Late Early and Middle Jurassic Sequence Stratigraphy and Depositional History, Sverdrup Basin, Arctic Canada*

Ashton Embry[1]

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Posted September 26, 2011

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Abstract

Late Early and Middle Jurassic (Pliensbachian -Callovian) strata of Sverdrup Basin comprise two 2nd order sequences which share a major 1st order boundary of latest Aalenian age. The Pliensbachian-Aalenian 2nd order sequence contains three 3rd order sequences and the strata consist of shallow to deep shelf siliciclastics. The shield areas to the east and south were the main source areas and sediment supply was moderate to low. The most extensive sandstone unit occurs in the upper portion of the Aalenian, 3rd order sequence and it prograded northwards. Crockerland, a source area which lay to the north, also contributed sediment and a Crockerland-derived, Aalenian sandstone occurs along the northwest margin of the basin.

Significant uplift occurred along the basin flanks in latest Aalenian and was associated with the final progradation of the Aalenian sandstone unit. In the far southwest portion of the basin, extensional faults which parallel the current Amerasia Ocean Basin developed for the first time. The oldest strata overlying the unconformity are earliest Bajocian.

The Bajocian-Callovian, 2nd order sequence consists of three 3rd order sequences which approximate the Bajocian, Bathonian and Callovian stages. Sediment supply to the basin was greatly reduced following the latest Aalenian, 1st order boundary. One input centre during the Bajocian-Callovian interval occurred in the southwestern corner of the basin and thick marine sandstone units derived from the south were deposited, with thicknesses partly controlled by north-south extensional faults. A small input centre occurred on northern Ellef Ringnes Island and Bajocian and Bathonian sandstones prograded southwards from the rift shoulder of the newly formed Amerasia rift system. Over most of the basin, Bajocian and Bathonian strata are thin, often condensed sediments. There is no evidence of sediments of this age having been derived from the south or east over most of the basin.

A unit of Callovian shale, derived mainly from the south, occurs over much of the basin and equivalent shallow marine sandstone units are rarely preserved. The Callovian strata are separated from the overlying Upper Jurassic, Oxfordian strata by a 2nd order sequence boundary. Following this brief tectonic episode, sediment supply greatly increased from the south and east and no northerly-derived Oxfordian sediments have been identified.

The latest Aalenian sequence boundary is interpreted to coincide with the onset of rifting in the adjacent Amerasia Basin. The Aalenian strata appear to be the final sedimentary wedge derived from Crockerland which was subsequently broken up and buried as the Amerasia Basin evolved from Bajocian through Albian. The Middle Jurassic is a time of greatly reduced sediment supply for the western Arctic from the Barents Shelf to the Alaskan North Slope.

