Large Scale Mixed Carbonate-Siliciclastic Clinoform Systems: Three types from the Mesozoic North American Atlantic Offshore*

Leslie Eliuk[1] and Grant D. Wach[1]

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*Adapted from oral presentation at AAPG Convention, New Orleans, Louisiana, April 11-14, 2010. Please see closely related article, "Regional Setting of the Late Jurassic Deep Panuke Field, Offshore Nova Scotia, Canada – Cuttings-Based Sequence Stratigraphy and Depositional Facies Associations - Abenaki Formation Carbonate Margin", S&D article #10259.

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Abstract

The continental shelf off eastern Canada and the United States exhibits seismically -imaged clinoforms with similar morphologies but very different origins. The longest in both time and space is the Mesozoic carbonate giga-platform, beginning in the Jurassic at the Grand Banks and continuing to the present off Florida. Today the margin comprises a siliciclastic slope, but since the Jurassic three large-scale progradational clinoform packages were produced by very different mixed siliciclastic-carbonate systems. The large distribution and thickness has them interpreted as smaller, isolated systems. Well control near the shelf margin is available in only two areas - the Nova Scotia Shelf and Baltimore Canyon Trough, but allows identification of representative carbonate and siliciclastic depositional facies and depth relationship.

Typically mixed systems are attributed to reciprocal sedimentation (alternating siliciclastic-carbonate-evaporite deposition) related to: a) changes in the sediment supply over time (temporal variation); or b) geographic changes of sediment input, e.g. delta lobe switching (spatial variation); or c) climatic variation, from humid to arid and semi-arid. Type I - prograding ramps between the large Late Jurassic-Early Cretaceous paleodelta near Sable Island (Sable Delta) and the Abenaki carbonate platform to the southwest, formed in comparatively shallow shelf and slope waters by oolites-coral/coralline sponge reefs and microbial slope mounds. Type II - examples of the intermediate type, of earliest Cretaceous age, occur off Nova Scotia and in Baltimore Canyon capping the Abenaki or equivalent carbonate platforms. Deltaic clinoforms grade laterally from Sable Delta or updip from nearshore small deltas and descend into deeper shelf waters with less argillaceous content and nutrient-rich waters that favour growth of sponge reef mounds and inter-reef beds. Type III - Late Cretaceous to Paleocene, comprise distal Wyandot Chalk with siliciclastic clinoforms of the overlying Banquereau Formation. This very different non-benthic system occurs in deep shelf and upper slope conditions, offshore Nova Scotia, where dilution of the pelagic carbonates is reduced by slower rates of

fine siliciclastic sedimentation. Exploration strategies will differ dramatically depending on which system generated the clinoforms. A broader perspective is essential for hydrocarbon exploration of mixed siliciclastic-carbonate depositional systems of this scale.

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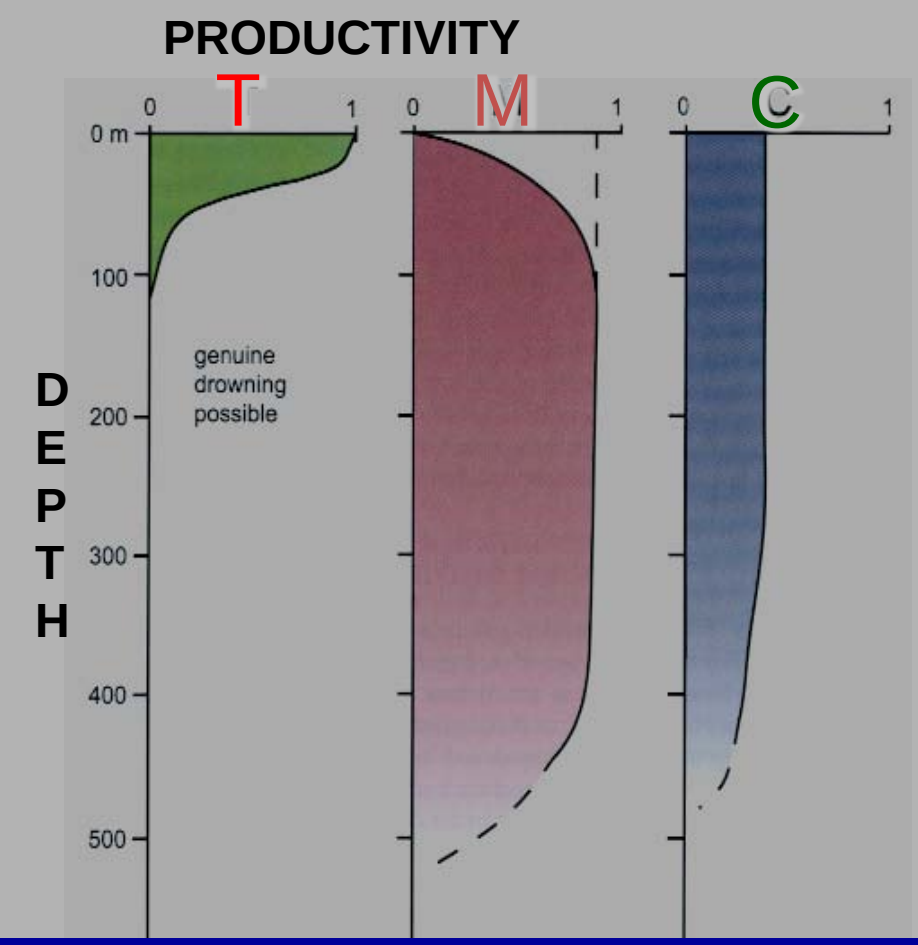
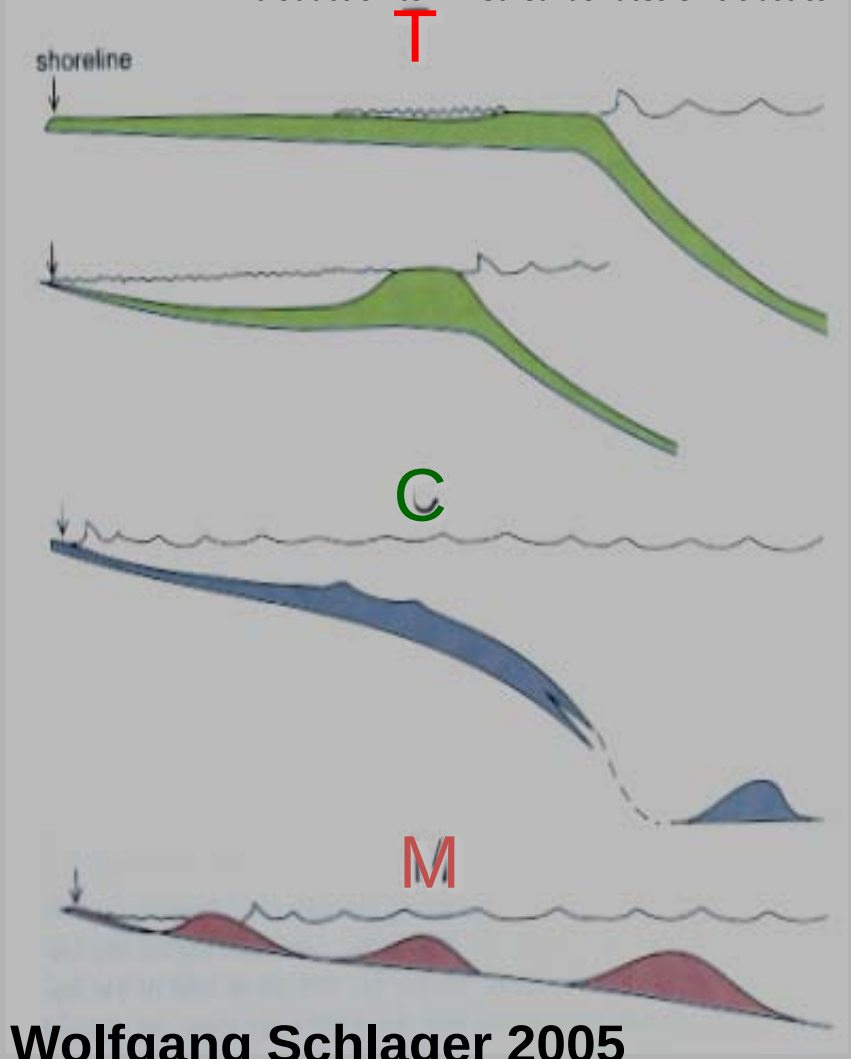
Dalhousie University Earth Sciences

'Two Solitudes'*

- **Carbonates VS Siliciclastics**
  (not so much in nature but in our geo-specialists)
- **Benthic VS Pelagic Carbonates**
  (new ideas on origin of armoured microplankton and coral symbionts, 'neritic lime mud factory' and the mid-Mesozoic revolution in ocean chemistry as well as paleontology)

•Hugh MacLennan's novel on Canadian anglophones-francophones (our NOLA 'cajun' =Acadien connection); now our black former-Haitian lady Governor-General says that's history & be happy





Wolfgang Schlager 2005

Carbonate Factories

T = tropical, topmost water, autotrophs (& symbionts)

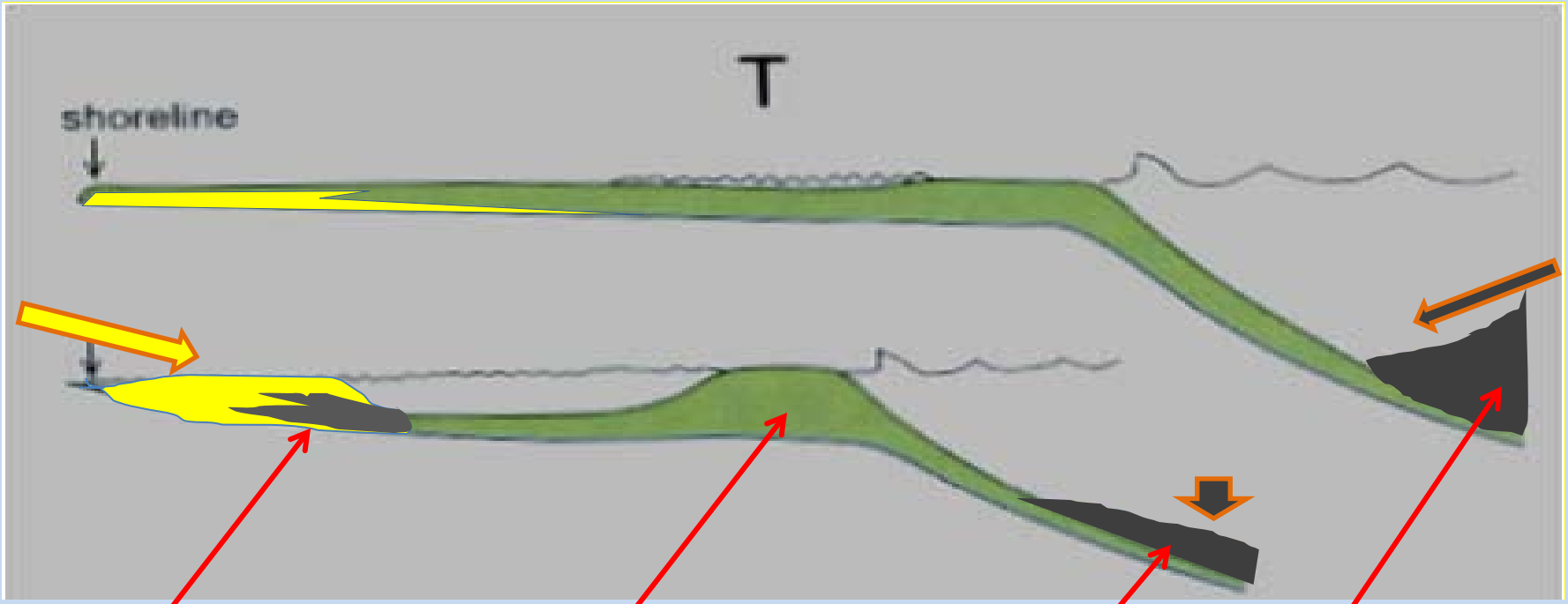
M = mud-mound, micrite, microbial (biotically induced)

C = cool-water, controlled precipitates, heterotrophs

UNIQUE:
In situ **biological production**

Benthic 'T' factory with Mixed Carbonates-Siliciclastics

LAND shelf-ramp BASIN



Sands-clays
near shore
paralic

Benthic Carbonate Factory

Along slope from passes

clays

Across basin

North America-Atlantic

Large Scale Mixed Carbonate-Siliciclastic Clinoform Systems:

