institute for Historical Microproductions (CIHM), Microfiche Series, F1001 C1155 Nos. 36639-36644 incl.

Marine Environmental Services Limited (MAREX). 1972. Iceberg Towing Manual. Marine Environmental Services Limited, Calgary, Alberta, 144 pp. plus 3 appendices; Appendix I, Operational Tables and Charts, pp. A1-A6, Appendix II, Equipment, Manufacturers and Costs, pp. A7-A13, Appendix III, Log of Previous Towing Experiences, pp. A15-A49; Index, 4 pp.

Marine Exploration Limited [MAREX]. 1971. Summary Report, Labrador 1971. Marine Exploration Limited, Cowes, Isle of Wight, England, 11 pp.

Marine Exploration Limited [MAREX]. [1972]. Environmental Data Analysis, Environmental Conditions Offshore Labrador Recorded by the Drill Ship "Typhoon". Report for Eastcan Exploration Limited, Total, Calgary, Alberta, Marine Exploration Limited, Cowes, Isle of Wight, England, 37 pp.

McMillan, N.J. 1990. Constraints for drilling, Boulder beds. pp. 768-770, *in* C.F.M. Lewis and M.J. Keen, editors. 1990. Constraints to Development. Chapter 14, pp. 743-823, *in* M.J. Keen and G.L. Williams, editors. 1990. Geology of the Continental Margin of Eastern Canada. Geological Survey of Canada, Geology of Canada Series, No. 2, 855 pp. plus map case; also Geological Society of America, The Geology of North America, The Decade of North American Geology (DNAG) project, Vol. I-1.

Meagher, Lauchie J., Alan Ruffman and John McG. Stewart. 1976. Marine Geological Data Synthesis, James Bay. Volumes 1 and 2. Geomarine Associates Ltd., Halifax, Nova Scotia, Project 75-05-5, Contract Report, Canada Department of Supply and Services, File #S203.KP806-5-F012, Report for Coastal Oceanography Division, Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Canada Department of the Environment, Dartmouth, Nova Scotia, Vol. 1, 352 pp.; Vol. 2, 14 appendices, pp. 353-661, plus 9 maps, scale 1:500,000, 1:100,000 and

1:25,000, total page count 661 pp.; later Geological Survey of Canada, Open File 497(1977).

Memorial University of Newfoundland Faculty of Engineering [and Applied Science]. Undated, film shot in June 1971; production c. 1972. Ice Tow. Sponsored by Eastcoast Petroleum Operators Association [as part of E.P.O.A. Project No. 2] participant members Amoco Canada Petroleum Company Ltd., Canadian Superior Oil Ltd., Imperial Oil Limited and Mobil Oil Corp. [sic = Mobil Oil Canada Ltd.], colour VHS videotape, no credits, ≈ 14 minutes, [narrated by Rob Parker].

Monahan, D. and R.F. Macnab. 1975. Macro- and meso-morphology of Flemish Cap, Flemish Pass and the northeastern Grand Banks of Newfoundland. *In* W.J.M. van der Linden and J.A. Wade, editors. Offshore Geology of Eastern Canada, Volume 2 - Regional Geology, Geological Survey of Canada, Paper 74-30, Vol. 2, pp. 207-216 plus map holder with Natural Resource Map 836-A, Bathymetry, Flemish Cap, Flemish Pass and northeastern Grand Banks of Newfoundland, transverse Mercator Projection, scale 1:500,000 and Natural Resource Map 830-M, Morphology, Flemish Cap, Flemish Pass and northeastern Grand Banks of Newfoundland, transverse Mercator Projection, scale 1:500,000.

Murray, John E. 1969. The Drift, Deterioration and Distribution of Icebergs in the North Atlantic Ocean. *In* Ice Seminar, A Conference Sponsored by The Petroleum Society of C.I.M. May 6-7, 1968, Calgary, Alberta, The Canadian Institute of Mining and Metallurgy, Special Volume No. 10, pp. 3-18.

Murray, J.W. and N.J. McMillan. 1982. Drilling problems encountered from boulder beds on the Labrador shelf and recommendations for resolution. *in* W.H. Mathews, editor. Glacial history of the eastern seaboard of Canada pertaining to boulder distribution on the continental shelf, an overview. Appendix in unpublished report, Canterra Energy Ltd., Calgary, Alberta, 43 pp. [not seen by author]

Pelletier, B[ernie]. R. 1971. Side Scan Sonar Surveys and Ice Scouring in the Beaufort Sea. *in* Proceedings of the Canadian Seminar on Icebergs, 6 and 7 December, 1971. Canadian Forces Maritime Warfare School, Canadian Forces Base Halifax, Maritime Command Headquarters, Canada Department of National Defence, Halifax, Nova Scotia, pp. 48-49.

Pelletier, B.R. and J.M. Shearer. 1972. Sea bottom scouring in the Beaufort Sea of the Arctic Ocean. *in* Proceedings 24th International Geological Congress, Montreal, Section 8, Marine geology and geophysics, pp. 251-261.

Reimnitz, E., P.W. Barnes, T. Forgatsch and C. Rodeick. 1972. Influence of grounding ice on the Arctic shelf of Alaska. Marine Geology, Vol. 13, No. 5, pp. 323-334.

Rex, R.W. 1955. Microrelief produced by sea ice grounded in the Chukchi Sea near Barrow, Alaska. Arctic, Vol. 8, pp. 177-186.

Ruffman, Alan. 1979. Iceberg Harrowing -- An important and an alternate process to iceberg ploughing which explains a number of the iceberg scour marks observed on the ocean floor [Abstract]. Geomarine Associates Ltd., Halifax, Nova Scotia, Project 79-13, The First Canadian Conference on Marine Geotechnical Engineering/Première Conférence Canadienne sur le Génie Géotechnique Marin, sponsored by the Associate Committee on Geotechnical Research of the National Research Council of Canada and The Canadian Geotechnical Society, April 25-27, Calgary, Alberta, Session 1 - Geological Aspects, Panel Discussion, Wednesday a.m., April 25, 1 p.

Ruffman, Alan. 1982; later 1985. Iceberg "Harrowing" As Opposed to Iceberg "Ploughing" [Abstract]. Geomarine Associates Ltd., Halifax, Nova Scotia, Project 82-10, Workshop on Ice Scouring, February 15-19, Montobello, Québec, February 16 presentation, 1 p.; later *In* R[oger]. Pilkington, editor. 1985. Workshop on Ice Scouring 15-19 February 1982., 251 pp. plus Appendices A and B, 10 pp., National Research Council of Canada, Associate Committee on Geotechnical Research, Snow and Ice Subcommittee, Technical Memorandum No. 136, April 1985, Addendum to T.M. 136, 1 p.

Ruffman, Alan. 1999. *TITANIC* Remembered The Unsinkable Ship and Halifax. Formac Publishing Company Ltd., Halifax, Nova Scotia, ISBN 0-88780-467-5, July 28, 1 figure, 59 colour and 41 black and white photographs, 72 pp.

Ruffman, Alan. 2004. Ottawa and others: A further consideration. Voyage, Titanic International Society, Inc., Freehold, New Jersey, No. 47, Spring, pp. 127-130.

Shearer, J.M., R.F. Macnab, B.R. Pelletier and T.B. Smith. 1971. Submarine pingos in the Beaufort Sea. Science, Vol. 174, pp. 816-818 plus cover.

Skinner, B.C. 1971. Investigation of ice island scouring on the northern continental shelf of Alaska. United States Coast Guard Academy, New London, Connecticut, Report No. RDCGA-23, 24 pp.