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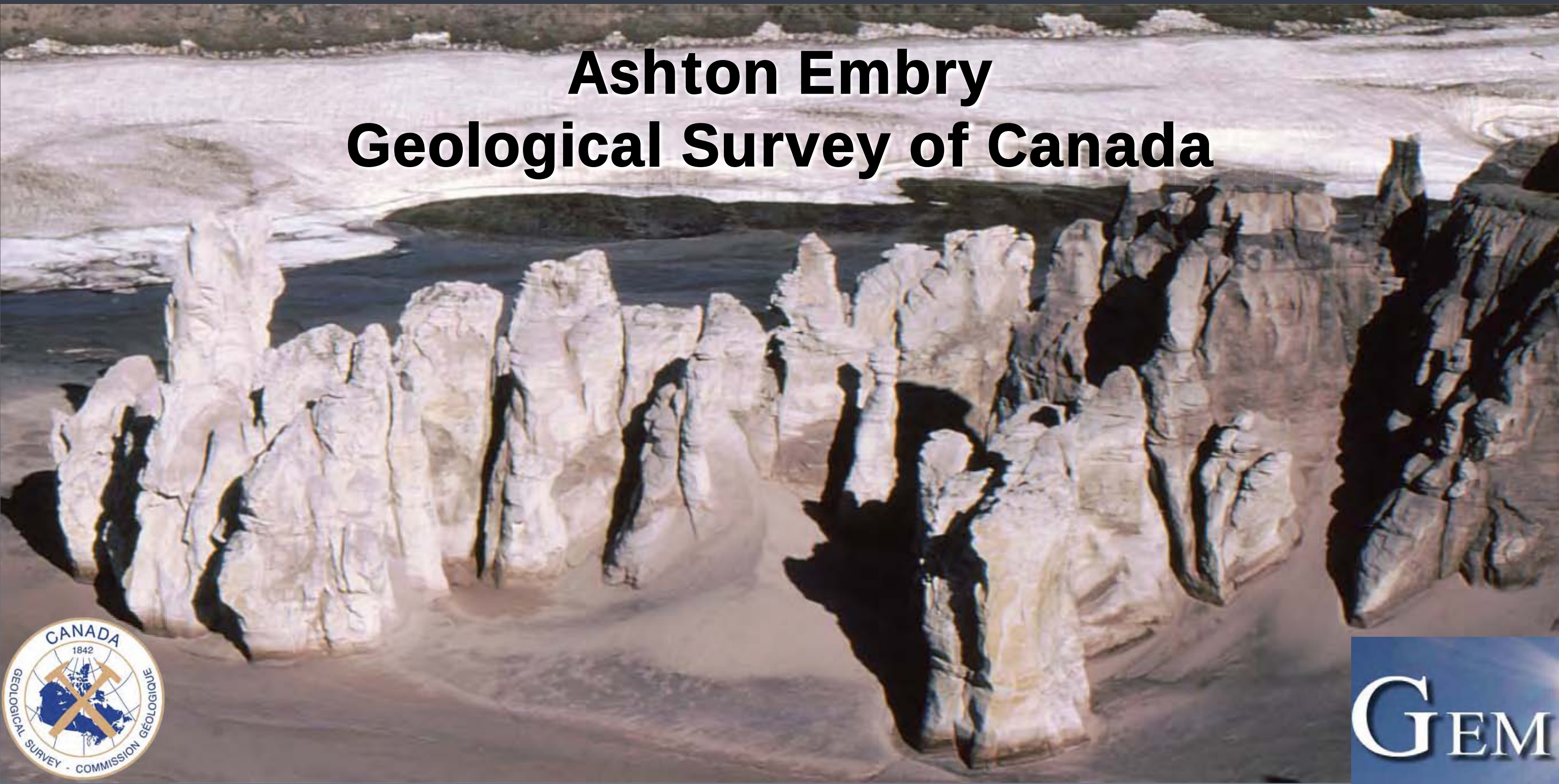
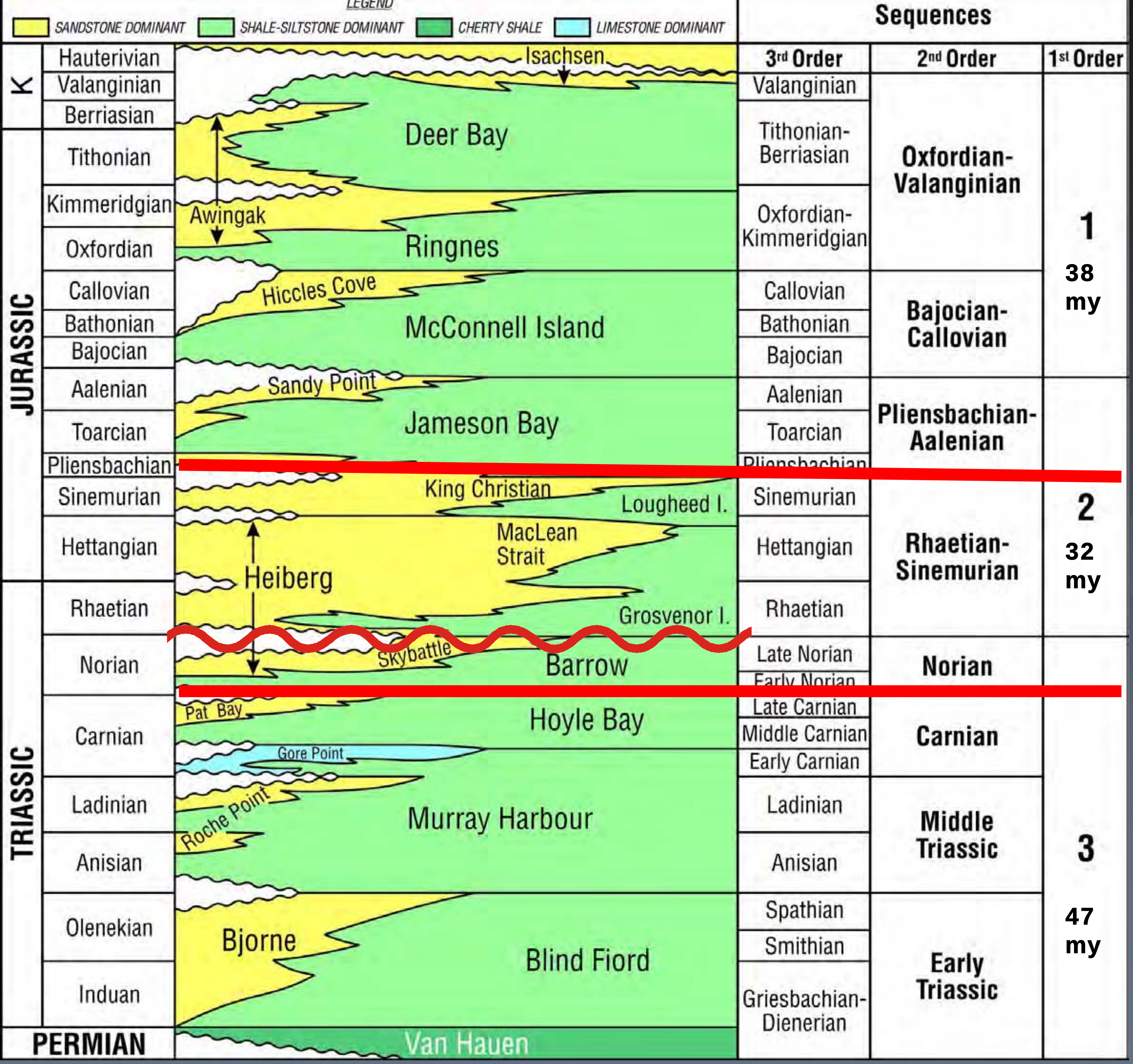
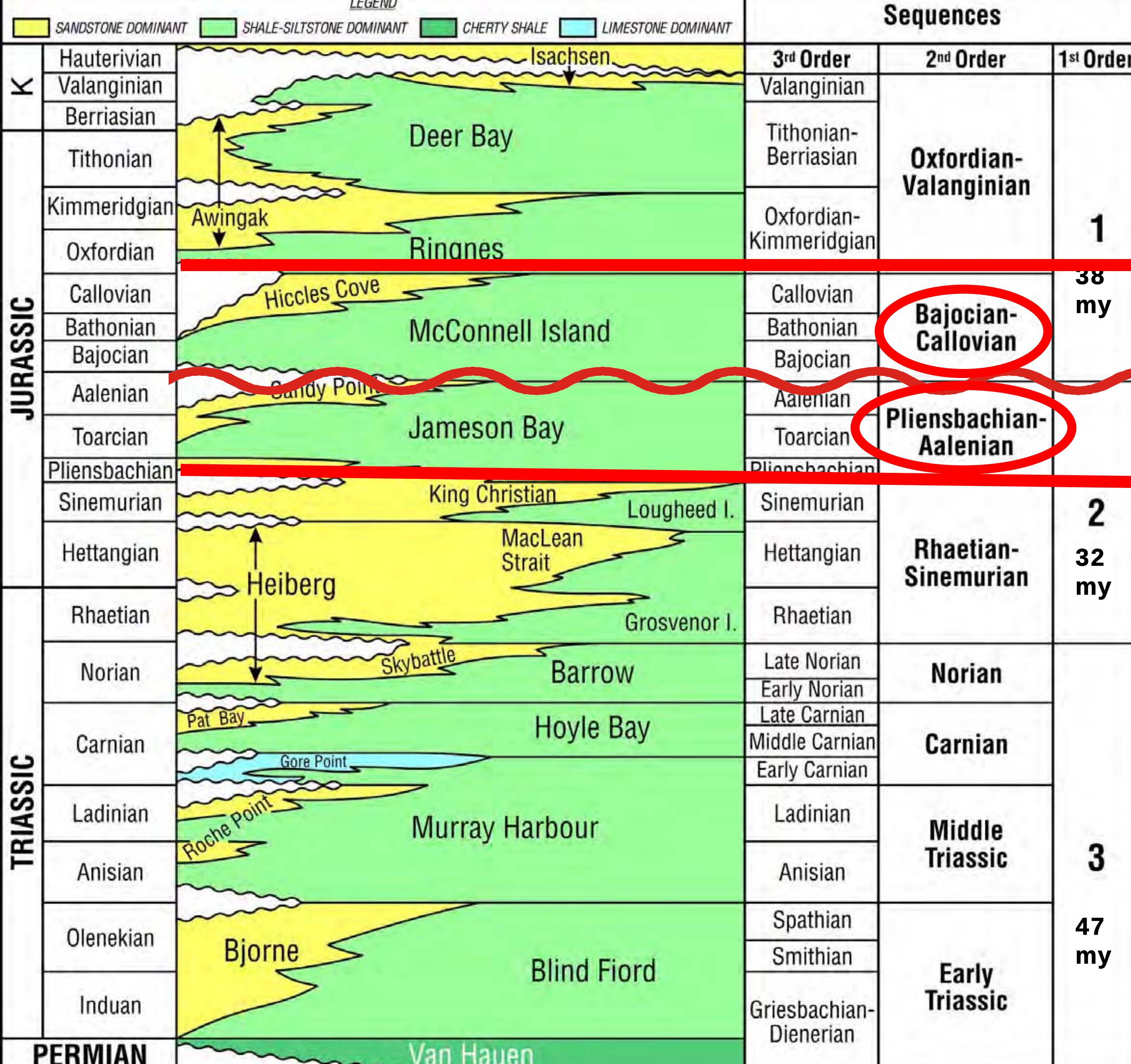
Geological Survey of Canada