Jurassic-Cretaceous gigaplatform (Poag 1990)

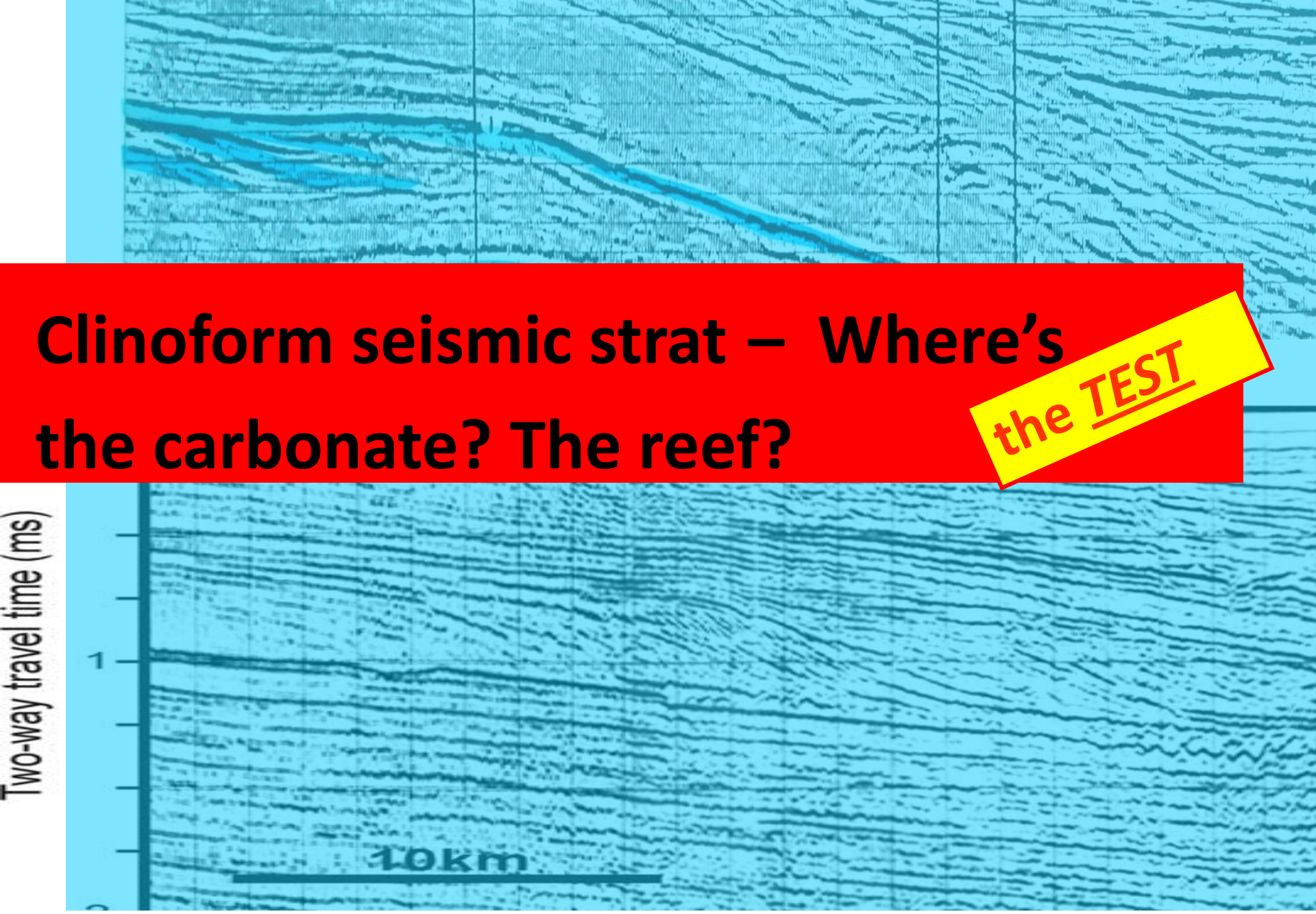
Type I – JK prograding ramps adjacent to Sable paleodelta (perhaps in Baltimore Canyon)

Type II – JK intermediate deltaic clinoforms down to sponge-rich argillaceous carbonates

Type III – Late Cretaceous-Paleocene shelf-slope siliciclastics down to pelagic carbonates

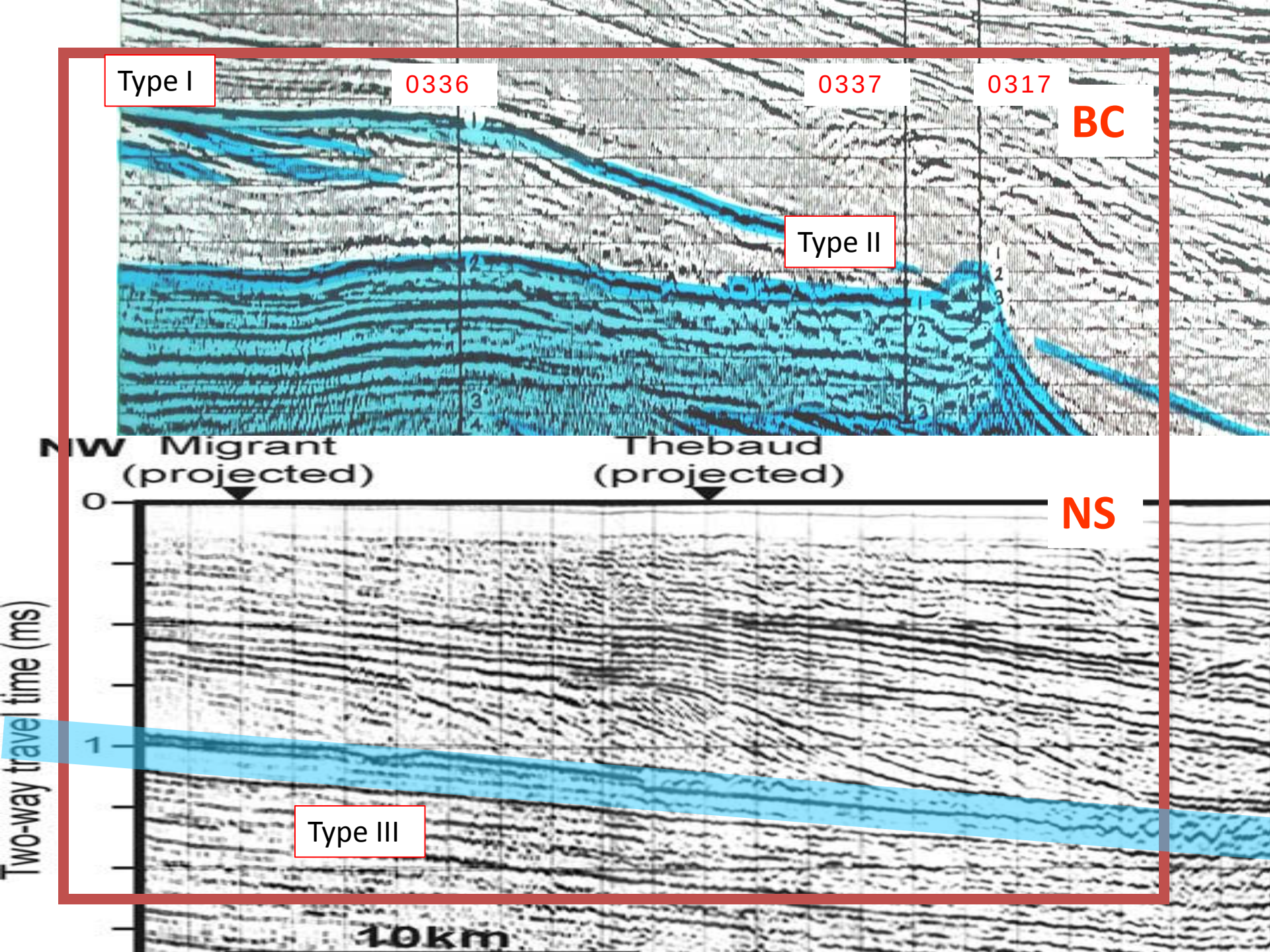
BUT

"First the test"



Clinoform seismic strat – Where's the carbonate? The reef?

the TEST


Type I
0336
0337
0317
BC
Type II
NW
Migrant
(projected)
Thebaud
(projected)
NS
0
1
Two-way travel time (ms)
Type III
10km

Large Scale Mixed Carbonate-Siliciclastic Clinoform Systems:

