Roberts Bank Nearshore Survey

PGC95003

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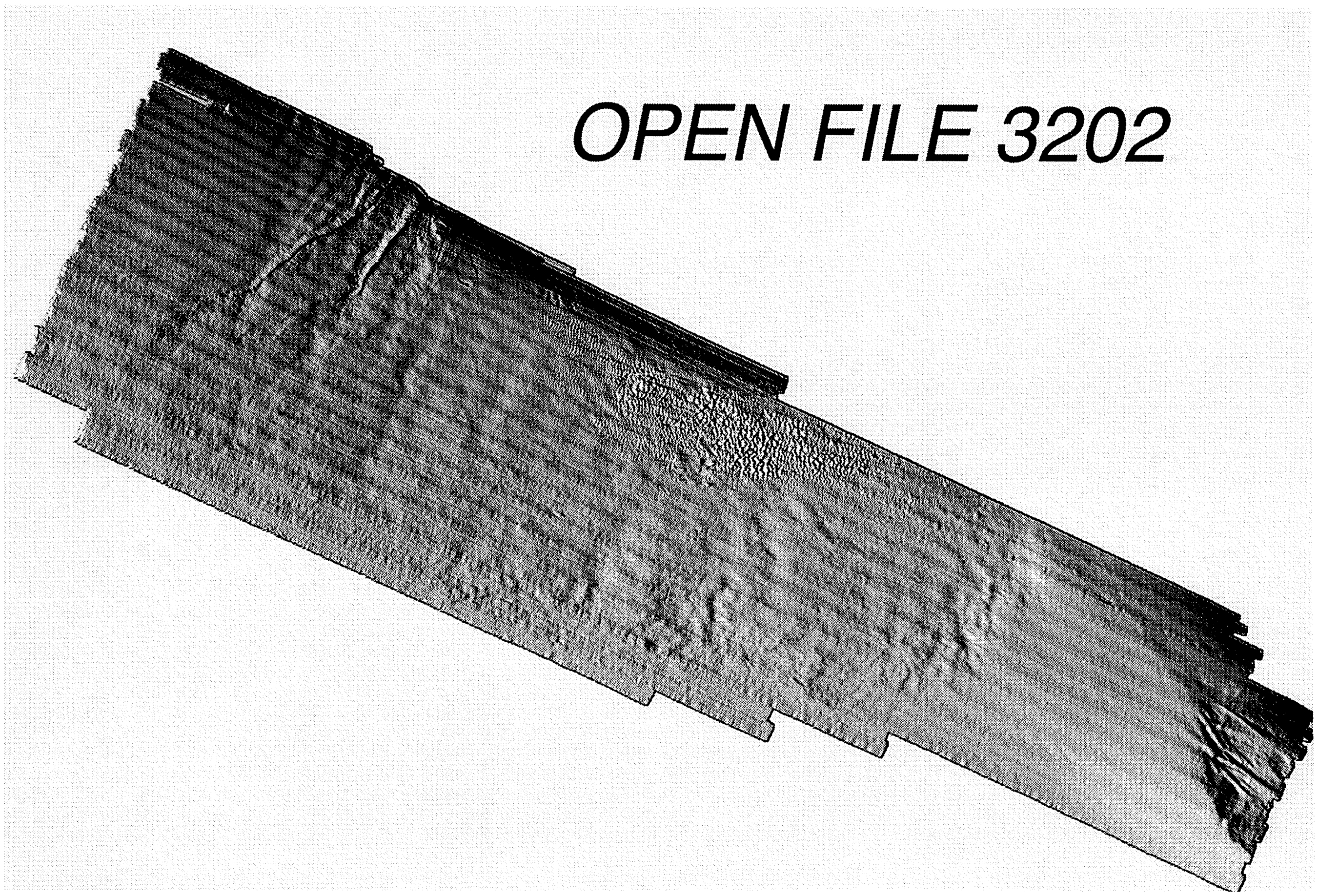

by:

David C. Mosher
Pacific Geoscience Centre
Geological Survey of Canada

GEOLOGICAL SURVEY OF CANADA

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PGC 95003

March 21 - 31, 1995

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Geological Survey of Canada
P.O. Box 6000, Sidney, B.C.
Canada, V8L 4B2

Executive Summary

Due to extensive tidal flats and extremely shallow water over most of Roberts Bank, it proved impossible to survey on the banks, except at their outermost margin. In addition, seismic reflection data quality is poor from shallow water (< 10 m). The problem of integrating onshore and offshore geophysics and collecting subbottom data from the intertidal and nearshore areas thus remains. Little information could be obtained from either high resolution boomer or airgun systems to correlate with geotechnical boreholes (which were placed in maximum water depths of 10 m) because of the shallow water depths of the boreholes and the presence of in situ gas.

Investigation of the failure complex was more successful. The base of the failure complex can be imaged with the airgun system on all of the slope profiles. These data show that the reflector marking the base is well within the subbottom (e.g. about 50 ms or 38 m below the sea floor) at the break in slope, where it is lost in multiple interferences. The implications of this fact are: 1) this reflector underlies engineering structures on the outer banks (such as the delta port), and 2), if this is in fact the lower surface of the failure complex, and the failure complex represents a single or multiple retrogressive slides, then the event(s) retrogressed well shoreward of the present break in slope. Little additional information on the failure wedge can be derived from more seismic surveying. Groundtruth samples through drilling are required to further refine interpretations.

Swath, sidescan and seismic reflection data have shown that there are extensive fields of apparently active sand waves on the uppermost slope of southern Roberts Bank. The present data provide a coherent picture of the extent of these fields in this area. Repetitive surveying may provide clues to the rates of migration of these features. Sidescan sonar is not a useful tool for the identification of BC hydro cables in this area, because it appears that most of the cables have been buried by these sand waves, or sedimentation subsequent to their emplacement.

PGC 95003 REVISOR Cruise Report

Introduction

Participants:

Scientific Staff:

David Mosher, PGC ... Chief Scientist
Ivan Frydecky, PGC ... technical support
Peter Simpkin, INRS ... Scientist (Seismic)
Peter Gross, MUSE (March 21-24) ... Digital Acquisition System
Bill Collins, PGC (March 27, 28) ... Scientist (Seismic)
Ralph Currie, PGC (March 29,30) ... Scientist (Magnetometer testing)
Dave Topham, DFO (March 29) ... Scientist - Plasma Gun testing

DFO

Ray Sanderson, DFO ... Captain

Equipment:

1) Simrad sidescan - 120 and 330 kHz operating frequencies.

2) Seistec high resolution seismic reflection profiling system with a 9 m Benthos external streamer.

3) 1 in^3. air gun with compressor and 9m Benthos external streamer

4) Knudsen dual frequency (50 and 200 kHz) sounder.

5) MUSE acoustic digital acquisition system for testing of digital acquisition of seismic and sidescan data.

6) Sony DAT recorder (8 channel)

7) Magnovax differential GPS receivers.

Objectives:

To survey the nearshore regions of the southern Strait of Georgia BC Hydro cable corridor with seismic and sidescan sonar technologies in order to:

1) Provide a link between offshore and onshore data.

2) Investigate the upslope extension of the Roberts Bank Failure Complex.

3) Investigate sediment erosion and transport in the upslope and shelf portions of Roberts Bank to

address their possible impact on offshore facilities.

4) To obtain geophysical ties to offshore and nearshore geotechnical boreholes, in particular the concurrent borehole taking place at the end of the Vancouver Deltaport/Westshore terminal.

Operations:

Sidescan sonar:

The Simrad Model MS992 was used to collect sidescan sonar records. Sidescan data were collected from March 22 (day 81) to March 26 (day 85). Range settings were typically 100 or 200 m per side. The sidescan fish was towed from a small boom on the port side of the after-deck of the Revisor. A small winch with a wire cable carried the load of the sidescan fish. This wire was marked at 2 m increments to calculate cable out for layback estimates. The sidescan cable was payed-out manually. The sidescan was tuned primarily for the 330 kHz mode and the 330 kHz channels were digitally recorded on the MUSE system, but all 4 channels (120 and 330 kHz) were recorded to Sony DAT tape. An Alden printer was used for hardcopy sidescan records. The printer occasionally locked up because of electromagnetic interference from the Seistec system.

Subbottom Profiling:

Seistec

The IKB-Seistec subbottom profiler was used to collect high resolution seismic data between days 81 and 85. The Seistec sled was towed off the starboard boom on the after deck. Enough scope was allowed to tow the sled level with, or slightly behind the stern of the vessel (about 10 m of wire out). A Honda 3 kW generator was used for the Geopulse power supply which was required to energize the boomer. Seistec was run at 175 Joules output, typically firing at a rate of about 1/4 second. Synchronized firing of the Seistec profiler and the sidescan fish avoided interference between the two systems. Return signals were received with internal and external hydrophones. The internal receiver was the 7 element line-in-cone array on the Seistec sled. The external receiver was the PGC-Benthos streamer - a 7 m, 9 element, oil-filled array. Hardcopy records were generated on an EPC 9800. In general the quality of the seismic data were very high, however, during periods where the weather conditions were marginal, aeration of the water under the boomer (and possibly the receiver) could cause "white-outs" for several seconds. Vertical motion due to wave action on the boomer catamaran exceeded 0.5 m during marginal weather conditions. This motion manifests itself on the seismic profile as displacement of the trace, resulting in deterioration of the overall quality of the image.