U.S. Department of Commerce. 1964. United States Coast Pilot No. 9 - Pacific and Arctic Coasts. National Ocean Survey, U.S. Government Printing Office, Washington, D.C.

van der Linden, W.J.M. 1974. The surficial geology of Hamilton Bank and periphery. Geological Survey of Canada, Paper 74-1B, pp. 157-160.

van der Linden, W.J.M., R.H. Fillon and D. Monahan. 1976. Hamilton Bank, Labrador Margin: origin and evolution of a glaciated shelf. Canadian Hydrographic Service, Marine Sciences Paper 14, 31 pp. (also Geological Survey of Canada, Paper 75-40, 31 pp.) plus Natural Resource Maps: 831-A, Bathymetry, Labrador Sea, Hamilton Bank; 831-G, Surficial Geology, Labrador Sea, Hamilton Bank; and 831-M, Morphology, Labrador Sea, Hamilton Bank, all transverse mercator projection, scale 1:250,000.

Verlet, Jean and Jean [J.] Duval. 1972. Eastcan Exploration Ltd. Labrador Project Leif E-38 Wellsite Survey [in August 1972]. Eastcan Exploration Ltd., Calgary, Alberta, September 7, 41 pp. plus 17 B&W photographs on the final 8 pp.; 49 pp. total; Resource Management and Conservation Branch, released August 28, 1974; Canada-Newfoundland Offshore Petroleum Board, Report file 8613-E2-1-IRE.

Woodward, R.W. 1948. Descriptive report to accompany Hydrographic Sheet H-7609, Peard Bay and Vicinity, Arctic Coast of Alaska, 1947. U.S. Coast and Geodetic Survey, Seattle, Washington, 20 pp.

Woodworth-Lynas, Christopher M.T. 1983. The Relative Age of Ice Scours Using Cross-cutting Relationships. Centre for Cold Ocean Resources Engineering (C-CORE), Memorial University of Newfoundland, St. John's, Newfoundland, C-CORE Publication No. 83-3, March, 54 pp. and errata page.

Woodworth-Lynas, C.M.T., A. Simms and C.M. Rendell. 1984a. Grounding and scouring icebergs on the Labrador Shelf. Iceberg Research, Scott Polar Institute, Cambridge University, Cambridge, England, Vol. 7, March, pp. 13-20; Centre for Cold Ocean Resources Engineering (C-CORE), Memorial University of Newfoundland, St. John's, Newfoundland, C-CORE Publication No. 84-8.

Woodworth-Lynas, C.M.T., A. Simms and C.M. Rendell. 1984b. Iceberg grounding and scour frequency, Labrador Sea. OCEANS 84 Conference Proceedings, Industry, Government, Education ... Design for the Future, September 10-12, Washington, D.C., Institute of Electrical and Electronics Engineers (IEEE), Vol. 1, pp. 259-262; Centre for Cold Ocean Resources Engineering (C-CORE), Memorial University of Newfoundland, St. John's, Newfoundland, C-CORE Publication No. 84-16.

Woodworth-Lynas, C.M.T., A. Simms and C.M. Rendell. 1985. Iceberg grounding and scouring on the Labrador continental shelf. Cold Regions Science and Technology, Vol. 10, No. 2, pp. 163-186.

Woodworth-Lynas, C.M.T., D.W. Bass and J. Bobbitt. 1986. Inventory of Upslope and Downslope Iceberg Scouring. Centre for Cold Ocean Resources Engineering (C-CORE), Memorial University of Newfoundland, St. John's, Newfoundland, Environmental Studies Revolving Funds (ESRF), Canada Oil and Gas Lands Administration, Canada Department of Energy, Mines and Resources and Northern Affairs Program, Canada Department of Indian Affairs and Northern Development, Report No. 039, ISBN 0-920783-38-4, Ottawa, Ontario, July, 103 pp.; C-CORE Publication No. 87-1.

Woodworth-Lynas, Chris, D. Christian, M. Seidal and T. Day. 1986. Relict Ice Scours on King William Island, N.W.T. *in* C.F.M. Lewis, D.R. Parrott, P.G. Simpkin and J.T. Buckley, editors. Ice Scour and Seabed Engineering, Proceedings of a Workshop on Ice Scour Research. 322 pp., held at Gulf Canada Resources Inc., February 5-6, 1985, Calgary, Alberta, Environmental Studies Revolving Funds, Canada Oil and Gas Lands Administration, Canada Department of Energy, Mines and Resources and Northern Affairs Program, Canada Department of Indian Affairs and Northern Development, Report No. 049, ISBN 0-920783-48-1, Ottawa, Ontario, December, pp. 64-72.

Woodworth-Lynas, Christopher M.T. 1993. The Geology of Ice Scour. Unpublished Ph.D. thesis, The University of Wales, Aberystwyth, Wales, dated November 1992, approved May 5, 269 pp.

Woodworth-Lynas, C.M.T. and J.Y. Guigné. 1990. Iceberg scours in the geological record: examples from glacial Lake Agassiz. *in* J.A. Dowdeswell and J.D. Scourse, editors. Glaciomarine Environments: Processes and Sediments. Geological Society of London, Special Publication No. 53, pp. 217-233.

Woodworth-Lynas, C.M.T., H.W. Josenhans, J.V. Barrie, C.F.M. Lewis and D.R. Parrott. 1991. The physical processes of seabed disturbance during iceberg grounding and scouring. Continental Shelf Research, Vol. 11, Nos. 8-10, pp. 939-961.

Woodworth-Lynas, C.M.T., J.Y. Guigné and E.L. King. 1992. Surficial and bedrock geology beneath the Strait of Belle Isle in the vicinity of a proposed power-cable crossing. Geological Survey Branch, Department of Mines and Energy, Government of Newfoundland and Labrador, St. John's, Newfoundland and Labrador, Report 92-2, 53 pp.

Woodworth-Lynas, Christopher and Jacques Yves Guigné. 2003. Ice keel Scour Marks on Mars: Evidence for Floating and Grounding Ice Flows in Kasei Valles. Oceanography, Vol. 16, No. 4, pp. 90-97.

Wright, C.S. and R.E. Priestly. 1922. British (Terra Nova) Antarctic Expedition, 1910-1913. Harrison and Sons Ltd., London, p. 411.

Appendix 1

Chronological Summary of the First Four Petroleum Company-Related Iceberg Towing Field Programs 1970-1971