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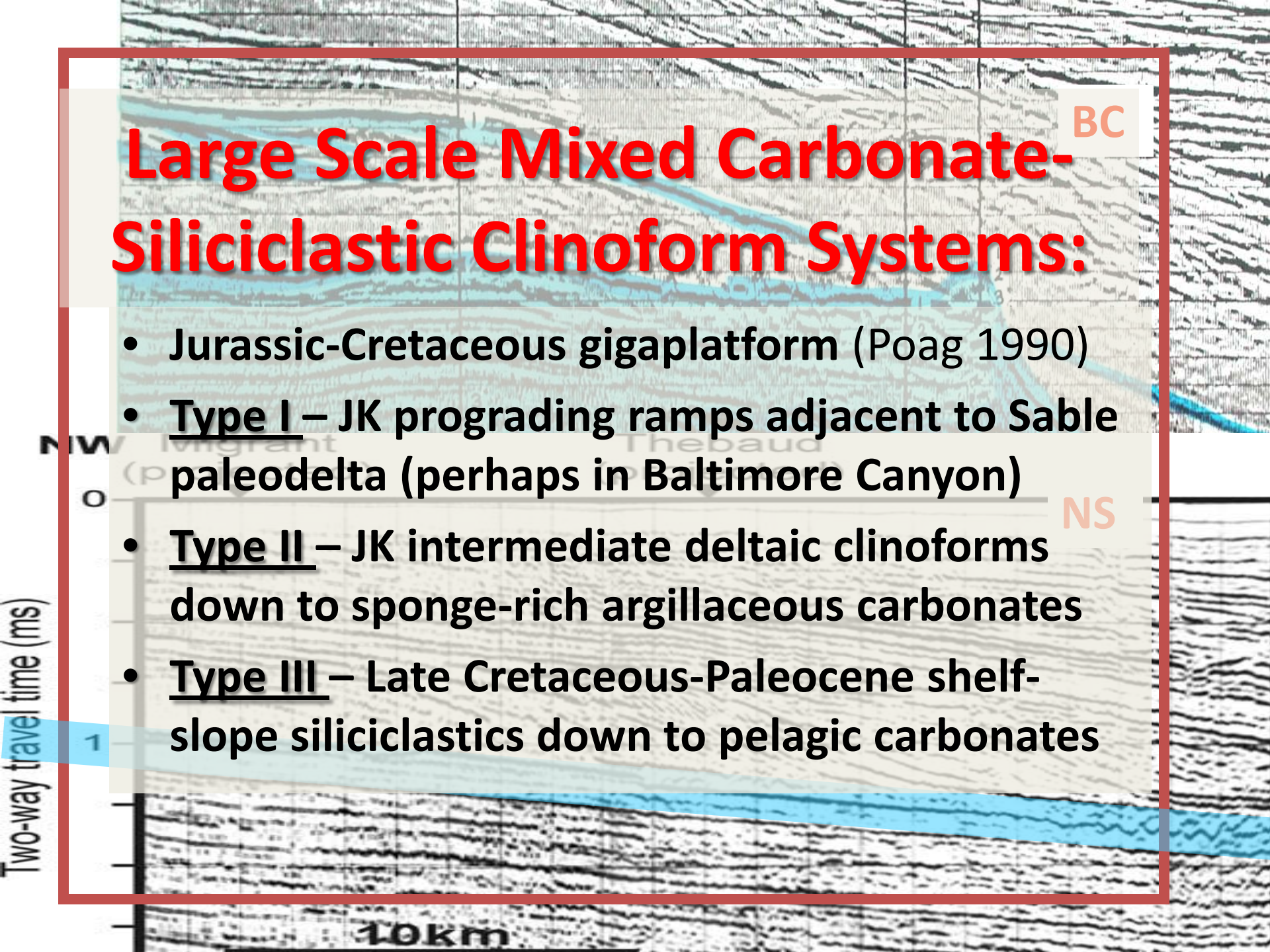
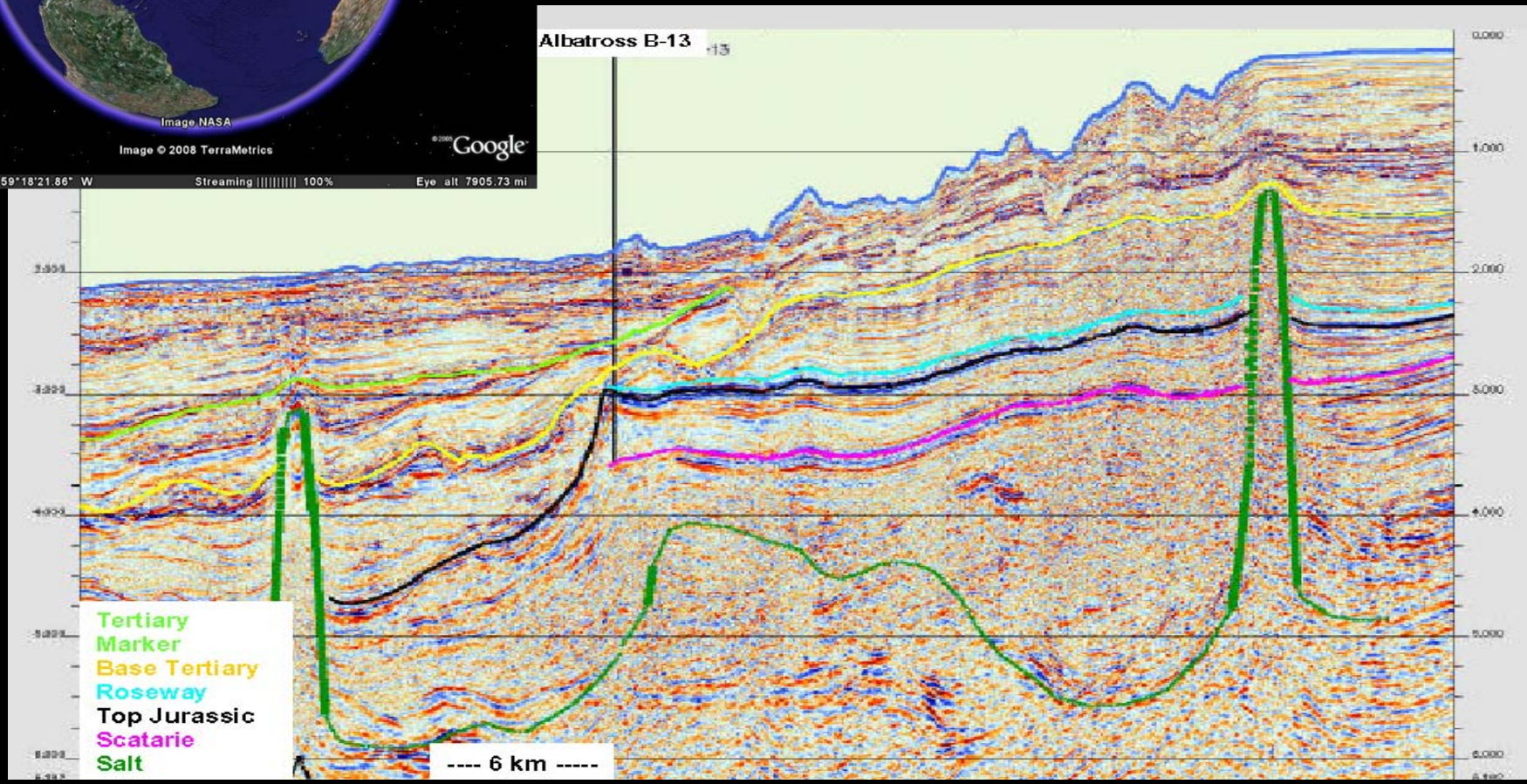
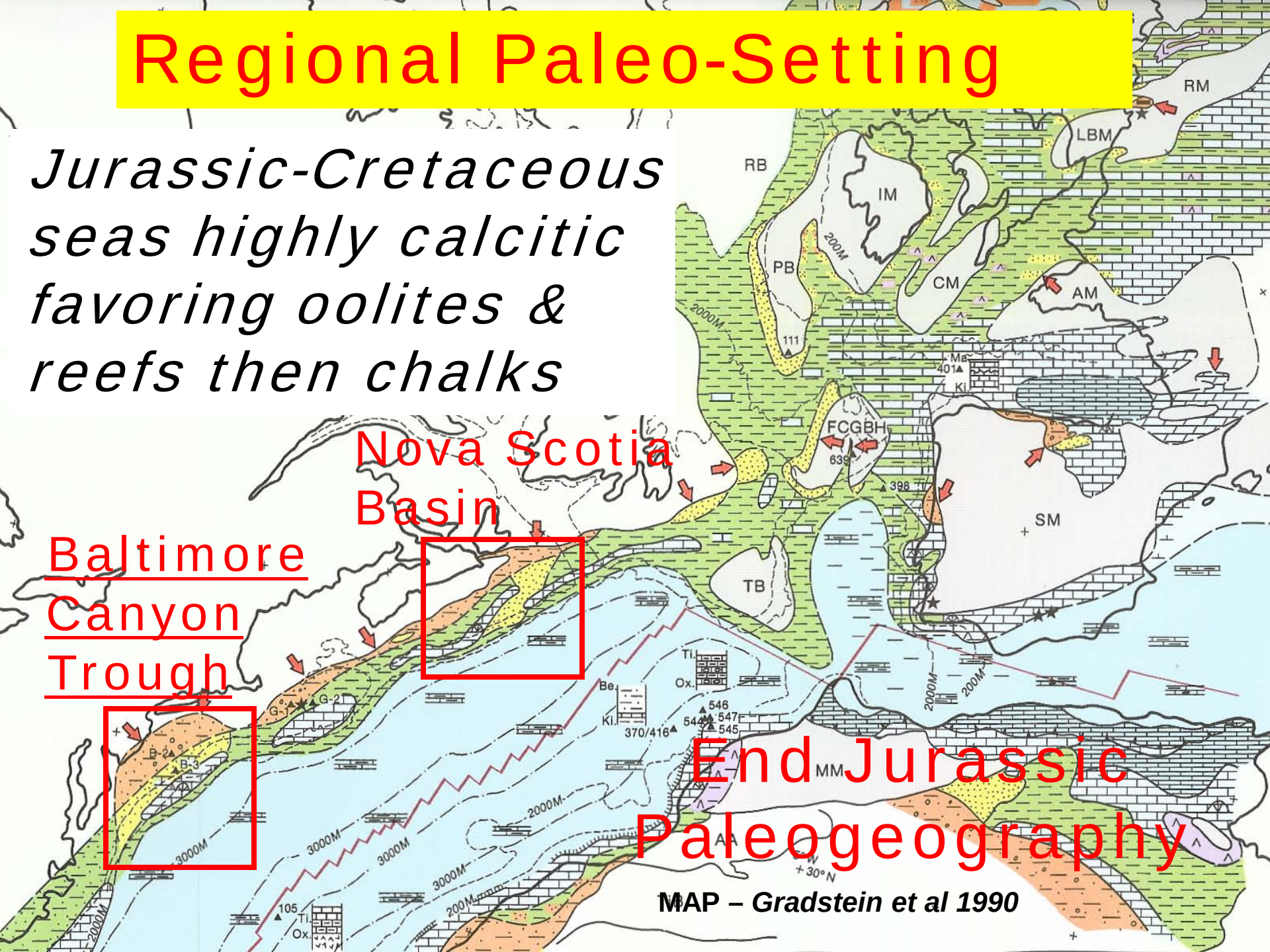