1 $in.^3$ airgun

A 1 $in.^3$ airgun was used from March 27 (day 86) to March 30 (day 89) to collect single channel seismic reflection data. This system was used instead of Seistec in the hopes of gaining increased subbottom penetration, due to its higher output energy and lower frequency content. The PGC Benthos streamer was used as the receiver (7 metre long, 9 element hydrophone streamer). Firing rates were typically 2 seconds running at 1500-1600 psi. The gun was towed on the port side off the steel cable formerly used for the sidescan towfish. The gun was towed 0.5 m below the sea surface; the Benthos streamer was towed 0.30 m below the sea surface.

Bathymetry:

The Knudsen sounder was mounted on the port rail of the quarter deck. The transducer was 1 m below sea surface. The sounder has two modes of operation: high frequency (200 kHz) which is suitable in shallow water, and low frequency (50 kHz), used in deeper water. Analogue chart records were collected at all times during surveying and bathymetric data digitally logged to a PC through a serial port, recorded at a rate of 1 sounding every 2 seconds.

Navigation:

Differential GPS navigation was logged on a PC. All shipboard clocks were synchronized to GPS time. Table 1 shows the start and end times of lines for referencing the navigation and data. Navigation data were logged every 5 seconds.

MUSE (Macintosh) data logger:

All sidescan and seismic data were logged digitally to Exabyte tape with the MUSE digital acquisition system (Euterpe). Peter Gross of MUSE Research, the developers of this system, participated on the initial phase of this cruise to test the equipment. It was highly successful and subsequent playback of the data has shown that the data were successfully recorded.

Results

The Revisor has a minimum operating water depth of 2 m. It was immediately obvious that, even during high tide, it would not be possible to survey very far onto Roberts Bank because of shallow water. Surveying was concentrated, therefore, at the shelf break on southern Roberts Bank, and around the Vancouver Deltaport shipping terminal, where dredging has permitted access to areas that would otherwise have been too shallow. A series of lines were run roughly parallel and perpendicular to the contour of the shelf break (about the 10 m contour) (Fig. 1), in an attempt to define the upper limit of the failure complex, and to look for evidence of sediment transport and erosion in this region. A number of these lines also pass close to the 1995 geotechnical borehole, that was being drilled concurrent with this surveying, at the end of the Deltaport facility. On one bad weather day (day 82) a survey up the Fraser River main arm, from Steveston to the Massey Tunnel, was conducted (Lines 63-70).

It was not possible to survey with all proposed equipment simultaneously, because of size constraints of the vessel. The Seistec high resolution subbottom profiler and Simrad sidescan sonar tools were deployed first (days 81-85; Lines 1-8, 24, 25, 60, 63-73). The 1 in.3 airgun survey followed, repeating lines already completed with the previous equipment as well as covering new territory (days 86-89; Lines 74-90). All data were recorded to the Sony DAT recorder. 330 kHz sidescan, Seistec (internal and external hydrophones), and airgun data were also recorded digitally with the MUSE data logger.

Sidescan sonar records from outer southern Roberts Bank and uppermost slope show that seafloor sediments are likely composed of sand. In fact, sand dunes are present over much of the seafloor in the region between about 10 and 120 m water depth (Fig. 2). These sand dunes are anywhere from 20 to 100 m in wave length and about 2-3 m in height, and appear recent or active from their appearance on sidescan records (sharp, definable edges, asymmetric shape). In general, their ridges are oriented roughly southwest-northeast and they are asymmetric with their lee (steep) sides to the northwest, indicating northwest migration of the dunes. Immediately around the Vancouver Deltaport causeway and outer "pod" that houses the shipping terminal, the seafloor shows abundant signs of anthropogenic activity. Irregular roughness to the seafloor is indicative of dredging and spoils dumping. Abundant debris, including anchor chains, buoy anchors, and logs are identifiable on the seafloor, especially between the shipping pod and the outermost pier, and in the turning basin. Construction in and around the turning basin, with the expansion of the Deltaport, includes caissons, fill material, and abundant channel markers and anchors, all of which can be seen on sidescan sonar records.

Subbottom profiles from the southern Roberts Bank include both the 1 $in.^3$ airgun and Seistec data. As discussed above, Seistec data were collected for their high resolution and airgun data were collected for the possibility of achieving deeper penetration. It was not known beforehand which system would give the better data, thus in part this cruise represents a test as to which is the better system in this environment. In a number of cases duplicate lines were run with the Seistec and airgun systems. In areas without subbottom gas, Seistec recorded on the external hydrophone streamer with gain recovery, gave excellent results with good penetration; comparable to the airgun but with higher resolution. When gas is present, however, the Seistec signal is rapidly attenuated and there is significantly less subbottom information at depth.

Little subbottom information is achieved by either system on the bank tops. Water depths are shallow enough that the direct wave interferes with the reflected signal and there are abundant multiple reflections. In addition, sediments near the surface appear to be highly reflective, and therefore much of the acoustic energy is returned from the surface and shallow subsurface, which in turn enhances multiple reflections. The result is, records from the bank tops appear to have a "ringing" characteristic. Sea surface wave height increases and period decreases in shallow water. This wave action further decreases data quality.

Contour parallel lines on the very uppermost slope show a complex subbottom. Underlying the sandwave field reflectors tend to be coherent and continuous. This unit can be from one to tens of metres thick. Where this unit pinches out and the sand waves are not present, a unit with an incoherent characteristic comes to surface. What little subbottom information that can be derived indicates a possible subsurface horizon which is very irregular with numerous channel-shaped features. Where this unit comes to surface the echo-character of the seafloor on sidescan records changes as well; there tend to be no sand waves, the bottom is more reflective (higher intensity returns), and the seafloor appears to be composed of coarser-grained material.

Further downslope (>30 m water depth), shallow gas impedes good subbottom imaging of the geology. Along slope profiles (parallel with the bathymetric contours) show occasional windows through the gas, exhibiting parallel, coherent reflections, some of which are clinoform-shaped. Surfaces of the gas-laden sediment yield high amplitude, phase reversed return signals. Many of these returns simulate point reflectors because of the discontinuity in the gas in the subsurface.

Sub-bottom profiles oriented downslope (roughly perpendicular to bathymetric contours) show a rough surface morphology between about 10-120 m water depth, reflecting the sand dunes prevalent at these water depths. Underlying these dunes, sediment subbottom reflections are coherent and parallel to subparallel. Shallow gas tends to disrupt signal coherency. The best profile is seen on Line 73 with the Seistec system (Fig. 3). This line is the furthest south in the survey area and duplicates an earlier line collected with the Huntec Sparker system (PGC95001 - Line 3c). Line 73 intersects the southern edge of the Roberts Bank failure complex and is an area where recent delta sediments are thin and Pleistocene till comes close to the seafloor (it outcrops further south at Pt. Roberts). Data from this line show a sequence of thin-bedded, coherent reflectors overlying a high amplitude, rough surface. This package thins in the offshore direction. Downslope, commencing in about 100 m of water depth, a high amplitude reflector in the subsurface outcrops at both ends - giving a lens-shape to the unit above the reflector. This unit is a maximum of about 12 m thick on this line. Further to the north, around the coal port, a series of slope lines show this subbottom reflector to be about 40 m deep and still about this depth at the break in slope (10 m water depth) (Figs. 4 and 5). In other words, the upslope termination of this reflector is not seen because it gets lost in the multiple interferences that occur on the bank tops. Suffice to say that it is still well in the subbottom at the break in slope. Very little subbottom information is recovered from below this horizon.

Discussion

Widespread active sand waves on the uppermost slope off Roberts Bank show sediment transport to the northwest is likely occurring at present (Figs. 1C and 2). This evidence has been noted in previous surveys. Repetitive surveying and data comparison can document active migration of these sand dunes. It is unlikely, however, that navigation was accurate enough in earlier surveys to make a comparison study worthwhile. Recent advances in navigation (differential GPS) may make future repetitive surveys advantageous. Similarly, repetitive bathymetric surveys, especially in the slope break region, can provide evidence for active sediment erosion and possible regression of the slope break. The resolution needed would require swath surveys, the results of one such survey are shown on Figure 1C from data collected during October, 1994 (Milner, 1994).

Evidence in subbottom records of buried channels at the shelf break is expected. Small channels are likely present from when the Fraser River drained through Canoe Pass or even further south on Roberts Bank. They were likely distributaries of the main channel or tidal channels influenced by river outflow. Surface expression of these buried channels are visible on the swath image of the seafloor in Figure 1C. In slightly deeper water, on the uppermost slope, subbottom evidence shows the sediments are coherent and reasonably flat lying to clinoform in shape. These sediments probably represent the upper prodelta sediments discharged through the aforementioned channels. Shallow biogenic gas, recognized throughout the sediments in the offshore portion of the delta, is present within the sediments and impedes acoustic subbottom imaging. Short sections without gas, or where the gas is deeper in the section allow imaging of the upper prodelta sediments. These sections have the appearance of channels, but the internal stratigraphy suggest they are not channels, but rather simply windows through the gas. The prodelta sediments overly a rough, high amplitude surface which is probably Pleistocene till. This surface can only be seen at the southernmost extent of the survey area, where it begins to shallow and eventually outcrop at Point Roberts (Fig. 3).

