GEOLOGICAL ASSESSMENT OF SHALLOW FAULTS AND STRUCTURAL DISTURBANCES FROM THE EASTERN SCOTIAN SHELF AND LAURENTIAN CHANNEL AREA

by

Paul W. Durling[1] and Gordon B. Fader

Geological Survey of Canada

Bedford Institute of Oceanography

P.O. Box 1006, Dartmouth, N.S. B2Y 4A2

1 Formerly with: Geomarine Associates Ltd., P.O. Box 41, Station 'M'
Halifax, N.S. B3J 2L4

ABSTRACT

An analysis of over 12,000 km of airgun seismic reflection profiles and Huntec DTS high resolution seismic reflection profiles revealed considerable tectonism on the eastern Scotian Shelf and Laurentian Channel area. Much of the deformation occurs within the bedrock of the Orpheus Basin and on the Cape Breton Island Shelf. The deformation appears to be mainly pre-Quaternary, as structural deformation within the surficial sediments appears quite limited. However, only 2,000 km of the high resolution seismic reflection profiles that could resolve surficial faulting exist in the area.

Forty-two clearly defined bedrock faults and two surficial sediment faults were identified. Displacements of up to 35 m were within pre-Quaternary bedrock. A displacement of 1 m within the surficial sediments was the maximum recognized. A relationship between bedrock and surficial sediment faulting was not determined mainly due to a lack of critical data. Furthur investigation with high resolutiion seismic reflection systems over areas of known bedrock faulting would resolve the relationships.

INTRODUCTION

An assessment of shallow faulting and structural disturbances within the bedrock and surficial sediments of the eastern Scotian Shelf and the Laurentian Channel area was undertaken by the Atlantic Geoscience Centre, the Earth Physics Branch and Geomarine Associates Ltd. The study was designed as part of a seismic risk analysis for the Venture hydrocarbon development in the Sable Island area. Principally, the research identified areas of seismic or tectonic instability with respect to Quaternary sediments and will assist in planning additional geophysical and geological cruises to further study the area.

The study area is located on eastern Scotian Shelf and Laurentian Channel area (Figure 1). The northern area (Map A) covers the Cape Breton Shelf and Laurentian Channel between latitudes 45°30'N and 48°00'W. The southern area covers Banquereau, Misaine Bank, Artimon Bank, St. Annes Bank, and the outer Laurentian Channel (Map B). In addition to Map B, figure 2 shows that portion of the study area which lies north of Sable Island.

The study involved a detailed assessment of high resolution, airgun seismic reflection records of the Scotian Shelf and Laurentian Channel collected by King and MacLean (1976), MacLean and King (1971), Fader _et al._ (1982), and of more recently acquired data. The data consists of 10,004 km of airgun reflection profiles and 2061 km of Huntec Deep Tow System (DTS) high resolution data. There were only two cruises (1207 km of data) where airgun and Huntec DTS profiles were collected simultaneously.

The study identified, classified, mapped and described faults and deformation structures occurring in the shallow bedrock and overlying sediments. An attempt was made to identify the relationship between bedrock faulting and surfical sediment deformation. The structural disturbances were classified into four categories on the basis of their clarity of expression on the seismic reflection profiles. The relationship between the bedrock deformation structures and the overlying Quaternary sediments, as mapped by MacLean and King (1971) and Fader et al. (1982), was studied.

PHYSIOGRAPHY

In the northern study area, the shelf off Cape Breton Island has low relief and is 60 m to 160 m deep. To the east of the shelf lies the Laurentian Channel, which is a deep NW-SE trending trough with an average depth of about 420 m. The floor of the channel is essentially flat, bounded by walls sloping 3° to 6°. The Laurentian Channel represents an ancient river channel that has been modified by glacial erosion (King and MacLean, 1970; Fader et al., 1982).

The southern area consists of several flat-topped bank areas, including Banquereau, Misaine Bank, and Artimon Bank (see Map B). Separating these banks is a complex network of dissected and partly disconnected ridges and troughs. Here, the morphology of the seafloor is characterized by high relief and steep slopes.

The Orpheus Basin (King and MacLean, 1970) is a subsurface basin filled with thick low density sediments. This feature, associated with a major negative gravity anomally, occurs south and southeast of Cape Breton Island and is bounded by the faults identified by King and MacLean (1976). The bedrock within the basin is folded and faulted.

DATA

The data consists primarily of airgun seismic reflection profiles collected by King and MacLean (1976) for regional bedrock mapping, and several more recent cruises, Hudson 79-011, Dawson 82-003, Baffin 82-039, Dawson 84-011 and Baffin 85-007 (ship's tracks on Maps A and B).

The equipment used on the early cruises (1967-69) consisted of a 16.4 cm^3 airgun fired at one-second intervals and recorded on a wet paper recorder at one-second sweep. Cruises Dawson 72-009 and Hudson 73-006 employed a 655 cm^3 airgun fired at two-second intervals and recorded on an EPC recorder at one-second sweep. The highest resolution seismic reflection data available in the study area were obtained during cruises 79-011, 82-003, 82-039, 84-011 and 85-007, during which a Huntec Deep Tow System (DTS) was deployed, but the data are of limited regional extent. Cruises 82-039 and 85-007 employed 16.4 cm^3 and 655 cm^3 airguns concurrently with the Huntec DTS.

While the ship tracks suggest relatively good regional coverage of the study area (Maps A and B) the data are poor for assessing Quaternary faulting. The seismic source, for approximately 83% of the data was an airgun and the consequent wide bubble pulse renders the first 10 m to 15 m of the geology on the seismic profile unresolvable (see Figures 4 and 5). In many areas the overlying sediments are thinner than 15 m and therefore their structure cannot be determined. The use of the deep tow system on the most recent cruises provides detailed information concerning the top most Quaternary sediments, but this information is of limited extent.

PREVIOUS WORK

King and MacLean (1970) discussed the Orpheus gravity anomaly in detail and defined two major faults along the southern boundary of a thick (6 km) sequence of low-density strata. They defined a fault along the northern boundary of the anomaly in 1976 and interpreted the three faults as part of a major zone of weakness in Eastern Canada, the Glooscap Fault System. The Glooscap Fault System is essentially Triassic in age, and extends from the Newfoundland Fracture Zone, across Nova Scotia and the Bay of Fundy beyond Grand Manan Island (King and MacLean, 1976). The pre-Tertiary strata within Orpheus Basin are gently folded and King and MacLean (1976) suggested that the last major adjustments on this fault system were in early Tertiary time or later.