Jurassic-Cretaceous Gigaplatform

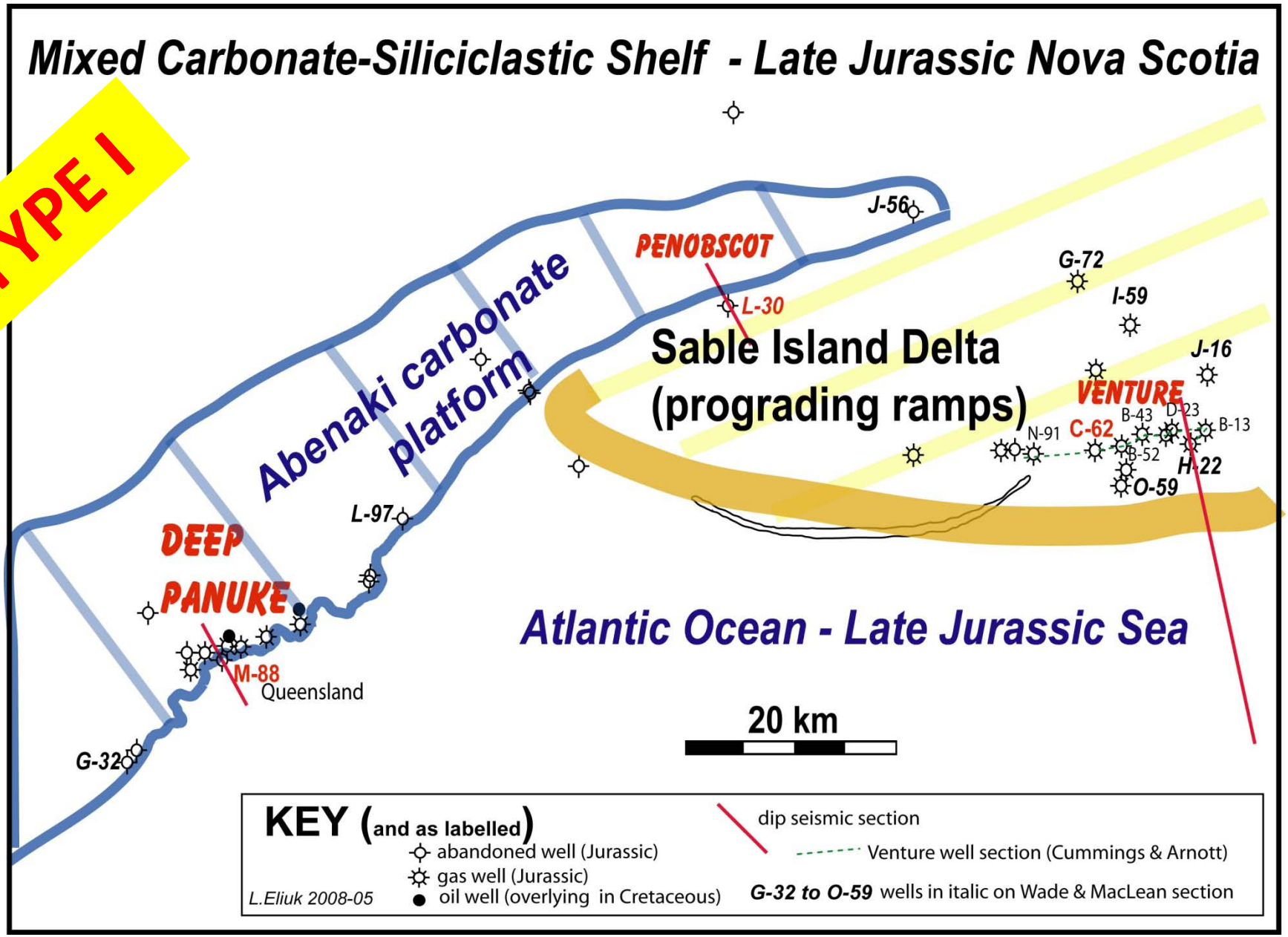


Regional Paleo-Setting

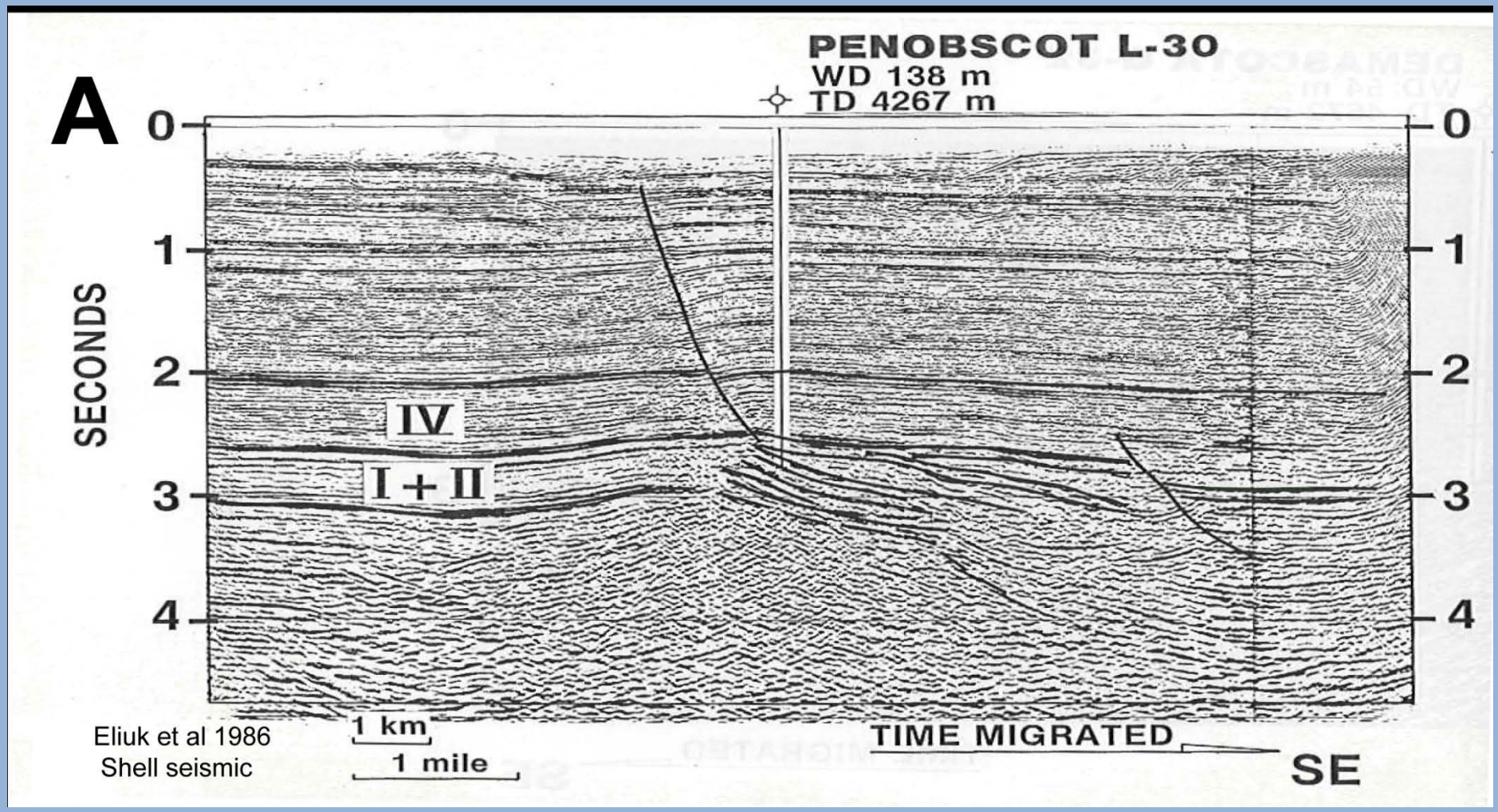
Jurassic-Cretaceous seas highly calcitic favoring oolites & reefs then chalks



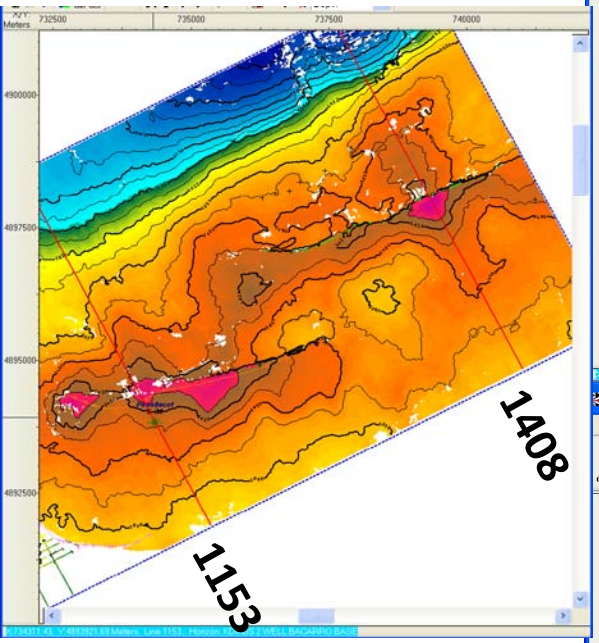
Abenaki-Sable Delta Setting

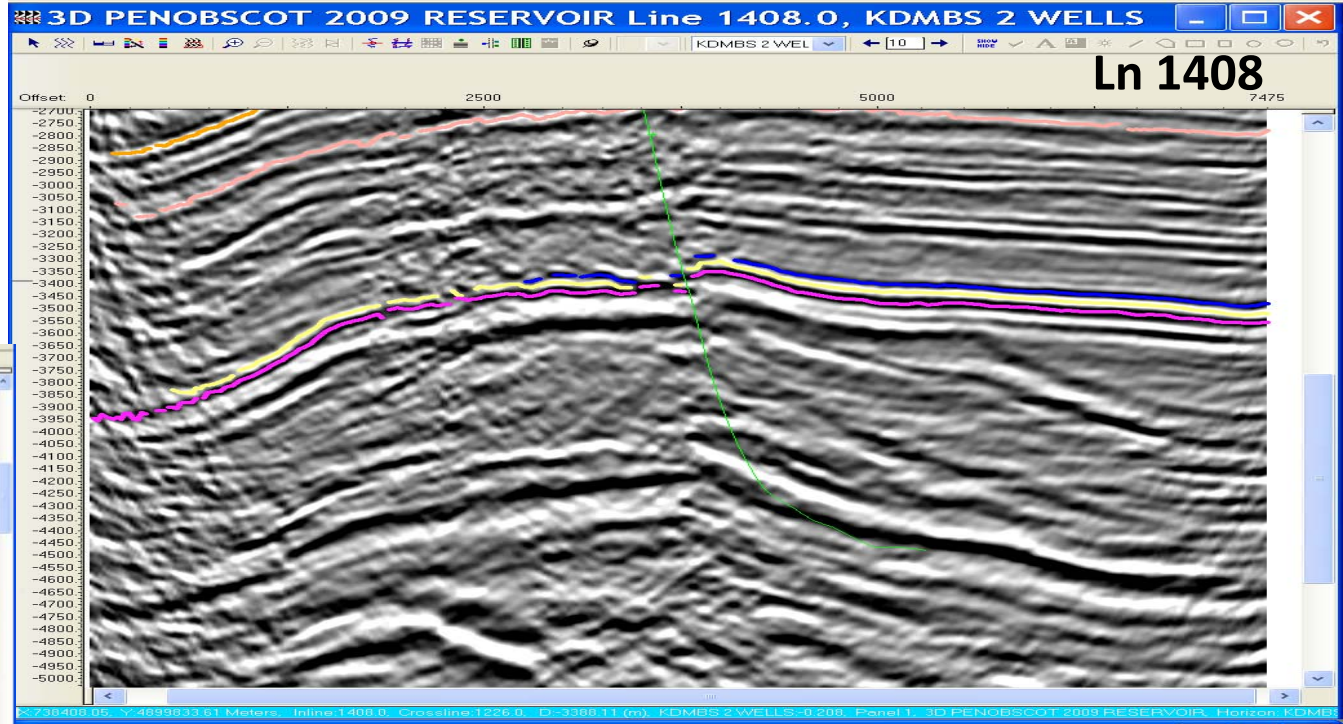


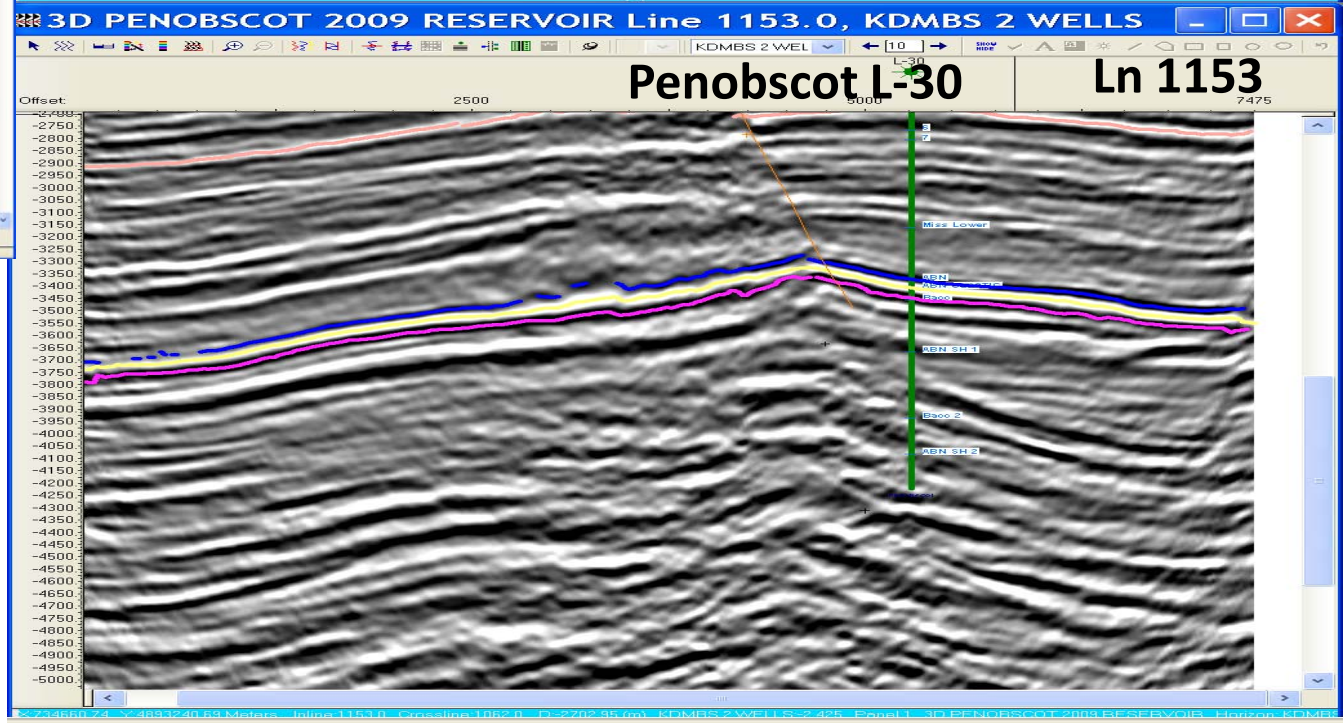
Prograding Sable Paleodelta & Abenaki Margin