BATHYMETRY OF THE ARCTIC OCEAN
NAVAL RESEARCH LABORATORY - ACOUSTICS DIVISION
ACOUSTIC MEDIA CHARACTERIZATION BRANCH
Sverdrup
Basin

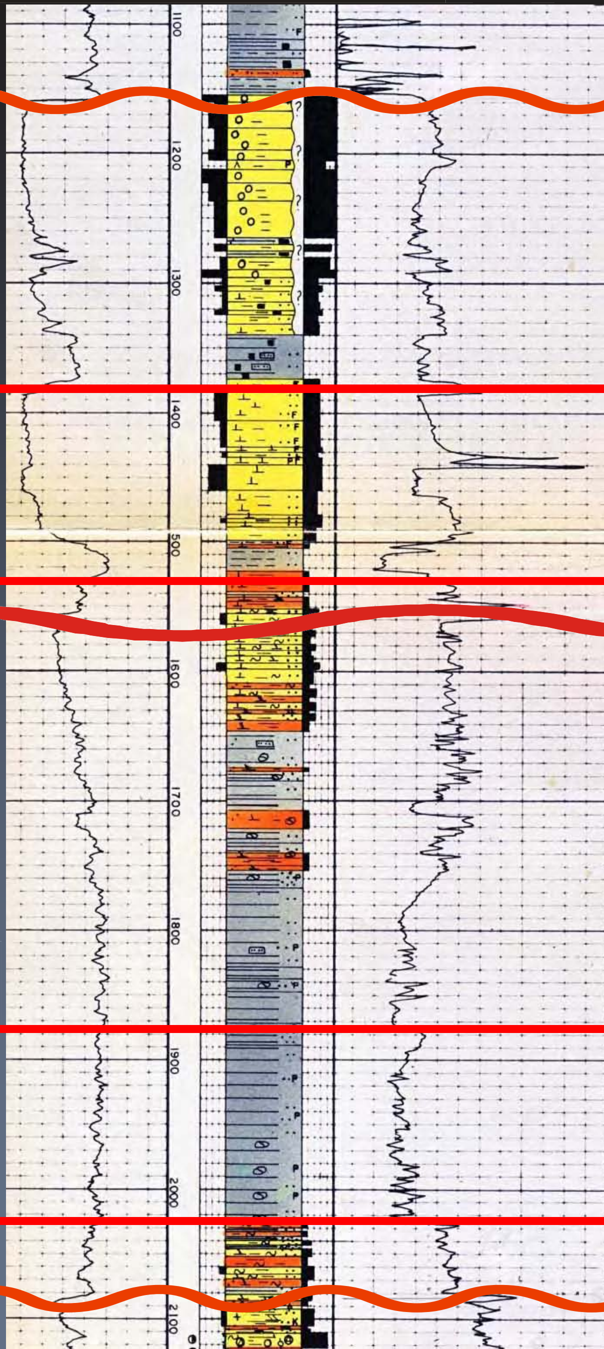


Previous Talk



This talk will look at two 2nd order sequences which are separated by a major 1st order boundary

