[PS]The East Georges Bank Basin, Offshore Nova Scotia: An Undrilled Basin with Significant Oil and Gas Potential*

Tako Koning[1]

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*Adapted from poster presentation at AAPG Annual Convention and Exhibition, New Orleans, Louisiana, April 11-14, 2010

[1]Public Relations, Tullow Oil, Luanda, Angola (tako.koning@tullowoil.com)

Abstract

The East Georges Bank Basin is located offshore Nova Scotia on the southeastern Canadian continental shelf. The basin covers 10,000 square kilometers (2.5 million acres) and is one of the last undrilled basins in North America.

The geological understanding of this basin is based on 16,000 km of seismic data which was studied and interpreted in the 1980's by Texaco Canada's geoscientists. The first public presentation of the interpreted data was at a conference of the Canadian Society of Petroleum Geologists in 1988 in St. John's, Newfoundland and thereafter the geological and geophysical interpretations were presented at a number of oil industry conferences worldwide (San Diego, Calgary, Lagos, Rio de Janeiro). This presentation is a re-presentation of the 1988 and subsequent papers. In 1988, the government placed an oil activity moratorium on Georges Bank. No activity such as seismic surveying has taken place since that time. Therefore, although this presentation is based on old seismic data, it must be viewed as up-to-date since no new data has been acquired on the bank for over twenty years.

The overall Georges Bank Basin formed during the Triassic when the landmass of Pangea began separating along rift zones. A prominent Paleozoic basement high, the Yarmouth Arch, separated the East Georges Bank Basin from the West Georges Bank Basin, and had a dominant influence on sedimentation until Middle Jurassic. During the Middle Jurassic, major growth faulting and halokinesis commenced in the basin.

The structural and stratigraphic evolution of the East Georges Bank Basin has resulted in the development of a number of significant and economically attractive seismically-defined prospects. The Geological Survey of Canada (GSC) published in 1983 (Proctor et al) that the average hydrocarbon expectation of the basin was 168 x 10^6 m^3 barrels oil (1.0 billion barrels) and 150 x 10^9

m^3 natural gas (5.3 TCFG). The GSC's speculative estimate for the basin was 350 x 10^6 m^3 barrels of oil (2.1 billion barrels) and 307 x 10^9 m^3 gas (10.8 TCFG). The East Georges Bank Basin remains under the moratorium until 2012 at which time the moratorium may either be lifted or continued.

The East Georges Bank Basin, Offshore Nova Scotia – an Undrilled Basin with Significant Oil & Gas Potential

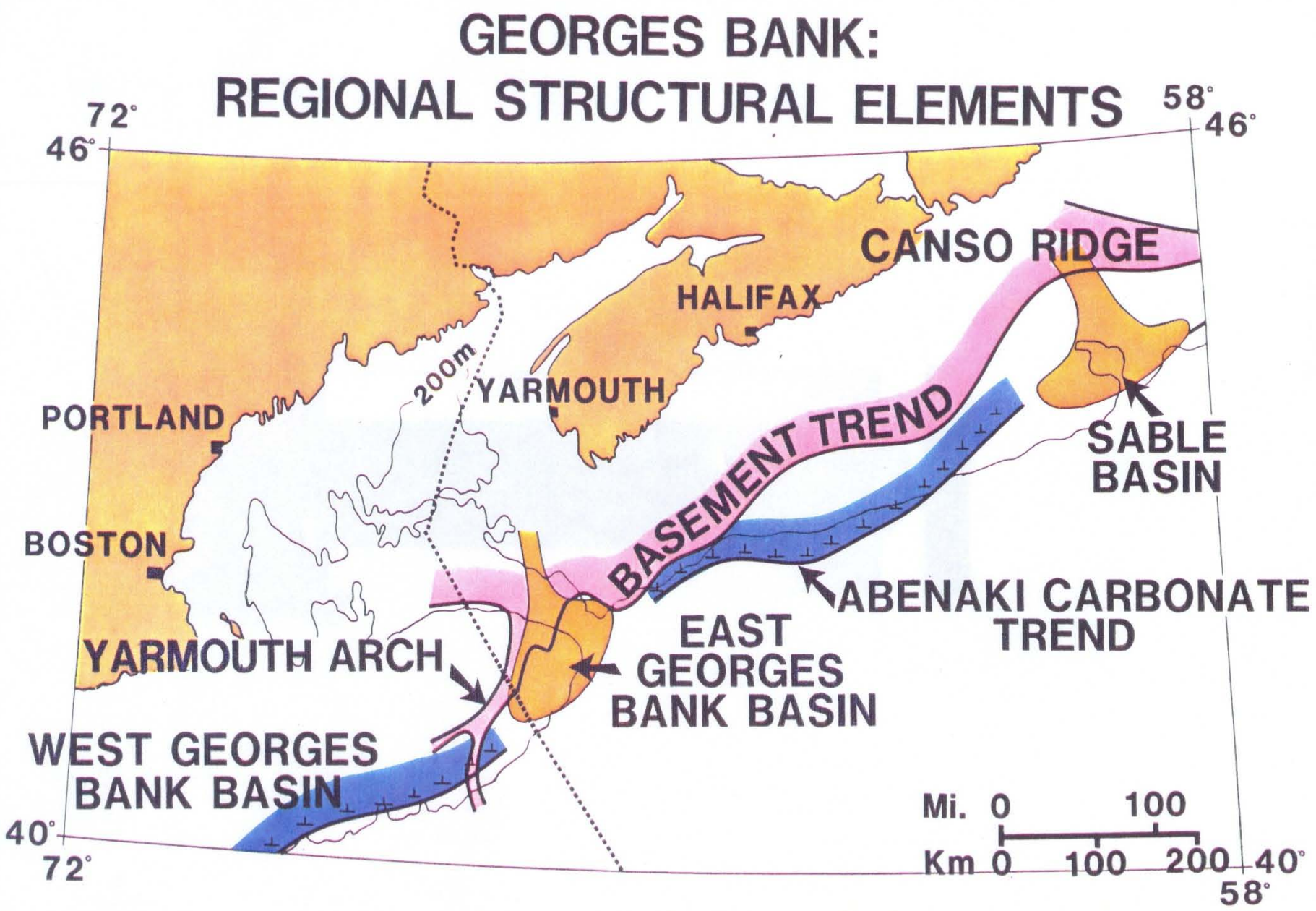
Tako Koning

Advisor – Tullow Oil

Luanda, Angola, West Africa

Poster Presentation at the 2010 Annual Convention of the American Association of Petroleum Geologists, New Orleans, Louisiana

FIGURE 7


GEORGES BANK:
REGIONAL STRUCTURAL ELEMENTS
72°
46°
58°
46°
CANSO RIDGE
HALIFAX
200m
YARMOUTH
PORTLAND
BASEMENT TREND
SABLE
BASIN
BOSTON
ABENAKI CARBONATE
TREND
EAST
GEORGES
BANK BASIN
YARMOUTH ARCH
WEST GEORGES
BANK BASIN
Mi. 0 100
Km 0 100 200
40°
72°
40°
58°

Previous presentations about the East Georges Bank Basin

- 1988 CSPG-GAC-MAC Symposium on "*Extensional Tectonics & Stratigraphy of the North Atlantic Margins*", St. John's, Newfoundland, authors Allan Carswell and Doug Hibbs, Texaco Canada Resources Limited
- 1990 Koning, T, Carswell, A, AAPG Convention, San Francisco
- 1991 Koning, T, Carswell, A, CSPG Convention, Calgary
- 1992 Koning, T, Carswell, A, CSEG Convention, Calgary
- 1992 Koning, T, NAPE Convention, Lagos, Nigeria
- 1993 Koning, T, CSPG Convention, Calgary
- 1998 Koning, T, CSPG International Division, Calgary
- 1998 Koning, T, AAPG International Confer., Rio de Janeiro, Brazil
- 2008 Koning, T, Conjugate Margins Conference, August 2008 Dalhousie University, Halifax, Nova Scotia
- 2009, Koning, T, CSPG International Division, Calgary
- 2010, Koning, T, AAPG Convention, New Orleans

Specific Information on Previous Presentation on East Georges Bank Basin

- Hibbs, Douglas C., Carswell, Allan, B., 1988 "*Structural and Stratigraphic Evolution of the Georges Bank Basin"*, Canadian Society of Petroleum Geologists- Geological Association of Canada – Mineralogical Association of Canada Symposium on "*Extensional Tectonics and Stratigraphy of the North Atlantic Margins*", St. John's, Newfoundland, May 1988
- Carswell, Allan, B., and Koning, Tako, "*Structural and Statigraphic Evolution of the East Georges Bank Basin, Offshore Nova Scotia, Canada",* poster paper presentation, American Association of Petroleum Geologists Annual Convention, San Francisco, California,
- Koning, T., & Carswell, B. 1991, "*The Geology of the East Georges Bank Basin, Offshore Nova Scotia*", Canadian Society of Petroleum Geologists Annual Convention, Calgary.
- Koning, T., & Carswell, B. 1992, "*A Seismic-Stratigraphic Interpretation of the Geology of the East Georges Bank Basin, Offshore Nova Scotia*", Canadian Society of Exploration Geophysicists Annual Convention, Calgary.
- Koning, T., 1992, "*Georges Bank and Morocco – Eastern and Western Counterparts along the Atlantic Margin*", Annual Convention of the Nigerian Association of Petroleum Explorationists (NAPE), Lagos, Nigeria.
- Koning, T., 1993, "*Stratigraphic Correlations & Similarities Between the East Georges Bank Basin, Offshore Nova Scotia and the Triassic and Jurassic Outcrops in the High Atlas Mountains, Central Morocco"*, Canadian Society of Petroleum Geologists, Annual Convention, Calgary.
- Koning, T., 1993, "*Stratigraphic Correlations & Analogues Between the East Georges Bank Basin, Offshore Nova Scotia and the Triassic and Jurassic Outcrops in the High Atlas Mountains, Central Morocco"*, Canadian Society of Petroleum Geologists, International Division, Calgary.
- Koning, T., 1993, "*Stratigraphic Correlations & Analogues Between the East Georges Bank Basin, Offshore Nova Scotia and the Triassic and Jurassic Outcrops in the High Atlas Mountains, Central Morocco"*, American Association of Petroleum Geologists, International Convention, Rio De Janeiro, Brazil.
- Koning, T., 2008, "*The East Georges Bank Basin: What the Explorationists Saw Two Decades Ago",* Conjugate Basins Conference, Dalhousie University, August 13 – 15, Halifax, Nova Scotia.
- Koning, T., 2009, "*The East Georges Bank Basin: What the Explorationists Saw Two Decades Ago*", Canadian Society of Petroleum Geologists, International Division, Calgary.
- Koning, T., 2010, "*The East Georges Bank Basin, Offshore Nova Scotia: An Undrilled Basin with Significant Oil & Gas Potential*", AAPG Annual Convention, April 2010, New Orleans, Louisiana

East Georges Bank Basin

- East Georges Bank Basin covers 10,000 sq km (2,200,000 acres)
- One of the last undrilled basins in North America
- This interpretation is based on 16,000 km of vintage seismic data shot by Texaco in the early 1980's (Jebco data)
- East Georges Bank Basin (Canadian side) is geologically very different from West Georges Bank Basin (USA side)
- Basin has significant hydrocarbon potential, likely for natural gas (not oil) albeit with high exploration risk
- In 1986, Texaco Canada was preparing to drill 2 exploration wells but a provincial and federal government imposed moratorium halted the program
- Oil & gas moratorium in place since 1986 (24 years)
- In May, 2010, the moratorium was extended from 2012 to 2015 due to the Nova Scotia government's concerns about BP's Gulf of Mexico oil well blow-out