The high amplitude, somewhat irregular reflector within the prodelta sediments between about 10 and 50 m subbottom depth as seen in the airgun records, is a gas-brightened horizon. Underlying gas causes a large impedance contrast with overlying gas-free sediments, hence acts as a strong reflector. It is believed this horizon is the lower bounding surface of what has previously been defined as the Roberts Bank Failure Complex. This reflection horizon can be seen on all airgun slope lines run in this survey. It is shallowest at the southernmost end (Line 73), and deepens to the north. Line 73 shows this horizon outcrops at the upslope end in about 100 m water depth. Survey lines further north around the Deltaport, however, show this reflector is still about 40 m subbottom at the break in slope, above which it is no longer imaged (Figs. 4 & 5). There is not enough evidence to qualify the significance of this reflector and the package of sediment overlying it. A Terra Surveys (1994) report suggest several plausible explanations, none of which have been ruled out by this survey. These interpretations range from a single massive prodelta sediment failure, and the reflector represents the lower bounding surface of this failure, to a river mouth failure complex, as presently exists off of Sand Heads, to simply a change in sediment facies. Swath bathymetry data of this complex (Fig. 1C), imaged and presented publicly for the first time in this report, are highly suggestive of the latter explanation. This image shows what appear to be buried channels oriented downslope. Marine electromagnetic results across this complex show a conductivity (hence apparent porosity) reversal within it (Mosher, Law and Quinn, 1995). These results likely indicating the complex is composed of a coarser material than surrounding sediments (i.e. possible medium to coarse sand), or that the failure process has served to consolidate the section somewhat, yielding lower porosities. Without direct sampling through drilling into this complex it is unlikely the interpretation can be further refined. What has been shown in this survey, however, is that the lower bounding surface (the high amplitude reflector) is still well in the subsurface at the break in slope and further inshore. The most serious consequence of this finding is that this reflector likely underlies engineering structures on the outer banks, such as the Vancouver Deltaport. If it represents a failure plane of a massive delta failure then it documents an event that has incised well back on the delta plane. If it represents a potential zone of weakness that can be affected by future ground shaking then it puts these engineering structures at greater risk.

Summary

In many respects, survey PGC95003 represented an experiment to test the feasibility of geophysical surveying with traditional marine techniques in shallow water, on the bank tops, and to test the applicability of two different seismic profiling tools in this same environment. The primary scientific objectives were to attempt to provide a link to onshore geophysical surveys, provide geophysical ties to outer bank geotechnical boreholes, to investigate the upslope extension of the Roberts Bank Failure Complex, and to study sediment erosion and transport phenomena in the upper slope, outer bank regions.

Due to extensive tidal flats and extremely shallow water over most of Roberts Bank, it proved impossible to survey on the banks, except at their outermost margin, even at high tides with a small vessel such as the Revisor. In addition, shallow water marine seismic reflection surveying was not successful because of multiple path interference and reverberation, and the gassy, highly reflective nature of the bottom sediments. The problem of interfacing onshore and offshore geophysics thus remains.

Direct comparison of data from Seistec and 1 in^3 airgun seismic reflection systems has shown that, in general, Seistec gives better quality data, and at higher resolution than the airgun. Recording an external hydrophone with the Seistec system and post-processing with filters and time-varying gains, can increase subbottom penetration. Signal from the Seistec geopulse source, however, is attenuated more rapidly than the airgun source, thus in gas-laden sediments, for example, the airgun is the preferred system for achieving subbottom data at any appreciable depth (e.g. > 50 ms). Because of the limitations in subbottom penetration caused by in situ gas, and multiple reflection interference in shallow water, little information could be obtained from either system to correlate with existing geotechnical boreholes (which were placed in maximum water depths of 10 m).

Investigation of the Roberts Bank failure complex was more successful. Swath bathymetry imaging of the area clearly delineates the area of the complex. Seismic imaging is successful at acquiring some subbottom information within the feature. A subbottom, high amplitude, gas-enhanced reflector has been observed on most airgun seismic profiles that are oriented perpendicular to the contours (i.e. up and down slope). It is thought that this reflector represents the base of the failure complex. These profiles have shown that this reflector is well within the subbottom (e.g. about 50 ms or 38 m below seafloor) at the break in slope, where it is lost in multiple interferences. The implication of this fact is that: 1) this reflector underlies engineering structures on the outer banks (such as the Deltaport), and 2), if this is in fact the lower surface of the failure complex, and the failure complex represents a single or multiple retrogressive slides, then the event(s) retrogressed well shoreward of the present break in slope.

Swath bathymetry, sidescan and seismic data have shown that there are extensive fields of apparently active sand waves on the uppermost slope of southern Roberts Bank. This fact was known previously. Swath bathymetry mosaicing provides a coherent picture of the extent of these fields in this area. Repetitive surveying may provide clues to the rates of migration of these features. Sidescan sonar is not a useful tool for the identification of BC Hydro cables in this instance because it appears that most of the cables have been buried by these sand waves, or other sources of sedimentation subsequent to their emplacement.

Recommendations

1. Geophysical surveying on the tidal flats of southern Roberts Bank will require a specifically designed program, using land-based techniques for seismic reflection, rather than marine. It is suggested that geophones be used rather than hydrophones, and therefore, they must be emplaced within the bottom sediment. There are specially designed airguns, known as mud guns, which rest on the seafloor and may work as a sound source. Alternatively, perhaps land-based techniques, such as a buffalo gun, may work and is logistically simpler than airguns. The program would be labour intensive.

2. In order to monitor rates of sediment erosion/slope retrogression it is suggested that an annual repetitive bathymetric survey program be undertaken, such as was conducted in 1994 (Milner, 1994). Only the break in slope area needs to be surveyed and such a task can be conducted by Department of Public Works multibeam vessels, such as operate at Sand Heads and the main channel, or the new Canadian Hydrographic Service EM5000 system. To determine rates of sediment transport, instrumentation should be installed on the seafloor and monitored over a period of time. These instruments might include current meters, sediment traps and transmissiometers, for example.

3. As a first step to the sediment transport/erosion program, enough sidescan sonar data presently exists in the southern Roberts Bank region to mosaic at least one and probably several complete data sets. This task would provide accurate mapping of surficial features and if several mosaics were possible, it may provide repetitive survey information (migration of bedforms, for example). This task is feasible now, and should be accomplished in the short term. In addition, it would be a useful complementary data set with the swath bathymetric survey data set of last year. It is a short term, labour intensive task.

4. It is unlikely that any more can be learned from the Roberts Bank Failure Complex with additional geophysical surveying. It is recommended that recent data (PGC93010, PGC95001, and PGC95003) be integrated with the compilation of the Terra Surveys contract report (1994) on the failure complex. The newer digital data has provided additional information and lends itself to digital interpretation techniques. Following on this, it is necessary to drill into and below the failure material with offshore geotechnical boreholes. Seismic imaging is good in the offshore and good correlation of geophysics to geology is expected from such a program. The program would provide groundtruth for the geophysics and provide in situ geotechnical data and sample for geotechnical testing.

References

Milner, P.R., 1994. Dolphin EM100 Mulibeam Project, Field Report. Canadian Hydrographic Service, Department Fisheries and Oceans, Institute of Ocean Sciences, Sidney, B.C., 31 pp.

Mosher, D.C., Law, L.K., and Quinn, R., 1995. Marine Electromagnetic and seismic high resolution profiling: results from coastal British Columbia. Canadian Coastal Conference Proceedings. October, 1995, p.621-635.

Terra Surveys Ltd. 1994. The Roberts Bank Failure Deposit, Fraser River Delta, British Columbia. Industrial Partners Program Report to British Columbia Hydro and Power Authority and the Geological Survey of Canada, January 10, 1994.

List of Figures

Table 1: Survey Lines

Line	Start Time	End Time	Line Length (metres)	Geographic Location	Equipment deployed
Line5	950812030	950812057	3151.04	Roberts Bank	Seis & Sidescan
Line6	950812105	950812140	3515.79	Roberts Bank	Seis & Sidescan
Line7	950812144	950812204	2589.74	Roberts Bank	Seis & Sidescan
Line8	950812213	950812236	2266.13	Roberts Bank	Seis & Sidescan
Line60	950812247	950812304	1774.82	Roberts Bank	Seis & Sidescan
Line24	950812334	950812344	1066.57	Roberts Bank	Seis & Sidescan
Line25	950812350	950820005	1503.59	Roberts Bank	Seis & Sidescan
Line 1	950820022	950820104	5862.63	Roberts Bank	Seis & Sidescan
Line63	950821733	950821905	7294.34	Fraser River	Seis & Sidescan
Line64	950821908	950821926	1670.26	Fraser River	Seis & Sidescan
Line65	950821929	950822001	1580.44	Fraser River	Seis & Sidescan
Line66	950822005	950822020	1595.19	Fraser River	Seis & Sidescan
Line67	950822022	950822104	1526.80	Fraser River	Seis & Sidescan
Line68	950822115	950822120	307.21	Fraser River	Seis & Sidescan
Line69	950822123	950822135	1219.17	Fraser River	Seis & Sidescan
Line70	950822152	950822201	583.66	Fraser River	Seis & Sidescan
Line5a	950841740	950841917	10090.51	Roberts Bank	Seis & Sidescan
Line4	950841917	950842112	8094.07	Roberts Bank	Seis & Sidescan
Line3	950842117	950842227	7905.06	Roberts Bank	Seis & Sidescan
Line71	950842250	950842318	2583.67	Roberts Bank	Seis & Sidescan
Line72	950842319	950842358	3425.52	Roberts Bank	Seis & Sidescan
Line2	950851757	950851957	10040.95	Roberts Bank	Seis & Sidescan
Line73	950852015	950852055	3429.58	Roberts Bank	Seis & Sidescan
Line74	950861925	950862150	22963.40	Roberts Bank	1 in^3 Airgun
Line75	950862216	950862246	2790.13	Roberts Bank	1 in^3 Airgun
Line76	950862256	950862326	3260.20	Roberts Bank	1 in^3 Airgun
Line77	950870027	950870037	887.50	Roberts Bank	1 in^3 Airgun
Line78	950871755	950872000	9703.13	Roberts Bank	1 in^3 Airgun
Line79	950872021	950872109	3944.91	Roberts Bank	1 in^3 Airgun
Line80	950872128	950872143	1377.87	Roberts Bank	1 in^3 Airgun
Line81	950872228	950872248	1747.90	Roberts Bank	1 in^3 Airgun
Line82	950872253	950872326	2884.95	Roberts Bank	1 in^3 Airgun
Line83	950872331	950880010	2880.33	Roberts Bank	1 in^3 Airgun
Line84	950881742	950881939	10853.64	Roberts Bank	Plasma gun
Line85	950882324	950882334	972.20	Roberts Bank	1 in^3 Airgun
Line86	950891817	950891840	2316.23	Roberts Bank	1 in^3 Airgun
Line87	950891901	950891930	2756.16	Roberts Bank	1 in^3 Airgun
Line88	950891936	950892000	2540.01	Roberts Bank	1 in^3 Airgun
Line89	950892005	950892025	2113.27	Roberts Bank	1 in^3 Airgun
Line90	950892030	950892100	3120.98	Roberts Bank	1 in^3 Airgun