Penobscot Structure and dip sections

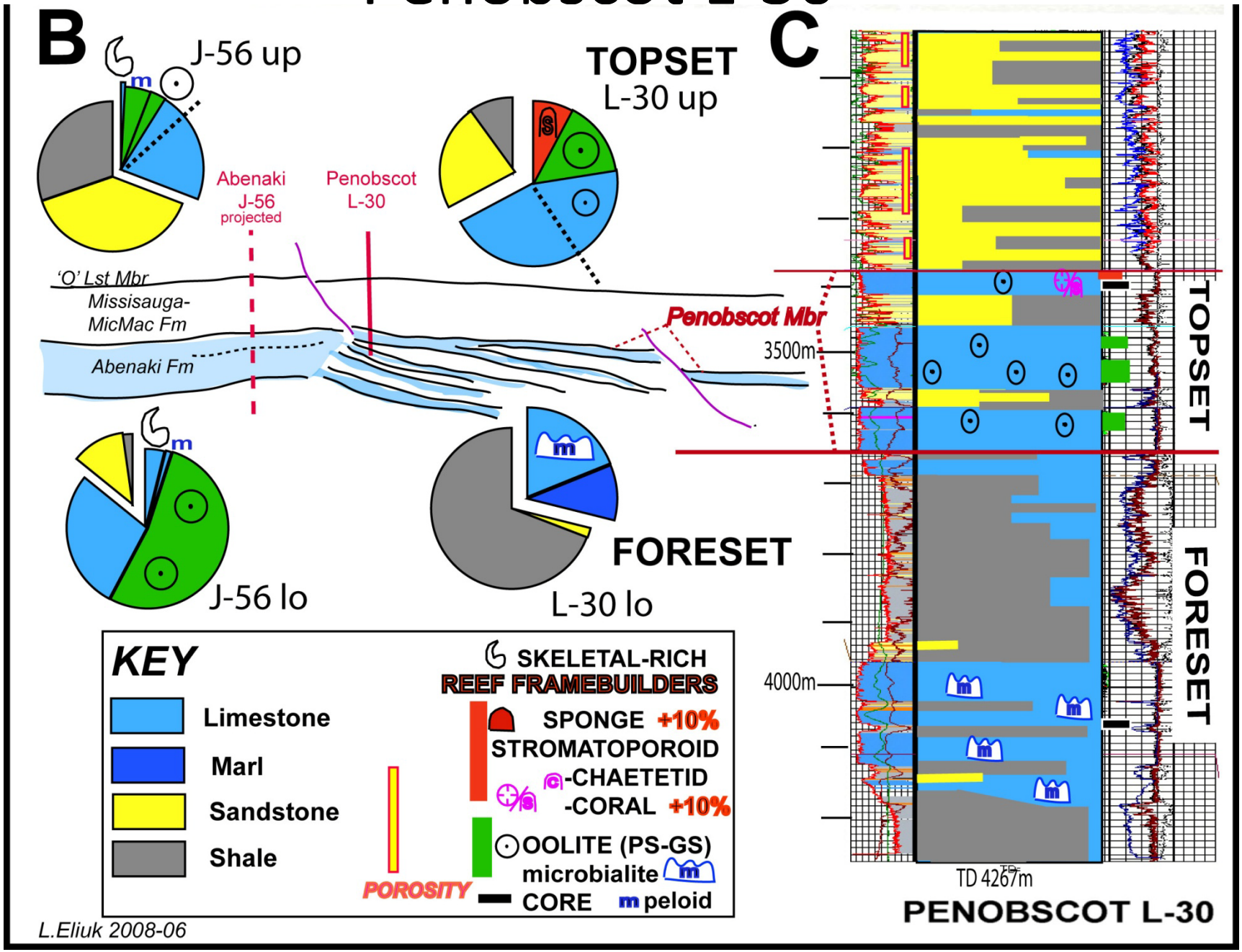


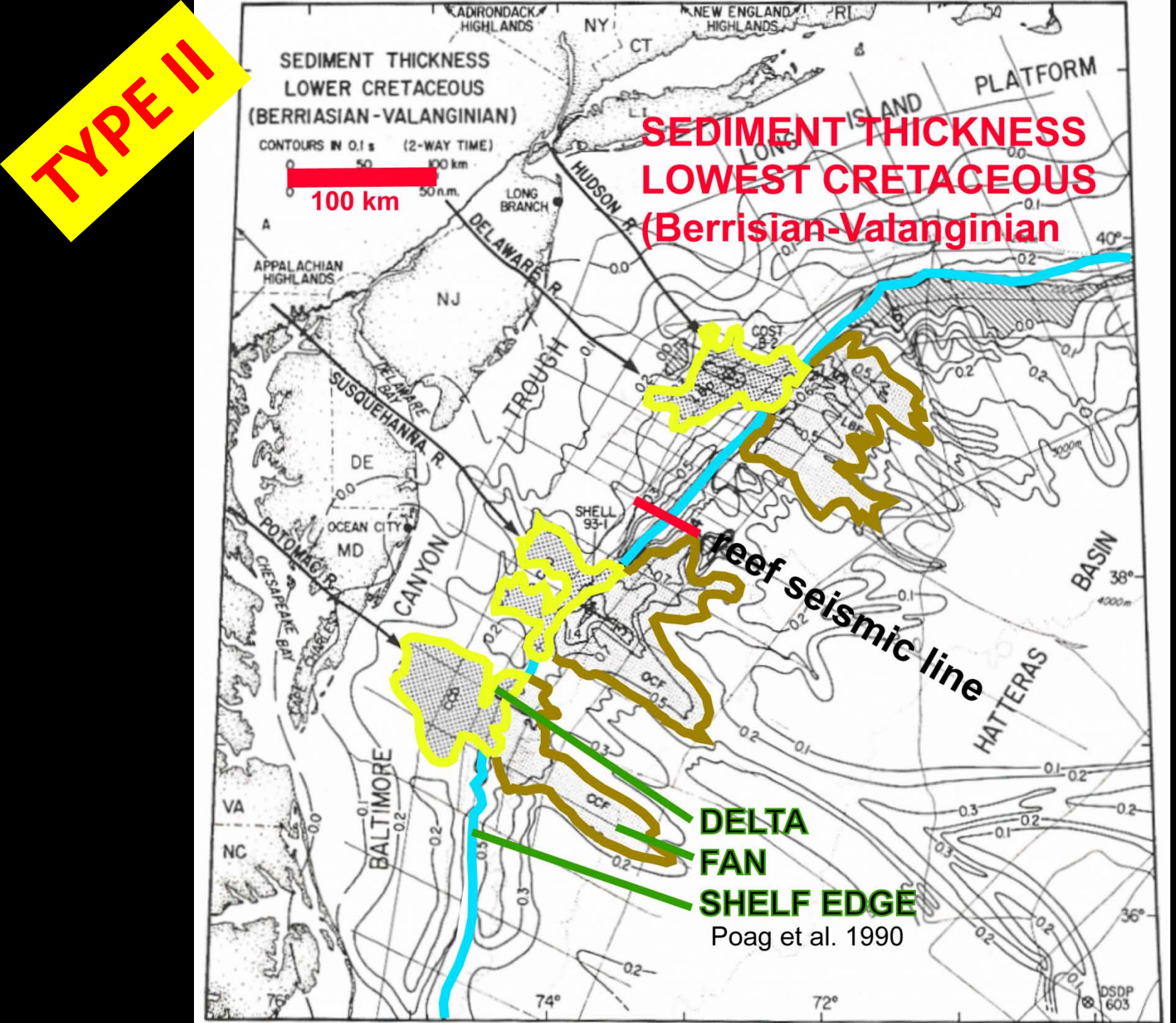




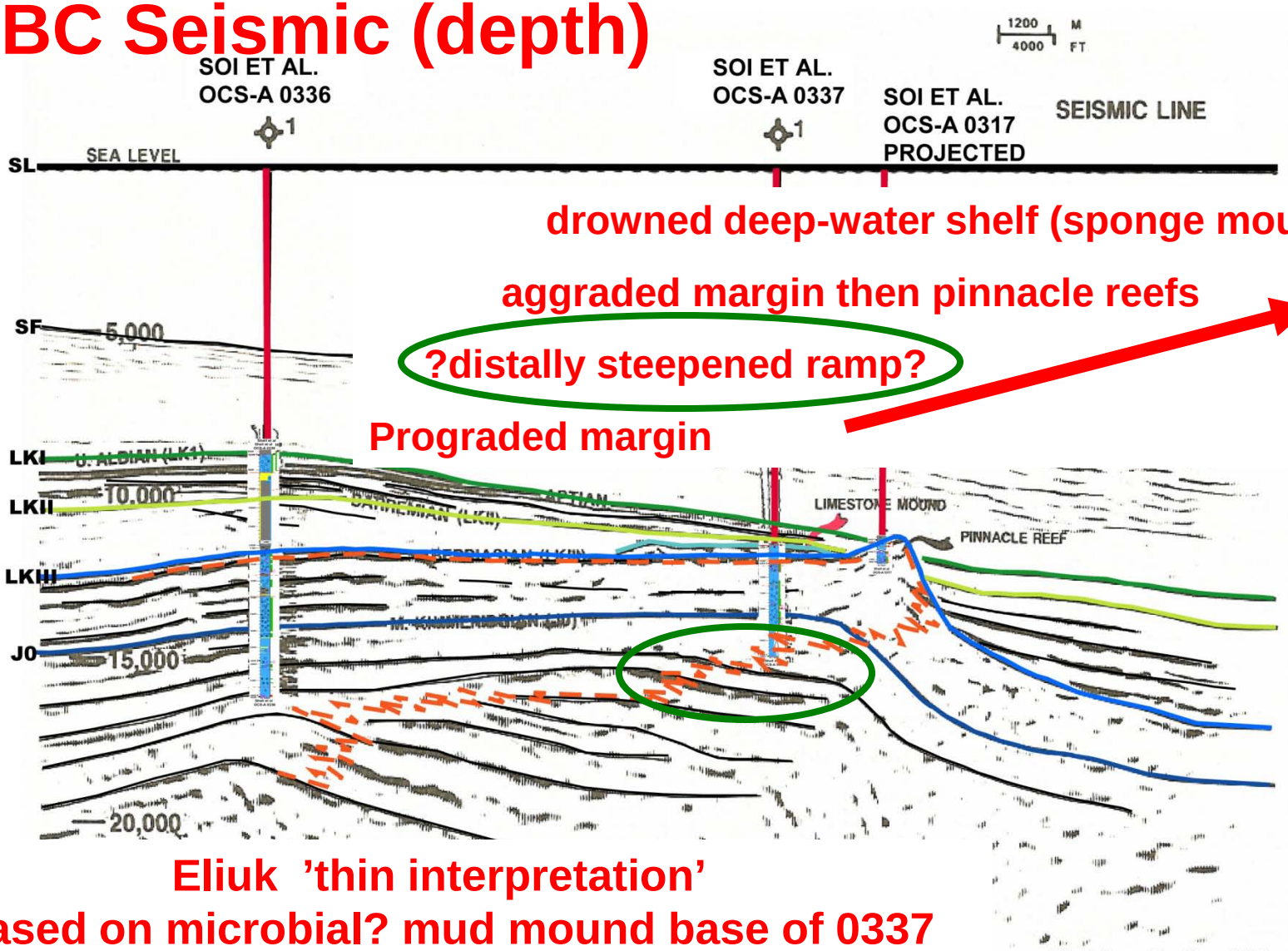
Courtesy Skip Hobbs and Bob Merrill of Ammonite Nova Scotia – see their website

Penobscot L-30




TYPE II
SEDIMENT THICKNESS
LOWER CRETACEOUS
(BERRIASIAN-VALANGINIAN)
CONTOURS IN 0.1 s (2-WAY TIME)
100 km
SEDIMENT THICKNESS
LOWEST CRETACEOUS
(Berrisian-Valanginian
reef seismic line
DELTA
FAN
SHELF EDGE
Poag et al. 1990
ADIRONDACK HIGHLANDS
NEW ENGLAND HIGHLANDS
NY
CT
RI
LONG ISLAND
PLATFORM
HUDSON R.
LONG BRANCH
DELAWARE R.
APPALACHIAN HIGHLANDS
NJ
TROUGH
SUSQUEHANNA R.
DELAWARE BAY
DE
MD
OCEAN CITY
POTOMAC R.
CHESAPEAKE BAY
CANYON
SHELL 93-1
BASIN
HATTERAS
BALTIMORE
VA
NC
COST B-2
LBF
OCF
DSDP 603
40°
38°
36°
74°
72°

BC Seismic (depth)

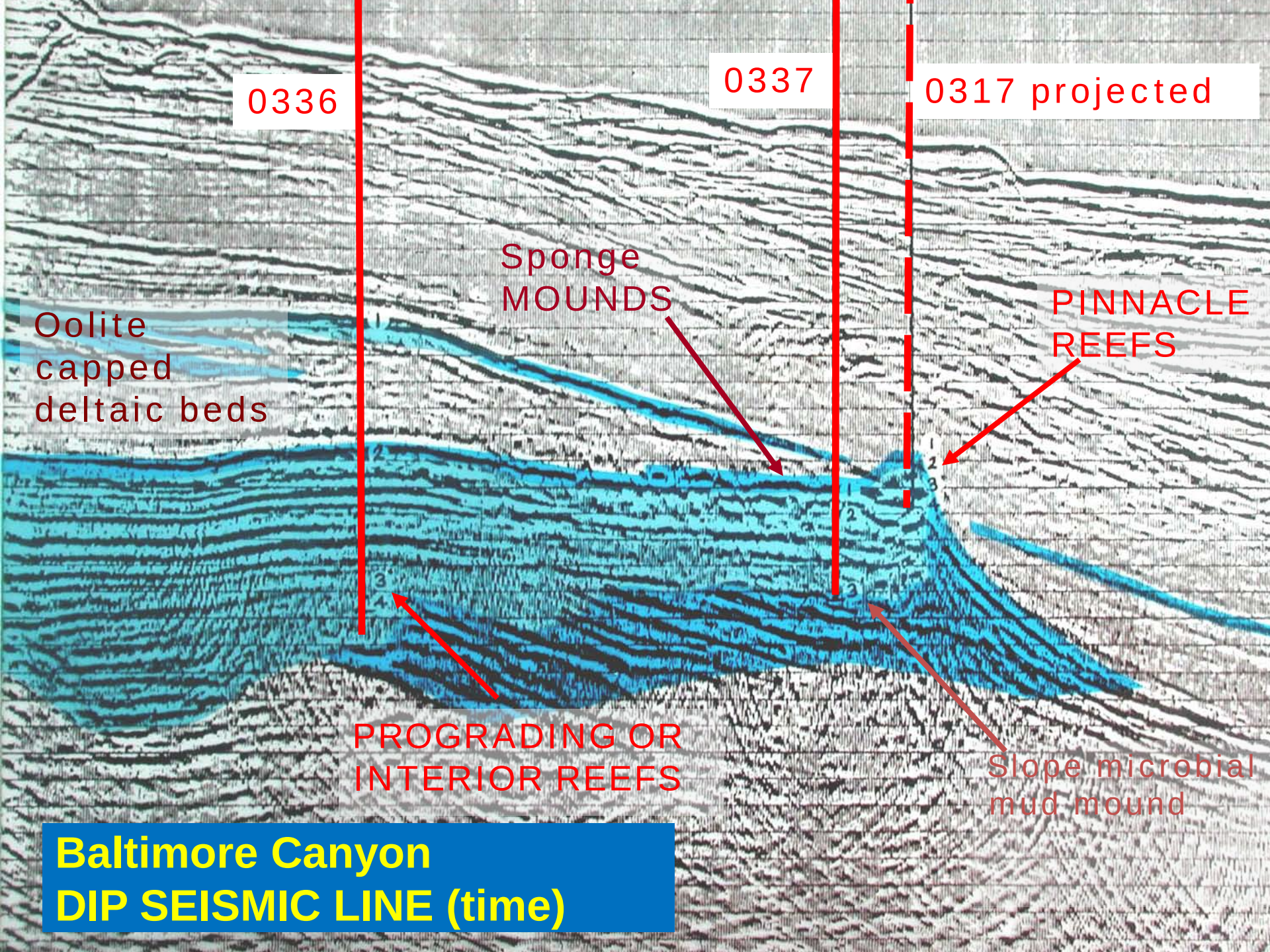


Eliuk 'thin interpretation'