FIGURE 2

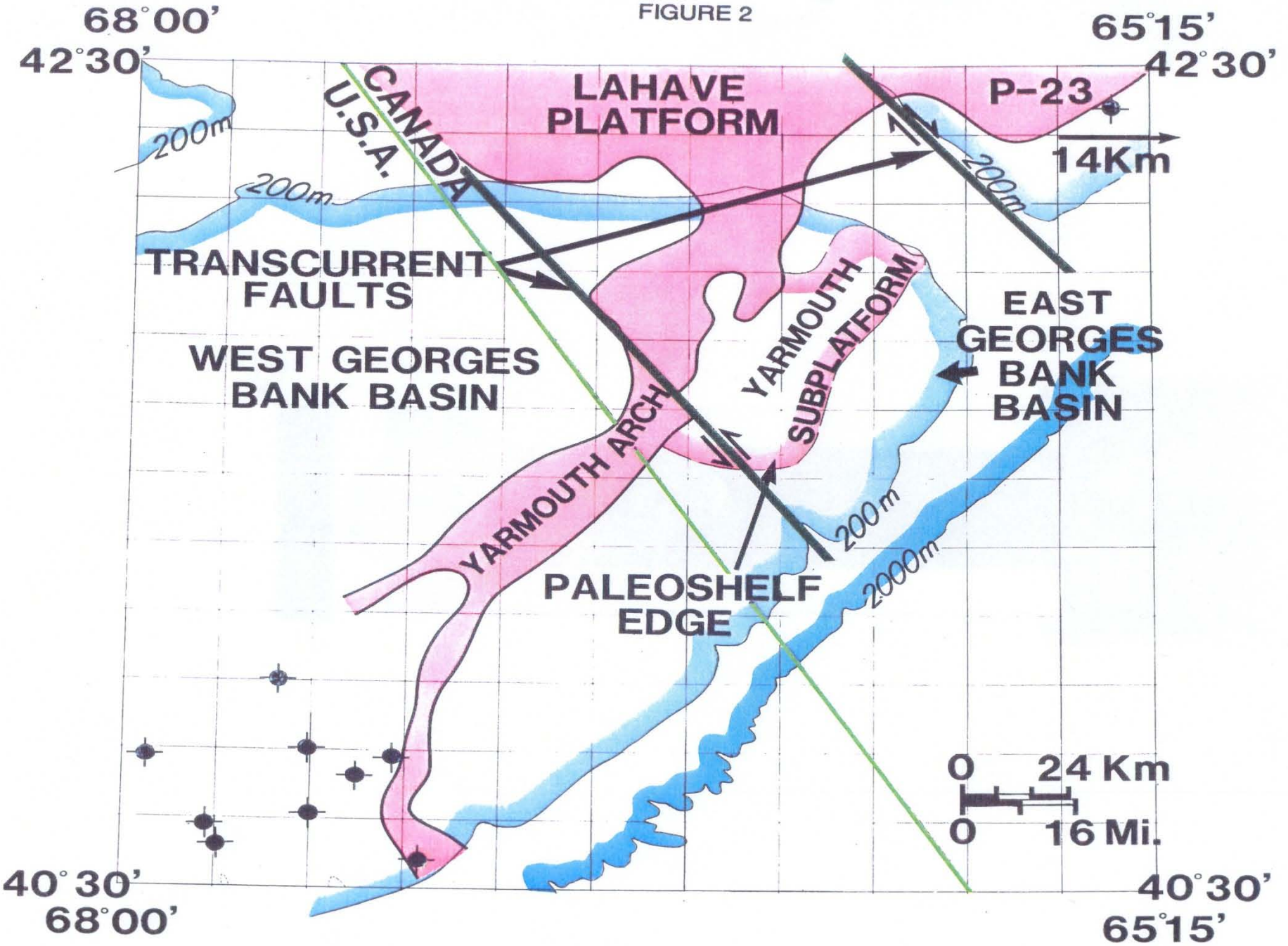
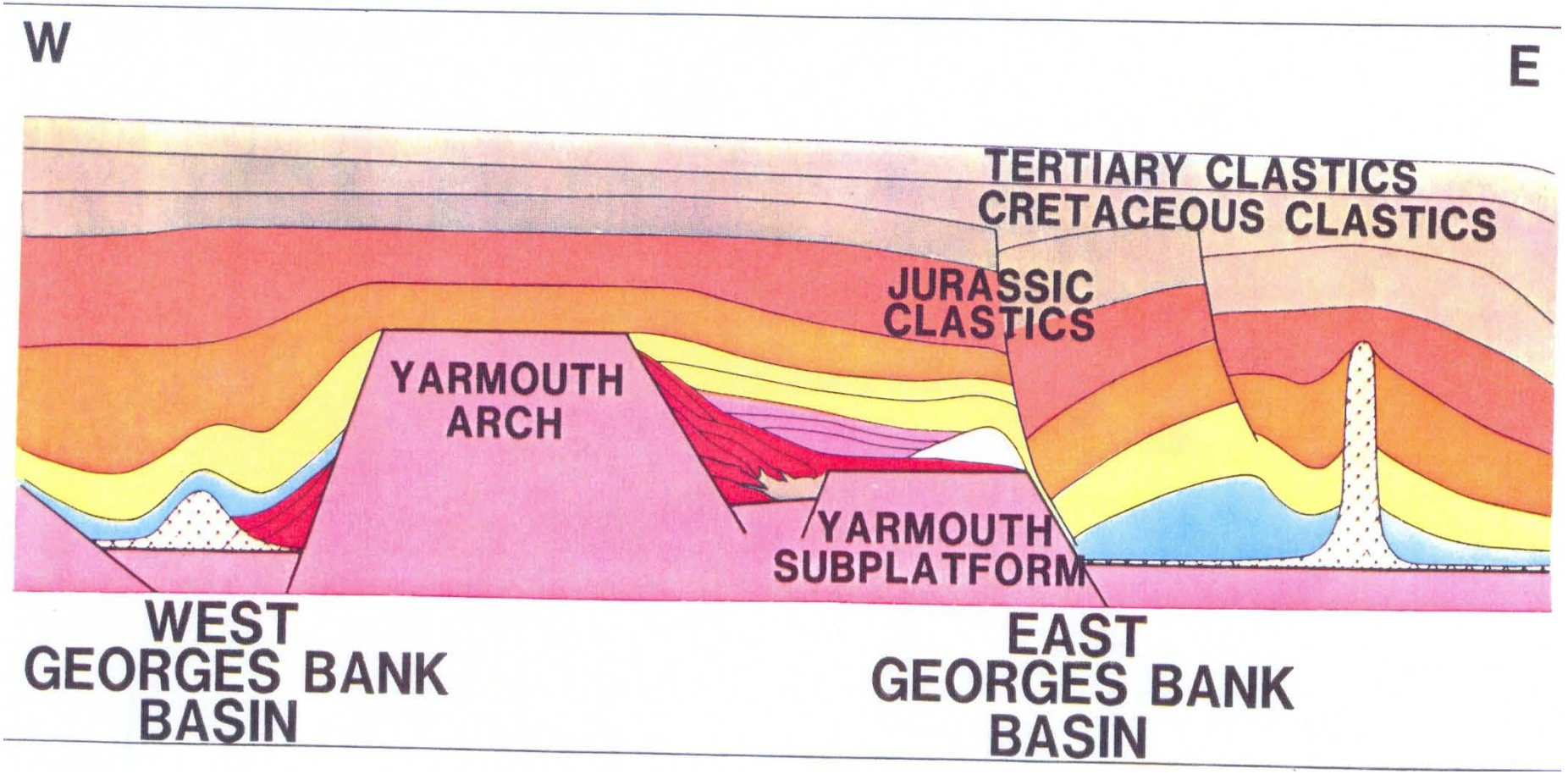

68°00'
65°15'
42°30'
42°30'
LAHAVE PLATFORM
P-23
14Km
U.S.A.
CANADA
200m
200m
200m
TRANSCURRENT FAULTS
WEST GEORGES BANK BASIN
YARMOUTH SUBPLATFORM
EAST GEORGES BANK BASIN
YARMOUTH ARCH
PALEOSHELF EDGE
200m
2000m
0 24 Km
0 16 Mi.
40°30'
40°30'
68°00'
65°15'

FIGURE 17

SCHEMATIC, REGIONAL CROSS-SECTION GEORGES BANK



Georges Bank Basin (USA side) Exploration History

- 1976 & 1977: Drilled 2 COST wells (Continental Offshore Stratigraphic Tests)
- 1979: Lease sale, total bonuses $816 MM
- 1981& 1982: 8 exploration wells drilled by Exxon, Conoco, Tenneco, Mobil, Shell
- Well water depths 210’ – 455’, drill depths from 14,100’ – 21,900’

RESULTS OF DRILLING IN GEORGES BANK (USA SIDE)

- West Georges Bank Basin is a minimally deformed basin (“layer cake”)
- Exploration wells were drilled on stratigraphic prospects all with high amplitude reflectors
- Only 4 wells penetrated Jurassic and older
- Low porosity carbonates intersected – no hydrocarbons
- No significant hydrocarbon source rocks encountered; sediments were “organically lean” (except Tenneco-1 with 1.65 TOC in Triassic)

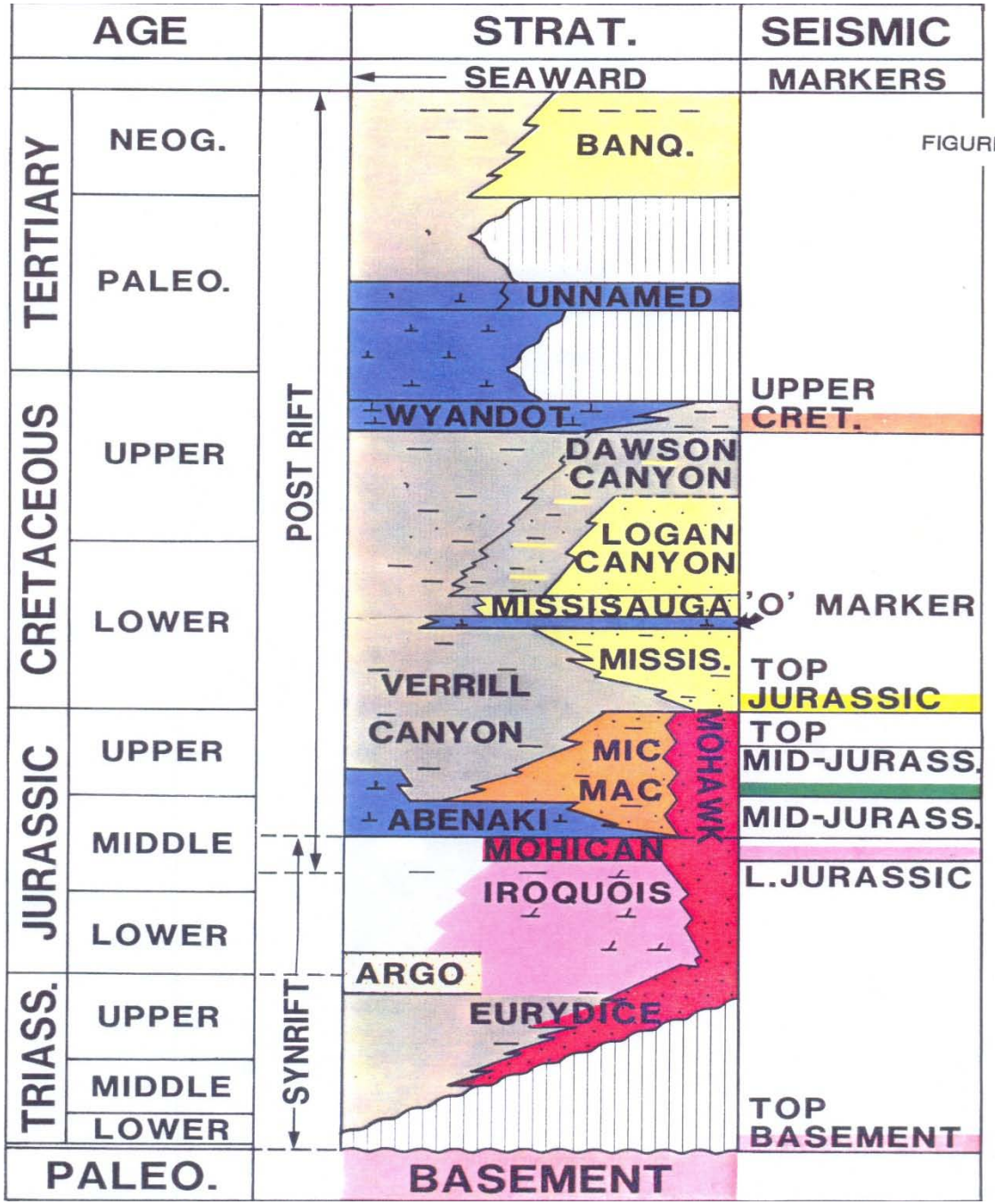

AGE
STRAT.
SEISMIC
SEAWARD
MARKERS
TERTIARY
NEOG.
PALEO.
CRETACEOUS
UPPER
LOWER
JURASSIC
UPPER
MIDDLE
LOWER
TRIASS.
UPPER
MIDDLE
LOWER
PALEO.
POST RIFT
SYNRIFT
BANQ.
UNNAMED
WYANDOT
DAWSON CANYON
LOGAN CANYON
MISSISAUGA
MISSIS.
VERRILL CANYON
MIC MAC
ABENAKI
MOHAWK
MOHICAN
IROQUOIS
ARGO
EURYDICE
BASEMENT
UPPER CRET.
'O' MARKER
TOP JURASSIC
TOP MID-JURASS.
MID-JURASS.
L.JURASSIC
TOP BASEMENT