Depot Island C-44



2

Callovian Sequence

3

Bajocian-Callovian

Bathonian Sequence

3

Bajocian Sequence 1

Aalenian Sequence

Pliensbachian-Aalenian

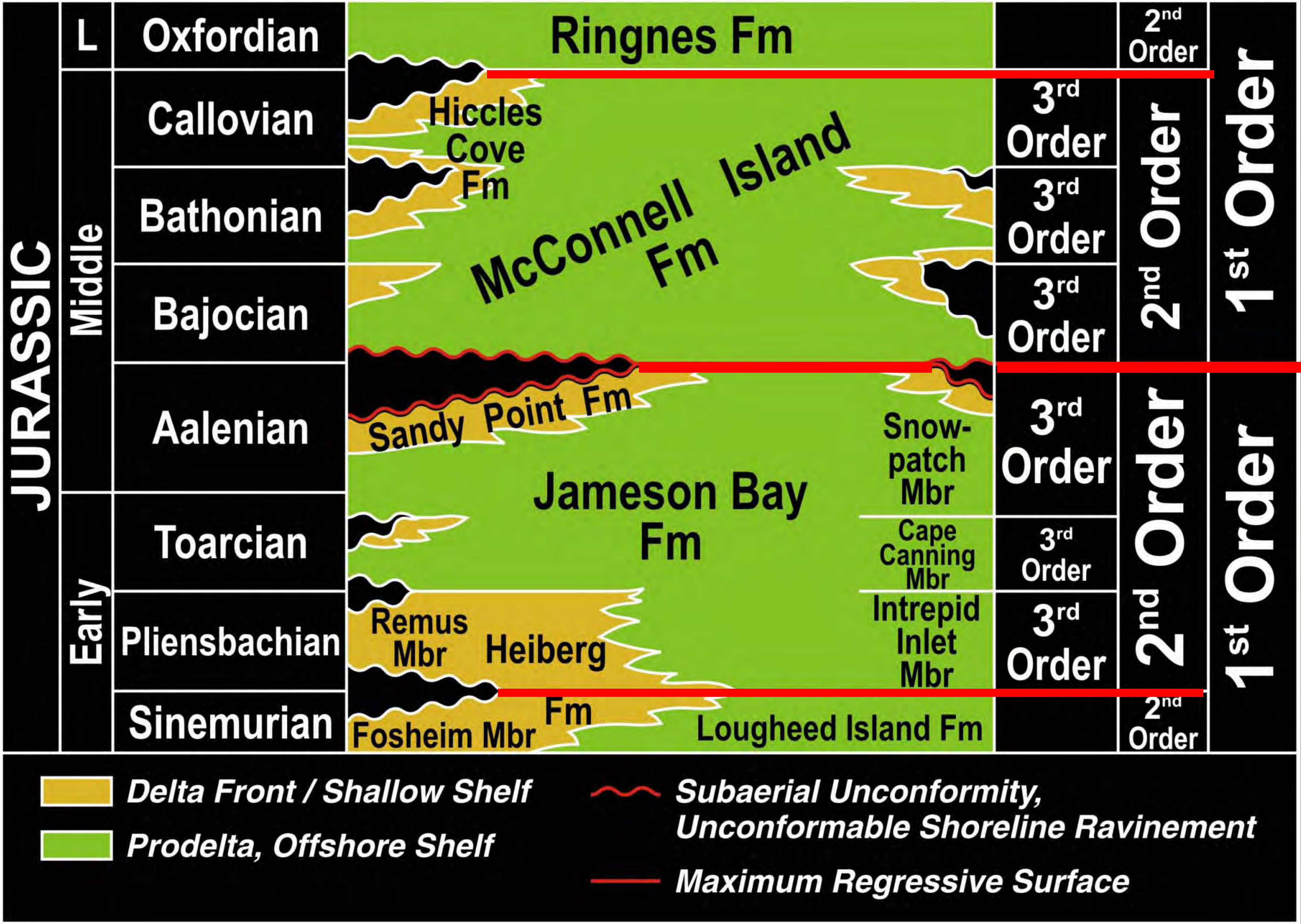
3

Toarcian Sequence

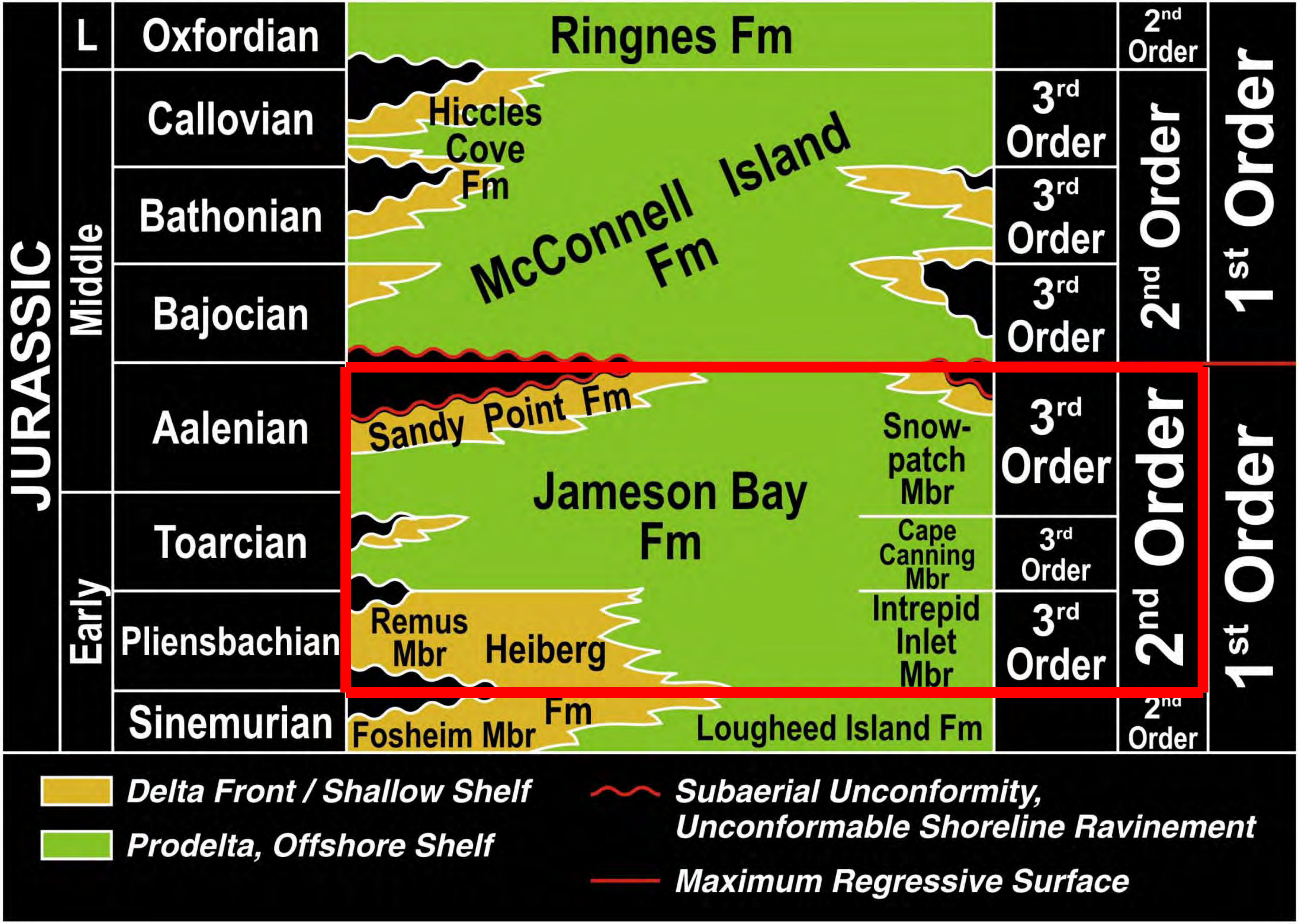
3

Pliensbachian Sequence

2



JURASSIC
L
Middle
Early
Oxfordian
Callovian
Bathonian
Bajocian
Aalenian
Toarcian
Pliensbachian
Sinemurian
Ringnes Fm
Hiccles Cove Fm
McConnell Island Fm
Sandy Point Fm
Jameson Bay Fm
Snow-patch Mbr
Cape Canning Mbr
Intrepid Inlet Mbr
Remus Mbr
Heiberg Fm
Fosheim Mbr
Lougheed Island Fm
2nd Order
3rd Order
3rd Order
3rd Order
3rd Order
3rd Order
3rd Order
2nd Order
2nd Order
2nd Order
1st Order
1st Order
Delta Front / Shallow Shelf
Prodelta, Offshore Shelf
Subaerial Unconformity, Unconformable Shoreline Ravinement
Maximum Regressive Surface