King and MacLean (1976) discussed five faults associated with the Cape Breton Island Shelf. The Cabot Fault and the Aspy Fault extend from the Cape Breton Island Shelf across Cabot Strait to Newfoundland where they join with the Long Range Fault and Cape Ray Fault, respectively. A fifth fault is a continuation of an on-land boundary fault extending from Cape Dauphin (46°21'N, 60°25'W) across the Cape Breton Shelf. These faults are all associated with shallow basement structures and are used to define the boundary between the Sydney Carboniferous Basin to the south of Cabot Strait and the Magdalen Basin to the north.

Five Quaternary faults have been identified on Nova Scotia. Two faults are at Caledonia Corner, one at each of Point Pleasant Park in Halifax and Fairy rocks at Lake Kejimkujik (Goldthwaite, 1924) and the Aspy Fault on Cape Breton Island (Grant, 1975). These faults have displacements from a few centimetres to over 0.3 m, except for the Aspy fault which has a vertical displacement of approximately 13 m. Displacement along the fault is relative to a wave-cut bench, which dates the Aspy Fault to at least 10,000 years (Grant, 1975).

MacLean and King (1971) and Fader et al. (1982) studied the Quaternary Geology of the area using a large data base of Kelvin Hughes 26B echograms and shallow airgun seismic reflection profiles. These authors make no mention of Quaternary faults; their echograms and shallow airgun reflection profiles were inadequate to resolve surficial faults.

REGIONAL GEOLOGY

The following is a description of the regional bedrock geology summarized from King and MacLean (1976). Maps A and B show the bedrock geology of the study area.

Acoustic basement to the north of Orpheus Basin consists of undifferentiated pre-Pennsylvanian rocks. The pre-Pennsylvanian rocks include Precambrian, Cambrian, and Mississipian sedimentary, metasedimentary, volcanic, and intrusive rocks.

Overlying the pre-Pennsylvanian unit are Pennsylvanian strata. These strata occur over much of the northern part of the study area and represent an offshore continuation of the strata in the Sydney Basin. To the south, these strata flank the north side of the Scatarie Basement Ridge, which is an east-west trending ridge from Cape Breton across the Laurentian Channel, composed of pre-Pennsylvanian rocks. To the south of this ridge is the fault-bound Orpheus Basin. This basin contains a thick sequence of low density strata, probably Triassic and pre-Carboniferous sediments (Loncarevic and Ewing, 1967). The sediments within the Orpheus Basin are gently folded and faulted, due to late movement along the Glooscap fault System during Tertiary time or later.

To the south of the Orpheus Basin are rocks of the Meguma Group. The Meguma Group includes highly metamorphosed Cambro-Ordovician quartz sandstones and mafic shales. Overlying most of the rocks in the southern portion of the study area is a thick wedge of Cenozoic-Mesozoic sediments. These strata reach a total thickness of 10 km and dip gently seaward at about 1 to 2°, except where locally folded in Orpheus Basin (see Maps A and B).

INTERPRETATION OF HUNTEC AND AIRGUN SEISMIC REFLECTION PROFILES

All existing Huntec and airgun seismic reflection data in the study area were carefully examined for possible faulting and structural disturbances. One hundred sixty-one structures were identified. The following criteria were applied for identification and classification of fault traces.

Table 1. Classification of Fault traces on Eastern Scotian Shelf and Laurentian Channel

Type	Description
1	Quaternary sediments demonstrating displaced or broken strata interpreted from Huntec seismic reflection profiles.
2	Sediments showing displaced or broken strata with measurable displacement clearly evidenced, interpreted from airgun seismic reflection profiles.
3	Sediments demonstrating moderate to strong ductile deformation and limited evidence of displacement or broken strata interpreted from airgun seismic reflection profiles.
4	Sediments demonstrating weak structural deformation or possible artifact of data collection (i.e., bad weather, poor system performance) interpreted from airgun seismic reflection profiles.

Features of types 3 and 4 do not necessarily define faults. These features represent weak to strong deformation, but, due to poor quality of data, the details of the folding or faulting are unclear. An example of each of the four categories is given and their locations are identified on Maps A and B. All of the faults in the study area were classified according to Table 1 above.

Figure 3 is an example of a type 1 Quaternary fault interpreted from Huntec DTS system. This structure is located near Artimon Bank (44°50'N, 58°40'W) in an area of high relief. The fault occurs in the Emerald Silt Formation, which is overlain by LaHave Clay. The highly stratified nature of the Emerald Silt facilitates easy identification of offset strata. The Huntec system has a resolution of 0.3 metres and the throw on this fault is about 1 metre. Beginning near the 1.5 km point in Figure 3 is a zone of hummocky seafloor. Within this zone sediments are structurally disturbed, as evidenced by their lack of continuous coherent reflections on the Huntec seismic reflection profile. There is no airgun seismic coverage to complement the Huntec data, so it is not known whether there is underlying bedrock faulting associated with this fault (but note that deeper Quaternary sediments may show no offset).

A second type one fault occurs at (45°14'N, 57°52'W) on Map B. This fault occurs in lift-off moraines, which are parallel ridges of till occurring on the surface of basal till in basin areas (King and Fader, 1985). Faults identified in lift-off moraines are questionable and the absence of a concurrent airgun seismic profile does not permit a complete interpretation of this possible fault.

Figure 4, located in the Orpheus Basin of the Laurentian Channel (45°40'N, 57°40'W; Map A), is a type 2 feature. This disturbed zone includes several well defined faults in the Pennsylvanian strata, with a maximum throw of approximately 35 metres. The structure in the sediments overlying the Pennsylvanian strata is partially obscured by the large bubble pulse of the airgun. Nevertheless, these rocks of Pleistocene age appear to be undeformed, suggesting that there has been no Quaternary movement on the bedrock faults. A high resolution seismic system towed near the seafloor would resolve near-surface stratification and might reveal small scale deformation in the surficial sediments overlying the bedrock faults.

Figure 5 is an example of a type 3 feature from the Cape Breton Island Shelf (46°40'N, 60°10'W; Map A). The structure is interpreted to represent a shear zone in the Pennsylvanian strata. It is a region of intense ductile deformation where reflectors are displaced, but little or no faulting can be clearly identified. These features may be more clearly resolved using a higher resolution system or by profiling at slower speeds.

The overlying Quaternary sediments in Figure 5 largely occur within the bubble pulse and it is again difficult to determine whether they are deformed. However, the shear zone is truncated by an erosional surface, suggesting that the deformation predates the overlying sediments.

An example of a type 4 feature is shown in Figure 6, from the Orpheus Basin (45°33'N, 59°46'W; Map B). This structure occurs in Cretaceous strata and resembles a syncline with straight undeformed limbs. There is no evidence of displacement and it appears as a very abrupt bending of strata over a short distance. Although such features could be produced by a ship's course change, this was not the case.