FIGURE 3

FIGURE 4

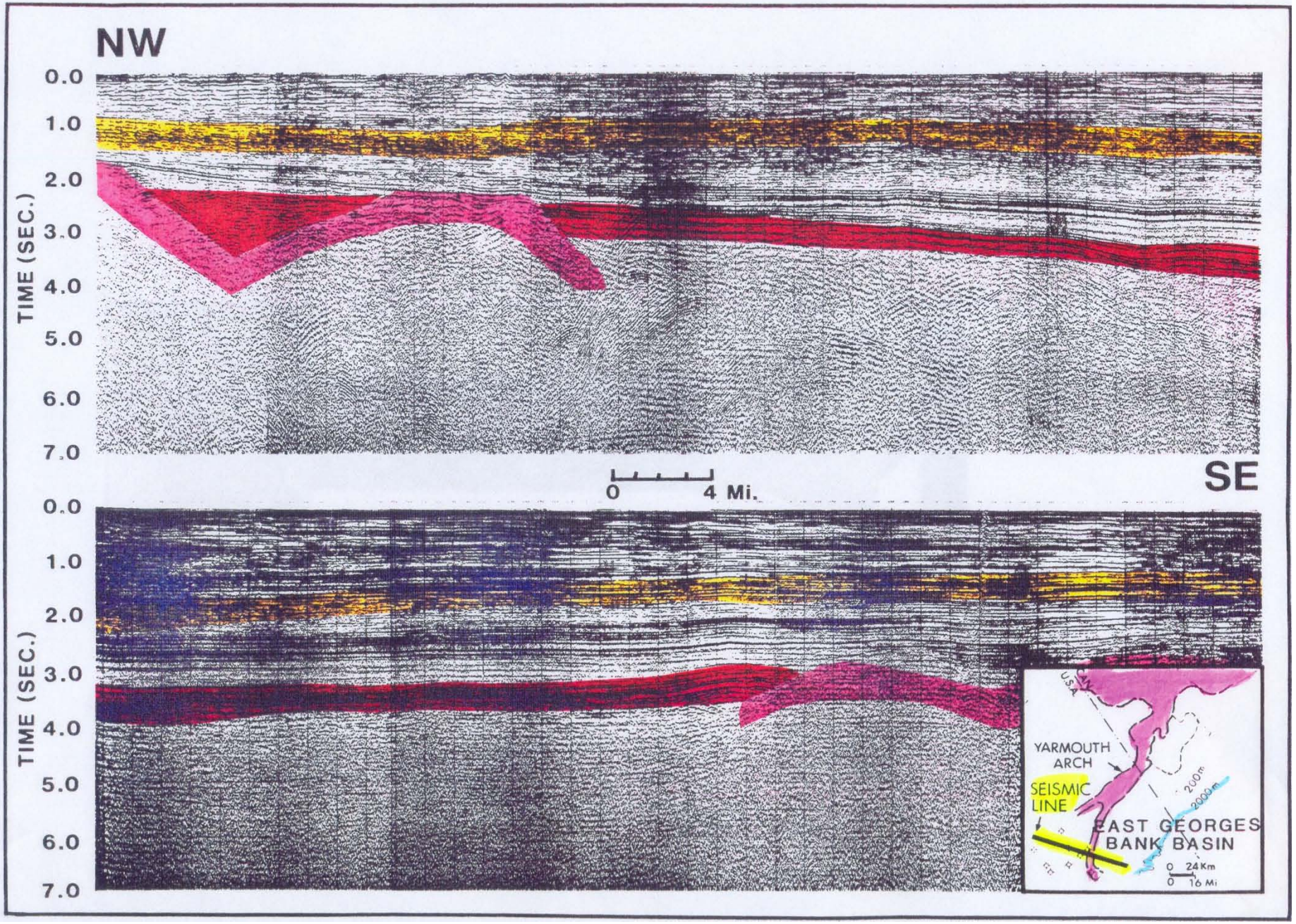

NW
SE
TIME (SEC.)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
0
4 Mi.
YARMOUTH ARCH
SEISMIC LINE
EAST GEORGES BANK BASIN
200m
2000m
0 24Km
0 16 Mi

FIGURE 6

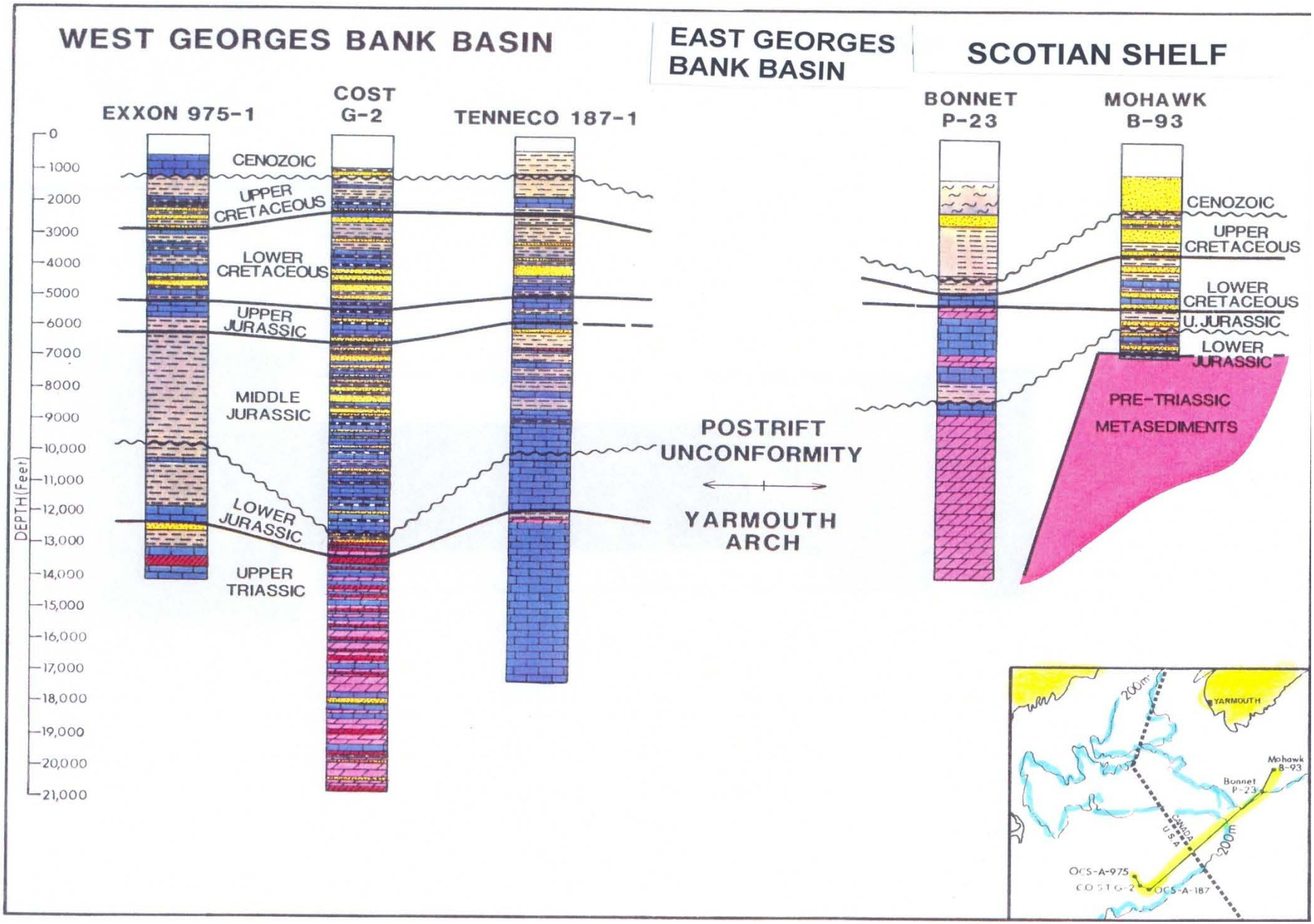

WEST GEORGES BANK BASIN
EAST GEORGES BANK BASIN
SCOTIAN SHELF
EXXON 975-1
COST G-2
TENNECO 187-1
BONNET P-23
MOHAWK B-93
DEPTH (Feet)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
19,000
20,000
21,000
CENOZOIC
UPPER CRETACEOUS
LOWER CRETACEOUS
UPPER JURASSIC
MIDDLE JURASSIC
LOWER JURASSIC
UPPER TRIASSIC
POSTRIFT UNCONFORMITY
YARMOUTH ARCH
CENOZOIC
UPPER CRETACEOUS
LOWER CRETACEOUS
U. JURASSIC
LOWER JURASSIC
PRE-TRIASSIC METASEDIMENTS
200m
YARMOUTH
Mohawk B-93
Bonnet P-23
CANADA
U.S.A.
200m
OCS-A-975
COST G-2
OCS-A-187

FIGURE 8A-1

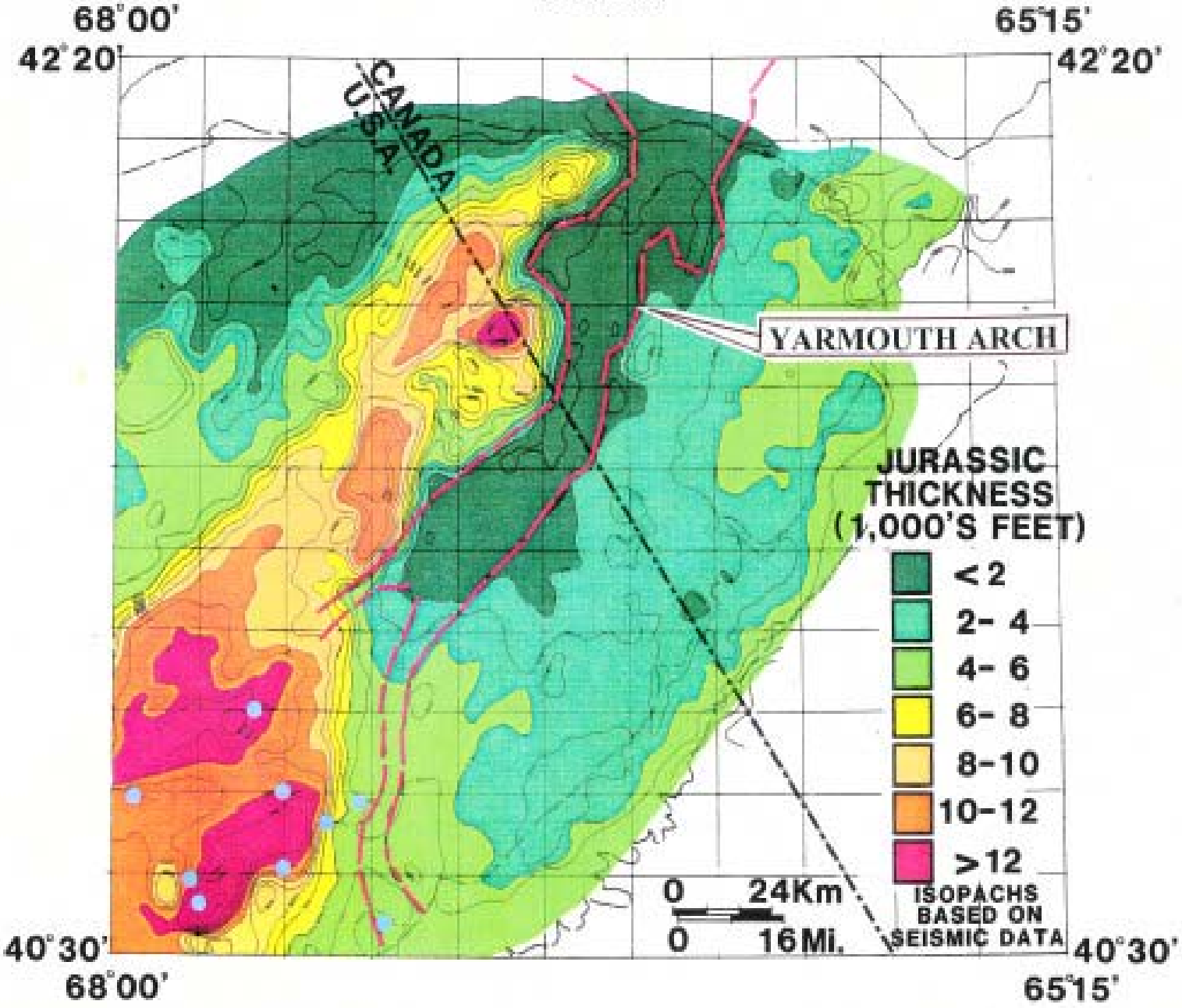

68°00'
42°20'
65°15'
CANADA
U.S.A.
YARMOUTH ARCH
JURASSIC
THICKNESS
(1,000'S FEET)
< 2
2- 4
4- 6
6- 8
8-10
10-12
>12
0 24Km
0 16Mi.
ISOPACHS
BASED ON
SEISMIC DATA
40°30'
68°00'
65°15'