Sponsoring Company or Agency (Reference)	Vessel Owner or Contracting Agency	Location	Date; Time of Tow; (Duration)	Iceberg Description; Type of Tow; Rates of Tow
Compagnie française des pétroles de France. In 1971, this project was accepted as the Eastcan Petroleum Operators Association (E.P.O.A.) Project	*Arctic Explorer* A single crew 300 HP wooden coastal trading vessel that was "completely unsuitable for serious towing". Owner not known.	Close to shore off southwest Greenland. Onshore survey point was 2,380 m from the iceberg in a direction perpendicular to the tow direction.	April 26, 1970 17:35 tow started but measurements not taken until 17:53-18:10 (0.28 hr). Iceberg motion recorded by onshore survey party.	Height: 19 m; waterline length: 80 m; mass: 135,000 tons; single ship tow using 60 mm polypropylene mixture berthing warps shackled to a 35 mm towing wire. Iceberg towed 61.2 m at speeds of 0.076 m/s over 7 min, 0.060 m/s over 5 min, and 0.037 m/s over the final 5 min with no power applied by the vessel to the towline for the final 3 minutes on. Operational bollard pull of vessel of full power was estimated at 1.4 tons. Seas were calm.
Eastcan Exploration Ltd	Mothership was *LADY OF ESSEX* with the tug *SIGYN* used for towing. Tug owned by F.M. Svitzers of Copenhagen, Denmark.	64°06'N 52°13'W off southwest Greenland. Note that on three of the five logs the latitude is listed at 67°06'N. This is incorrect per Heyda and Szymanski (1983).	May 30, 1971 11:00-12:35 (1.58 hr). Hookup took 0.5 hr and detachment operation took 0.5 hr.	Height: 20 m; waterline length: 87 m; mass: 200,000 tons. Single ship tow using a floating synthetic line on a grounded iceberg. Tow did not budge the iceberg. Bollard tow of vessel: 10 tons. Wind: 14 kts. This iceberg was later observed to have rolled "but remained grounded in about the same spot".
Eastcan Exploration Ltd	Mothership was *LADY OF ESSEX* with the tug *SIGYN* used for towing.	64°06'N 52°13'W off southwest Greenland.	May 30, 1971 14:40-16:35 (1.92 hr). Floating iceberg was close to the above grounded berg, and the rate of the tow was measured by the towing vessel relative to the grounded berg.	Height: 9 m; waterline length: not recorded; mass: 16,000 tons. Single ship tow using a floating synthetic line. Iceberg towed at 1.46 kts (0.752 m/s) after the iceberg drift of 0.8 kts was removed. Operational bollard pull: 10.5 tons. Wind 20 kts.
Eastcan Exploration Ltd	Mothership was *LADY OF ESSEX* with the tug *SIGYN* used for towing.	64°06'N 52°13'W off southwest Greenland.	May 30 [sic 31], 1971 14:30-17:00 in a 220° T direction. A grounded iceberg was used as a reference to get the tow speed. 17:00-20:45 Tow direction changed to due north. (6.25 hr)	Height: 9 m; waterline length: 60 m; mass: 200,000 tons. Single ship tow using a floating synthetic line. Iceberg towed at 0.24 kts (0.124 m/s) after the iceberg drift of 0.3 kts was removed. Operational bollard pull: 10 tons. Wind 20 kts. Tow speed not determined since radar observations were not available. Operational bollard pull: 10 tons. Wind 20 kts.

Chronological Summary of the First Four Petroleum Company-Related Iceberg Towing Field Programs 1970-1971

Sponsoring Company or Agency (Reference)	Vessel Owner or Contracting Agency	Location	Date; Time of Tow; (Duration)	Iceberg Description; Type of Tow; Rates of Tow
Eastcan Exploration Ltd	Mothership was *LADY OF ESSEX* with the tug *SIGYN* used for towing.	64°06'N 52°13'W off southwest Greenland. Location identified as close to Tovqussaq Bank which agrees with a latitude of 64°06'N per Heyda and Szymanski (1983).	May 31-June 1, 1971. At 23:40 May 31 towline was attached and tensioned. "The line immediately slid up the side of the berg and caught on the peak, turning the berg over. 00:45-08:00 towed on the rolled iceberg. Tow progress and speed were monitored from the anchored *LADY OF ESSEX*. (7.25 hr)	Height: 15 m; waterline length: 20 m; mass: 10,000 tons. Single ship tow using a floating synthetic line. Iceberg towed at 1.1 kts (0.566 m/s). Operational bollard pull: 13 tons. Wind 6 kts. Iceberg was barely visible on the radar of the *LADY OF ESSEX*, so they tracked the towing vessel *SIGYN*.
Eastcan Exploration Ltd	Mothership was *LADY OF ESSEX* with the tug *SIGYN* used for towing.	64°06'N 52°13'W off southwest Greenland.	June 5, 1971 11:56-16:54 Tow direction begun at 220°T, altered at 13:59 to 310°T, and back to 220°T at 15:40. (4.97 hr)	Height: not recorded; waterline length: not recorded: mass: not recorded. Single ship tow using a floating synthetic line. Operational bollard pull: not recorded. No wind; calm. First direction change was done with the line tension at an estimated 18 tons. The second direction change was carried out with 9 to 10 tons of tension and took only 10 min vs 20 min for the first direction change. The report noted "It is expected that a change in direction could be carried out in 5 mins with the towline slackened." Tow was only 0.25 n mi over 5 hr and was "considered to be much slower than expected." -- Possibly the berg was grounded?
Eastcoast Petroleum Operators Association (E.P.O.A.) Project No. 2 Project Operator: Amoco Canada, Calgary, Alberta.	*PERCY M. CROSBIE* chartered by Faculty of Engineering and Applied Science of Memorial Univ. of Newfoundland from Chimo Shipping. Chief Scientists: Angus A. Bruneau and Robert (Bob) T. Dempster; Project Coordinator: Colin Langford. Captain: Clarence Dyke	off northeast Newfoundland Cape St. John 50°N, 55°25'W off Gull Island.	June 2, 1971 Tow No. 1 15:25-18:37 NST (3.20 hr)	Cruise mobilized May 24-29, sailed May 29, 1971 to Long Pond to add concrete ballast, then on May 31 to Cape St. John. Iceberg 1B or 'Colina'. Dimensions not recorded. Mass: 106,000 tons est. Operational bollard pull: 26.5 tons. Towing sling of two 1 in wires separated by 5/16 in chains 30 ft in length, sling suspended from pvc floats.
Eastcoast Petroleum Operators Association (E.P.O.A.) Project No. 2	*PERCY M. CROSBIE*	East of the North Peninsula of Newfoundland off the Grey Islands 50°42'N 55°40'W west of Bell Island.	June 5, 1971 Tow No. 2 12:35-≈16:30 NST (3.92 hr)	Iceberg 4F or 'St. Anthony'. height: 48 ft = 14.6 m length: 300 ft = 91.4 m width: 180 ft = 54.9 m mass: 122,000 tons Operational bollard pull: 13.3 to 26.0 tons Towing sling of two 1 in steel wires.

Appendix 1 (Continued)

Chronological Summary of the First Four Petroleum Company-Related Iceberg Towing Field Programs 1970-1971