JURASSIC
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Middle
Early
Oxfordian
Callovian
Bathonian
Bajocian
Aalenian
Toarcian
Pliensbachian
Sinemurian
Ringnes Fm
Hiccles Cove Fm
McConnell Island Fm
Sandy Point Fm
Jameson Bay Fm
Snow-patch Mbr
Cape Canning Mbr
Intrepid Inlet Mbr
Remus Mbr
Heiberg Fm
Fosheim Mbr
Lougheed Island Fm
2nd Order
3rd Order
3rd Order
3rd Order
2nd Order
1st Order
3rd Order
3rd Order
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Delta Front / Shallow Shelf
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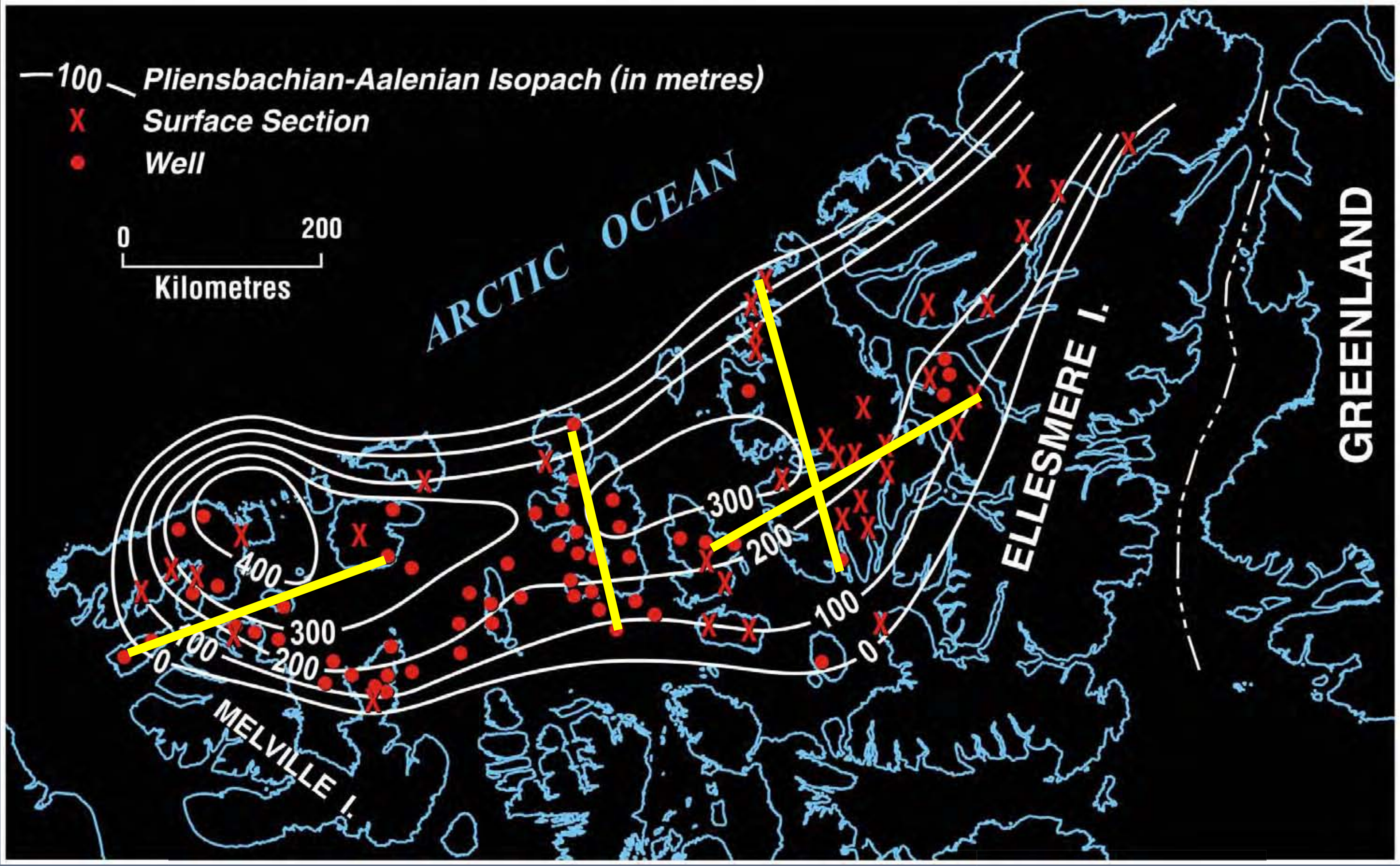
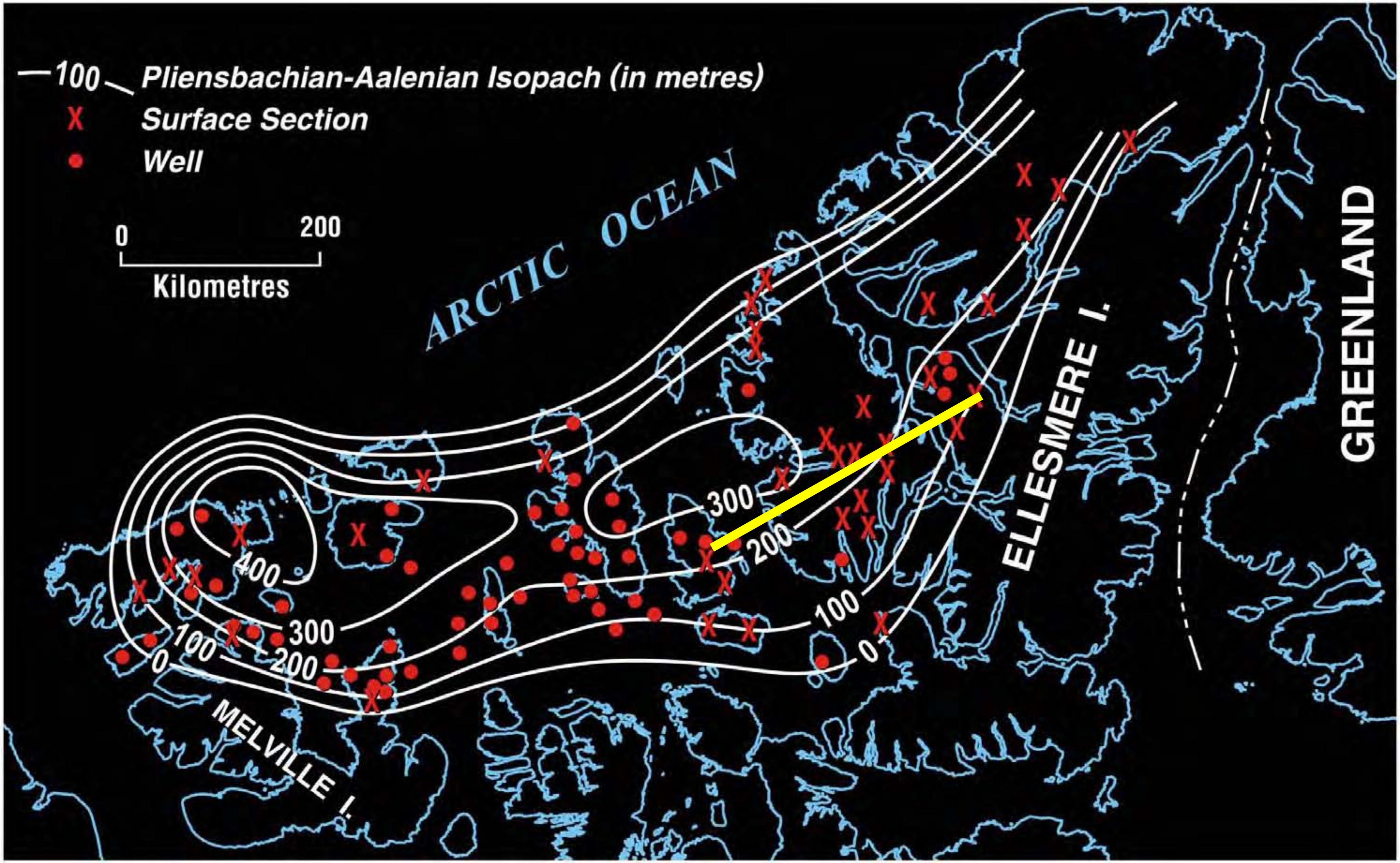
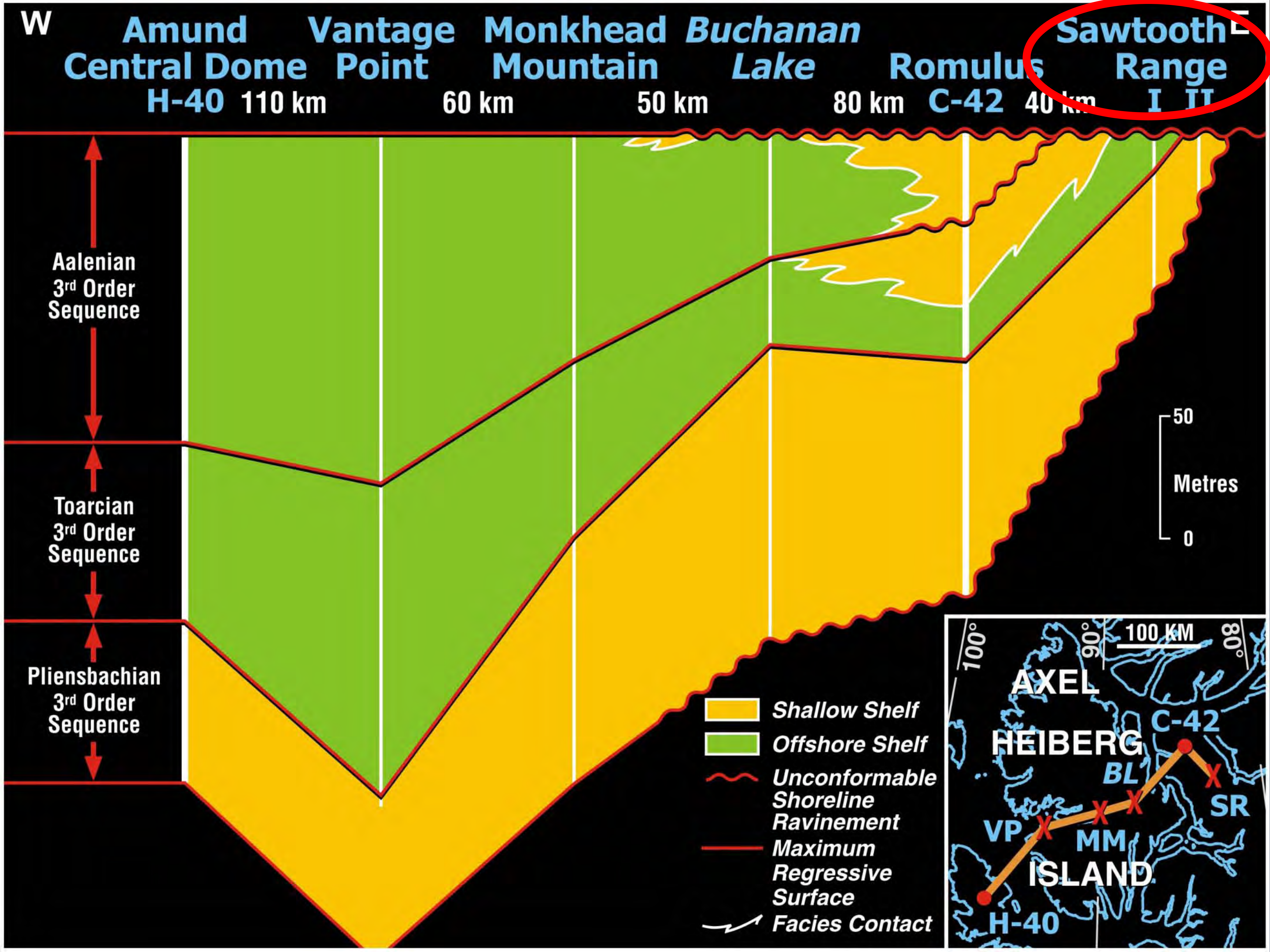