Appendix A

Daily Logs:

J.D. 80 (March 21, 1995) I.Frydecky, P. Simpkin, P. Gross, and D. Mosher

Finished loading Revisor and setting up equipment. Sailed into Saanich Inlet to test equipment in the water. Navigation not working. Borrowed Magnovax receiver from CHS and sailed for Steveston at 1500hrs. Arrived Steveston 1800hrs.

J.D. 81 (March 22, 1995) I.Frydecky, P. Simpkin, P. Gross, and D. Mosher

Sailed at 0900hrs and arrive coal port 1030hrs. Final set up with computers, DAT tape, navigation, etc. Running Seistec and sidescan concurrently during the first part of this survey. Sidescan fails temporarily. Very low power transmitting but all systems check out OK. Raised system, reset plugs and all worked fine. Using factory gain settings and records look good. Using new transducers in sidescan (narrower beam width to reduce water bottom return). Started running lines about noon with Lines 5-8 between the end of the coal pod and the pier. Ran contour lines but could not run very far up on the banks - water depths too shallow for even the Revisor. Clearly not going to able to run the survey grid I had laid out because of water depths. Ran offshore with Line 60 (an arbitrary line), then in line 24, out line 25, and turned onto line 1 and proceeded to Steveston at 1715hrs.

J.D. 82 (March 23, 1995) I.Frydecky, P. Simpkin, P. Gross, and D. Mosher

Underway 0900hrs. Out to Sand Heads - too rough with NW winds at 20 knots (wrong direction for surveying to north of Coal Port). Surveyed Fraser River instead, up to Massey Tunnel. Collected some great data from around the tunnel (Lines 63-70). Line 65 is a particularly good example. A number of problems with the Alden printer loosing sync and sidescan stopping. Apparently caused by interference with the Seistec, particularly in this fresh water it seems (i.e. grounding less efficient).

J.D. 83 (March 24, 1995)

Weather still too rough - 35 knots.

J.D. 84 (March 25, 1995) I.Frydecky, P. Simpkin, P. Gross, and D. Mosher

Departed Steveston jetty at 0900 and proceeded to coal port. Weather much improved but still rough. Run line 5 (called 5a) starting at N end of Canoe Passage, then lines 4, and 3, then upslope and into turning basin for line 71 and downslope for line 72 with sidescan and Seistec. Switched digitizing signals to processed internal (linear TVG ramp and bandpass of 1-10 kHz to MUSE system. So signals to MUSE: internal signal (line-in-cone array) is processed through Seistec unit and through Kronhite filter - Kronhite used to increase gain by 20 dB and BP of 500-9000 Hz. External signal (Benthos streamer) is raw (not passed through Seistec) and BP of 5-9000 Hz. 1810 changes external BP 500-9000 Hz; 1810 changed external BP 1000-9000 Hz; 1810 changed 330 kHz sidescan gains; 1948 changed external BP 500-9000 Hz.; 2018 changed location of Seistec external streamer away from bow wake of tow sled (much quieter now); 2133 Sidescan logging hung on MUSE system, restarted with new file number (#8). 2358hrs - end line 72 and end day.

J.D. 85 (March 26, 1995) I.Frydecky, P. Simpkin, and D. Mosher

1757hrs start Line 2 at Canoe Pass. Put external on channel 6 of Sony DAT tapes. Filters on external set at 200-9000 Hz. Increase gains on external to 40 dB (20 in and 20 out). Took tail float off of streamer. Towing about 1 ft below surface. 2020hrs start seistec line down slope

(Line73) from Ferry terminal - duplicating Huntec sparker line 3c from PGC95001. 2034hrs changing firing rate to 1/4 sec (from 3/16) to accommodate deep water. 2055hrs end line 73, proceed to the turning basin to conduct calibrated hydrophone tests. Conducted Seistec calibrated hydrophone tests to acquire source signature data. Recorded on Simpkin's Sony DAT recorder.

J.D. 86 (March 27, 1995) I.Frydecky, P.Simpkin, W.Collins

Switch over to 1 cu. in. airgun (load compressor and airgun and set up). 1105hrs (local) depart Steveston for Line 3. 1205hrs (local) airgun in water and stream gear. Running only airgun and PGC streamer. 1225hrs Start line 3. 1244hrs change firing rate to 2 secs to attempt to build up air pressure - running at 1500 psi. 1416hrs (local) start line 75 in from of drill rig. Let out eel and gun. Ran lines 76 and 26. 1645hrs pull gear and head for Steveston.
Seismic data being logged on Channels 2 and 3 of MUSE system.
Ch.2 = Raw signal, BP 200-9000 Hz with 80 dB gain
Ch.3 = Processed, BP 400-4000 Hz with 60 dB gain + ramp gain.

J.D. 87 (March 28, 1995) I.Frydecky, P.Simpkin, W.Collins, D. Mosher

0955 Start line 78. Reduced distance from float to gun - yesterday was about 1 m, today about 0.5 m. 10 m layback to gun, 15 m to start of streamer. Recording setup same as yesterday except gain on Raw is 60 dB and gain on Processed is 40 dB. 1822hrs(GMT) changed gain on Ch.2 raw data, down to 40 dB. 2200hrs (GMT) blow seal on airgun, stop Line 81 - repair and finish line 81. Line 82 and 83 (Lines 81-83 are slope lines north of Coal Port). Show failure wedge comes right up to the shelf break.
NB Knudsen clock is 12 seconds slow from beginning of cruise.

J.D. 88 (March 29, 1995) I.Frydecky, P.Simpkin, D.Topham, R. Currie, D. Mosher

Start with line 84 from Canoe Pass to Coal Port. 1939hrs (GMT) stop line 84, into turning basin to conduct signature tests of 1 cu. in. airgun.
-Tape 6, file 2 on MUSE is signature test of airgun = 50 ms at 40μs sampling rate and 20 dB gain, running at 1825 psi pressure. Gun 0.75 m below sea surface and hydrophone 5 m below gun.
-file 3 signature test with gun at 1.2 m and 1700 psi
- file 4 signature test of plasma gun (Dave Topham's experiment). Failure because too much ringing of plasma gun, due to the pressure case housing, probably.
- file 5 Plasma gun line (Line85) lots of ringing!
abort plasma gun tests and reconfigure for airgun. Could not get logging system to work. Replaced/rewired all BNC cables and system now works.