Sponsoring Company or Agency (Reference)	Vessel Owner or Contracting Agency	Location	Date; Time of Tow; (Duration)	Iceberg Description; Type of Tow; Rates of Tow
Eastcoast Petroleum Operators Association (E.P.O.A.) Project No. 2	*PERCY M. CROSBIE*	East of the North Peninsula of Newfoundland off the Grey Islands 50°48'N 55°40'W west of Groais Island.	June 8, 1971 Tow No. 3 17:20-19:45 NST (2.42 hr)	Iceberg 7E or 'Annette' height: 77 ft = 23.5 m length: 375 ft = 114.3 m width: 285 ft = 86.9 m mass: 292,000 tons Operational bollard pull: 27.0 tons Towing sling of two 1 in steel wires.
Eastcoast Petroleum Operators Association (E.P.O.A.) Project No. 2	*PERCY M. CROSBIE*	East of the North Peninsula of Newfoundland off the Grey Islands 50°48'N 55°40'W.	June 9, 1971 no tow: aborted when the iceberg calved during the process of deploying the towing sling.	Iceberg 7E or 'Annette' altered in shape as a result of the 'foundering down'. Towing sling of two 1 in steel wires.
Eastcoast Petroleum Operators Association (E.P.O.A.) Project No. 2	*PERCY M. CROSBIE*	East of the North Peninsula of Newfoundland off the Grey Islands 50°42'N 55°40'W west of Bell Island.	June 10, 1971 Tow No. 4 11:15-≈18:00 NST (6.75 hr)	Iceberg 9A or 'Whalesback' height: 27 ft = 8.2 m length: 235 ft = 71.6 m width: 120 ft = 36.6 m mass: 85,000 tons Operational bollard pull: 27.0 tons Towing sling of two 1 in steel wires.
Eastcoast Petroleum Operators Association (E.P.O.A.) Project No. 2	*PERCY M. CROSBIE*	East of the North Peninsula of Newfoundland off the Grey Islands 50°42'N 55°40'W southwest of Bell Island.	June 11, 1971 Tow No. 5 11:15-≈18:00 NST (6.75 hr)	Iceberg 7E or 'Annette' (modified by calving) height: 110 ft = 33.5 m length: 300 ft = 91.4 m width: 295 ft = 89.9 m mass: 235,000 tons Operational bollard pull: 28.5 tons Towing sling of two 1 in steel wires.
Eastcoast Petroleum Operators Association (E.P.O.A.) Project No. 2	*PERCY M. CROSBIE*	East of the North Peninsula of Newfoundland off the Grey Islands 50°42'N 55°40'W northeast of Groais Island.	June 14, 1971 Tow No. 6 ≈16:45-≈18:15 NST (1. 0 hr). Tow terminated when iceberg rolled and threw off towing wire after a large piece calved off the berg.	Iceberg 13A or 'Mary Ellen' height: 50 ft = 15.2 m length: 310 ft = 94.5 m width: 215 ft = 65.5 m mass: 208,000 tons Operational bollard pull: 31.5 tons Towing wire was a single 1 in steel wire suspended by 5 ft chains on pvc floats.
Eastcoast Petroleum Operators Association (E.P.O.A.) Project No. 2	*PERCY M. CROSBIE*	East of the North Peninsula of Newfoundland off the Grey Islands 51°00'N 55°40'W northeast of Groais Island.	June 15, 1971 Tow No. 7 12:00-18:00 NST (6. 0 hr). Iceberg appeared to rock dangerously on several occasions during the 6 hr tow.	Iceberg 13A or 'Mary Ellen' (modified by calving) height: 85 ft = 25.9 m length: 280 ft = 85.3 m width: 225 ft = 68.6 m mass: 190,000 tons Operational bollard pull: 31.0 tons. Towing by a single 1 in steel wire. Vessel returned to St. John's June 16 and demobilization occurred June 17-19, 1971. Vessel engaged 27 days; at sea 18.5 days.
Memorial Univ. of Newfoundland, Faculty of Engineering and Applied Science & Bedford Institute of Oceanography	C.S.S. *DAWSON* Cruise No. 71-021 of the Bedford Institute of Oceanography Chief Scientist: John H. Allen Captain: Fred Mauger. Erik Banke responsible for towing using a launch and a load cell.	off the coast of Wadham Island near the Straight Shore of Northeast Newfoundland	June 11, 197 1200-1230 (0.5 hr)	"small growler" height: ≈1.5 m length: 4 m width: 3 m mass: n/a Towed in seas 3-4 m high with winds of 8-10 m/s. Cruise from June 2 to 12, 1971. Concluded that bottom drag of an ice floe could be determined through such a towing experiment.

Appendix 1 (Continued)

Chronological Summary of the First Four Petroleum Company-Related Iceberg Towing Field Programs 1970-1971

Sponsoring Company or Agency (Reference)	Vessel Owner or Contracting Agency	Location	Date; Time of Tow; (Duration)	Iceberg Description; Type of Tow; Rates of Tow
Tenneco Oil & Minerals Ltd. Operator of Leif wells drilled by ship-shape drilling platform *TYPHOON*.	*SMIT-LLOYD 7* and *SAN JACINTO* owned and operated by Smit-Lloyd N.V., Rotterdam, The Netherlands and Freeport Operations of Freeport, Texas respectively.	Hamilton Bank off Labrador 54°17'29.87"N 55°05'52.17"W Tenneco *et al.*. Leif P-48 July 6 - 27,1971 Leif L-38 July 31 - Aug 13, 1971 and finally Leif E-38 Aug. 14 - Sept. 25, 1971	June 29, 1971 Leif P-48 while the drillship *TYPHOON* was setting anchors.*TYPHOON* moved itself 1,000 ft astern when tow failed.	Iceberg A-5 height: not recorded waterline length: not recorded mass: not recorded Two-ship tow using a single wire rope. "Towing attempt made but [a] fitting in [the] handling lines ... parted. Tow was aborted." Total operational bollard pull: 40 tons. Towing not successful. Wind 20 kts. Track plot in MAREX (1971) from 18:30 June 28 to 11:00 June 30, 1971.
Tenneco Oil & Minerals Ltd. Operator of Leif wells drilled by ship-shape drilling platform *TYPHOON*.	*SMIT-LLOYD 7* and *CAY W* owned and operated by Smit-Lloyd N.V., Rotterdam, The Netherlands and Dearborn Marine Corp. Freeport, Texas respectively.	Hamilton Bank off Labrador 54°17'29.87"N 55°05'52.17"W	June 29, 1971 Leif P-48 14:30-15:45 (1.25 hr)	Iceberg A14 height: 18 m waterline length: 90 m mass: 500,000 tons Two-ship tow using a single 6 in circumference steel *SMIT-LLOYD* hawser. Combined bollard pull: 40 tons. Tow was termed "successful". No tow speed was given. Track plot in MAREX (1971) from 10:00 July 4 to 03:00 July 7, 1971.
Tenneco Oil & Minerals Ltd. Operator of Leif wells drilled by ship-shape drilling platform *TYPHOON*.	*CAY W* or *SAN JACINTO* exact vessel not identified.	Hamilton Bank off Labrador 54°17'29.87"N 55°05'52.17"W	July 11, 1971 Leif P-48 ≈13:00 after bergy bit broke into two pieces. No tow attempted because braided towline had not yet arrived.	height: 23[sic = 2.3 m?] Waterline length: not recorded mass: not recorded Towing gear not available; was on *SMIT-LLOYD 7* which was away from site. Bergy bit was "pushed haphazardly" out of the mooring buoy pattern until it was ≈ 1 n mi southwest of the *TYPHOON*. Ramming the bergy bit would not break it up. Wind 10 kts. No tow was attempted.
Tenneco Oil & Minerals Ltd. Operator of Leif wells drilled by ship-shape drilling platform *TYPHOON*.	*SMIT-LLOYD 7*	Hamilton Bank off Labrador 54°17'29.87"N 55°05'52.17"W	July 15, 1971 Leif P-48 no tow attempted.	Height: 61 m waterline length: 91 m Tow vessel made an inspection of berg at 3 n mi from the drillship *TYPHOON* with new synthetic hawser available. Berg approached no closer to *TYPHOON*. Wind 6 kts.
Tenneco Oil & Minerals Ltd. Operator of Leif wells drilled by ship-shape drilling platform *TYPHOON*.	*CAY W*	Hamilton Bank off Labrador 54°17'29.87"N 55°05'52.17"W	July 27, 1971 Leif P-48 no tow attempted.	Height: not recorded waterline length: not recorded mass: not recorded "17 bergs visible, 9 on radar." Tow vessel dispatched when one berg came within 0.5 n mi of platform wave rider buoy. Wind 7 kts. Drilling rig abandoned the site and went to L-38 site.
Tenneco Oil & Minerals Ltd. Operator of Leif wells drilled by ship-shape drilling platform *TYPHOON*.	*SMIT-LLOYD 7*	Hamilton Bank off Labrador 54°17'29.87"N 55°05'52.17"W	August 3, 1971 Leif P-48 21:05 - 21:15 (0.17 hr) Iceberg measurements only found in MAREX (1971). Track plot in MAREX (1971) from 08:00 Aug. 2 to 16:00 Aug. 4, 1971.	Iceberg B-30 height: 12 m waterline length: 44 m mass: "small" Single ship tow using floating synthetic three-strand line. Berg at 15:00 at 2.65 n mi appeared to be passing the drillship, then at 1600 it turned and came toward *TYPHOON*; at 20:55 it was at 0.87 n mi. 'Blue spunstron' used to tow at 21:05. Berg started to roll at 2112. Bollard pull 30 tons. Wind 10 kts. Tow vessel backed off and tow line got caught by the propeller and had to be cleared by divers.