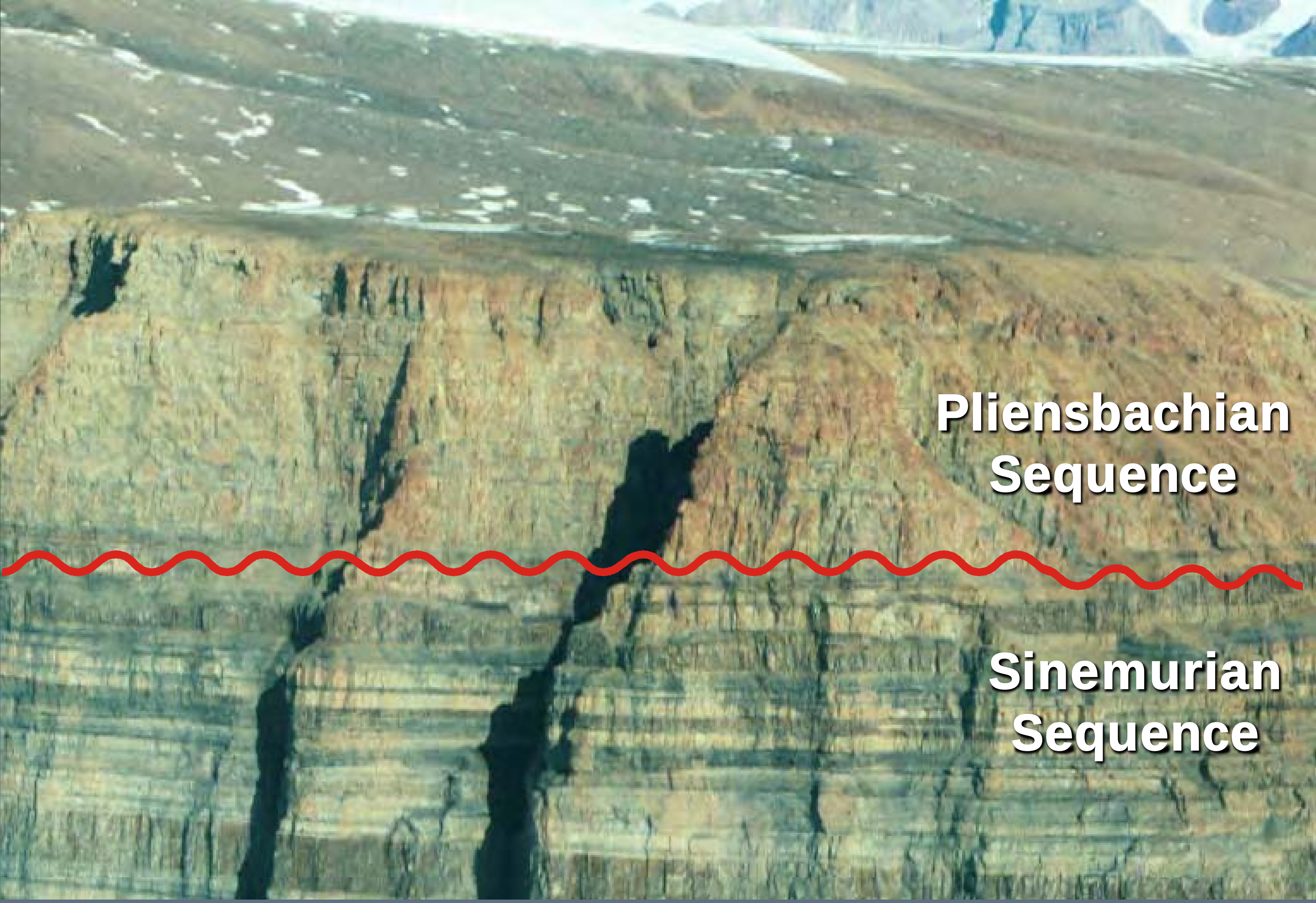
Isopach Pliensbachian-Aalenian 2nd Order Sequence