J.D. 89 (March 30, 1995) I.Frydecky, R. Currie

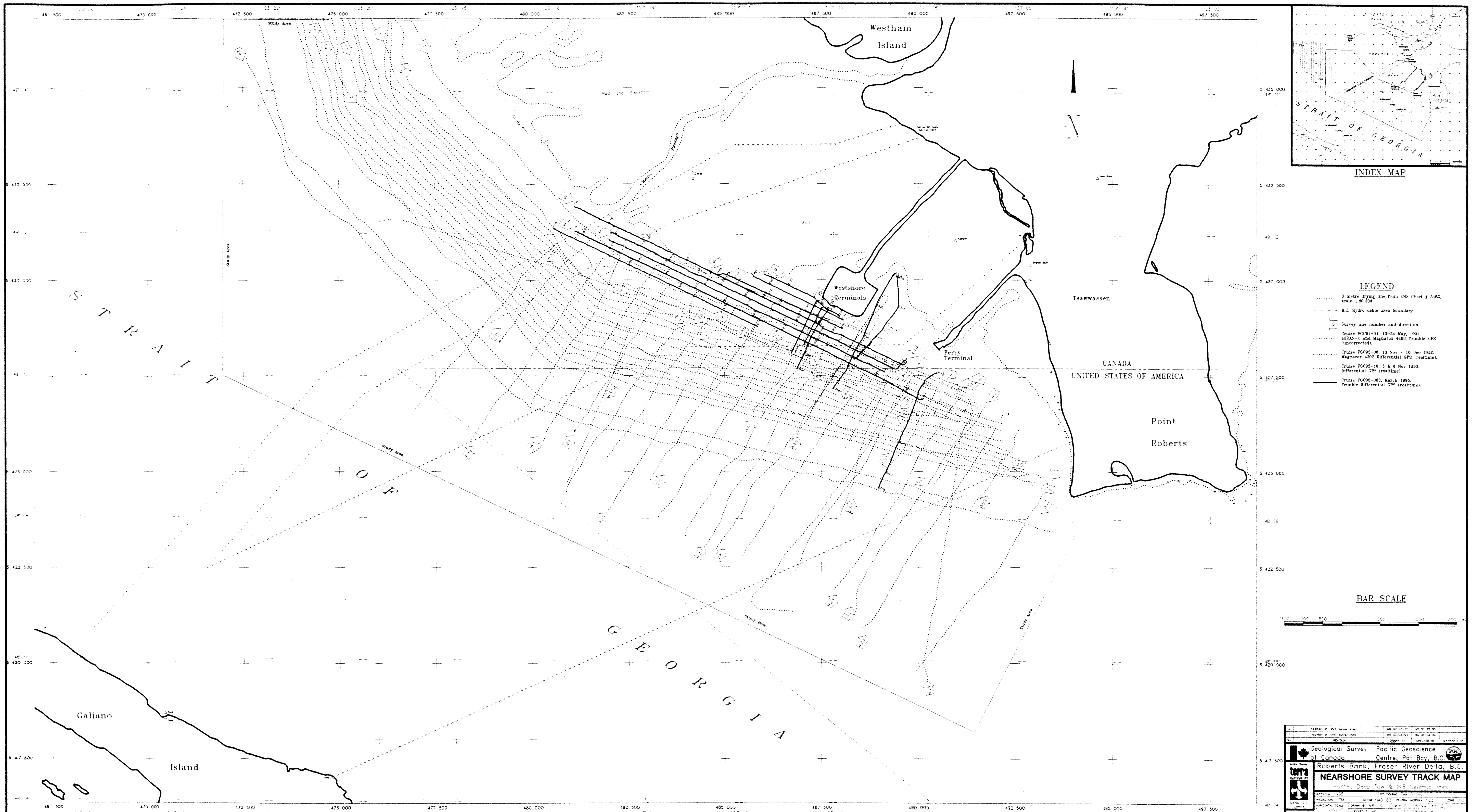
Depart Steveston at 0850hrs (local) and transit to westshore terminal. SOL 86 at 1817hrs (GMT). Traced high frequency noise problem to the autopilot. continued line to 2100 GMT, then switched gear to Magnetometer. Deployed 30 m cable behind ship, and navigation another 7m forward (i.e. position of antenna). Water depth ~100m. Started line 2148hrs (GMT) at 3.5 knots.
2211hrs a/c to starboard - run reciprocal course in 50 m water depth (900 m to starboard).
2220 start SE line offset 900 m to NE of original line
2249 through cable corridor
2308 a/c to 117° to cross Tsawwassen cable corridor.
2315 entering cable corridor

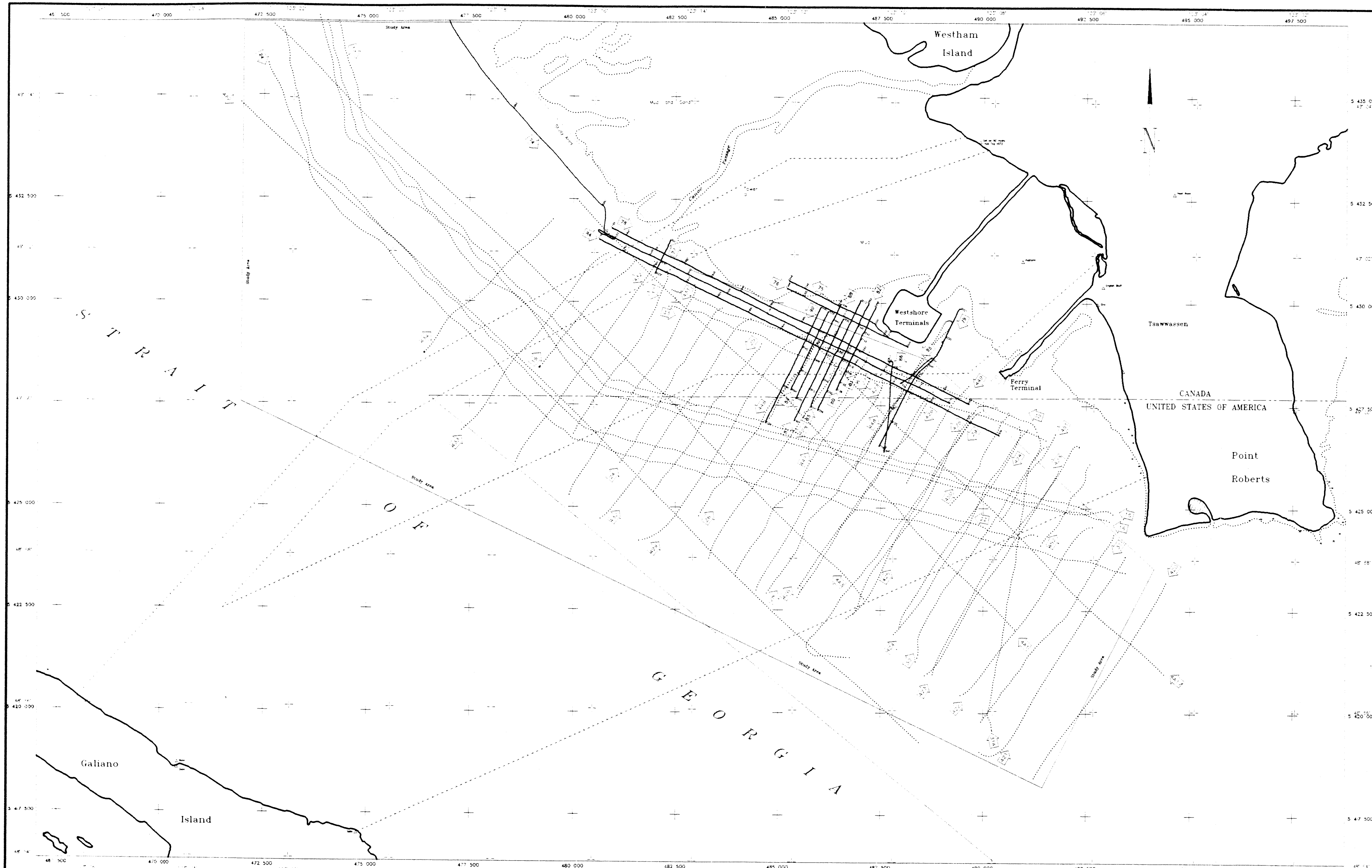
2347 end survey - no anomalies recognized.
return to Steveston. End of Survey

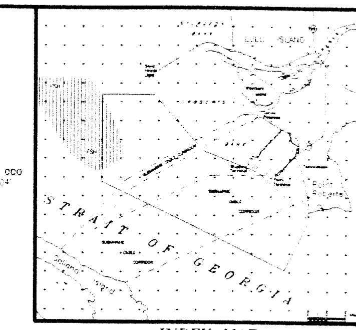
J.D. 90 (March 31, 1995) - Revisor returns to IOS

Appendix B

Location of PGC95003 tracklines in relation to previous survey tracks.


Westham Island
Westshore Terminals
Ferry Terminal
Tsawwassen
CANADA
UNITED STATES OF AMERICA
Point Roberts
STRAIT OF GEORGIA
Galiano Island
INDEX MAP
LEGEND
0 metre drying line from CHS Chart # 3463, scale 1:80,000
B.C. Hydro cable area boundary
5 Survey line number and direction
Cruise PGC91-04, 13-24 May, 1991. LORAN-C and Magnavox 4400/Trimble GPS (uncorrected).
Cruise PGC92-06, 13 Nov - 10 Dec 1992. Magnavox 4200 Differential GPS (realtime).
Cruise PGC93-10, 5 & 6 Nov 1993. Differential GPS (realtime).
Cruise PGC95-003, March 1995. Trimble Differential GPS (realtime).
BAR SCALE
Addition of 1995 survey lines
Addition of 1993 survey lines
Geological Survey of Canada
Pacific Geoscience Centre, Pat Bay, B.C.
PGC
terra surveys ltd
Roberts Bank, Fraser River Delta, B.C.
NEARSHORE SURVEY TRACK MAP
3a of 7
FIGURE 3A





INDEX MAP

LEGEND

- 0 metre drying line from CHS Chart # 3463, scale 1:80,000
- B.C. Hydro cable area boundary
- 5 Survey line number and direction
- Cruise PGC91-08, 20-27 Nov. 1991. LORAN-C and Magnavox 4400 GPS (uncorrected).
- Cruise PGC92-06, 13 Nov - 10 Dec 1992. Magnavox 4200 Differential GPS (realtime).
- Cruise PGC93-10, 5 & 6 Nov 1993. Differential GPS (realtime).
- Cruise PGC95-003, March 1995. Trimble Differential GPS (realtime).

BAR SCALE

No.	REVISION	DRAWN BY	CHECKED BY	APPROVED BY
2	Addition of 1995 survey lines	MR 07/28/95	HC 07/28/95	
1	Addition of 1993 survey lines	MR 03/04/94	HC 03/04/94	

Geological Survey of Canada — Pacific Geoscience Centre, Pat Bay, B.C.

terra surveys ltd, Sidney, B.C. Canada

Roberts Bank, Fraser River Delta, B.C.