Appendix 1 (Continued)

Chronological Summary of the First Four Petroleum Company-Related Iceberg Towing Field Programs 1970-1971

Sponsoring Company or Agency (Reference)	Vessel Owner or Contracting Agency	Location	Date; Time of Tow; (Duration)	Iceberg Description; Type of Tow; Rates of Tow
Tenneco Oil & Minerals Ltd. Operator of Leif wells drilled by ship-shape drilling platform *TYPHOON*.	*SMIT-LLOYD 7*	Hamilton Bank off Labrador 54°17'29.87"N 55°05'52.17"W	Aug. 6, 1971 Leif L-48 first tow 04:57 - 06:20 (1.38 hr) second tow 20:15 - 21:30 (1.25 hr) Iceberg measurements only found in MAREX (1971).	Iceberg X-43 height: 12 m waterline length: 53 m mass: "small" Single ship tow using floating synthetic three-strand line. At 06:20 berg rolled in the direction of the tow and the line was cut. Tow recommenced with mended line at 20:15. At 2130 berg rolled again. Wind 12 kts. This iceberg was called B40 on the 19:00 Aug. 5 to 11:00 Aug. 8, 1971 iceberg drift radar plot on p. 33 of MAREX [1972].
Tenneco Oil & Minerals Ltd. Operator of Leif wells drilled by ship-shape drilling platform *TYPHOON*.	*SAN JACINTO* and *SMIT-LLOYD 7*	Hamilton Bank off Labrador 54°17'29.87"N 55°05'52.17"W	Aug. 8, 1971 Leif L-48 first tow 11:00 - 12:55 (1.92 hr) second tow 13:30 - 14:35 (1.08 hr) third tow of piece 17:15 - 17:30 (0.25 hr) Iceberg measurements only found in MAREX (1971).	Iceberg B41 height: 28.0 m waterline length: 74.7 m mass. "small" Two-ship tow using floating synthetic three-strand line. Operational bollard pull estimated to be 10-15 tons. At 12:37 revs increased to give 15-ton bollard pull and line on the *SAN JACINTO* parted at 12:55. Tow recommenced at 13:30. At 14:35 berg rolled and broke up. The three attempts to tow pieces saw the towline slip over the top or bottom of the bergy bit which had been renumbered B41A. Iceberg drift radar plot from 06:15 Aug. 6 to 24:00 Aug. 8, 1971 found on p. 33 of Marex [1972].
Tenneco Oil & Minerals Ltd. Operator of Leif wells drilled by ship-shape drilling platform *TYPHOON*.	*CAY W* towed line out to *SMIT-LLOYD 7* when four heaving attempts failed to get a line onto the *SMIT-LLOYD 7* from the *TYPHOON* drilling rig.	Hamilton Bank off Labrador 54°17'29.87"N 55°05'52.17"W	Sept. 26, 1971 Leif L-48 21:00 for only a few minutes	Iceberg Y12 height: not recorded waterline length: not recorded mass: not recorded Single ship tow using floating synthetic three-strand line. "The day [Sept. 26] started quietly with moderate radar visibility, strong winds and fairly large waves. Several bergs, up to three at once, approached on radar. These were brought out from the coast by the West and N.W. winds. One berg (Y12) steadily approached the ship [from 16 n mi since Sept. 25. The riser had been disconnected since strong winds and rough seas on September 24.] Snow fell at noon -- gale force winds -- very high gusts. After several hours of drifting south-east, to pass the ship on the starboard side, the current slacked off and when the wind increased, the berg tried to pass, N.E., to port of the ship. At 18:00, the current gained strength and pushed the berg back towards the ship. The drilling superintendent was informed, as requested, at 1.5 N.M. range. He called in the *S.L. 7* (9 miles away) and the "*Cay W*". The weather was still rough but an attempt to tow the berg was decided upon at 17:00. By 21:00, the line [sic = berg] ([after] 4 attempts at heaving, then at [sic = after] towing line out from *Typhoon* to *S.L. 7*) was in tow by *S.L. 7*, but the drilling superintendent decided there was not enough time, as the berg, at 0.47 miles, was within the anchor pattern. Spring buoys were slipped and anchor lines cut, and the ship moved off location." (Marex, 1972). Wind 30 kts from 235°T direction, significant wave heights 10 m. It took from 17:00 to 21:00 (4 hrs) to get rigged up for a tow in this critical case.

Appendix 1 (Continued)

Chronological Summary of the First Four Petroleum Company-Related Iceberg Towing Field Programs 1970-1971

Sponsoring Company or Agency (Reference)	Vessel Owner or Contracting Agency	Location	Date; Time of Tow; (Duration)	Iceberg Description; Type of Tow; Rates of Tow
Memorial Univ. of Newfoundland, Faculty of Engineering and Applied Science & Bedford Institute of Oceanography	C.S.S. *DAWSON* Cruise No. 71-022 of the Bedford Institute of Oceanography Chief Scientist: John H. Allen J.W. Gorman responsible for bergy bit towing.	East of Saglek Bay, Northern Labrador ≈58°45'N ≈62°30'W	Aug. 12, 1972 near Current Meter D mooring 13:40 GMT aborted when bergy bit threw off sling. sea state: waves <1 ft. ≈ force 6 winds	Bergy Bit No. 1 height: n/a length: n/a width: n/a mass: n/a Towing sling was a modified 0.625 in nylon cargo sling with a 2 ft mesh size. Bergy bit was too small and it rolled over as the tow began.
Memorial Univ. of Newfoundland, Faculty of Engineering and Applied Science & Bedford Institute of Oceanography	C.S.S. *DAWSON* Cruise No. 71-022 of theBedford Institute of Oceanography Chief Scientist: John H. Allen J.W. Gorman responsible for bergy bit towing.	East of Saglek Bay, Northern Labrador ≈58°45'05"N ≈62°30'01"W ship's radar fixes on shore	Aug. 13, 1972 near Station No. 2 16:30 - 18:30 GMT (2 hr)	Bergy Bit No. 2 height: 2.6 m length: 15.5 m width: n/a draft: n/a mass: ≈1,032 tons Operational bollard pull: < 1.6 to 3.7 tons Towing sling of a modified cargo sling sea state: as above Towed in 216° direction for 2.0 hr for a distance of 3.4 n mi at a speed of 1.48 kt.
Memorial Univ. of Newfoundland, Faculty of Engineering and Applied Science & Bedford Institute of Oceanography	C.S.S. *DAWSON* Cruise No. 71-022 of theBedford Institute of Oceanography Chief Scientist: John H. Allen J.W. Gorman responsible for bergy bit towing.	East of Saglek Bay, Northern Labrador ≈58°41'N ≈62°19"W ship's radar fixes on shore	Aug. 16, 1972 southwest of Station No. 45 14:00 - 16:00 GMT (2 hr)	Bergy Bit No. 3 height: 2.1 m length: 5.2 m width: 4.6 m draft: 6.1 m mass: ≈680 tons Operational bollard pull: 1.1 to 2.6 tons sea state: as above Towed in ≈217.5° direction for 2.0 hr for an average distance of 3.8 n mi at an average speed of 1.9 kt.

Research on Sable Island Still Alive

by Cathy Von Kintzel
from Halifax Herald Limited
Thursday, April 7, 2005

TRURO - The federal government wasn't horsing around in January when it agreed to resume day-to-day management of the remote Sable Island Meteorological Station.

"It's full speed ahead," says Dave Wartman, acting director of Environment Canada's environment conservation branch.

The federal departments of Environment and Fisheries and Oceans announced in late January they would assume responsibility for the station and its four employees by April 1 [of this year].

Supporters of the island, known for its famed wild horses, applauded the move.

Mr. Wartman said the decision means the Sable Island Preservation Trust, which took over management of the station in 2000, can focus its efforts on education, research and awareness instead of managing infrastructure.

He said the change is basically in management only and Ottawa is committed to employing at least three and likely four people on the island year-round, including workers who have been there for years.

"There will be continuity with the people who have been on the island as employees of the Trust," Mr. Wartman said. "It won't be a bunch of brand new people going out there."