FIGURE 8B-1

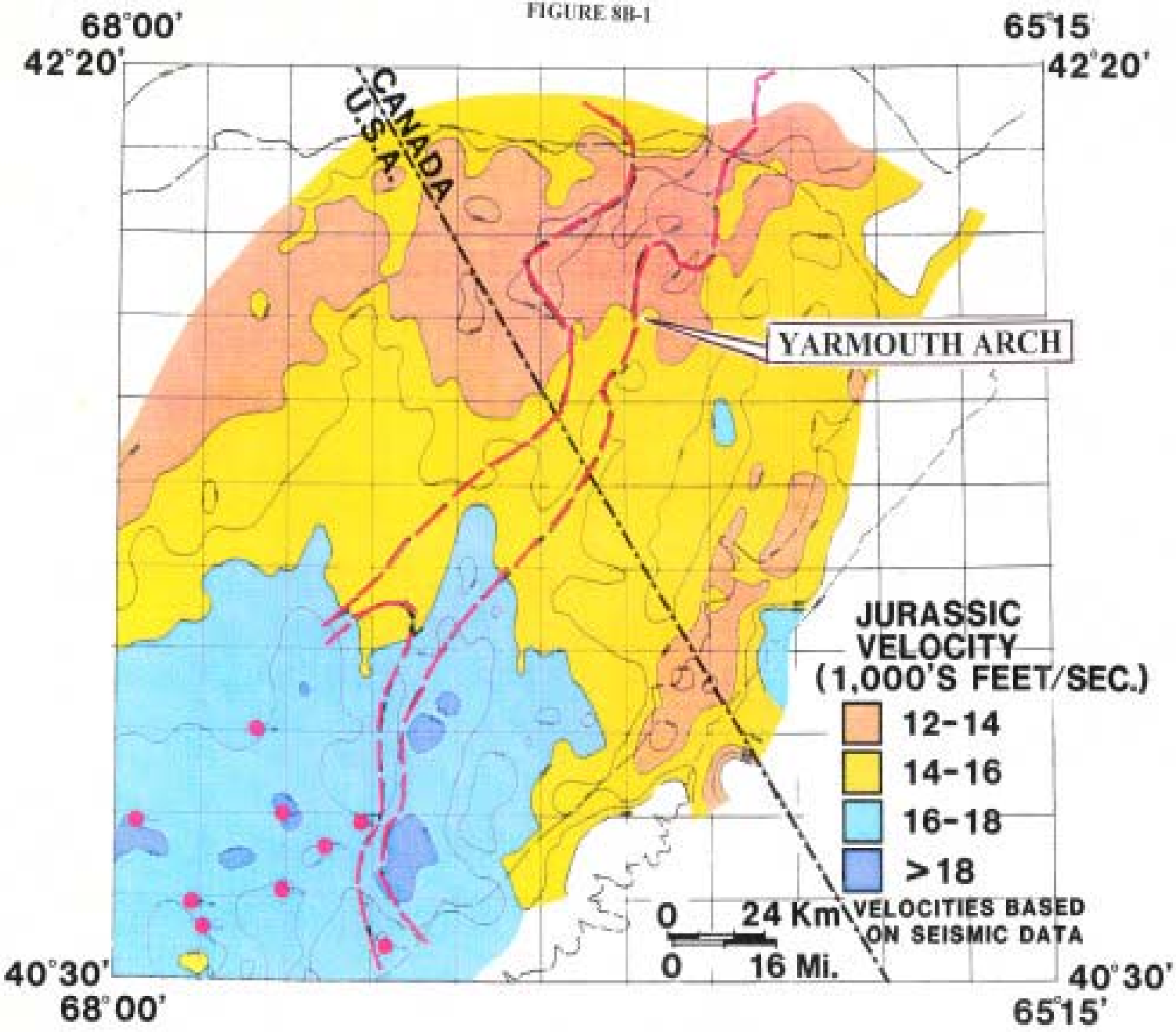
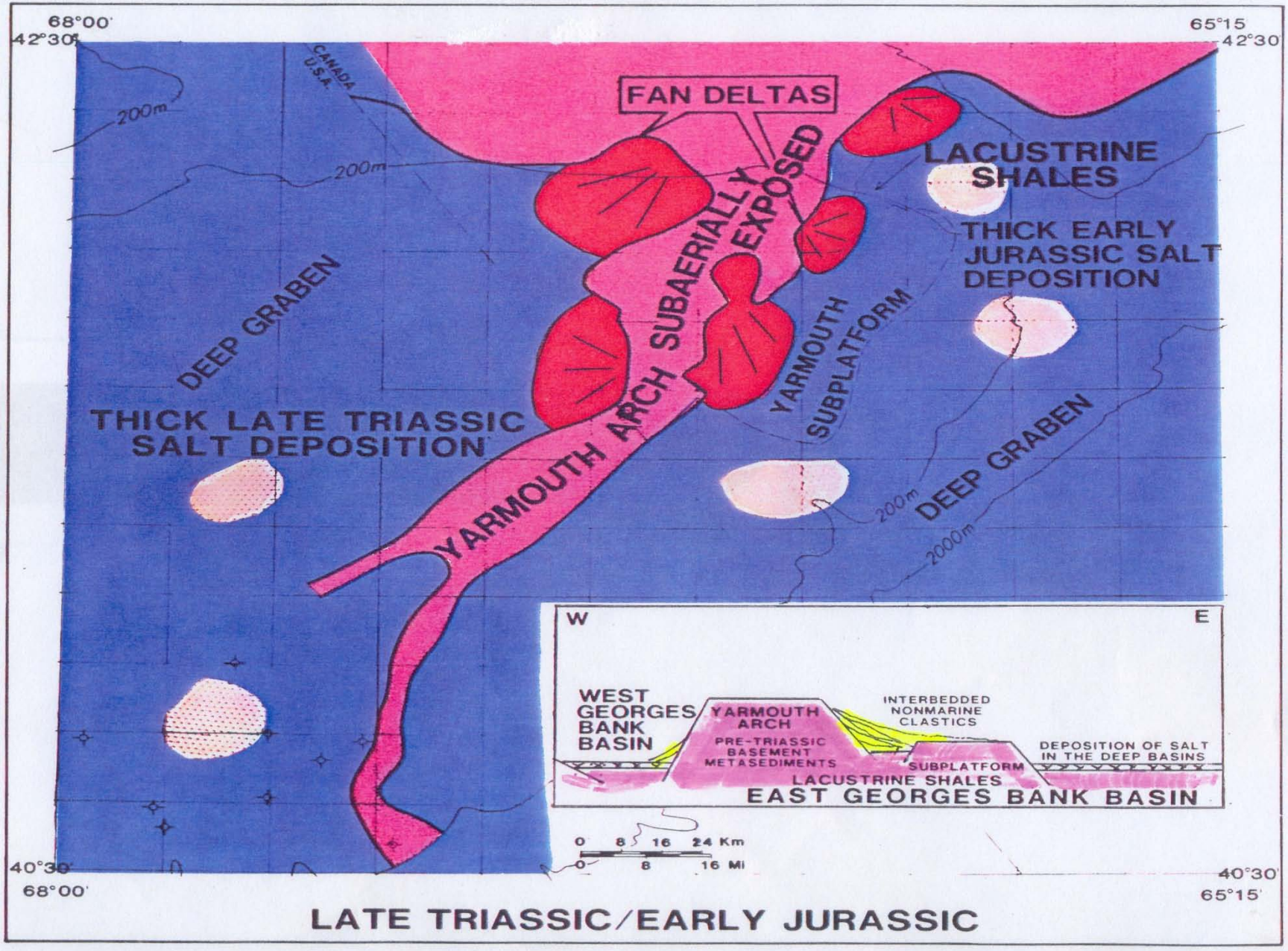

68°00'
42°20'
65°15'
42°20'
CANADA
U.S.A.
YARMOUTH ARCH
JURASSIC
VELOCITY
(1,000'S FEET/SEC.)
12-14
14-16
16-18
>18
VELOCITIES BASED
ON SEISMIC DATA
0 24 Km
0 16 Mi.
40°30'
68°00'
40°30'
65°15'