NEARSHORE SURVEY TRACK MAP

1995 Airgun/sleevegun seismic lines

PROJECTION UTM — DATUM NAD 83 — HORIZONTAL SCALE 1:100,000 — DRAWN BY MR — DATE 01/19/94 — REV 2

2a of 7

FIGURE 2A

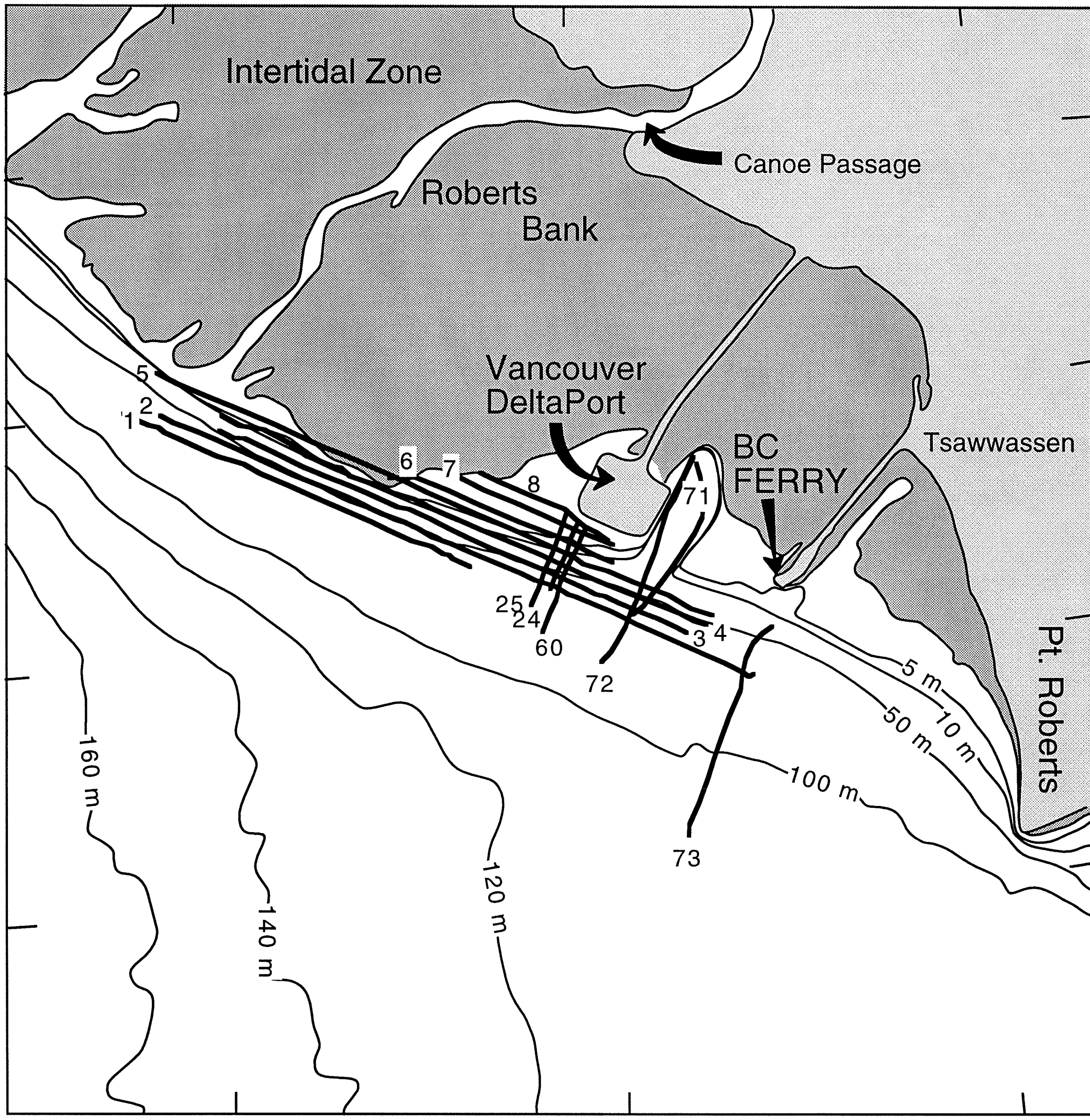
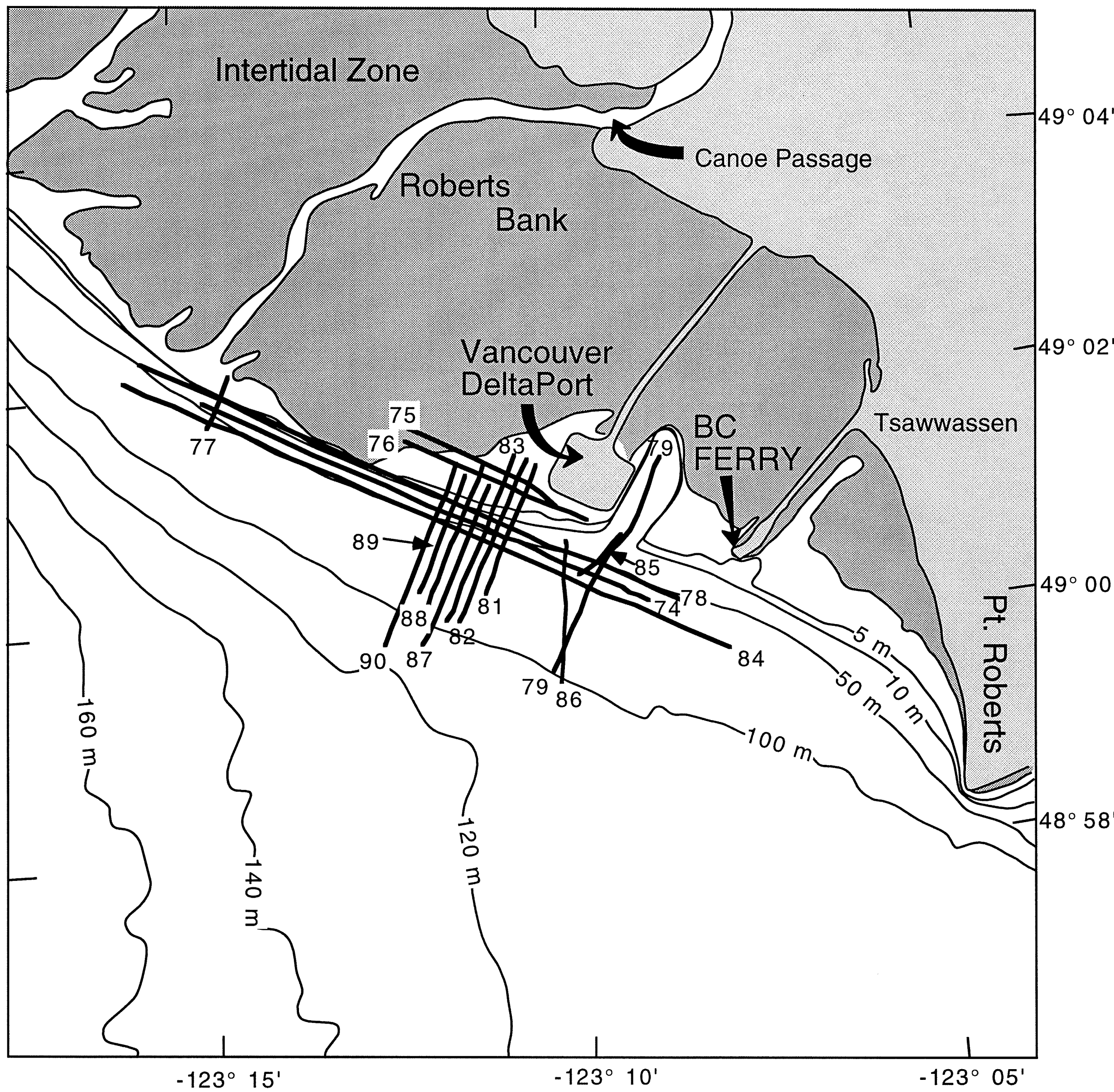
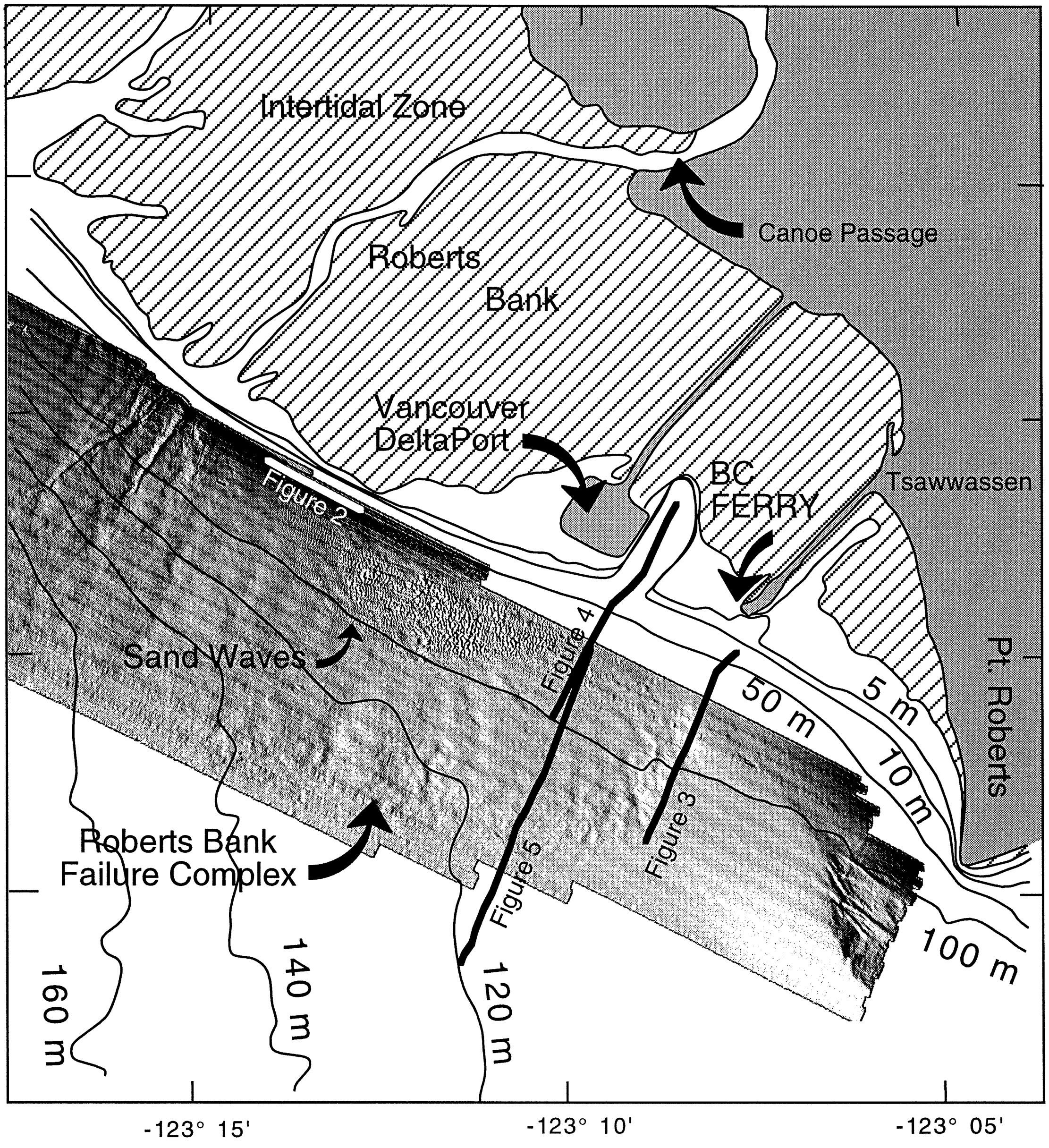