Mark Butler, marine co-ordinator for the Ecology Action Centre in Halifax, called it a good move.

He's looking forward to the creation of a stakeholders advisory group, which the federal government is working on and which should hold its first meeting in late April or early May.

The group is intended to advise governments on issues affecting the island. Its terms of reference are in the works and interested parties will be invited to attend the inaugural meeting.

"We've seen that Canadians, not just Nova Scotians and people in the conservation community, care about the island," Mr. Butler said. "It really strikes a chord."

"We need to continue to let the Canadian people know about this special place and that it's being looked after."

Zoe Lucas, president of the Sable Island Green Horse Society, wrote by e-mail from the island that everything seemed to be going according to plan regarding station staff.

The Sable Island Station - the air chemistry building is in the foreground.. Photograph is courtesy of Zoe Lucas

"They are government employees as of today," she said Friday, the first day of the management change. "It's a huge improvement for the operation, a significant step forward."

Ms. Lucas said that once the advisory group is in place, there will be more information available about the short- and long-term plans for the island.

It costs about $1 million annually to operate the meteorological station, the only permanent facility on the island, which is about 300 kilometres southeast of Halifax in the North Atlantic.

Staff study everything from the wild horses and the sensitive ecosystem to pollution, climate change, seal populations and the stranding of marine mammals. They also operate lights and beacons, collect weather data and maintain helipads and refuelling capacity for search and rescue aircraft and crews.

The Canadian Coast Guard will continue to be responsible for administering access to the island under the Canada Shipping Act, and the federal government will work with the Nova Scotia government on preservation and other projects.

Note from the editor: "Republished with permission from The Halifax Herald Limited".

Reference: *Save our Station - Save our Island* by Zoe Lucas, *CMOS Bulletin SCMO*, Vol.32, No.6, pp.163-164.

Des données météorologiques précises peuvent entraîner des économies de coûts appréciables

soumis par Vered Levant[1]

Alors que la météo continue de faire les manchettes dans le monde, les données météorologiques précises et opportunes prennent de plus en plus d'importance. Même si la plupart des Canadiens associent l'expertise météorologique à un secteur traditionnel comme l'agriculture, la météorologie peut également avoir une incidence sur le transport, la construction et le tourisme. Des prévisions exactes et précises offrent un potentiel extraordinaire d'économies.

Le sondage des spécialistes canadiens de la météorologie (*2005 Changing Climate: Canadian Meteorological Employment*), que vient de publier ECO Canada (Organisation pour les carrières en environnement), a pour but de permettre une meilleure compréhension du secteur canadien de la météorologie en soulignant les emplois habituels du secteur de la météorologie, en documentant les conditions actuelles et futures du marché de l'emploi, et en offrant des recommandations sur les étapes à suivre pour soutenir cet important secteur.

Produit à la demande du comité du secteur privé de la Société canadienne de météorologie et d'océanographie (SCMO), le sondage révèle qu'il existe des obstacles importants à la croissance du secteur auxquels il faudra s'attaquer si l'on veut assurer au secteur son plein potentiel d'emploi et son plein potentiel économique.

«Il est important que le Canada comprenne les besoins en ressources humaines du secteur de la météorologie pour assurer le maintien de sa croissance et de sa prospérité» déclare Ian Rutherford, directeur exécutif de la SCMO.

Au total, 9 200 spécialistes de la météorologie travaillent actuellement au Canada, et ce nombre devrait augmenter. La demande future projetée de spécialistes qualifiés est élevée — 2 350 d'ici 2010. Au même moment, les employeurs du secteur privé soulignent la pénurie de météorologistes qualifiés, aggravée par les faibles taux d'inscription aux programmes d'enseignement connexes. Cela pourrait avoir une incidence sur la qualité des renseignements météorologiques fournis aux Canadiens et aux entreprises canadiennes.

Selon Vered Levant, chercheur lié au marché de l'emploi chez ECO Canada, il existe de solides arguments économiques justifiant l'évaluation de l'importance de la météorologie pour la société, notamment la taille des effectifs actuels dans ce secteur. «Des prévisions météorologiques opportunes et précises permettent à l'industrie et aux Canadiens en général d'épargner des centaines de millions de dollars, et réduire les risques de pertes de vie», raconte-t-il.

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Note from the Editor: The English version of this article was published in the last issue of the *CMOS Bulletin SCMO*, Vol.33, No.3, p.70.

[1] Gestionnaire de projet, ECO Canada

Rectificatif

Il est fait mention dans la description de la page couverture du numéro de juin (*CMOS Bulletin SCMO*, Vol.33, No.3, p.66) que les médailles Parsons ont été octroyées durant le petit-déjeuner. Elles ont en fait été distribuées lors du déjeuner.

En page couverture du même numéro, l'image du bas à droite illustre l'envers de la médaille Parsons. Il faudrait tourner l'image de 90° dans le sens des aiguilles d'une montre pour la visionner correctement.

Oups!

On the cover page of the June issue (*CMOS Bulletin SCMO*, Vol.33, No.3), the bottom right image shows the back of the Parsons medal. It should be turned by 90° clockwise to look at the picture correctly.

Voulez-vous faire la critique d'un livre?

Si vous êtes intéressés à faire la critique d'un des livres dont la liste apparaît à la page 128 pour le *CMOS Bulletin SCMO*, prière de contacter le rédacteur-en-chef à l'adresse électronique bulletin@scmo.ca. Bien entendu, le livre vous appartient lorsque vous avez terminé la critique. Les instructions qui doivent être suivies lors de la critique d'un livre dans le *CMOS Bulletin SCMO* vous parviendront avec le livre. Merci pour votre collaboration.

Hard Choices
Climate Change in Canada

Editors: Harold Coward and Andrew J. Weaver

Published for
The Centre for Studies in Religion and Society
by Wilfrid Laurier University Press

Paper: ISBN 0-88920-442-X, 284 pp. $29.95, June 2004

Book reviewed by Pat Spearey[2]

This is a book of essays by Canadians and for Canadians on the nature and impacts of climate change for Canada and its inhabitants plus views on what can be done to reduce or avoid adverse consequences and gain from positive changes.

Many of the 20 authors contributing individually or co-operatively are known to CMOS members. Their disciplines and occupations are varied with the core being scientists, engineers, social scientists and humanists. A majority of the writers are on the teaching faculties of or associated with the University of Victoria. The range of essays embraces physical sciences, political, economic, social, technological, ethical and religious viewpoints and presents a commendable inter-disciplinary approach to the human and scientific challenges of climate change faced by Canadians.

Eleven essays are bracketed by an apt and thought-provoking introduction by a philosopher and poet and some lucid, crisply-presented concluding remarks by one of the editors, a respected and acclaimed scientist. In Part *One "What's Happening and Going to Happen ?"*, three essays cover climate change science, the human challenges, and the impacts of climate change, the last pertaining only to Canada and, helpfully, by region. Five shorter essays comprise Part Two, entitled *"What Can We Do ?"*. Terrestrial carbon sinks and climate change mitigation, the technology of climate change, the economic aspects of change, Canadian regional adaptation strategies, and the legal scenario are the topics. Part Three, *"Hard Choices"*, echoing the title of the book, sees a Canadian policy chronicle, some thoughts "beyond Kyoto", and an essay pondering how ethics and decision-making in religious states (e.g., Iran), in contrast to secular states, influence what individuals and groups can do.

The IPCC process and its assessments are satisfactorily covered. The positive and negative features and possible outcomes of the Kyoto Protocol appear in many essays with the emphasis on the Canadian and US positions and the complex emissions trading process. The impacts paper recognizes the greater-than-average changes in the north of Canada. There is just enough coverage of oceanic influences. Natural processes and forcing could have received more attention. The Canadian policy chronicle essay is a tight 12-page summary of activities since 1979. I would have liked to see more detail. The ethical and religious content of the final essay is a worthwhile component of a publication that aims to include all perspectives of climate change.