Immediately to the west of the axis of the structure (Figure 6) is a small fault (not shown on Map B) with a throw of about 5 metres. This is a type 2 feature and does not appear to be accompanied by faulting of the overlying sediment. However, the seafloor appears terraced, which may be related to the subsurface fault. Structures of this type require more study using higher resolution data.

During this study, all features which could be interpreted as faults were, mapped, and classified. Table 2 lists the number of faults of each type identified in this study. No attempt was made to correlate faults between ship's tracks or to identify fault systems during the study because of the wide line spacing of ship's tracks. Individual faults may have been traversed several times, but in each case the fault was identified as a 'new' fault, rather than an extension of an existing fault. On Maps A and B, the fault symbols are drawn perpendicular to the ship's track lines, not representing the true orientation of the faults. Naturally the true orientation of the faults is not established by one track crossing, therefore the observer should not be mislead by the apparent strike of the mapped symbols.

Table 2. Relationship Between Fault Classification and Fault Occurrences

Fault Type	Number of Faults Identified
1	2
2	42
3	22
4	95
Total	161

On either of maps A and B, two seismic lines may cross where one profile reveals a fault and the second does not. These occurrences are probably due to navigational errors/or a preferred orientation of the structure. Navigation was rather poor prior to the introduction of Loran-C in the 1970's. Many of the regional seismic lines in the study area are 1973 and earlier.

QUATERNARY FAULTING

Neither of the two Quaternary faults identified in the study area using a Huntec DTS source had concurrent airgun seismic profiles. Hence, the relationship between Quaternary faulting and bedrock faulting could not be determined. Additional data comprising concurrent DTS and airgun profiling are required to determine the relationship between Quaternary and deeper bedrock faulting.

For each of the bedrock faults, the nature of overlying sediments was determined (Table 3). A detailed discussion of the Quaternary sediments of the Scotian Shelf is provided by MacLean and King (1971) or Fader *et al.* (1982).

Table 3. Relationship Between Bedrock Faulting and Surficial Sediments

Sediment Type	Percentage of Faults Occurring in Underlying Bedrock (%)
[1]Scotian Shelf Drift	7
[2]Emerald Silt	6
[3]Sambro Sand	30
[4]LaHave Clay	42
[5]Sable Island Sand and Gravel	15

[1] dark greyish-brown cohesive and poorly sorted sediment (incoherent reflections with occasional point reflections on seismic data).

[2] very dark brown, poorly sorted stratified sediment (high to low amplitude continuous to discontinuous coherent reflections on seismic data).

[3] dark greyish-brown, fine- to coarse-grained rarely stratified sediments (generally thin veneer, closely spaced continuous coherent reflections).

[4] silty clay and clayey silt (generally acoustically transparent).

[5] dark greyish-brown to buff, fine- to coarse-grained sand that grades laterally into gravel (similar to Sambro Sand).

The seismic character of the overlying surficial sediments determines whether a bedrock fault can be followed through to the seafloor. Table 3 defines the surficial sediment types outcropping at the seafloor and the number of faults occurring in the underlying bedrock. LaHave Clay, Sambro Sand and Sable Island Sand and Gravel (which usually occur as thin veneers) are generally underlain by Emerald Silt and Scotian Shelf Drift (King and Fader, 1985). Emeralt Silt is highly stratified and hence is ideal for identifying deformation structures within the surficial sediments. Therefore, Quaternary faults may be readily recognized on a high resolution Huntec DTS profile. However, areas where lift-off moraines are present, identification of faults is difficult due to the discontinuous nature of the Emerald Silt.

On the bank top areas, Banquereau for example, massive sands may occur as thick as 35 m. Any faults occurring in these sediments may not be recognized due to the lack of reflectors in the sand. Concurrent airgun records may not resolve any bedrock deformation. The shallow water in the area makes interpretation difficult. The only recognizible reflector is the bedrock/surficial sediment contact, represented by a high amplitude continuous coherent reflector.

All the sediments listed in Table 3 are susceptible to slumping or liquefaction due to seismic shaking in varying degrees; thick accumulations being more susceptible than thin veneers. Sediments in water depths of less than 110 m to 120 m were reworked by wave action during the late Pleistocene-Holocene transgression. These sediments are fairly coarse and dense and hence are less susceptible to seismic shaking than comparable sediments which have not been reworked (Jacques/McClelland, 1982). Generally, surficial sediments occurring above the 110 m isobath include Sambro Sand and Sable Island Sand and Gravel, and sediments occurring below the 120 m isobath include Scotian Shelf Drift, Emerald Silt, and LaHave Clay. In the subsurface, Scotian Shelf Drift and Emerald Silt may be found in channels and bedrock depressions above the 120 m isobaths.

The Scotian Shelf and Laurentian Channel are expected to be stable under seismic shaking, especially on flat bank tops and the floor of the Laurentian Channel where bedrock is close to the seafloor. Potential areas for instability are steep valley slopes, particularly where thick unconsolidated or soft sediments have accumulated (Jacques/McClelland, 1982). Examples of such areas are the flanks of the Laurentian Channel and areas of high relief north of Banquereau. Both of the identified Quaternary faults occur on steep (greater than 6°) slopes. One fault occurs in LaHave Clay and Emerald Silt (Figure 3), and the other occurs in Emerald Silt and Scotian Shelf Drift.

BEDROCK FAULTING

The faults identified in this study compare very well with those mapped by King and MacLean (1976), although substantially more faults and areas of structural disturbance were identified in this study. Seventy-five percent of all identified faults occurred within 20 km of those identified by King and MacLean. One Quaternary fault occurs within 1.5 km of the southernmost fault bounding the Orpheus Basin.

King and MacLean (1976) mapped the faults they identified as defined, approximate and assumed. The present researchers did not map these distinctions when mapping these faults. Consequently, ship's tracks may cross the faults where we do not recognize any deformation.

This study reinforces the results of King and MacLean that movement along the Glooscap Fault System is responsible for much of the deformation in the Orpheus Basin. Most deformation is in pre-Tertiary rocks. King and MacLean (1976) also believe that salt tectonism is responsible for some compressional folding in the area. Webb (1973) noted 17 possible salt diapirs in the study area and 16 of these are plotted on Maps A and B. The diapirs occur most frequently in the southern area of Map B near Banquereau Bank and Sable Island.

CONCLUSIONS AND RECOMMENDATIONS

The tectonic activity in the area can be divided into three main categories on the basis of faulting: (1) Orpheus Basin; (2) Cape Breton Shelf north of Orpheus Basin; and (3) Banquereau and eastern Scotian shelf south of Orpheus Basin.