-based on microbial? mud mound base of 0337 over 'double flexure'/distally steepened ramp style

modified from Prather 1991

Also Meyer 1989 Shell


0336
0337
0317 projected
Sponge
MOUNDS
PINNACLE
REEFS
Oolite
capped
deltaic beds
PROGRADING OR
INTERIOR REEFS
Slope microbial
mud mound
Baltimore Canyon
DIP SEISMIC LINE (time)

Ringer model in Eliuk and Prather 2005/2008

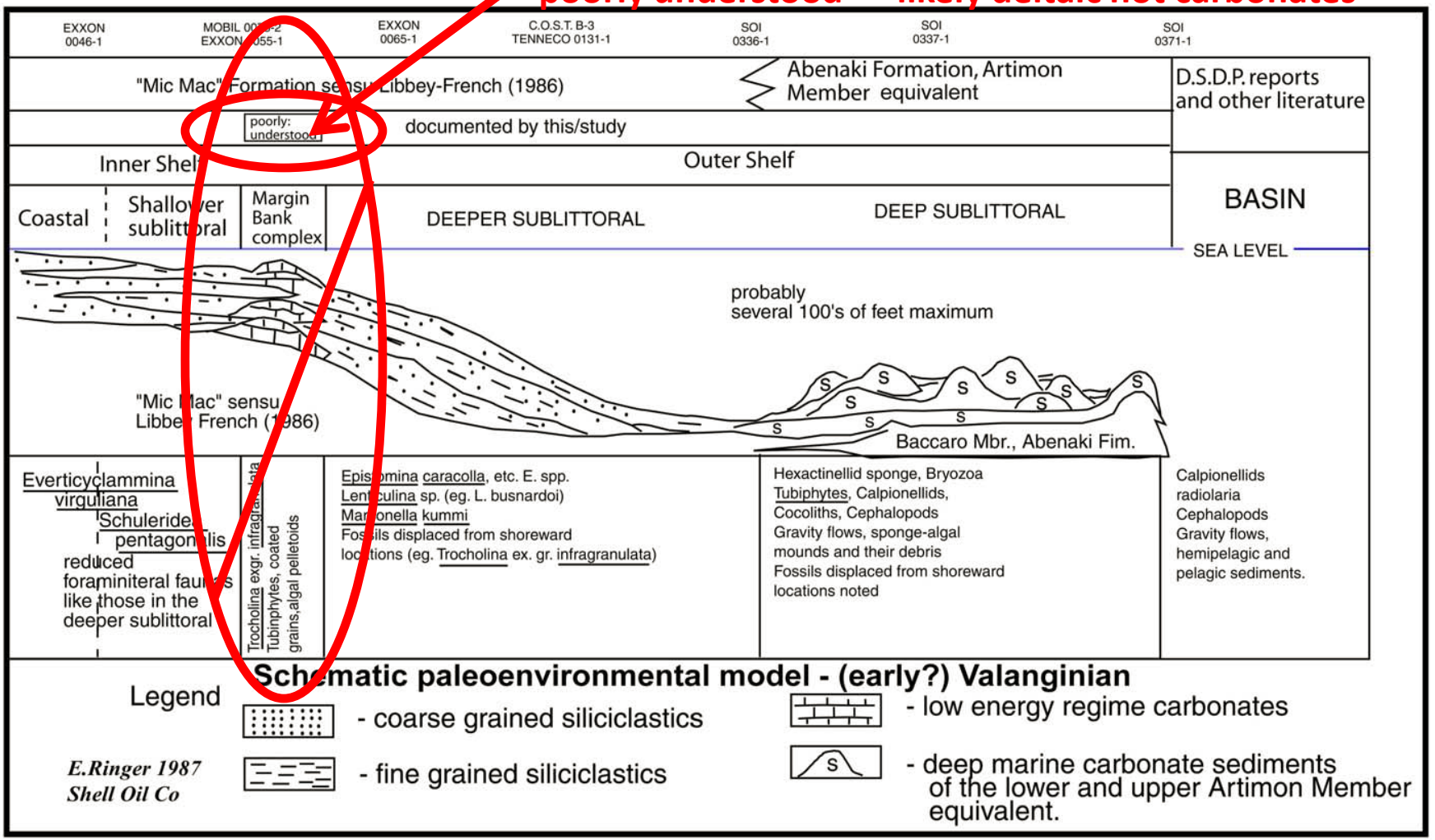
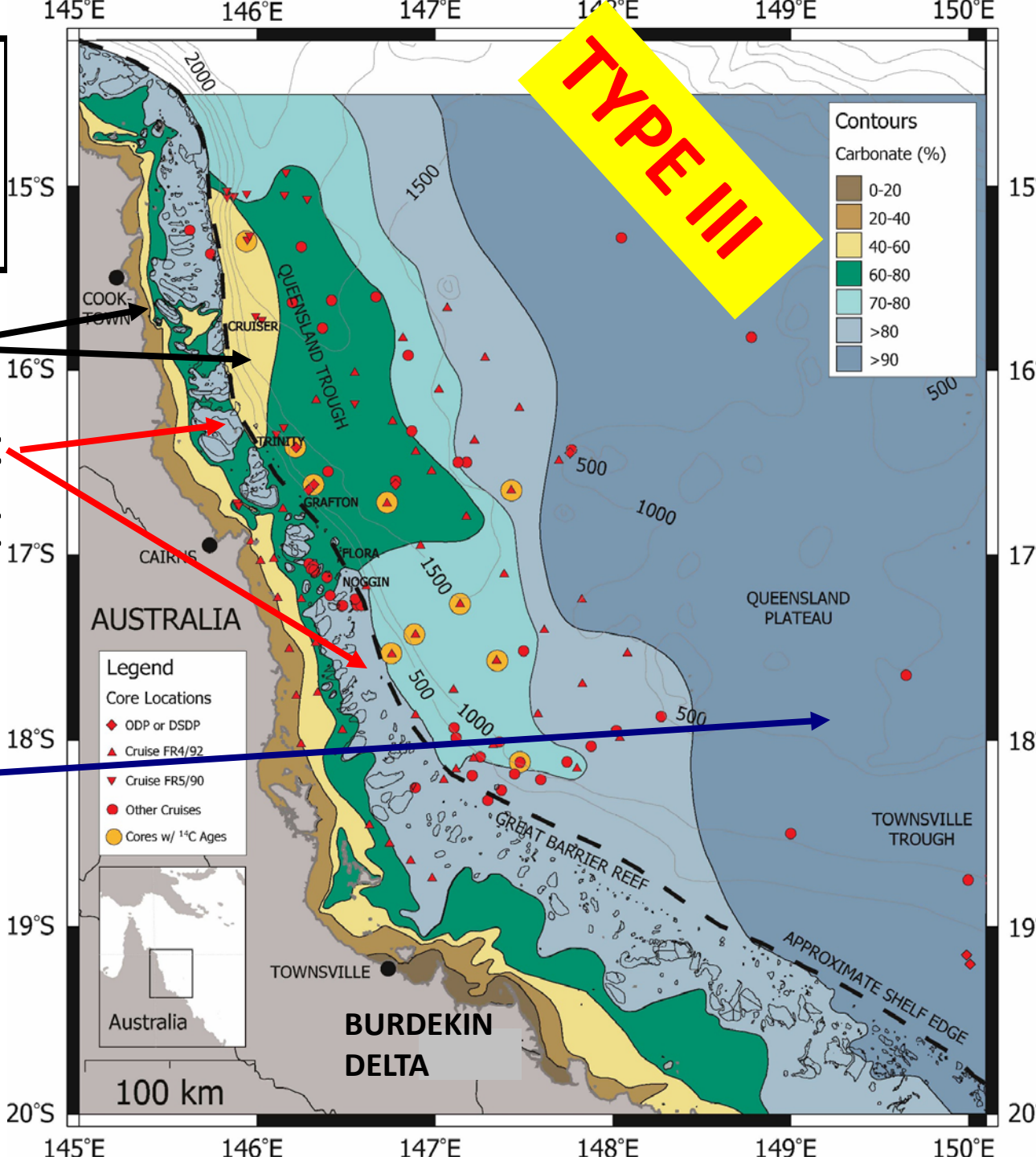


Figure 8. Schematic paleoenvironmental model for the (early?) Valanginian of the Baltimore Canyon Basin, with some significant enviromnental indicators noted. Cited wells are illustrative. Note the shoreward displacement of margin bank (possible Knowles equivalent) due to eustatic rise in sea level during the earliest Creataceous.

Great Barrier Reef mixed carbonate-siliciclastic system,
Queensland Australia

- Siliciclastics
- Reefs & benthic carbonate: HMC (High Mg calcite) & aragonite
- Pelagic carbonate: LMC (Low Mg calcite)