The generally easy-to-read narratives, with a few helpful figures (although some are very small in size) and tables in Parts One and Two, are supplemented at the end of each essay by references, some dated as late as 2003, to books, articles in scientific periodicals and reports (including "ATMOSPHERE-OCEAN"), newspaper items, and web site addresses. The nine pages of the index are thorough and accurate.

The book should be of value to both the non-expert entering the climate change arena and to those requiring an update or refresher on some or all of the aspects of the subject and all its uncertainties and challenges. It will assist a wide audience: the general public, researchers, government and company managers and staff – particularly planners, politicians at all levels, and high school and higher level students. I reviewed one of the copies in the Ottawa Public Library system. I hope it appears in other libraries and on individual's bookshelves.

Measuring the Natural Environment

by Ian Strangeways

Cambridge University Press, 2003
Paperback: ISBN 0 521 52952 2, 534 pages, US$70

Book reviewed by Shayne D. Keetley[3]

When it comes to studies or other activities relating to the natural environment, measurements are vital, for it is through these measurements that an understanding of the processes involved can be reached. Measurements are the cornerstone of predicting and assessing the prediction that was made. *Measuring the Natural Environment* is a book that investigates how the natural world is measured.

Chapter one focuses on the origins of measurements and notes recent advances in instrumentation, and draws a

[2] CMOS Member, Ottawa Centre.

[3] Meteorological Service of Canada

comparison between old and new instruments. This brief introduction is followed by a definition of terms used throughout the book. The chapter concludes with a plan of the book and reasoning behind the order in which it is presented.

The second through sixth chapters research the principles of radiation, temperature, humidity, wind and barometric pressure. Each chapter begins with a preliminary discussion about the variable and is followed by the units and terminology, followed by a look at measurement techniques, as well as common measurements that are made such as maximums, minimums and means. A list of references concludes each chapter.

Chapters seven through ten deal with processes of evaporation, precipitation, soil moisture and groundwater, and rivers and lakes and they have the same outline, sections to introduce the variable, definitions of units and terms, measurement techniques and a list of references.

The eleventh and twelfth chapters examine data logging and telemetry. Chapter eleven examines the construction, programming, operation, collection and protection of the data logger. The telemetry chapter delves into the reasoning for telemetering data, structure of the system, communication links, and satellite communications. Both of these chapters also include an extensive list of references.

The thirteenth through sixteenth chapters focus on the variables related to visibility, clouds, lightning and the upper atmosphere. These four chapters follow the familiar formula of an introduction of the variable and its history, followed by a summary of the units and terms. The chapters examine the measuring techniques, calibration and accuracy of the instruments and conclude with further references.

Chapter seventeen dives into the oceans with a look at the history of their measurement. It examines the sensor compatibilities between salt and freshwater, and comparisons using ships, moored buoys and drifting buoys as instrument platforms, and closes with the familiar list of references.

The eighteenth chapter looks at cold regions and the problems that arise from taking observations at low temperatures. Concepts explained are de-icing, manned and automatic stations, both directly and indirectly. Further, a short section is included on the hazards and techniques for taking observations from sea ice and icebergs. The chapter ends with a brief reference list.

Chapter nineteen is devoted to remote sensing, encompassing satellite orbits, electromagnetic spectrum, radiation and calibration of the instruments used to measure these variables. This chapter also contains a lengthy section on how to interpret satellite images and soundings. This chapter ends with a small section on the strengths and weaknesses of remote sensing, and a reference list.

Chapter twenty looks at the atmospheric composition, beginning with the prerequisite history of the atmospheric variables and their measurement. The author investigates greenhouse gases and reactive gases and progresses into deposition from the atmosphere, both dry and wet. The ozone layer is examined at great length and is followed by a lengthy reference list.

The twenty-first and final chapter looks into the future at emerging technology, ongoing research and reiterates that for one to understand the natural environment, we must measure it.

Measuring the Natural Environment is a well-written and organized book with the chapters reflecting the sequence of natural processes. The extensive use of pictures and diagrams allows the reader to gain a thorough understanding of the concepts presented. The inclusion of the history of each variable provides the reader with some interesting background information. The author notes his book is not intended as a manual or handbook for a technician; instead, it is aimed at the user that needs or wants to know background information, or install instruments, or collect field data.

Next Issue *CMOS Bulletin SCMO*

Next issue of the *CMOS Bulletin SCMO* will be published in **October 2005**. Please send your articles, notes, workshop reports or news items before **September 9, 2005** to the address given on page 98. We have an URGENT need for your written contributions.

Prochain numéro du *CMOS Bulletin SCMO*

Le prochain numéro du *CMOS Bulletin SCMO* paraîtra en **Octobre 2005**. Prière de nous faire parvenir avant le **9 septembre 2005** vos articles, notes, rapports d'atelier ou nouvelles à l'adresse indiquée à la page 98. Nous avons un besoin URGENT de vos contributions écrites.

Interested in doing Book Review ?

If you are interested in reviewing one of the books listed below for the *CMOS Bulletin SCMO*, please contact the Editor at the e-mail address provided at page 98. Of course, when completed, the book is yours. The instructions to be followed when reviewing a book for the *CMOS Bulletin SCMO* will be provided with the book. Thank you for your collaboration.

Books in search of a Reviewer
Livres en quête d'un critique

Climate Change 2001, Synthesis Report, Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, by Robert T. Watson, Editor, April 2002, Cambridge University Press, Paperback Cover, ISBN 0-521-01507-3, US$40.00.

The High-Latitude Ionosphere and its Effects on Radio Propagation, by Robert Hunsucker and John Hargreaves, Cambridge University Press, Hardback Cover, ISBN 0-521-33083-1, US$140.00.

An Introduction to Ocean Remote Sensing, Seelye Martin, Cambridge University Press, Hardback Cover, ISBN 0-521-80280-6, US$75.00.

Glaciers, by Michael Hambrey & Jürg Alean, Cambridge University Press, November 2004, ISBN 0-521-82808-2, Hardback cover, US$60.00.

Particulate Matter Science for Policy Makers: A NARSTO Assessment, Edited by Peter McMurry, Marjorie Shepherd & James Vickery, Cambridge University Press, November 2004, ISBN 0-521-84287-5, Hardback cover, US$150.00.

Flood Risk Simulation, by F.C.B. Mascarenhas, co-authored with K. Toda, M.G. Miguez and K. Inoue, WIT Press, January 2005, ISBN 1-85312-751-5, Hardback cover, US$258.00.

SHORT NEWS / NOUVELLES BRÈVES

Canada's Oceans Action Plan

The Government of Canada has announced the release of Phase I of Canada's Oceans Action Plan (OAP) with $28 million in funding. The OAP serves as the overarching umbrella for coordinating and implementing oceans activities, and provides a framework to sustainably develop and manage Canada's oceans. For information, including a background document, please access http://www.dfo-mpo.gc.ca/media/newsrel/2005/hq-ac47_e.htm. "Canada's Oceans Action Plan: For Present and Future Generations" is also available at http://www.dfo-mpo.gc.ca/canwaters-eauxcan/oap-pao/index_e.asp.

Breaking Ice: Renewable Resource and Ocean Management in the Canadian North

This new book represents the results of a three-year project undertaken by a team of researchers from the Integrated Management Node of Canada's Ocean Management Research Network (http://www.omrn.ca). The book attempts to define the nature of competing demands on ocean and coastal resources and assesses their impact. Ordering information is available at http://www.uofcpress.com/1-55238/1-55238-159-5.html.