The airgun data on the Cape Breton Shelf and the absence of Huntec data in the area leaves the interpreter with poor quality data for assessing Quarternary faulting. As a result, no Quaternary faults were identified on Cape Breton shelf. This area lies 330 km from the proposed Sable Island Venture development and, although the area should be further studied for Quaternary faulting and regional hazard assessment, it may have limited impact on seismic risk for the Venture development.

The Orpheus Basin shows much evidence for Quaternary faulting and there is strong bedrock deformation relative to adjacent areas. However, the relationship between Quarternary and bedrock faulting cannot be established in this study because of the poor quality and resolution of the seismic reflection data. Further data collection is required to establish these relationships.

The eastern Scotian Shelf north and east of Sable Island also shows evidence of Quarternary faulting. Seismic reflection data in this area is good since Huntec DTS and airgun data were collected simultaneously. There was deep (200-600 ms) tectonism identified but Quaternary faulting was not recognized. These relationships may be confirmed through further study of the area.

We recommend that further studies be undertaken in the Orpheus Basin area and on the eastern Scotian Shelf north and east of Sable Island. We also recommend that Huntec DTS and airgun seismic reflection profiles be collected simultaneously. In addition, sidescan sonar should also be collected to provide additional data on the surface expression of subsurface faulting. During collection of the data the area should be surveyed at slow speeds (<3 knots) to provide better spatial resolution for detailed structure. To determine the orientation of faults, the survey should be designed to cross the faults at various angles and, in essence, perform a detailed site survey. The survey should in turn be tied into the existing grid of seismic reflection lines to establish the regional setting of the faulted zones.

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Figure Captions

Figure 1: Index for the study area showing the locations of Map A, Map B and Figure 2.

Figure 2: Ship's tracks, bedrock geology, and identified faults northwest of Sable Island on the eastern Scotian Shelf.

Figure 3: Huntec DTS high resolution seismic reflection profile showing a Quaternary fault (Type (1) feature) in upper sections of Emerald Silt and LaHave Clay. Note the 1.5 m offset displayed by the broken reflections of the Emerald silt. A large area of sea-floor is disturbed from 1.2 km to the end of the profile and this may also be related to the faulting.

Figure 4: Numerous bedrock faults occuring in Pennsylvanian bedrock. Considerable displacement (up to 35 m) is shown on these faults, however the overlying Pleistocene sediments (till) appear to be undisturbed. High resolution seismic reflection profiles over these faults would determine whether Quaternary faulting is associated with these faults.

Figure 5: A shear zone in Pennsylvanian bedrock illustrates the type three classification. Note that the shear zone is truncated by an unconformity, which is in turn overlain by surficial sediment. The structure and distribution of the surficial sediments is unclear due to the low resolution of the airgun seismic reflection system.

Figure 6: Otherwise straight reflections in Cretaceous bedrock are deformed by an abrupt change in attitude. This possible fault characterizes the type four classification. Note a smaller fault to the left at the 1.1 km mark. A seafloor depression above the small fault may be associated with the deformation, however, the Quaternary sediment appears undeformed.

Figure 7: Summary fault map of the study area through interpretation of seismic reflection data. Most of the faulting is associated with the Glooscap Fault system across the shelf (King and MacLean, 1976) and the area between Cape Breton Island and Newfoundland.