Intertidal Zone
Canoe Passage
Roberts
Bank
Vancouver
DeltaPort
BC
FERRY
Tsawwassen
Pt. Roberts
49° 04'
49° 02'
49° 00'
48° 58'
-123° 15'
-123° 10'
-123° 05'
5 m
10 m
50 m
100 m
120 m
140 m
160 m
1
2
3
4
5
6
7
8
24
25
60
71
72
73

Figure 1A



Intertidal Zone
Canoe Passage
Roberts Bank
Vancouver DeltaPort
BC FERRY
Tsawwassen
Pt. Roberts
49° 04'
49° 02'
49° 00'
48° 58'
-123° 15'
-123° 10'
-123° 05'
5 m
10 m
50 m
100 m
120 m
140 m
160 m
75
76
77
83
79
89
85
78
74
88
81
82
87
90
84
79
86

Figure 1B



Intertidal Zone
Canoe Passage
Roberts
Bank
Vancouver
DeltaPort
BC
FERRY
Tsawwassen
Figure 2
Sand Waves
Figure 4
Figure 3
Figure 5
Roberts Bank
Failure Complex
Pt. Roberts
5 m
10 m
50 m
100 m
120 m
140 m
160 m
49° 04'
49° 02'
49° 00'
48° 58'
-123° 15'
-123° 10'
-123° 05'

Figure 1C

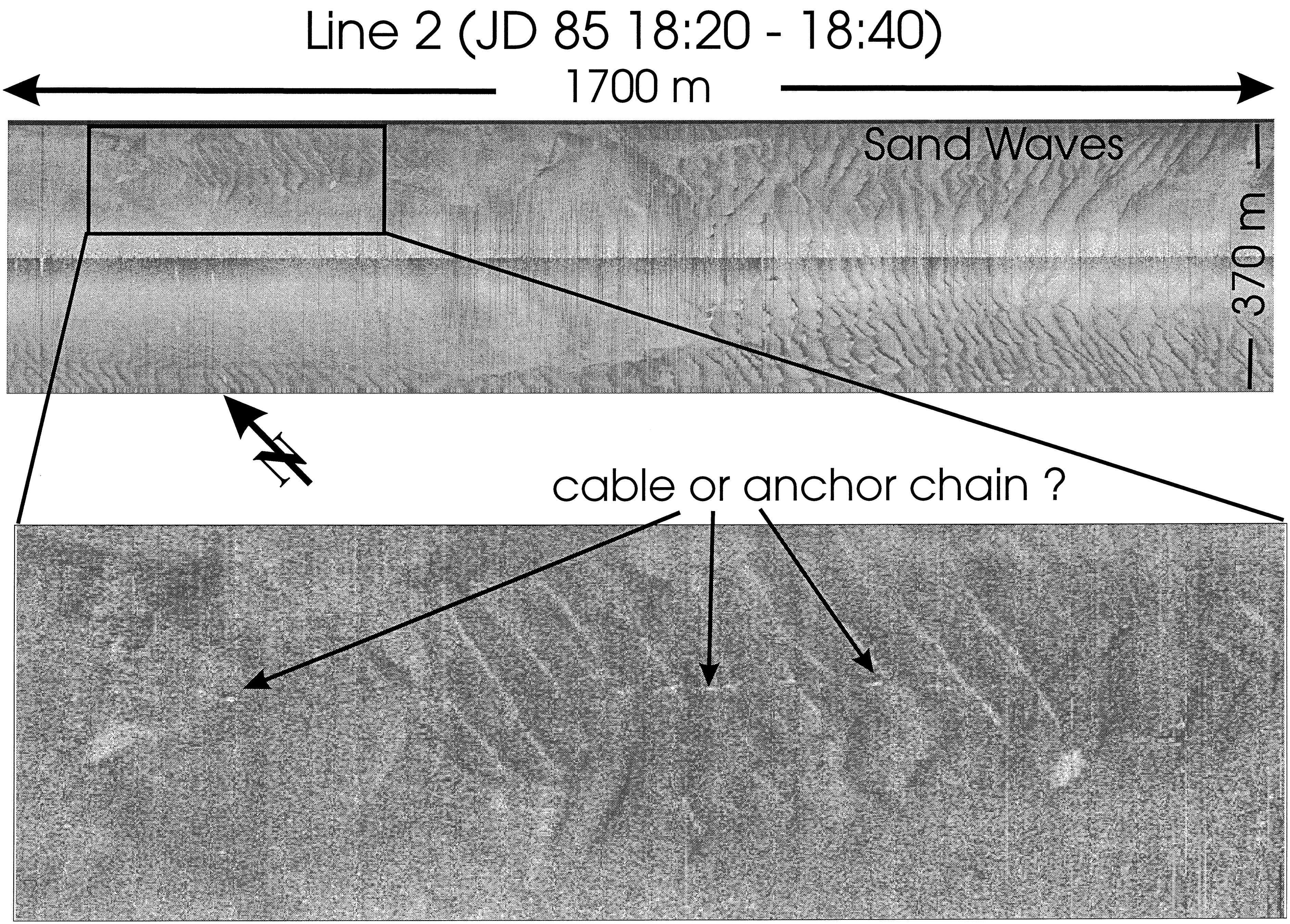

Line 2 (JD 85 18:20 - 18:40)
1700 m
Sand Waves
370 m
N
cable or anchor chain ?