UN Atlas of our Changing Environment

The United Nations Environment Programme (UNEP) has recently published an atlas entitled "One Planet Many People - Atlas of Our Changing Environment". The Atlas shows human impacts on the environment with both current and historical satellite imagery. The Atlas is available at http://www.na.unep.net/OnePlanetManyPeople/AtlasDownload.php

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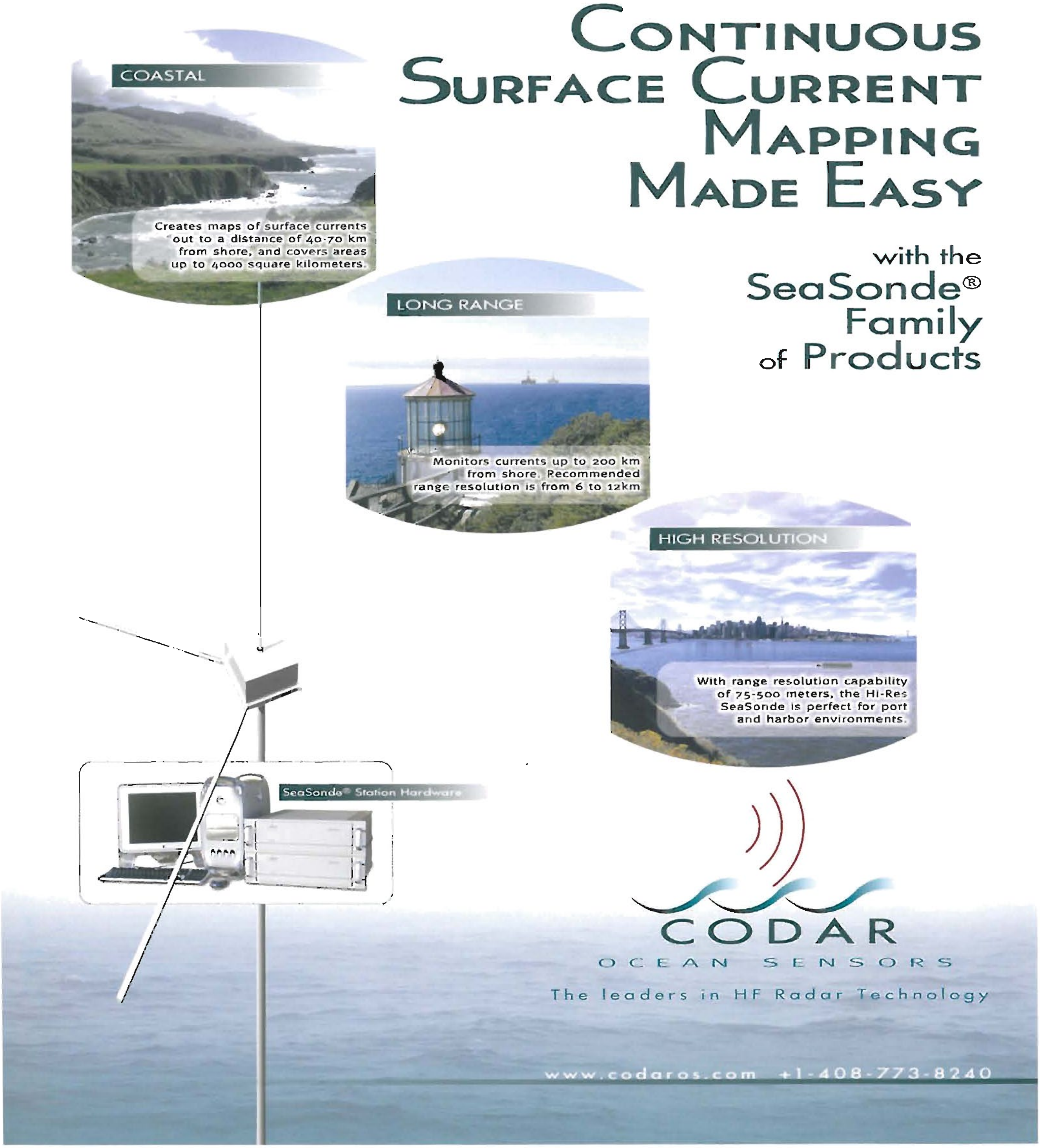
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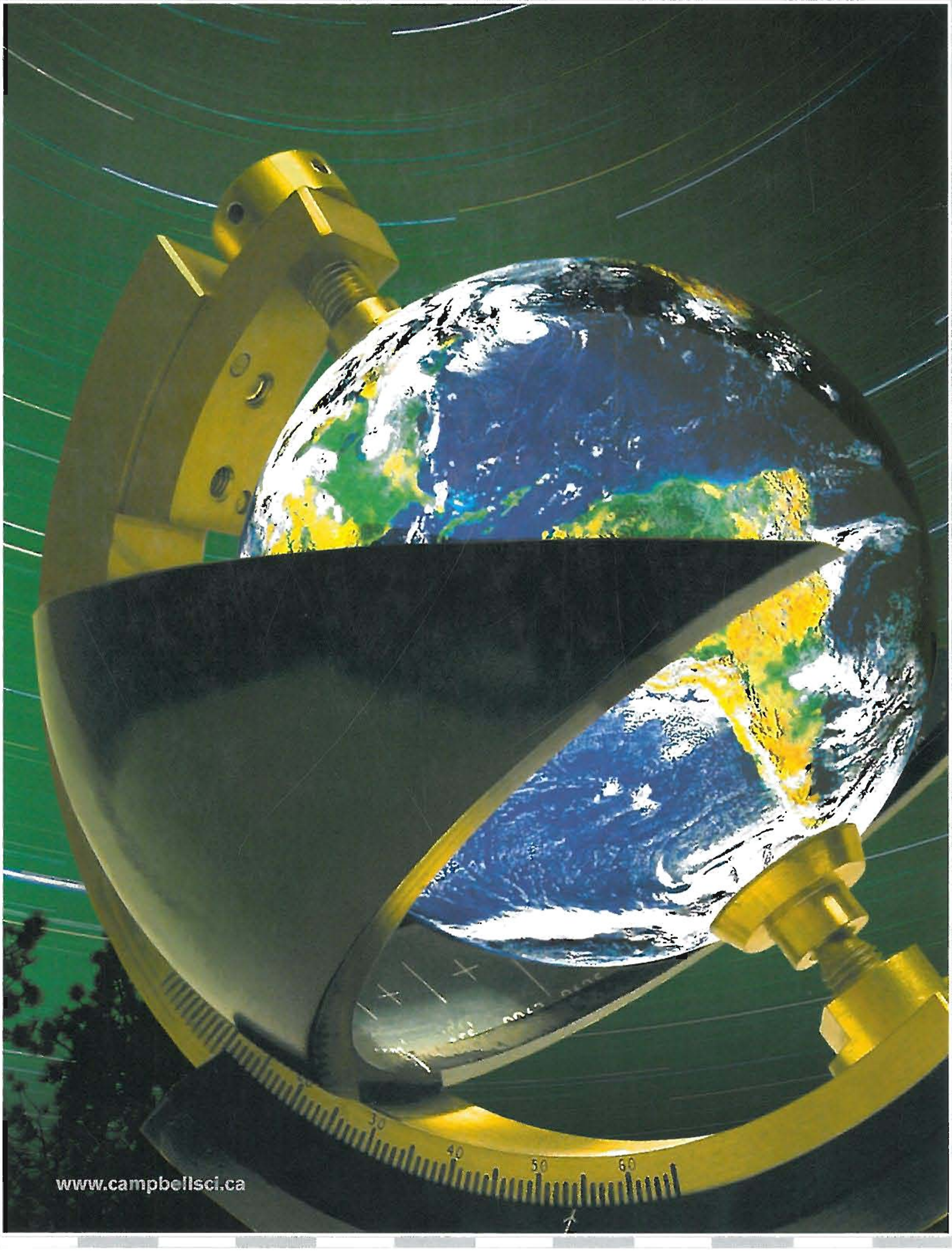

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