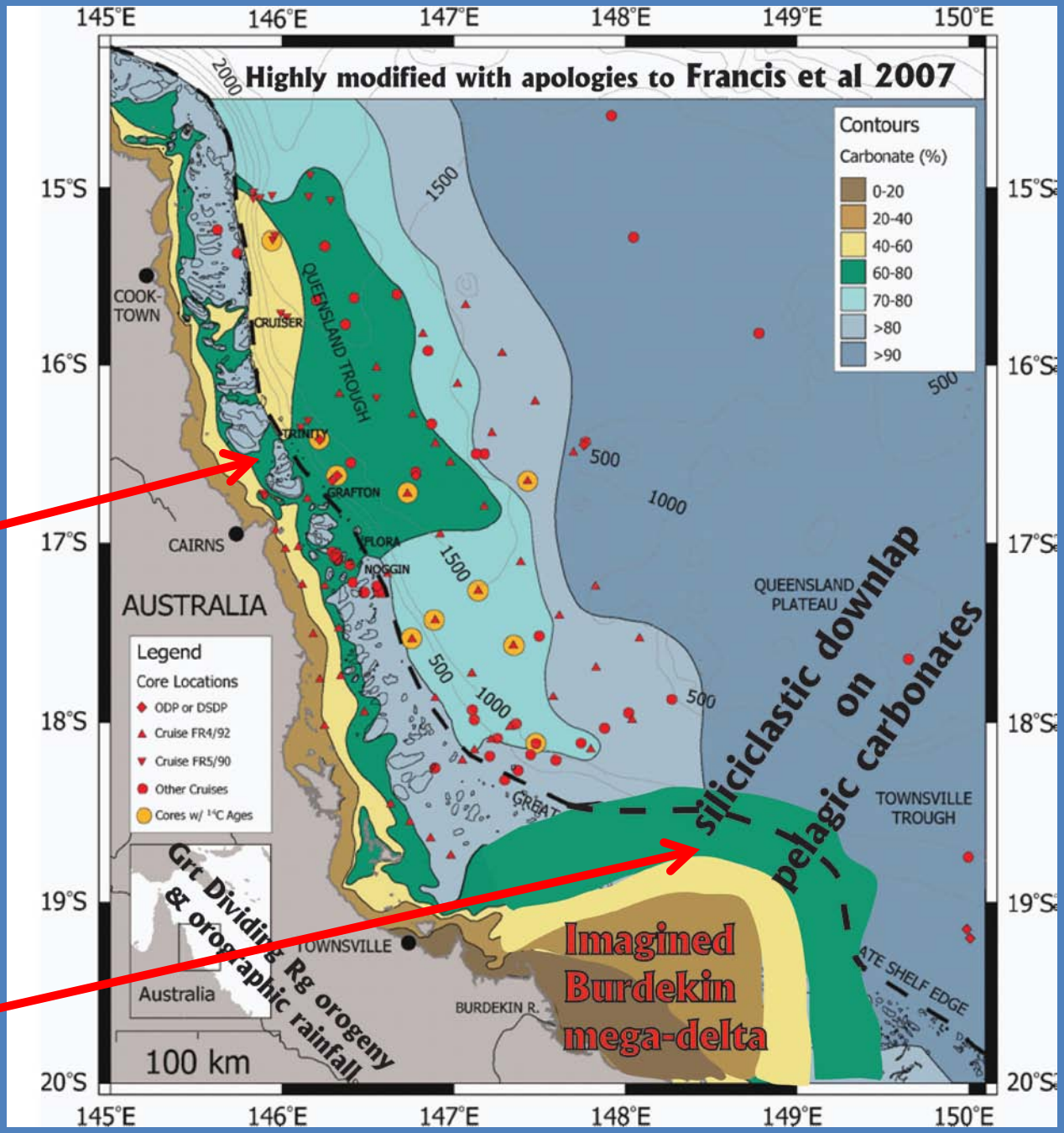


Francis, Dunbar, Dickens, Sutherland and Droxler 2007

Eliuk's 'Ai' forward modelling

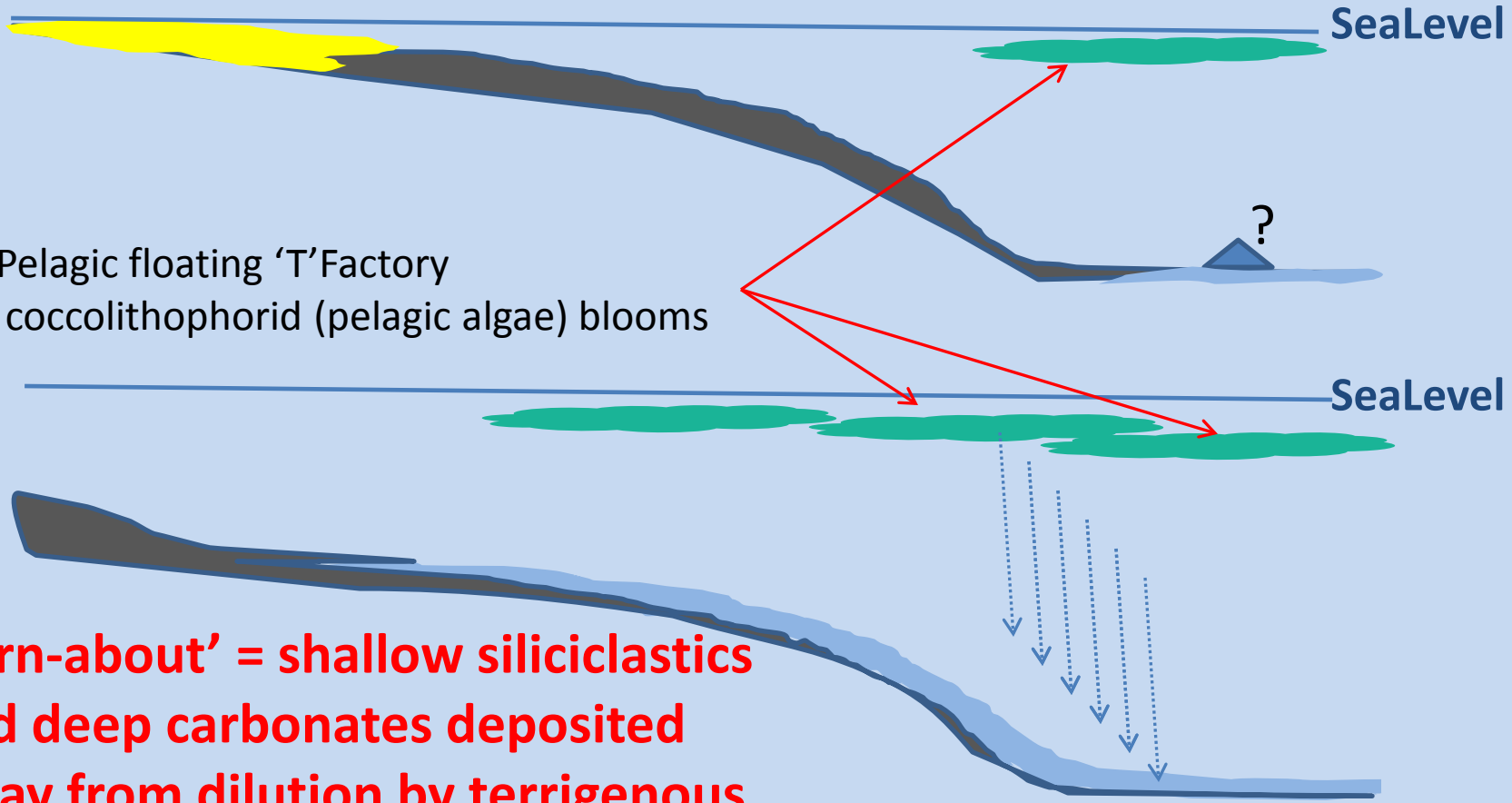
Standard or classic mixed siliciclastics-carbonates in 'T' benthic factory setting

Pelagic-benthic mixed siliciclastics-carbonates in 'T' pelagic factory setting

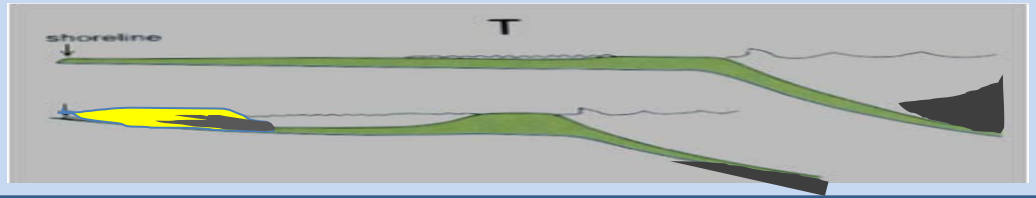


'Ai' = Adobe Illustrator , in other words geological imagination

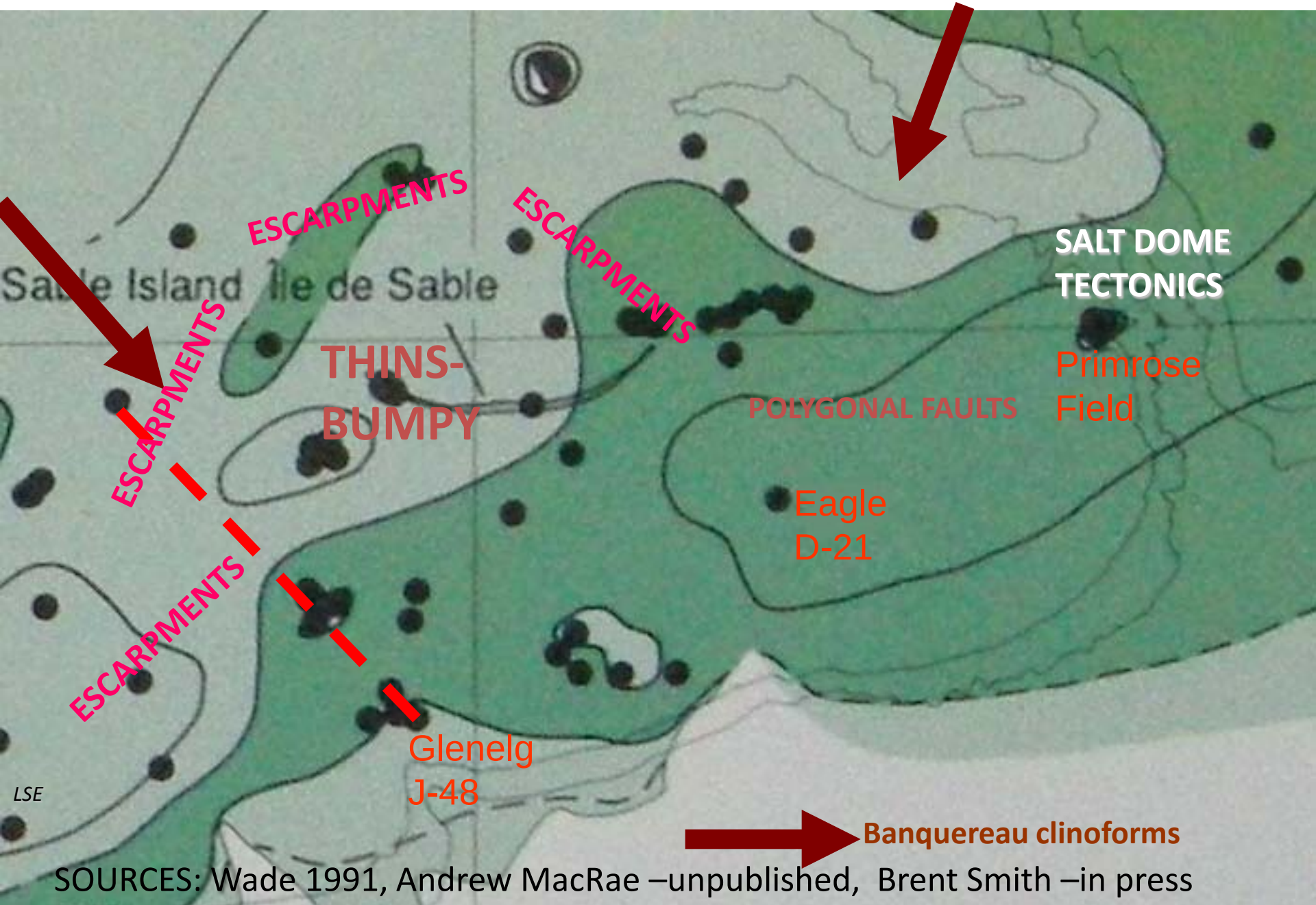
Pelagic ‘T’ factory with Mixed Carbonates-Siliciclastics



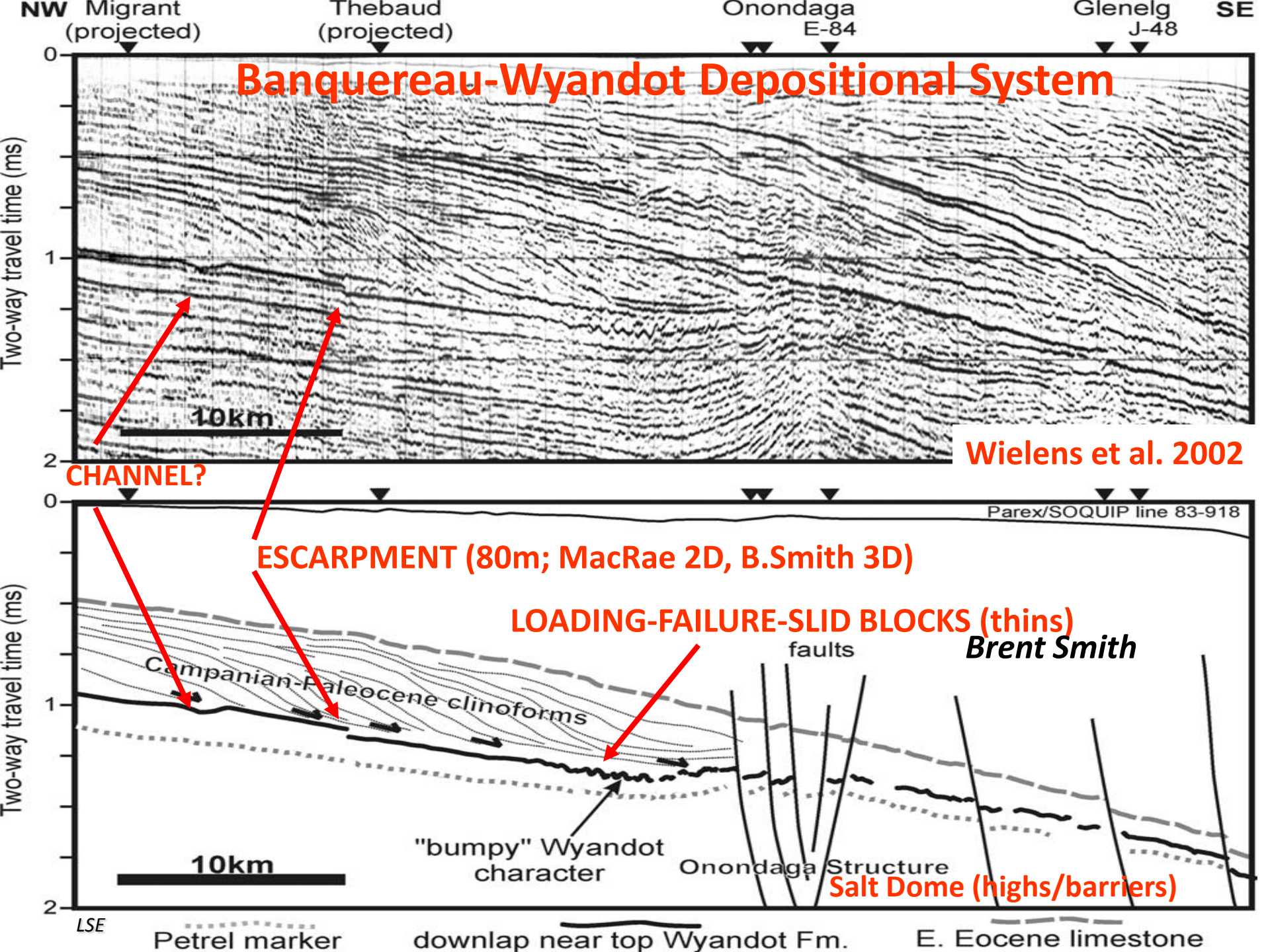
‘turn-about’ = shallow siliciclastics and deep carbonates deposited away from dilution by terrigenous clastics