Figure 2

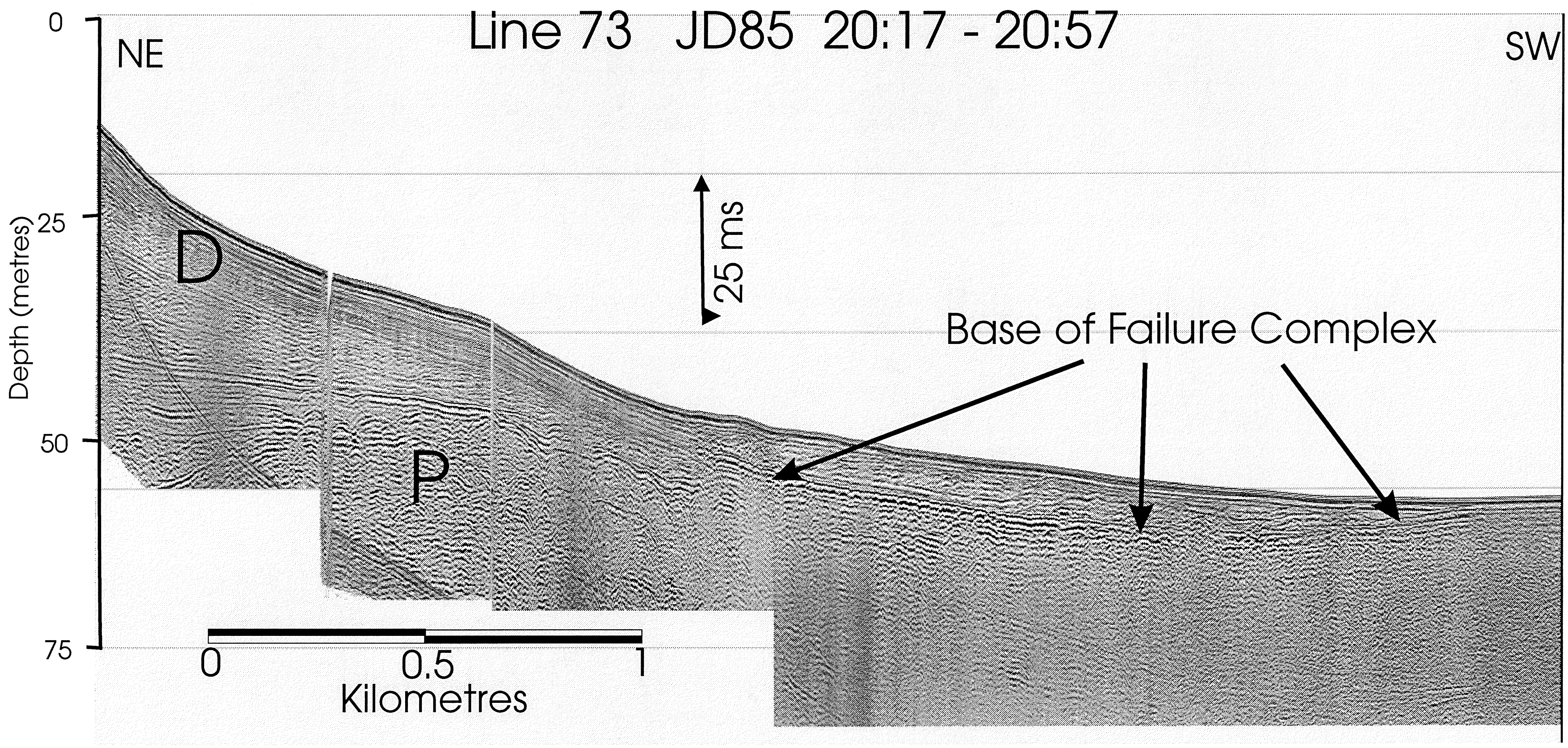

Line 73 JD85 20:17 - 20:57
NE
SW
Depth (metres)
0
25
50
75
D
P
25 ms
Base of Failure Complex
0
0.5
1
Kilometres

Figure 3

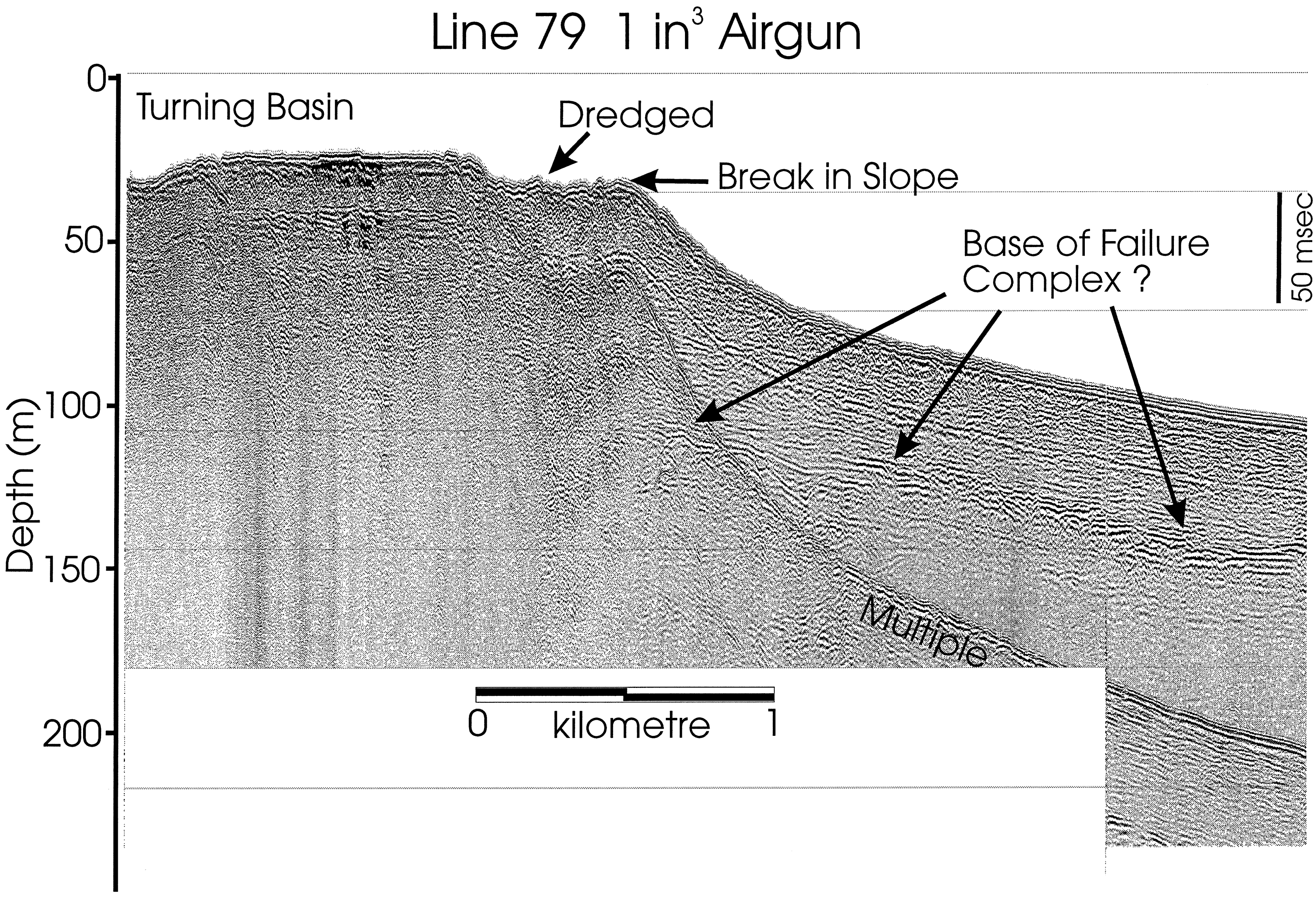

Line 79 1 in³ Airgun
Turning Basin
Dredged
Break in Slope
Base of Failure
Complex ?
50 msec
Multiple
0 kilometre 1
Depth (m)
0
50
100
150
200

Figure 4

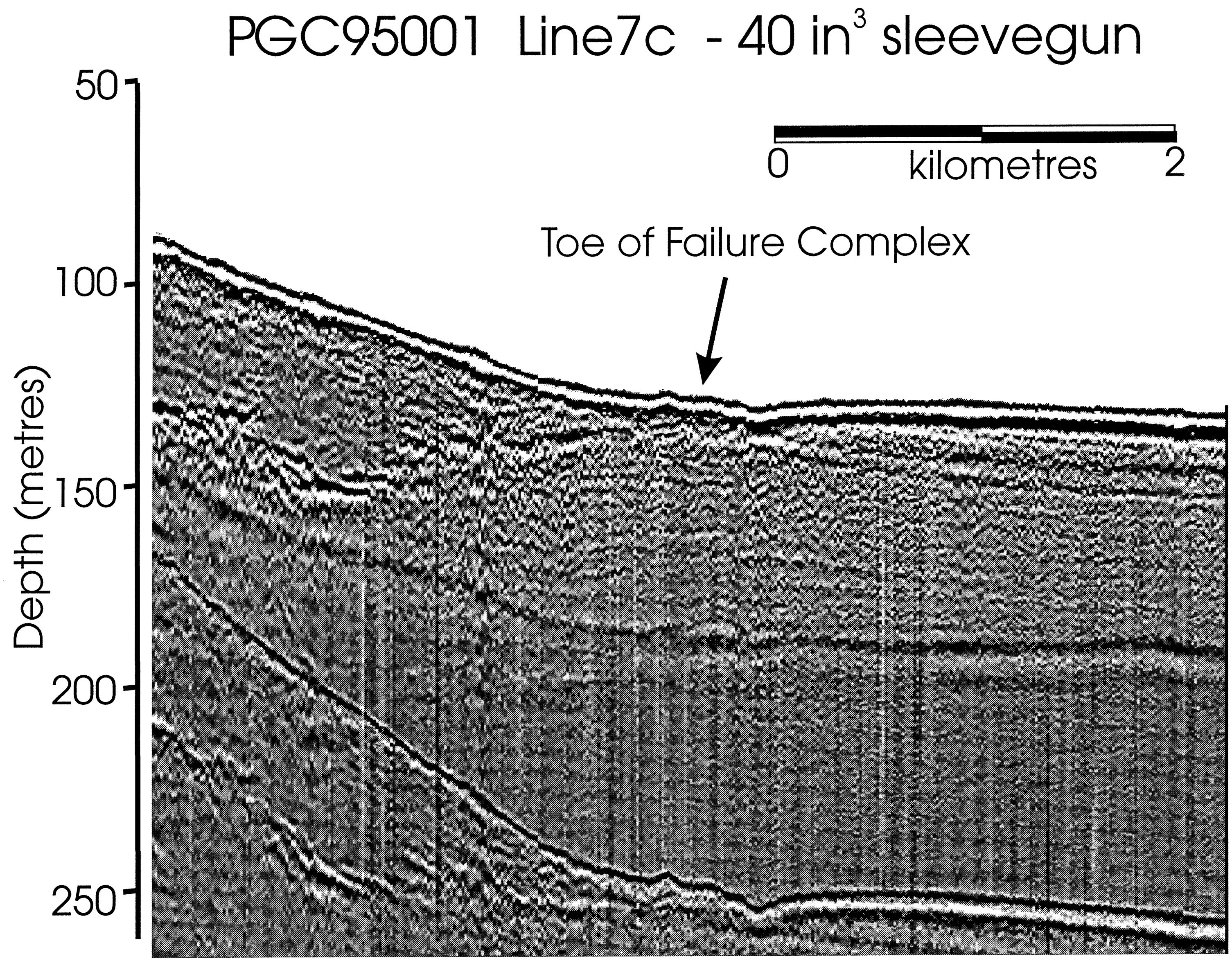

PGC95001 Line7c - 40 in^3 sleevegun
0
kilometres
2
Toe of Failure Complex
Depth (metres)
50
100
150
200
250

Figure 5