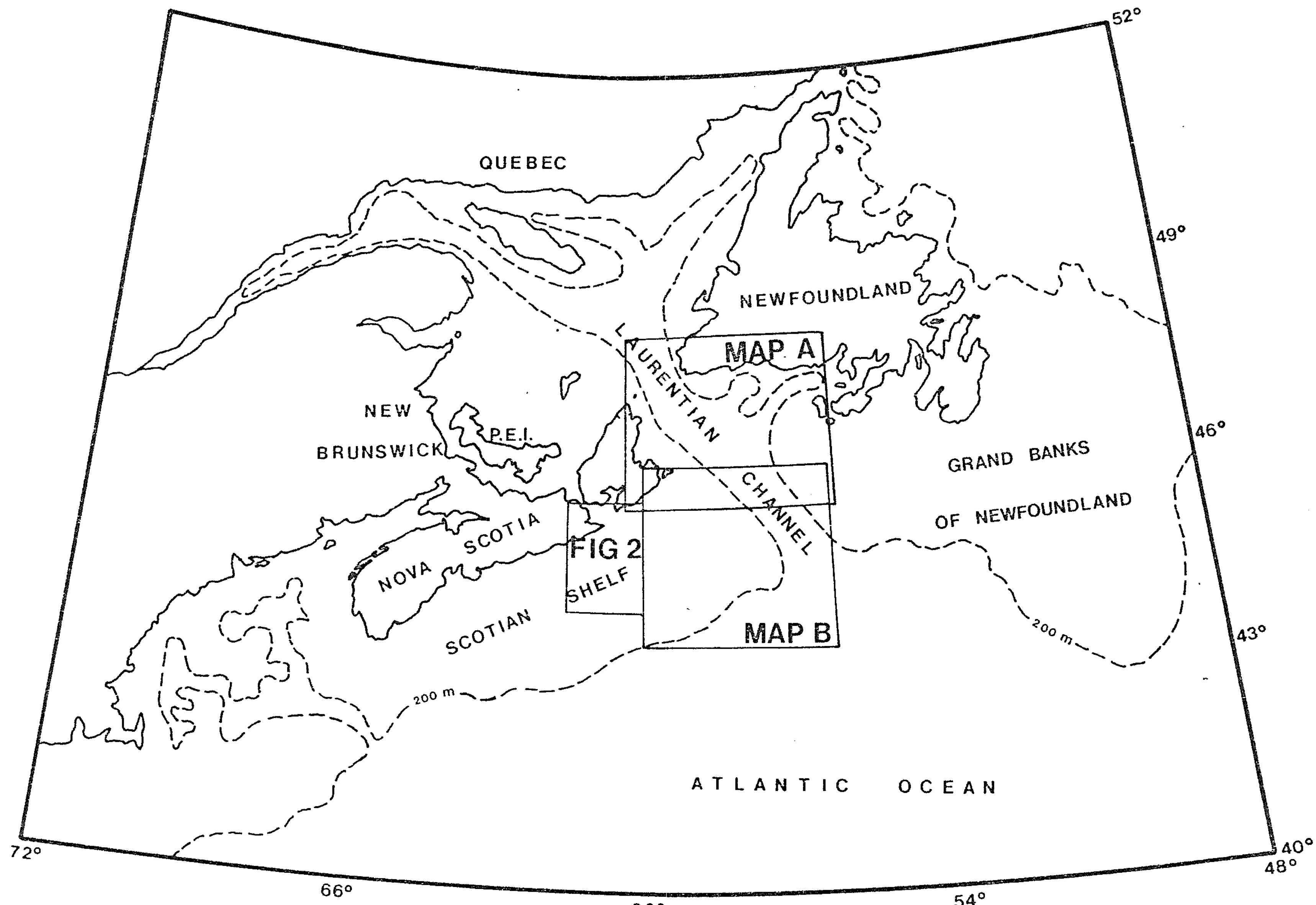
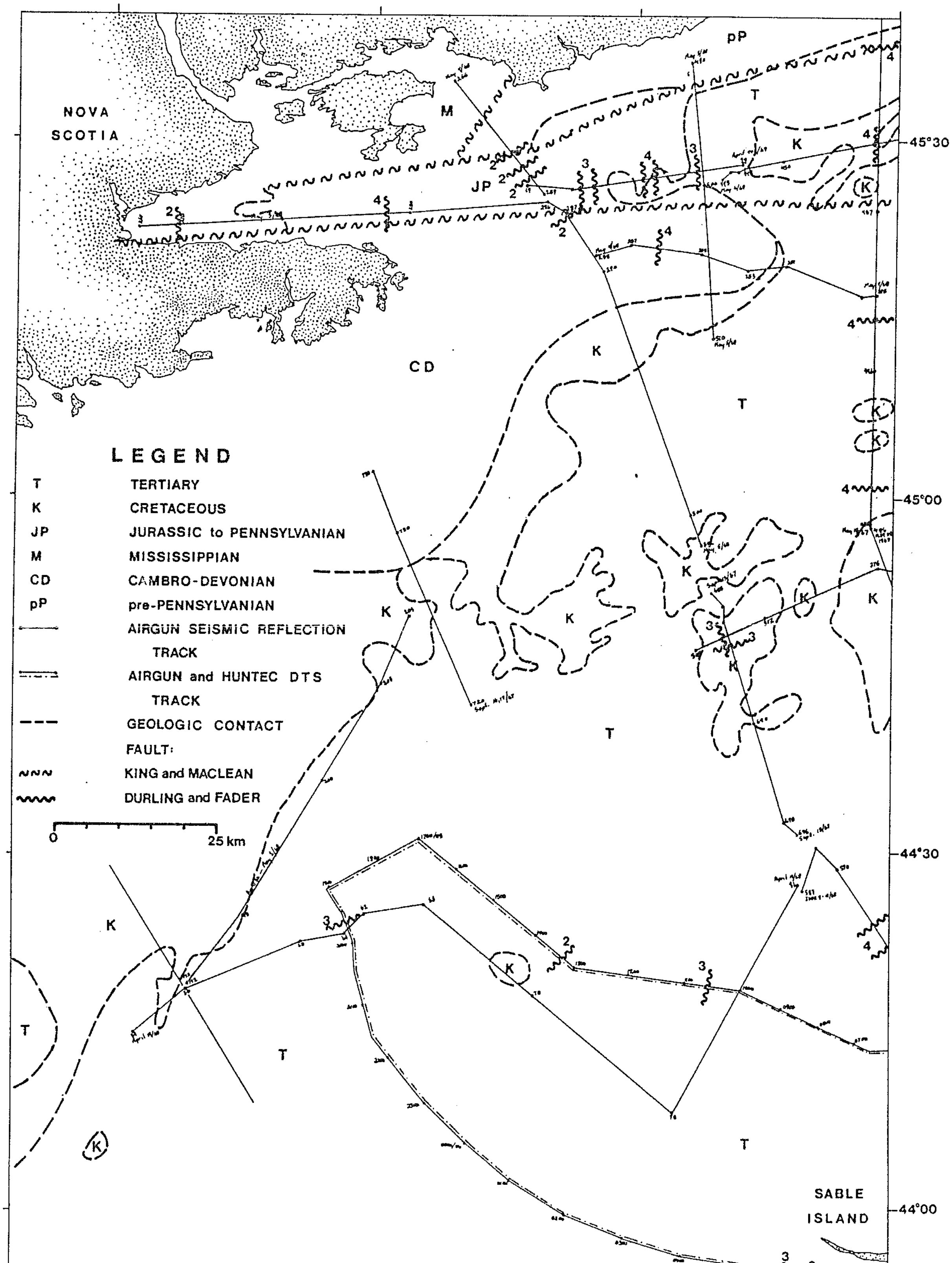

52°
49°
46°
43°
40°
48°
54°
60°
66°
72°
QUEBEC
NEWFOUNDLAND
NEW
BRUNSWICK
P.E.I.
NOVA SCOTIA
SCOTIAN SHELF
LAURENTIAN CHANNEL
GRAND BANKS
OF NEWFOUNDLAND
MAP A
MAP B
FIG 2
200 m
200 m
ATLANTIC OCEAN