FIGURE 9



LATE TRIASSIC/EARLY JURASSIC

FIGURE 10

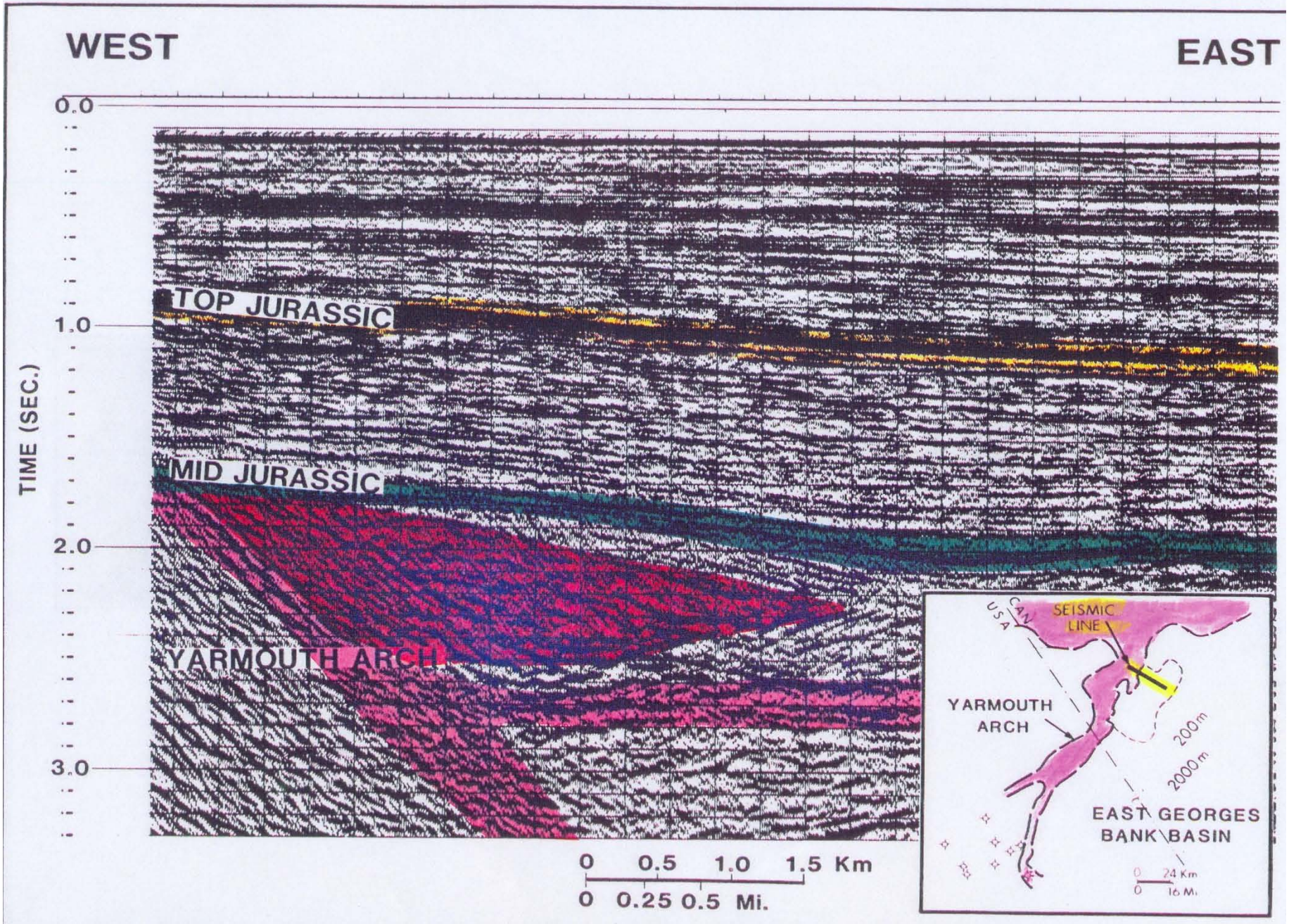
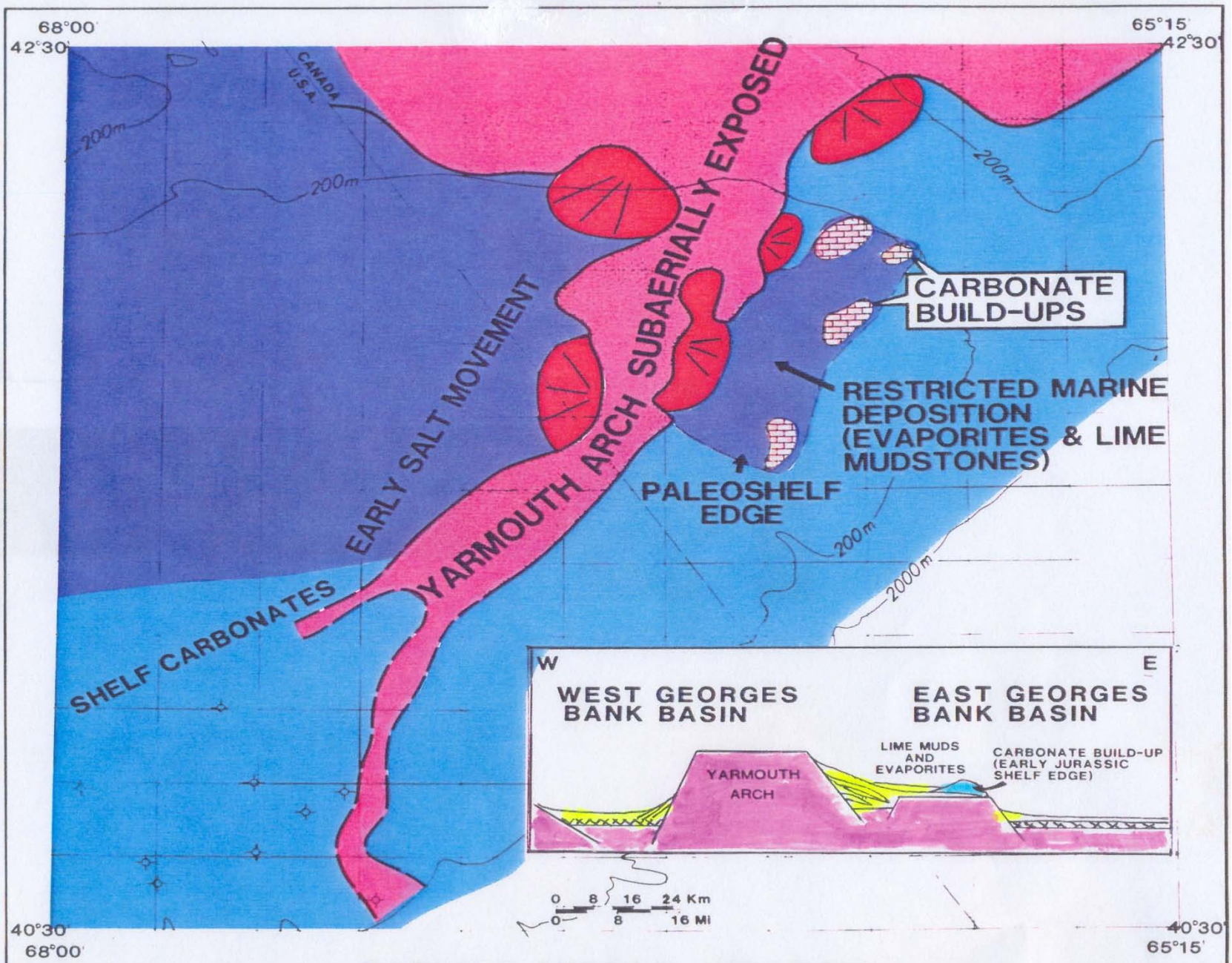

WEST
EAST
0.0
1.0
2.0
3.0
TIME (SEC.)
TOP JURASSIC
MID JURASSIC
YARMOUTH ARCH
0 0.5 1.0 1.5 Km
0 0.25 0.5 Mi.
CAN
USA
SEISMIC LINE
YARMOUTH ARCH
200m
2000m
EAST GEORGES BANK BASIN
0 24 Km
0 16 Mi

FIGURE 11



EARLY & MIDDLE JURASSIC

FIGURE 12

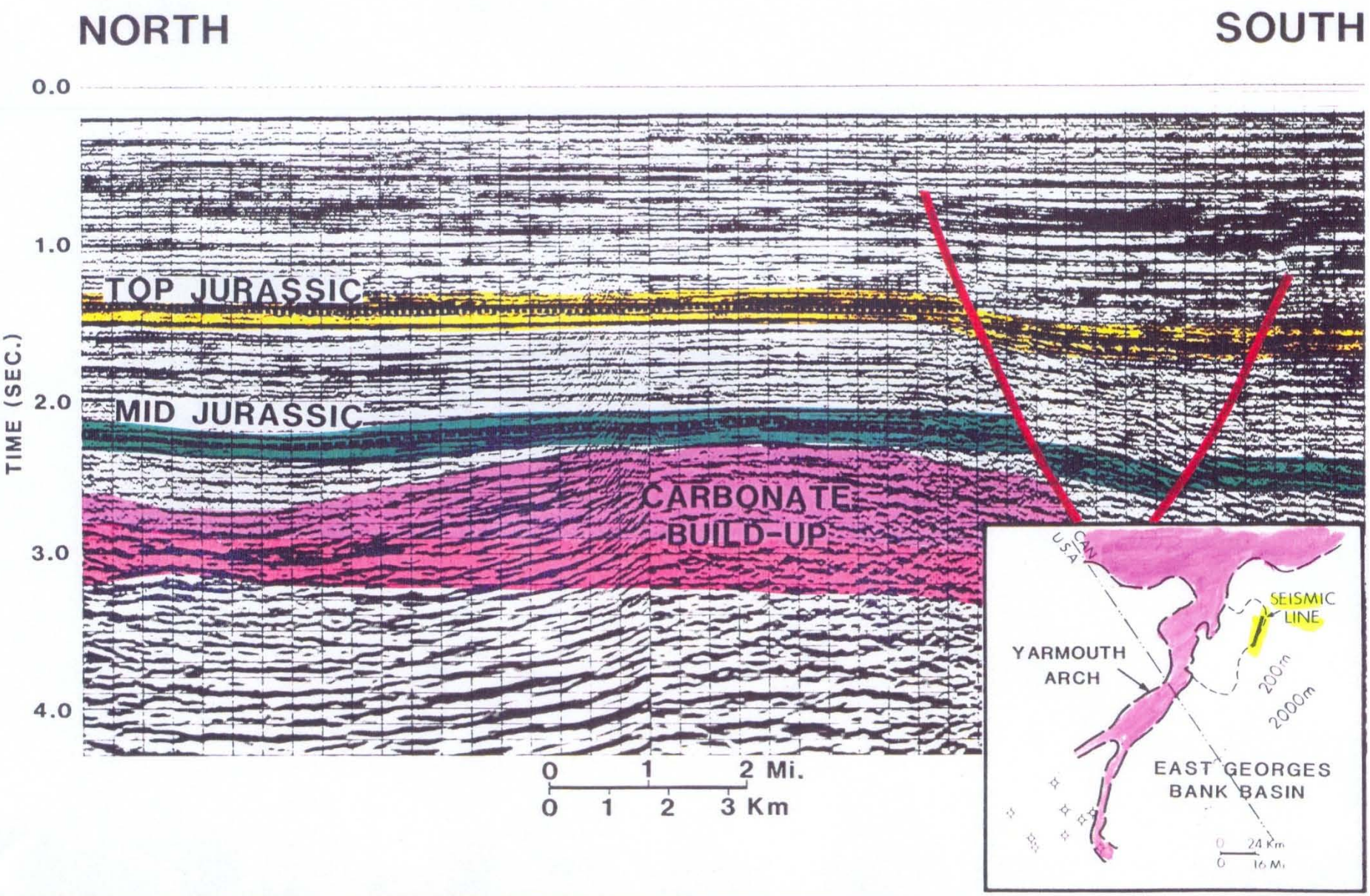

NORTH
SOUTH
0.0
1.0
2.0
3.0
4.0
TIME (SEC.)
TOP JURASSIC
MID JURASSIC
CARBONATE BUILD-UP
0 1 2 Mi.
0 1 2 3 Km
CAN
USA
SEISMIC LINE
YARMOUTH ARCH
200m
2000m
EAST GEORGES BANK BASIN
0 24 Km
0 16 Mi