CRETACEOUS Wyandot CHALK: Primrose-Eagle-Sable

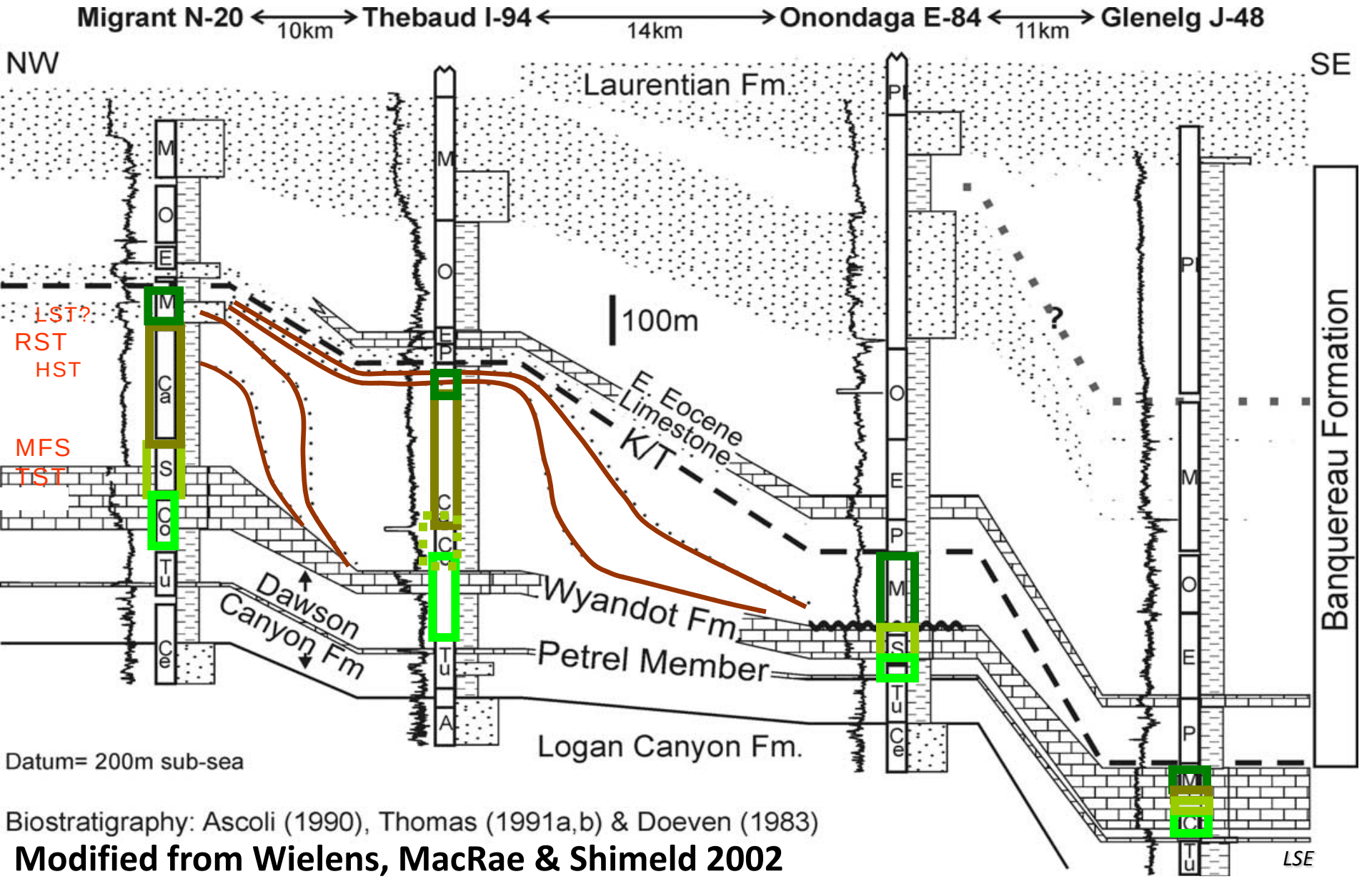


SOURCES: Wade 1991, Andrew MacRae –unpublished, Brent Smith –in press


NW
Migrant (projected)
Thebaud (projected)
Onondaga E-84
Glenelg J-48
SE
Banquereau-Wyandot Depositional System
Two-way travel time (ms)
0
1
2
10km
Wielens et al. 2002
CHANNEL?
ESCARPMENT (80m; MacRae 2D, B.Smith 3D)
Parex/SOQUIP line 83-918
LOADING-FAILURE-SLID BLOCKS (thins)
Brent Smith
faults
Campanian-Paleocene clinoforms
"bumpy" Wyandot character
Onondaga Structure
Salt Dome (highs/barriers)
LSE
Petrel marker
downlap near top Wyandot Fm.
E. Eocene limestone

Banquereau-Wyandot Depositional System

Diachronous; more distal = less diluted pelagics = cleanest condensed chalks



Modified from Wielens, MacRae & Shimeld 2002

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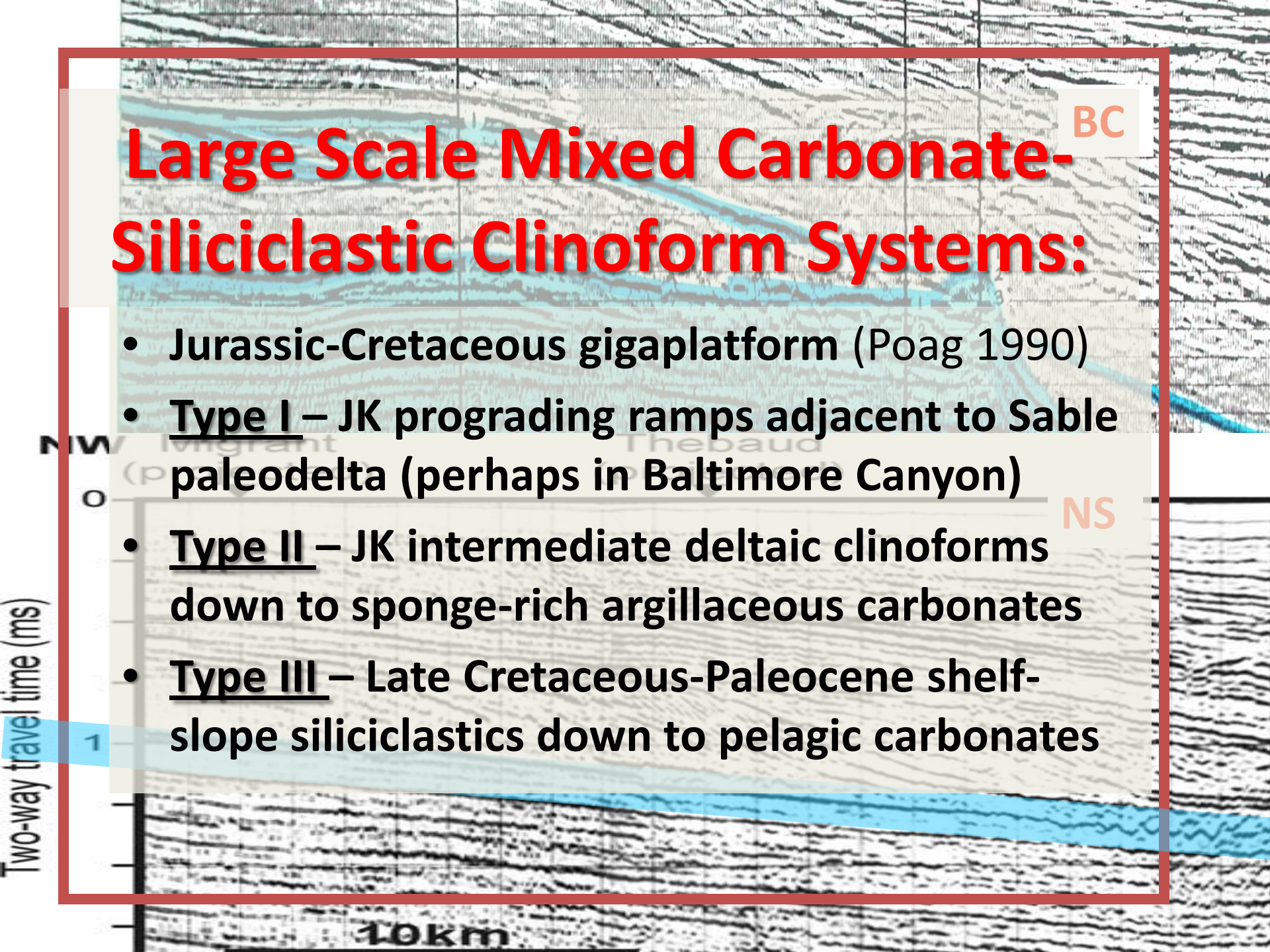

Thank you and Shell, EnCana, Ammonite, OETR & CNSOPB & Hans Wielens

Dedicated to the memory
of the late

Dr. Hans Wielens

past co-worker and recently retired
geologist
Geological Survey of Canada
Atlantic Canada
Bedford Institute of Oceanography,
Nova Scotia, Canada

In Memoriam
Dr. Hans Wielens - Adjunct Professor

Wielens, Hans, 62, South Rawdon, passed away on Friday Aug.6, 2010 at the QEII, New Infirmary Site, Halifax. Hans was born March 5, 1948 in Berg en Dal, The Netherlands and was a son of the late Johannes and Maria (Horstman) Wielens. Hans studied at the universities of Utrecht and Amsterdam, where he earned a Ph.D in Geology. He emigrated to Canada (Calgary) in 1979 and worked as a petroleum geologist for Shell, the GSC, and Unocal before starting his own consulting company. Hans moved to NS in 1999 to work at the BIO, from which he retired in July 2010. As an adjunct professor at Dalhousie University he assisted in the Earth Sciences department. Through his work, he met many wonderful people. For Hans, Nova Scotia is a geologist's paradise. He had a passion for geology, woodworking, gardening, hiking and photography. Hans was very proud of his three sons and he will be missed by the many whose lives he touched. He is survived by his wife of 37 years, Jeanette (Dederen), sons Olaf, Nils and Bjorn. His sisters, Tessy (Chris) and Jose, and a niece and nephews in the Netherlands. Cremation has taken place and a celebration of his life will be held at a later date. Many thanks to the staff of unit 5.2 at the QEII for their care. In lieu of flowers, a donation may be made to the Windsor & Area education fund, to a science scholarship in memory of Hans Wielens, P.O. Box 700, Windsor NS. B0N 2T0 Arrangements have been entrusted to the compassionate care of the J. Wilson Allen Funeral Home, Hwy 215, Summerville, Ph 19026332431or e-mail condolences to: allenfuneral @ ns.sympatico.ca