Fig 1


NOVA SCOTIA
pP
M
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T
K
CD
LEGEND
T TERTIARY
K CRETACEOUS
JP JURASSIC to PENNSYLVANIAN
M MISSISSIPPIAN
CD CAMBRO-DEVONIAN
pP pre-PENNSYLVANIAN
AIRGUN SEISMIC REFLECTION TRACK
AIRGUN and HUNTEC DTS TRACK
GEOLOGIC CONTACT
FAULT:
KING and MACLEAN
DURLING and FADER
0
25 km
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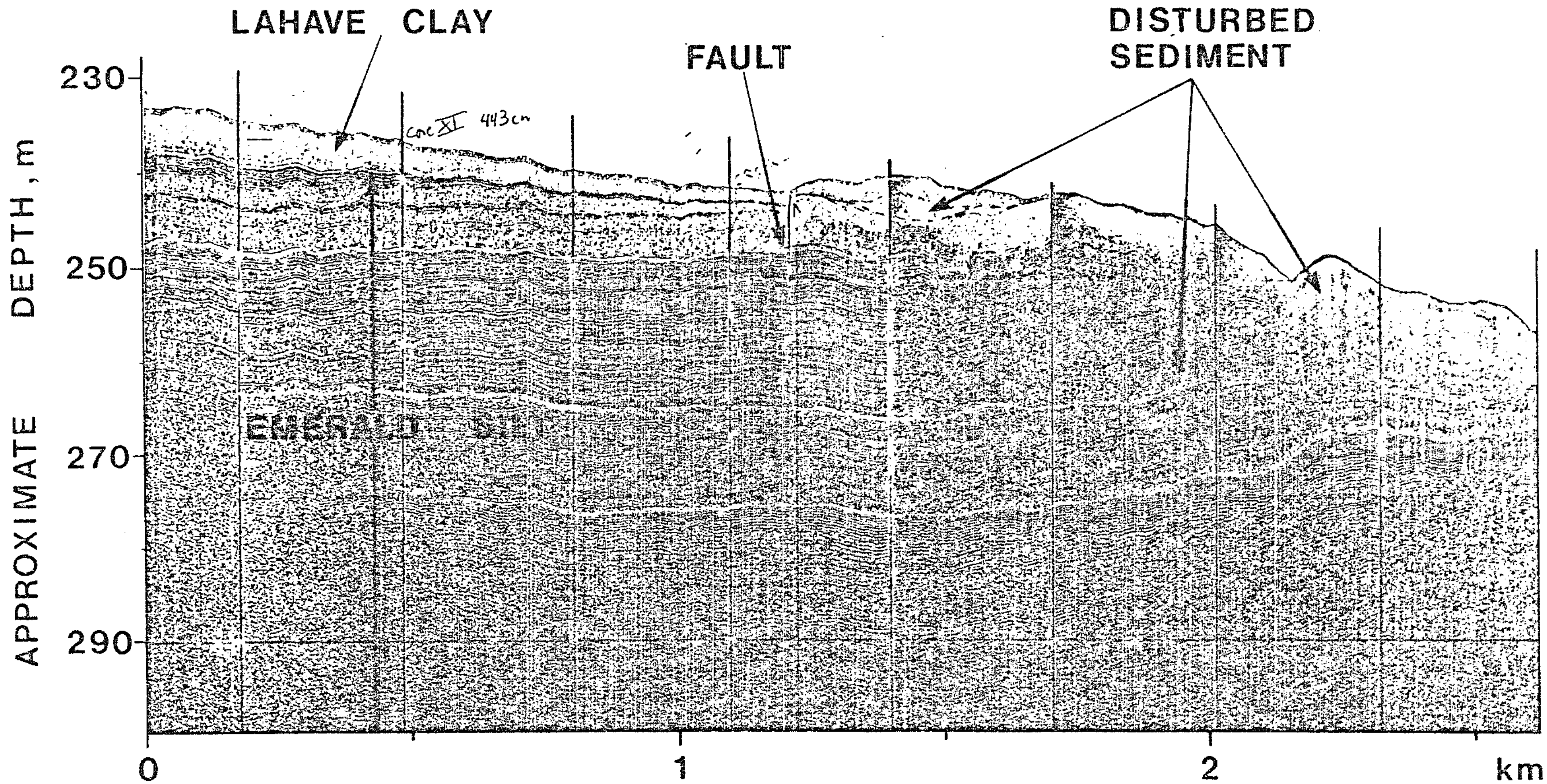
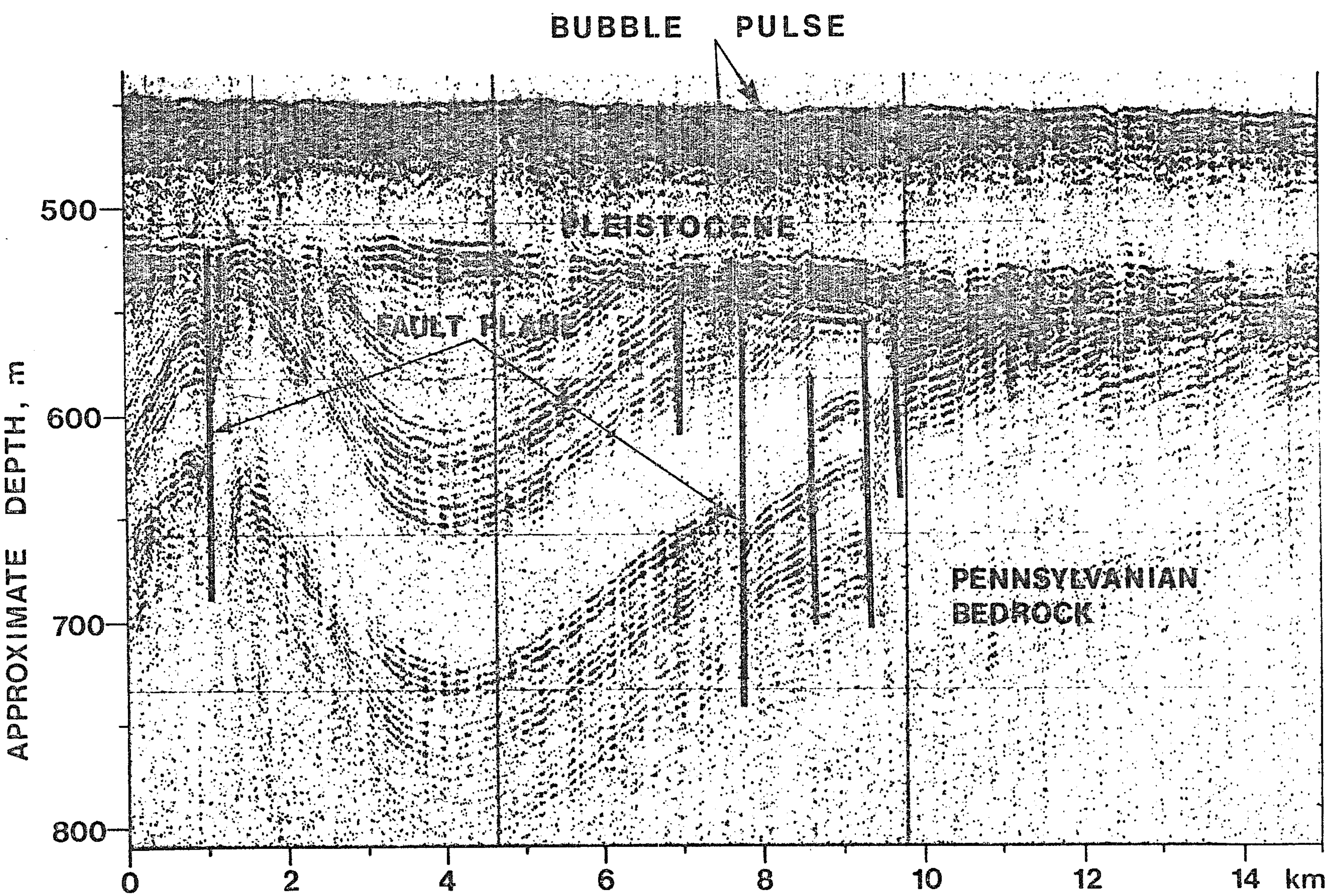
61°00
60°30
60°00