FIGURE 13

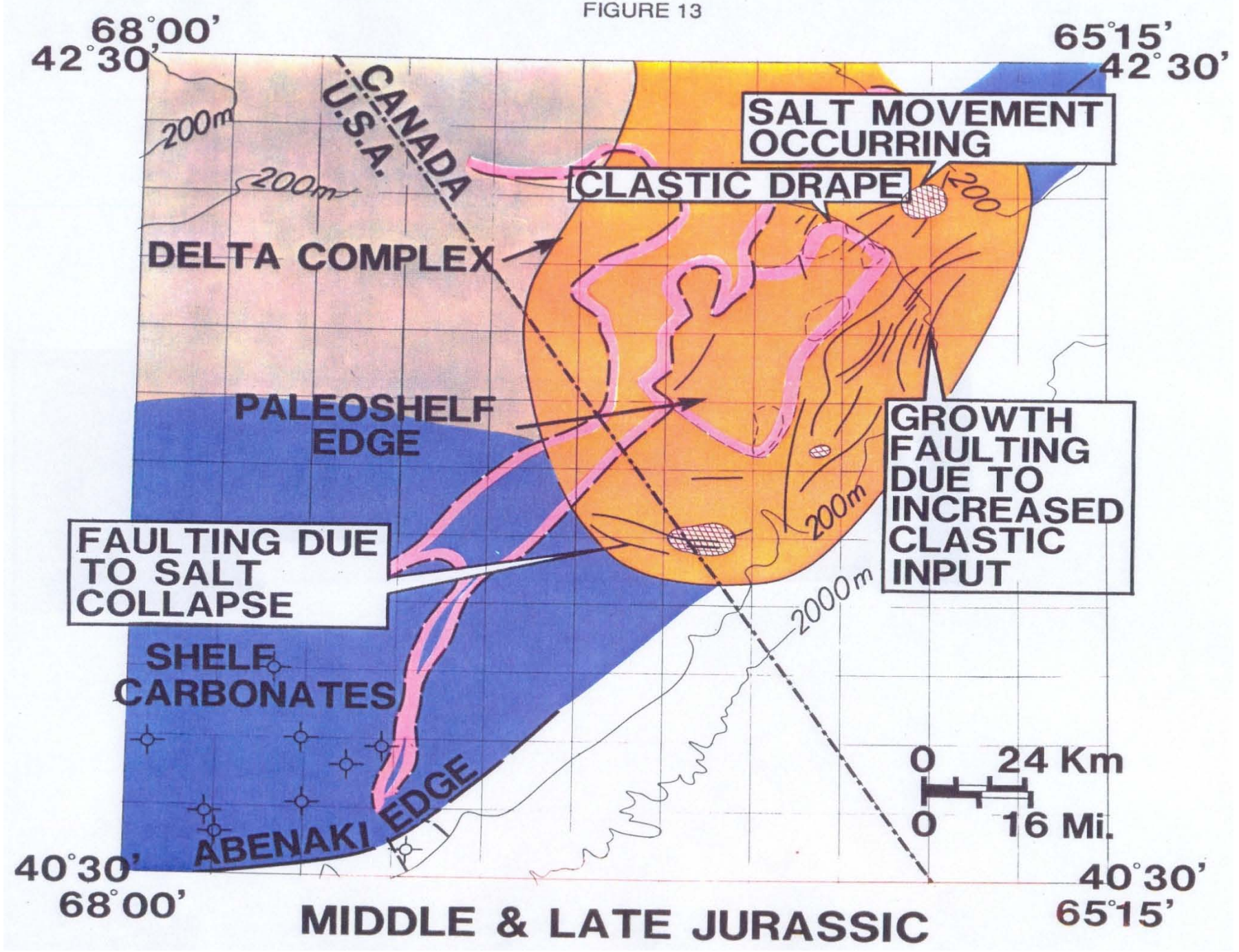

68°00'
42°30'
65°15'
42°30'
CANADA
U.S.A.
200m
200m
SALT MOVEMENT OCCURRING
CLASTIC DRAPE
200
DELTA COMPLEX
PALEOSHELF EDGE
GROWTH FAULTING DUE TO INCREASED CLASTIC INPUT
200m
FAULTING DUE TO SALT COLLAPSE
2000m
SHELF CARBONATES
0 24 Km
0 16 Mi.
ABENAKI EDGE
40°30'
40°30'
68°00'
65°15'
MIDDLE & LATE JURASSIC

FIGURE 14 – A

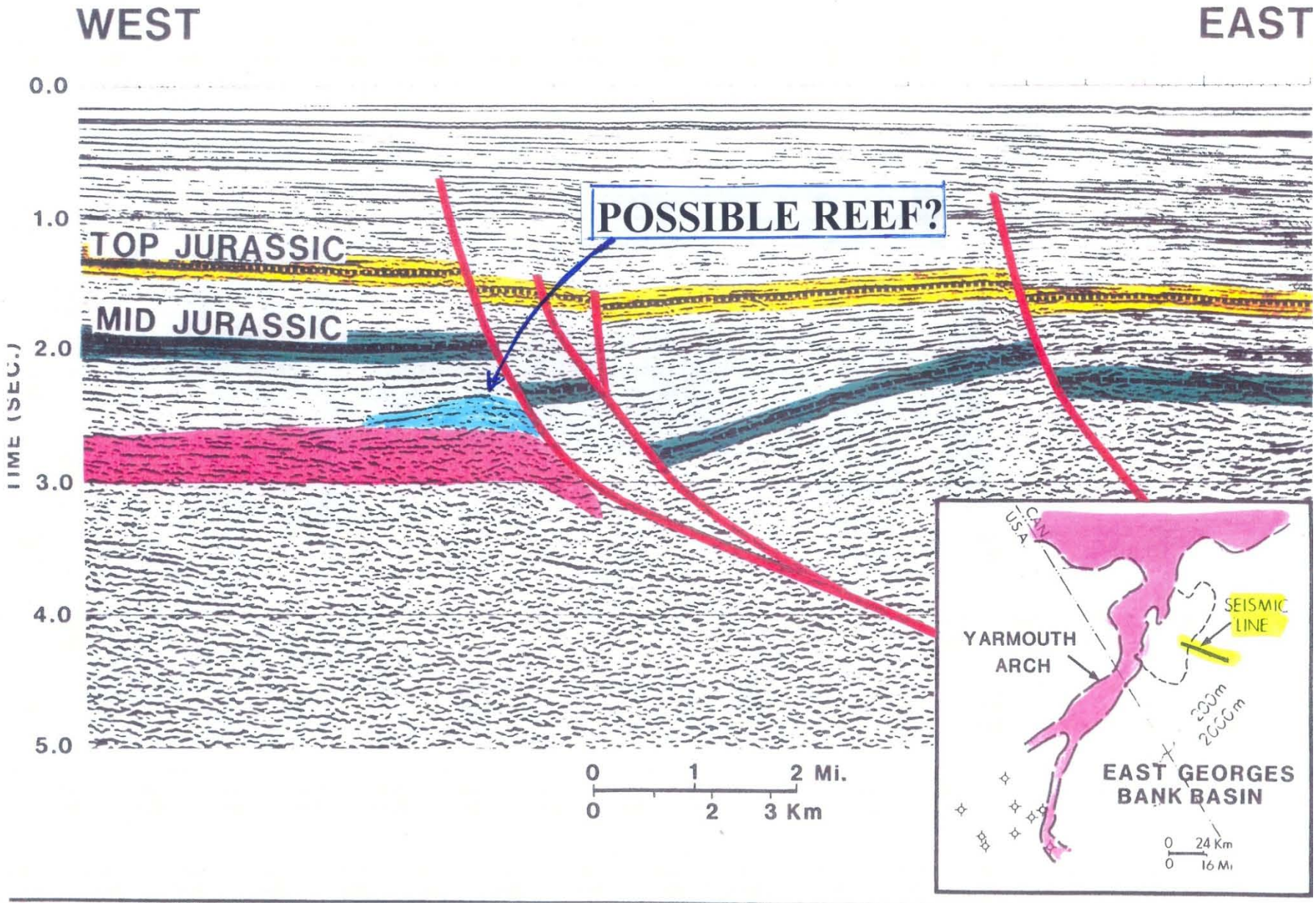

WEST
EAST
0.0
1.0
2.0
3.0
4.0
5.0
TIME (SEC.)
POSSIBLE REEF?
TOP JURASSIC
MID JURASSIC
0 1 2 Mi.
0 2 3 Km
CAN
USA
SEISMIC LINE
YARMOUTH ARCH
EAST GEORGES BANK BASIN
0 24 Km
0 16 Mi

FIGURE 15

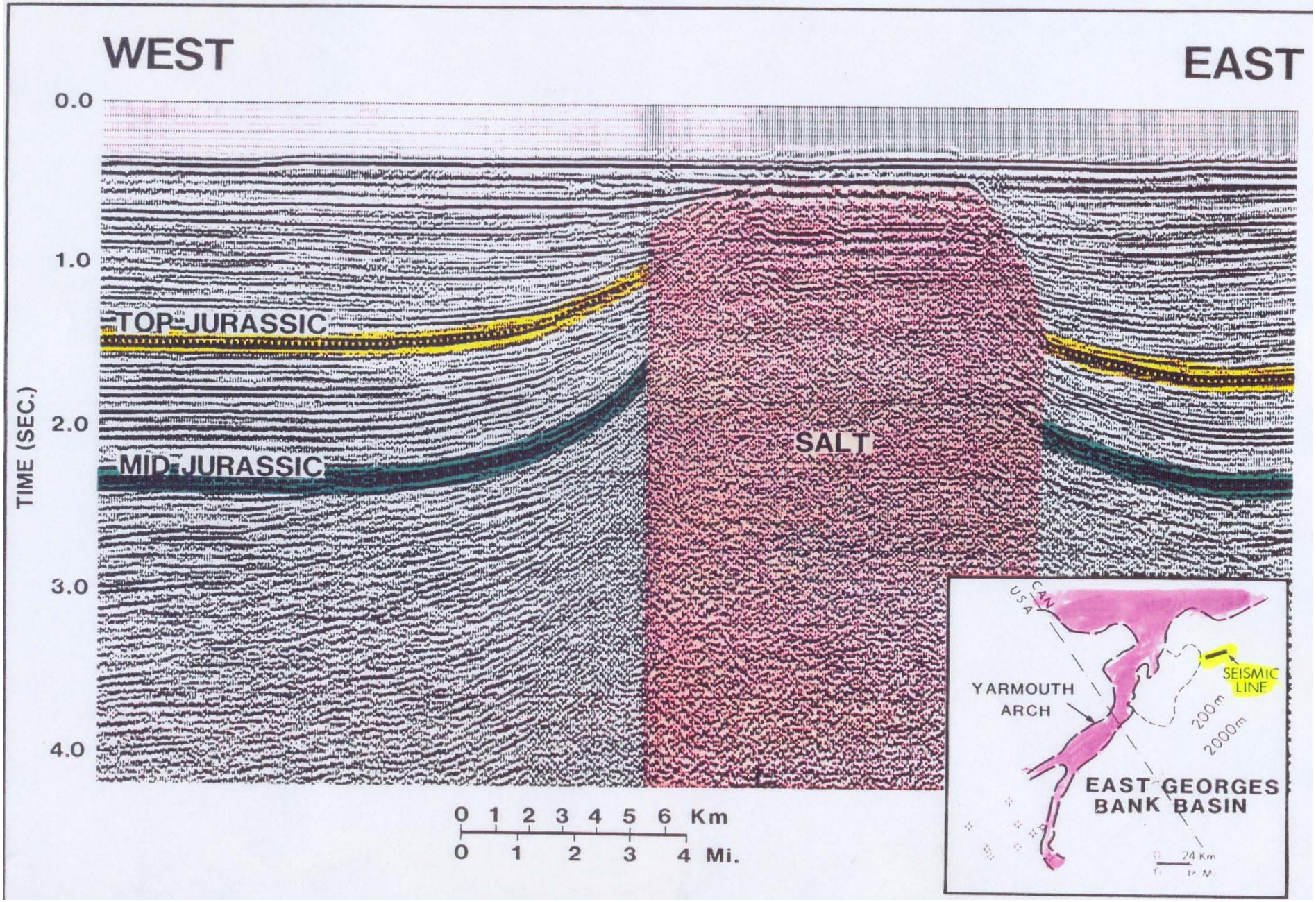
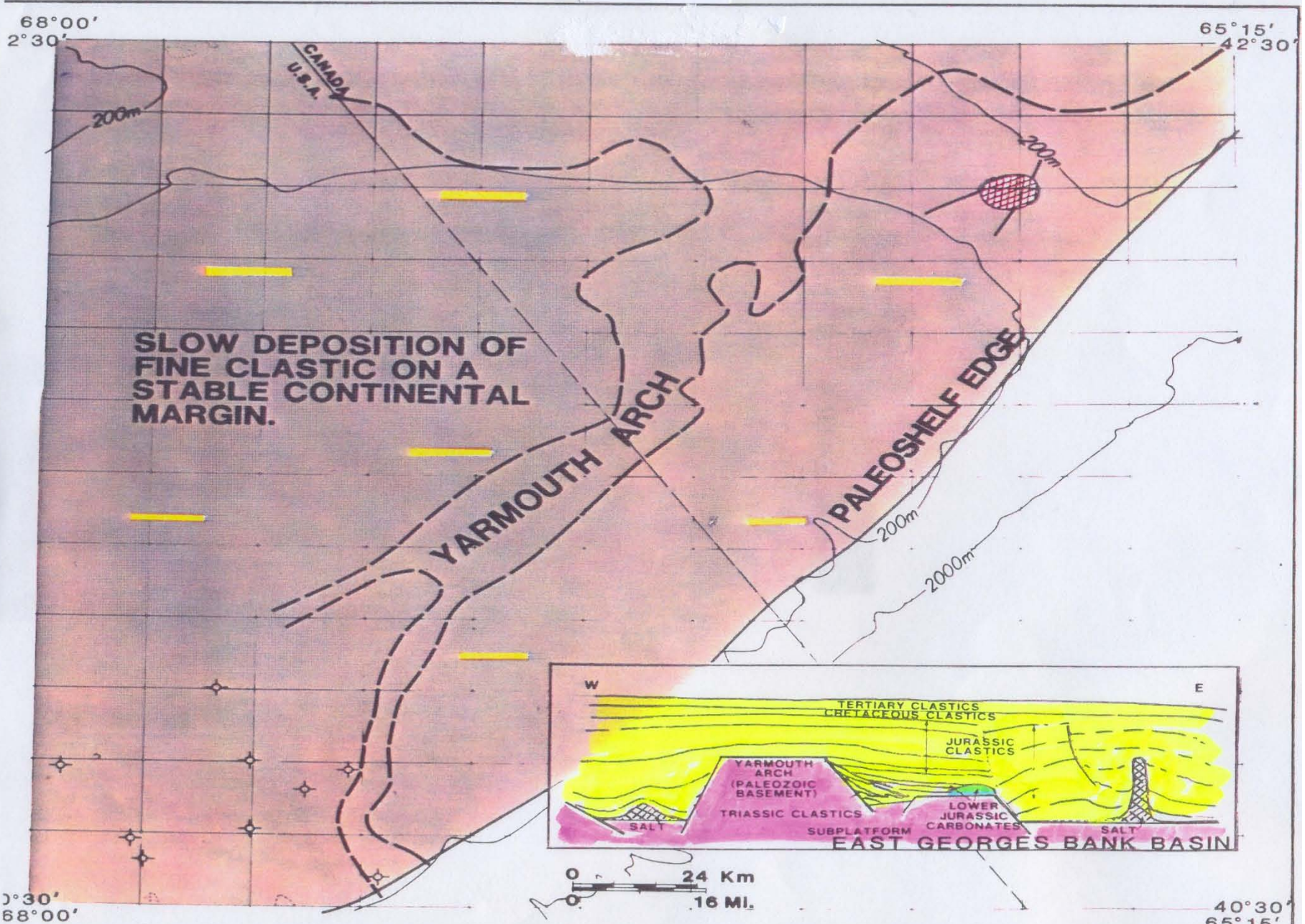

WEST
EAST
0.0
1.0
2.0
3.0
4.0
TIME (SEC.)
TOP JURASSIC
MID JURASSIC
SALT
0 1 2 3 4 5 6 Km
0 1 2 3 4 Mi.
CAN
USA
YARMOUTH
ARCH
SEISMIC
LINE
200m
2000m
EAST GEORGES
BANK BASIN
24 Km

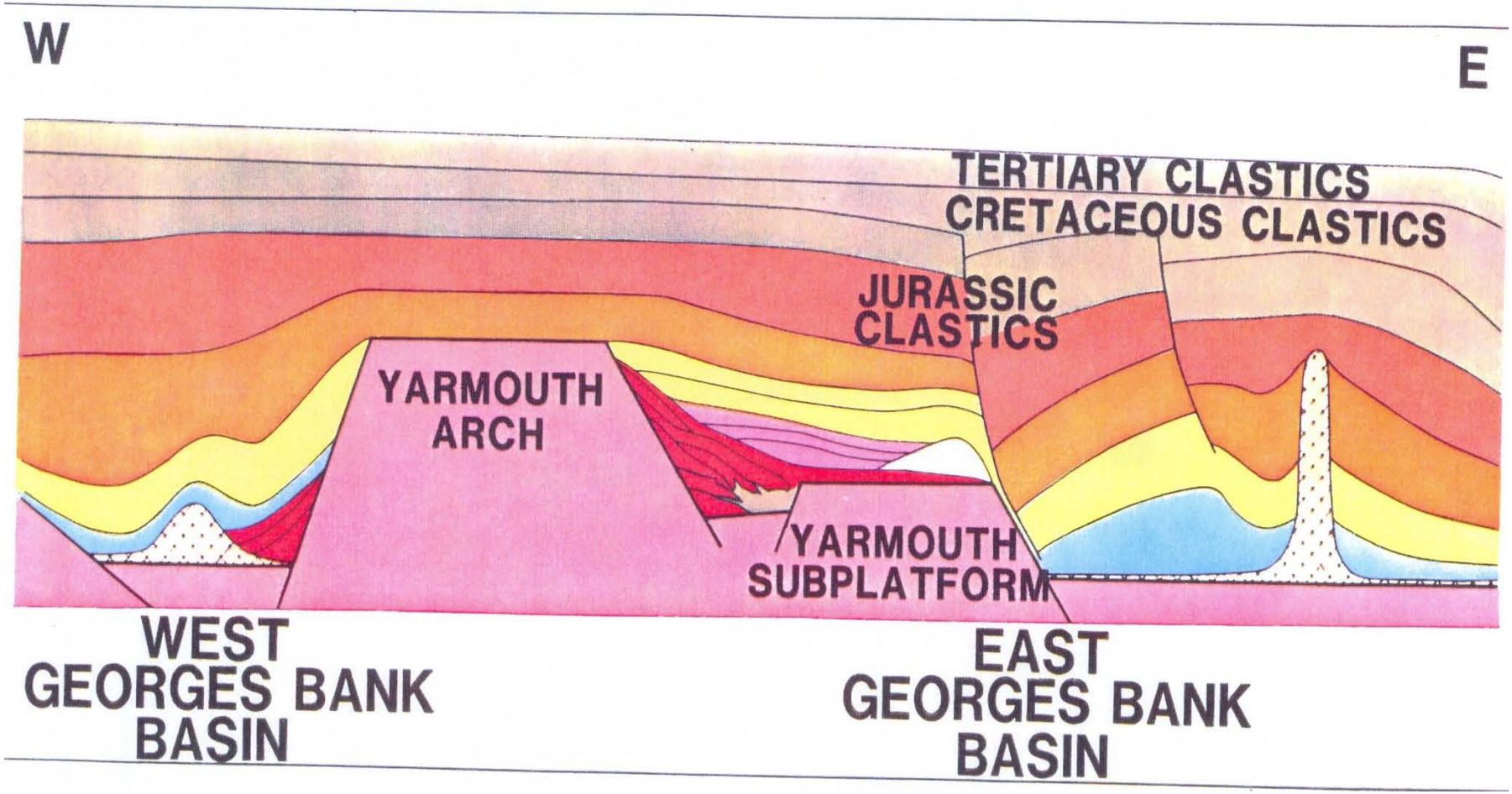
FIGURE 16



CRETACEOUS TO PRESENT

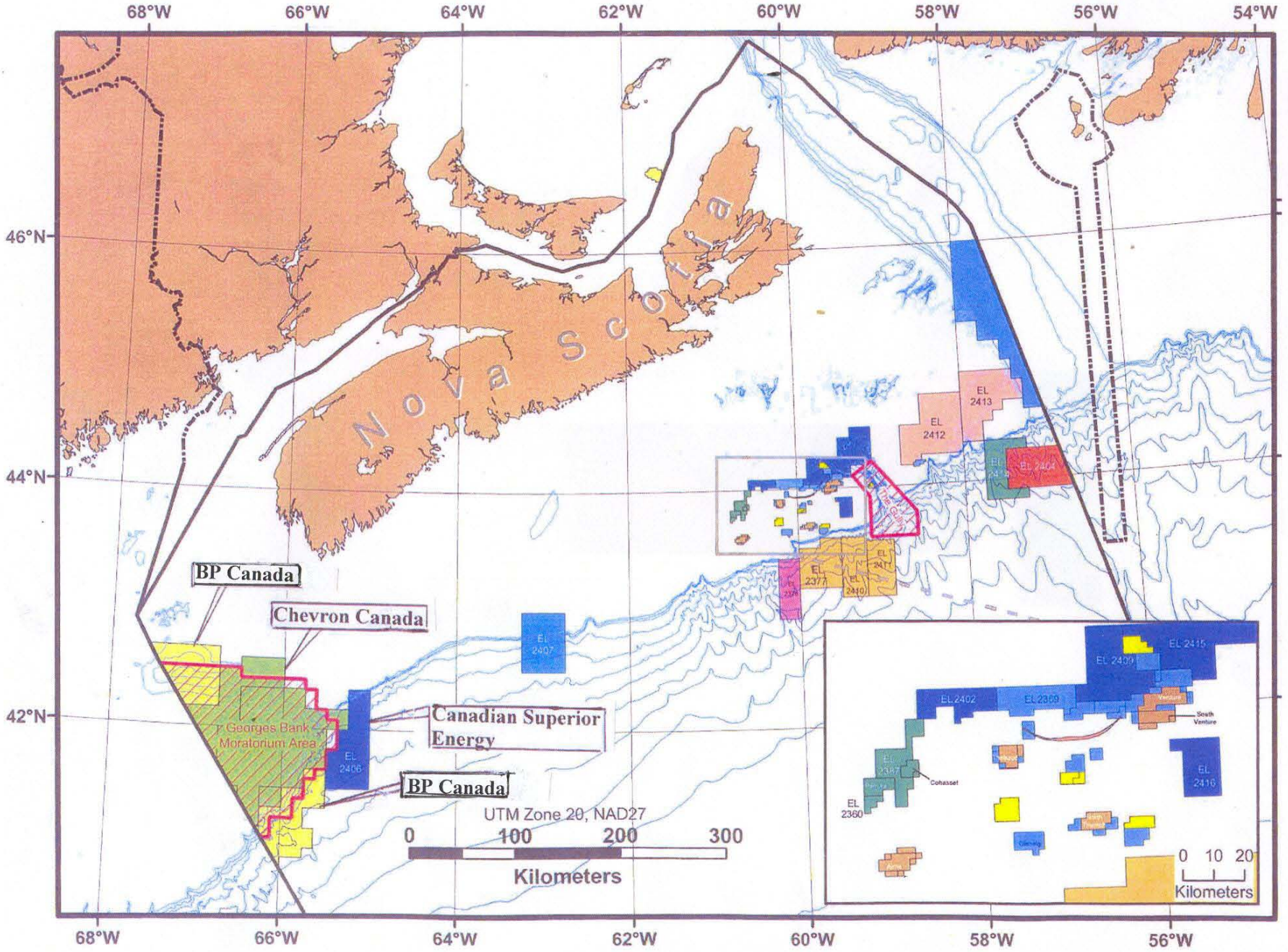
FIGURE 17

SCHEMATIC, REGIONAL CROSS-SECTION GEORGES BANK



Summary: Geological Differences Between USA Side of Georges Bank and the Canadian Side

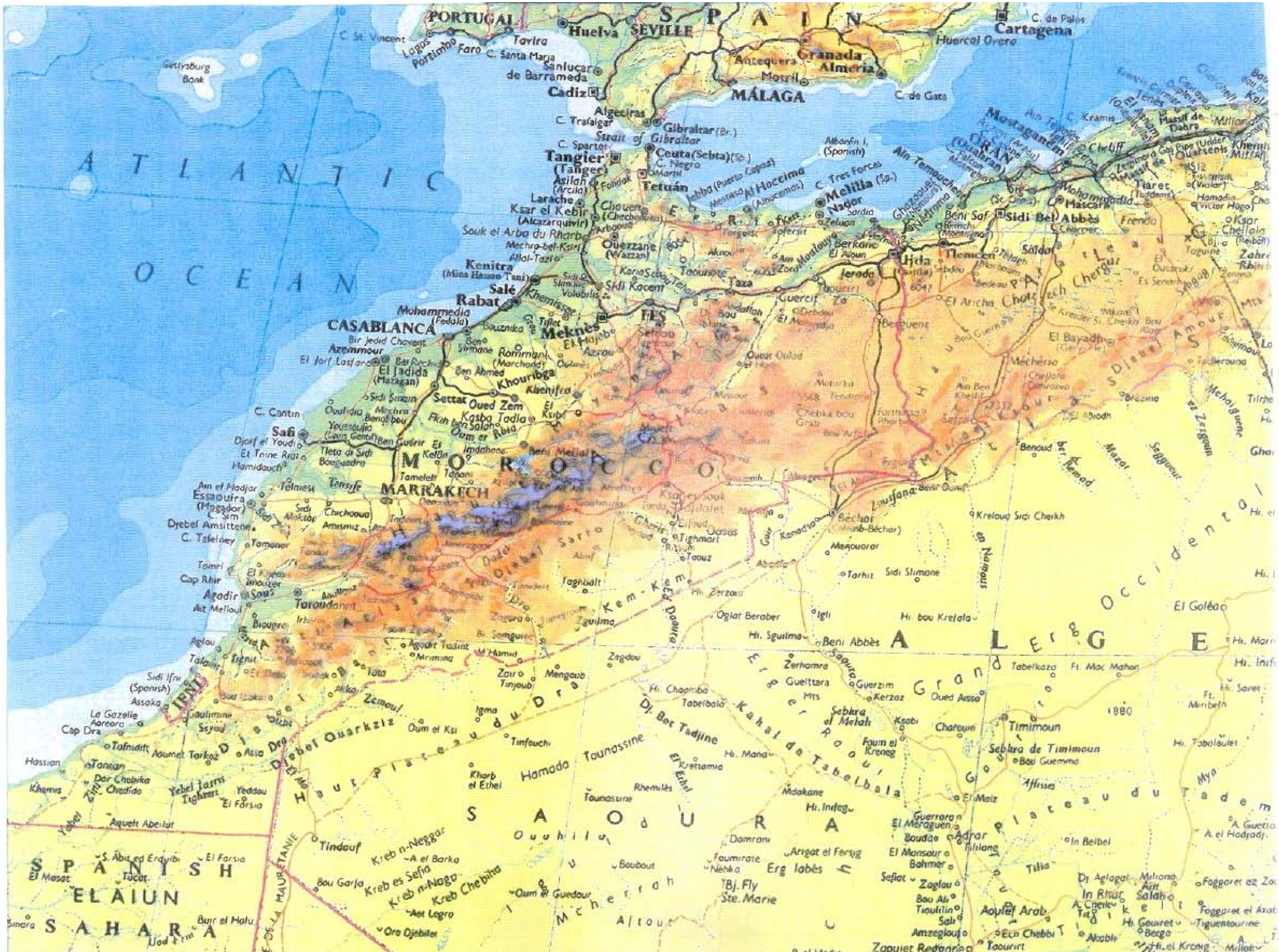
- The Jurassic section is very thick on the USA side (west of the Yarmouth Arch) with up to 12,000 feet of sediments in comparison to up to 2,000 to 4,000 feet of section on the Canadian side (east of the Yarmouth Arch)
- Jurassic velocities are very fast on the USA side with average velocities of 16,000 – 18,000 feet per second (indicating carbonates & confirmed by well control) whereas velocities on the Canadian side are slower at 14,000 – 16,000 feet per second indicating likelihood of sandstones
- The USA side is structurally “layer cake” whereas the Canadian side is highly structured with many seismically defined growth faults, well defined salt structures and indications of possible Jurassic age reefs
- This infers that the East Georges Bank Basin is geologically very different from the West Georges Bank Basin and that the dry holes drilled on the USA side do not downgrade the oil & gas potential on the Canadian side