LAHAVE CLAY
FAULT
DISTURBED
SEDIMENT
EMERALD SIL
APPROXIMATE DEPTH, m
230
250
270
290
0
1
2
km

Fig 3


BUBBLE PULSE
PLEISTOCENE
FAULT PLANE
PENNSYLVANIAN
BEDROCK
APPROXIMATE DEPTH, m
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600
700
800
0
2
4
6
8
10
12
14 km

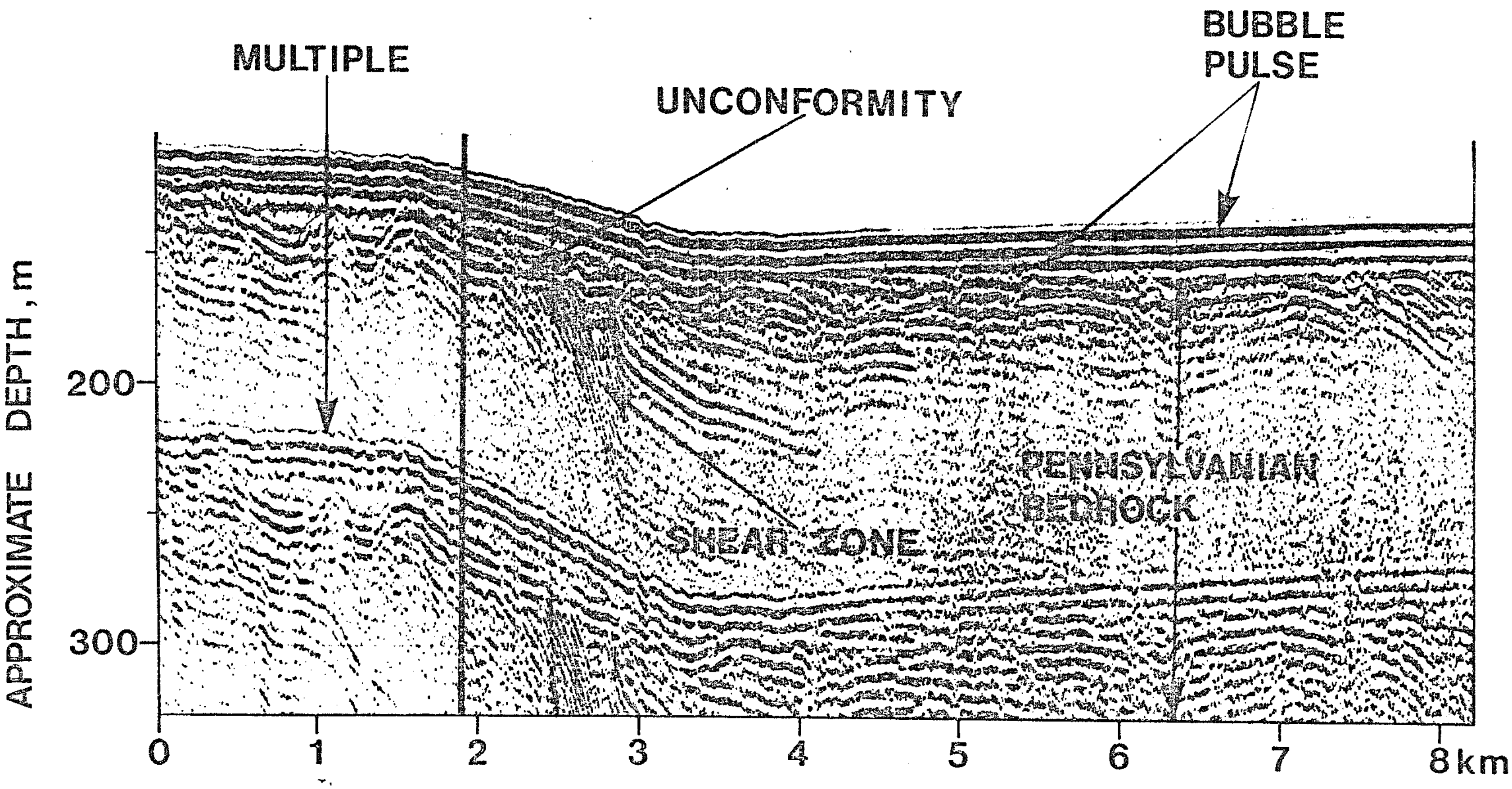

MULTIPLE
UNCONFORMITY
BUBBLE
PULSE
PENNSYLVANIAN
BEDROCK
SHEAR ZONE
APPROXIMATE DEPTH, m
200
300
0
1
2
3
4
5
6
7
8km

Fig 5

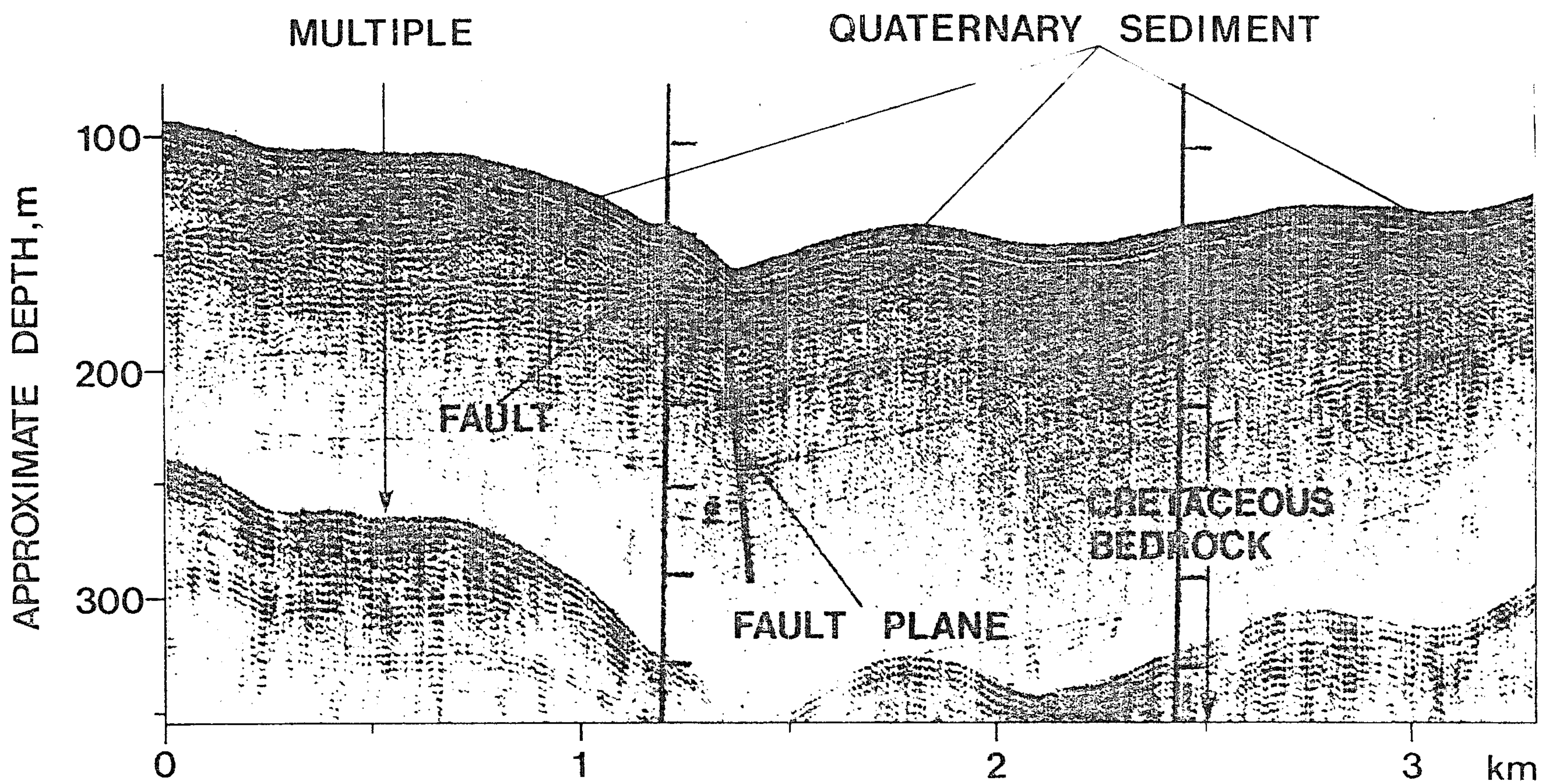
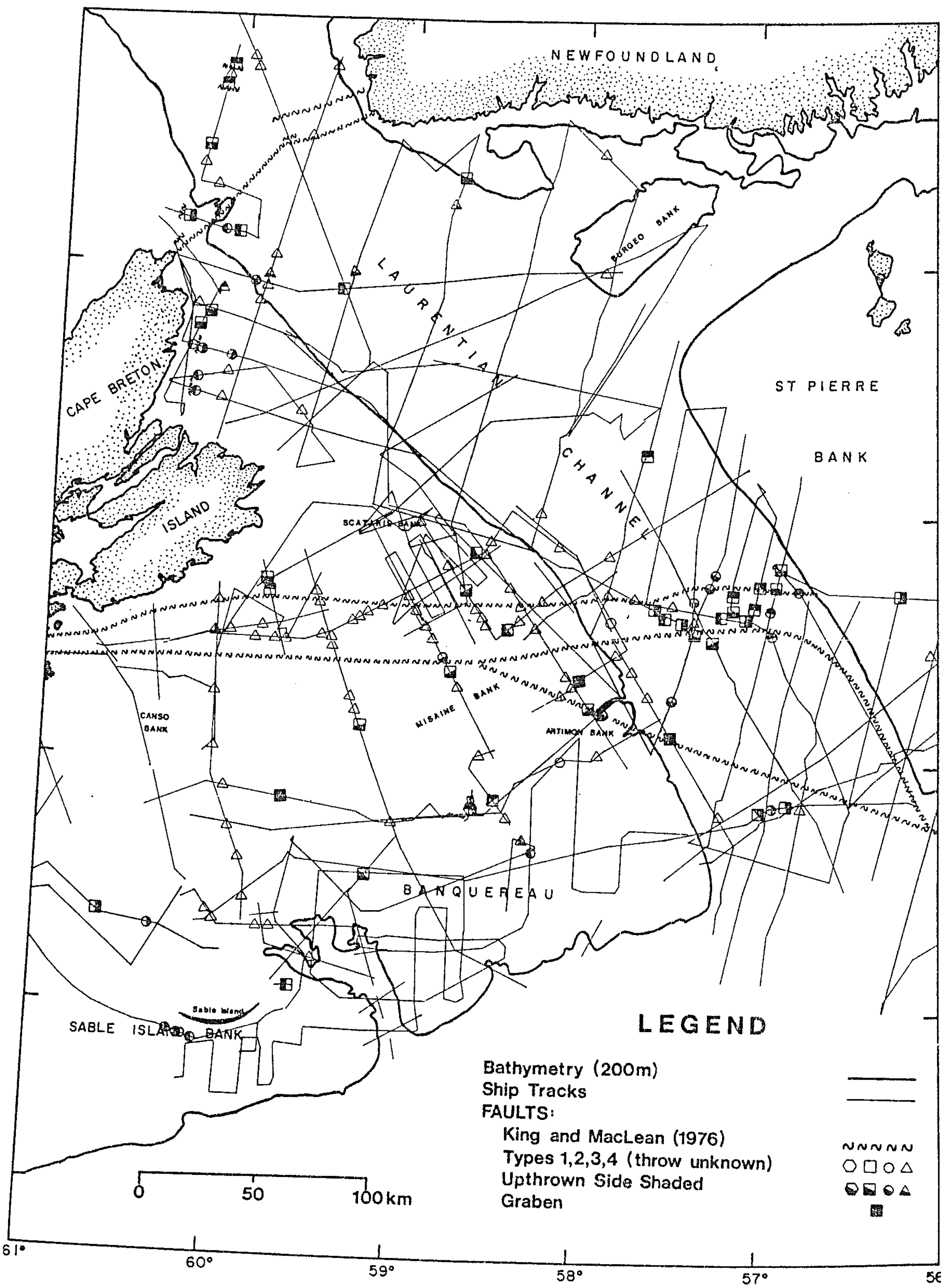

MULTIPLE
QUATERNARY SEDIMENT
100
200
300
APPROXIMATE DEPTH, m
FAULT
FAULT PLANE
CRETACEOUS
BEDROCK
0
1
2
3
km

Fig 6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CAPE BRETON
ISLAND
LAURENTIAN
CHANNEL
BURGEO BANK
ST PIERRE
BANK
SCATARIE BANK
MISAINE BANK
CANSO BANK
ARTIMON BANK
BANQUEREAU
Sable Island
SABLE ISLAND BANK
48°
47°
46°
45°
44°
43°
61°
60°
59°
58°
57°
56°
0
50
100km
LEGEND
Bathymetry (200m)
Ship Tracks
FAULTS:
King and MacLean (1976)
Types 1,2,3,4 (throw unknown)
Upthrown Side Shaded
Graben