From: Canada – Nova Scotia Offshore Petroleum Board
July 2007

Looking for analogues in Morocco

- AAPG field trip in 1992 (led by Dr. John Warme)
- You can observe in outcrop everything that has been interpreted on seismic in the subsurface of the East Georges Bank Basin including alluvial fan deposits (red beds), turbidites and reefs

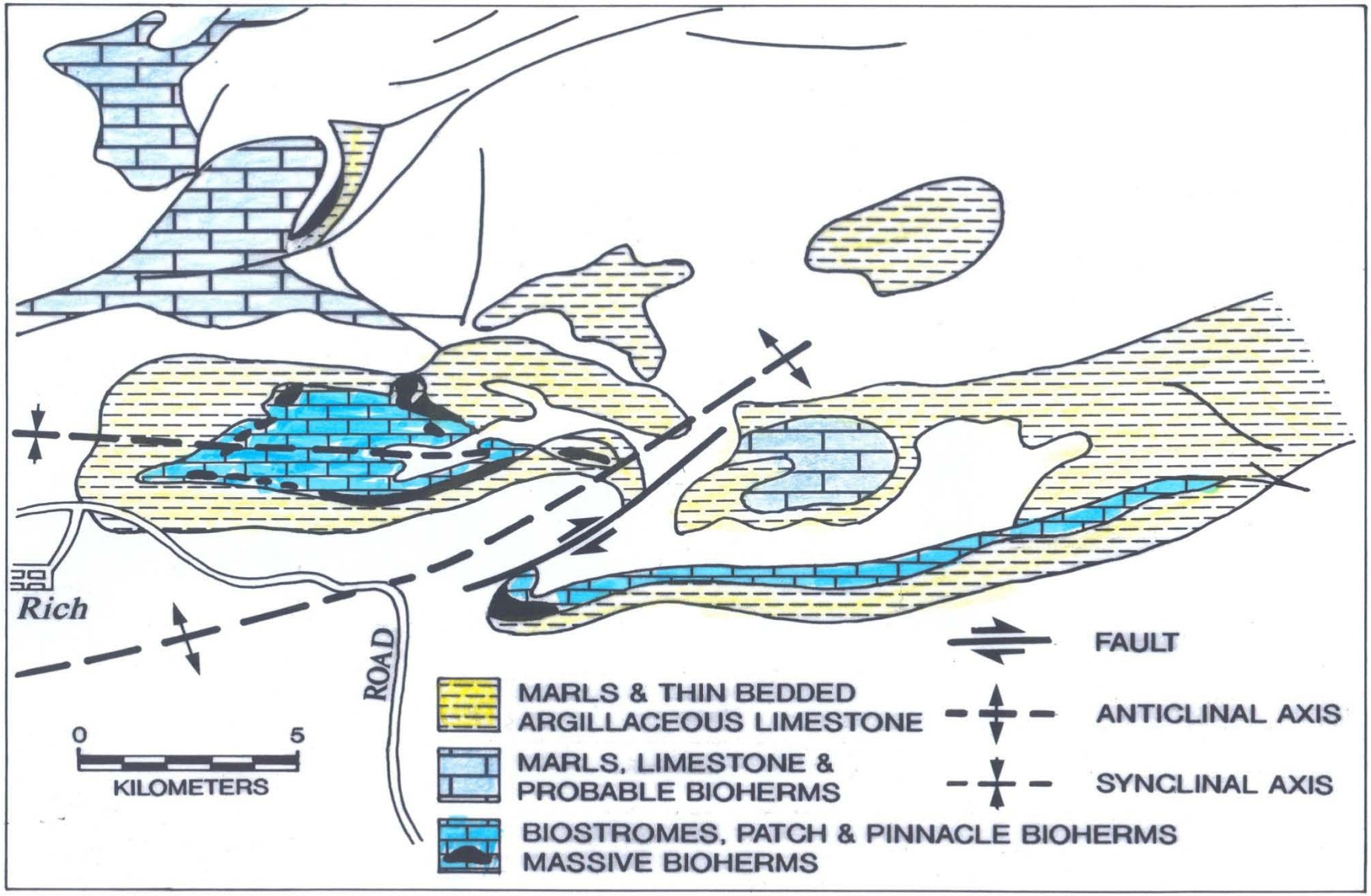


PORTUGAL
SPAIN
C. St. Vincent
Lagos
Portimão
Faro
Tavira
C. Santa Maria
Huelva
SEVILLE
Sanlúcar de Barrameda
Cadiz
Antequera
Granada
Almeria
Motril
MÁLAGA
C. de Gata
Cartagena
C. de Palos
Huercal Overa
Gettysburg Bank
ATLANTIC
OCEAN
Algeciras
C. Trafalgar
Gibraltar (Br.)
Strait of Gibraltar
C. Spartel
Tangier (Tanger)
Ceuta (Sebta) (Sp.)
C. Negro
Asilah (Arcila)
Tetuán
Larache
Ksar el Kebir (Alcazarquivir)
Souk el Arba du Rharb
Mechra-bel-Ksiri
Allal-Tazi
Chouen
Ouezzane (Wazzan)
Al Hoceima (Alhucemas)
Alborán I. (Spanish)
C. Tres Forcas
Melilla (Sp.)
Nador
Zeluan
Berkane
El Aioun
Taounate
Taza
Kenitra (Mina Hassan Tani)
Salé
Rabat
Khemisset
Sidi Kacem
Volubilis
Mohammedia (Fedala)
CASABLANCA
Bir Jedid Chavent
Azemmour
El Jorf Lasfar
El Jadida (Mazagan)
Meknès
FES
El Hajeb
Azrou
Rommani (Marchand)
Ben Ahmed
Khouribga
Khenifra
Settat
Oued Zem
Kasba Tadla
Fkih ben Salah
Oum er Rbia
C. Cantin
Safi
Djorf el Youdi
Et Tnine Rgat
Hamidouch
Tleta di Sidi Bouguedra
MOROCCO
Tamelelt
MARRAKECH
Ain el Hadjar
Essaouira (Mogador)
C. Sim
Djebel Amsittene
C. Tafelney
Chichaoua
Amizmiz
Tamri
Cap Rhir
Agadir
Sous
Ait Melloul
Taroudannt
Biougra
Aglou
Tiznit
Sidi Ifni (Spanish)
Assaka
IFNI
La Gazelle
Cap Dra
Hassian
Khemis
Dor Chebika
Chedida
Aqueit Abeilut
SPANISH
EL AIUN
SAHARA
Smara
Buir el Halu
S. Abit ed Erguibi
El Farsia
Tindouf
Kreb n-Neggar
Kreb es Sefia
Kreb n-Nago
Kreb Chebiha
Bou Garfa
Oum el Ksi
Tinfouchi
Djebel Ouarkziz
Zemoul
Hamada Tounassine
Haut Plateau du Dra
SAOURA
Ouahila
Oum el Guedour
Ma'cherrah
Altou
Boubout
Tounassine
Rhemilès
Dj. Bet Tadjine
Kahal de Tabelbala
Tabelbala
Erg er Raoui
Erg Iabès
Sebkra el Melah
Beni Abbès
Igli
Oglat Beraber
Kerzaz
Guerzim
Timimoun
Sebkra de Timimoun
Grand Erg Occidental
El Goléa
Adrar
Plateau du Tademait
Tilia
In Salah
Aoulef Arab
Zaouiet Reggane
Tidikelt
Béchar (Colomb-Béchar)
Kenadsa
Mengouba
Zagora
Tagounit
Zegdou
Oujda
Jerada
Tlemcen
Sidi Bel Abbès
Mascara
Mostaganem
ORAN (Ouahran)
Beni Saf
Saïda
Frenda
Tiaret
El Bayadh
Méchéria
Ain Sefra
Figuig
Beni Ounif
Guercif
Ain Temouchent
Chott ech Chergui
Benoud
Brezina
Djebel Amour
Kreloua Sidi Cherkh
Sidi Slimane
ALGERIA
Hi. bou Krelala
Hi. Sguilma
Gueltara
Tabelkaza
Ft. Mac Mahon
Ouled Aissa
Charouin
Mdakane
Boudaa
El Mansour
Bahmer
Zaglou
Sali
Amzeglouf
Taourirt
In Belbel
Aoulef
Tinjoub
Zaouiet
Hi. Inifegu
Guerrara
Mzab
Ain Salah
Foggaret ez Zoua
Hi. Gouret
Tiguentourine

THE HIGH ATLAS MOUNTAINS, CENTRAL MOROCCO

TRIASSIC-EARLY LIASSIC REDBEDS (DRY RIFT PHASE)

MIDDLE JURASSIC - RIFT FILLS, SHALLOW MARINE TO CONTINENTAL



SURFACE GEOLOGY MAP, RICH AREA, HIGH ATLAS MOUNTAINS, MOROCCO SHOWING GENERALIZED DOGGER (L. JURASSIC) REEF FACIES AND LITHOFACIES

(AFTER BURKE AND WARME, 1992)

MIDDLE JURASSIC (DOGGER) PINNACLE REEFS (4 EXPOSED) ALONG FAULT SCARP

MIDDLE JURASSIC PINNACLE REEF CONSISTING OF CORALGAL REEF BUILDERS (UP TO 90 M THICK)

CONCLUSIONS

- East Georges Bank Basin covers 10,000 sq km (2.5 million acres) and is one of the last undrilled basins in North America
- Geological interpretations are based on 16,000 km of 1980's and earlier seismic data
- The East Georges Bank Basin is geologically different from the West Georges Bank Basin
- Geological Survey of Canada in 1983 published average hydrocarbon expectation of the basin was 1.0 billion barrels oil and 5.3 TCF gas; speculative estimate was 2.1 billion barrels oil and 10.8 TCF gas
- In comparison, Sable Offshore Energy Project has produced 1.5 TCF gas, full life will be 2.0 TCF gas and Deep Panuke will be about 0.7 TCF gas, thus in comparison, East Georges Bank Basin represents the potential for highly important reserves of gas for the province of Nova Scotia