Eastern Margin to Basin Centre Cross Section
Pliensbachian-Aalenian 2nd Order Sequence

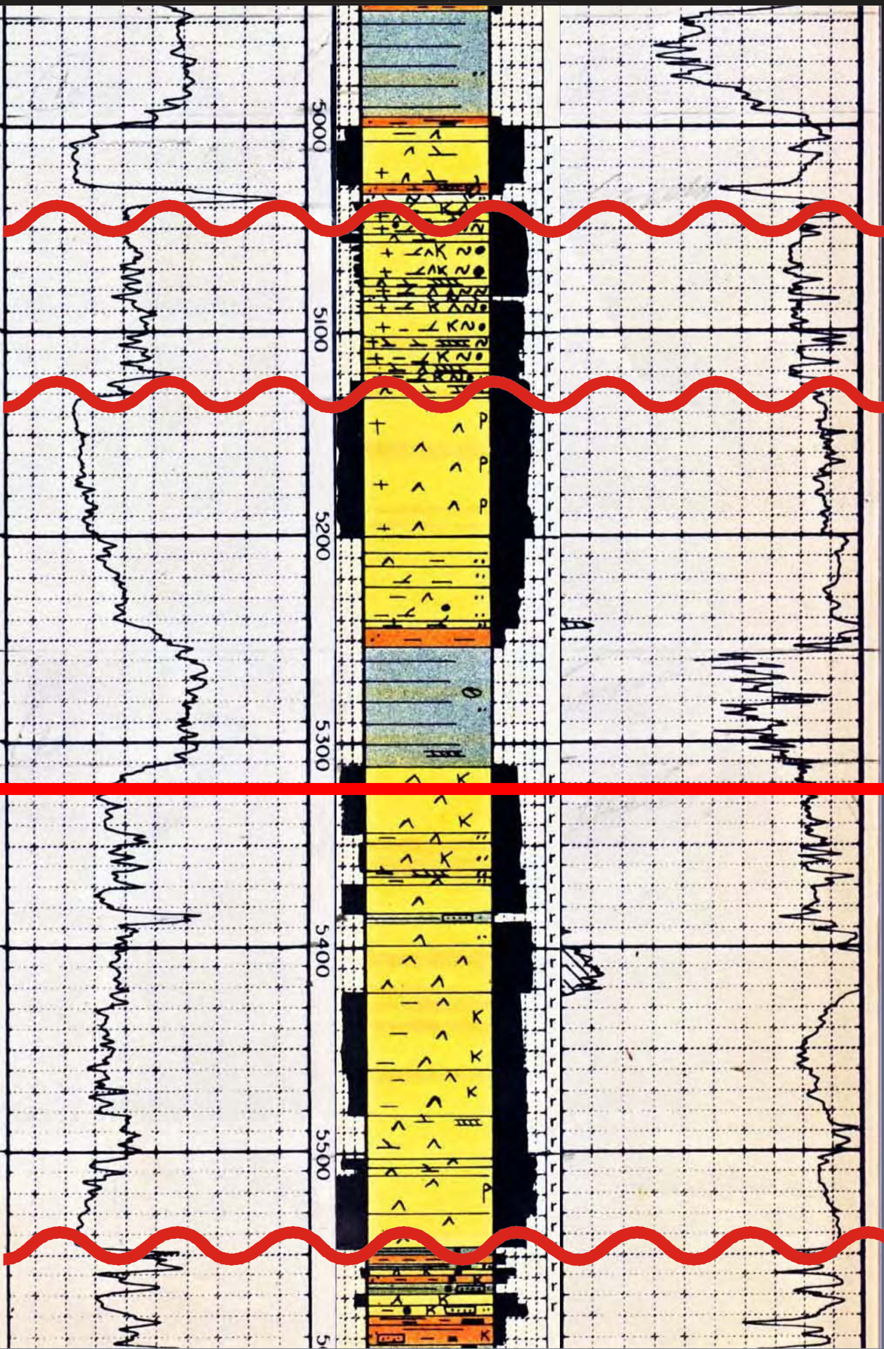

W
E
Amund Central Dome H-40
110 km
Vantage Point
60 km
Monkhead Mountain
50 km
Buchanan Lake
80 km
Romulus C-42
40 km
Sawtooth Range
I
II
Aalenian 3rd Order Sequence
Toarcian 3rd Order Sequence
Pliensbachian 3rd Order Sequence
50
Metres
0
Shallow Shelf
Offshore Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact
100°
90°
80°
100 KM
AXEL
HEIBERG
ISLAND
C-42
BL
SR
VP
MM
H-40

NE Sawtooth Range, Ellesmere Island



Yelverton Pass, NE Ellesmere Island

Taleman J-34

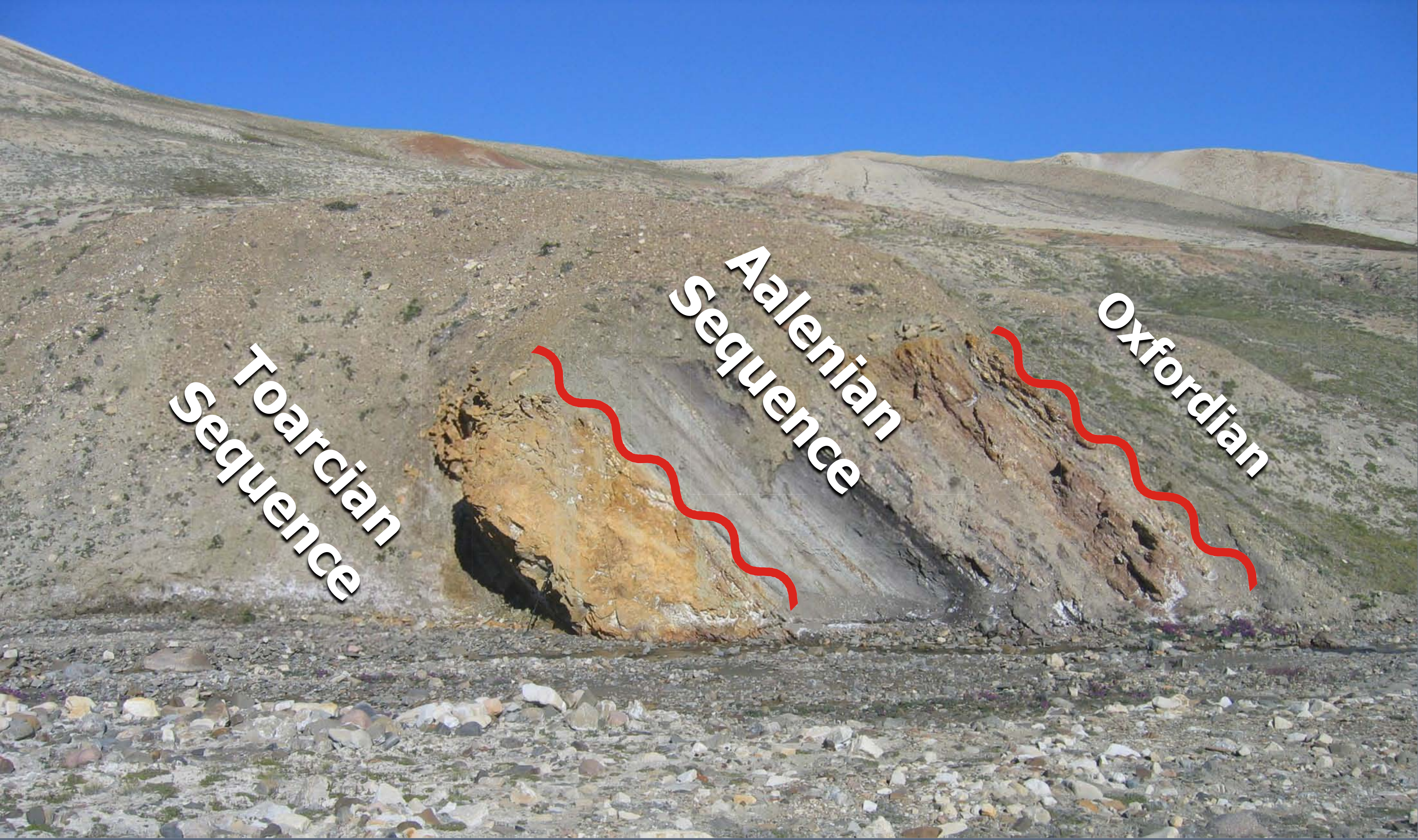


Oxfordian Sequence

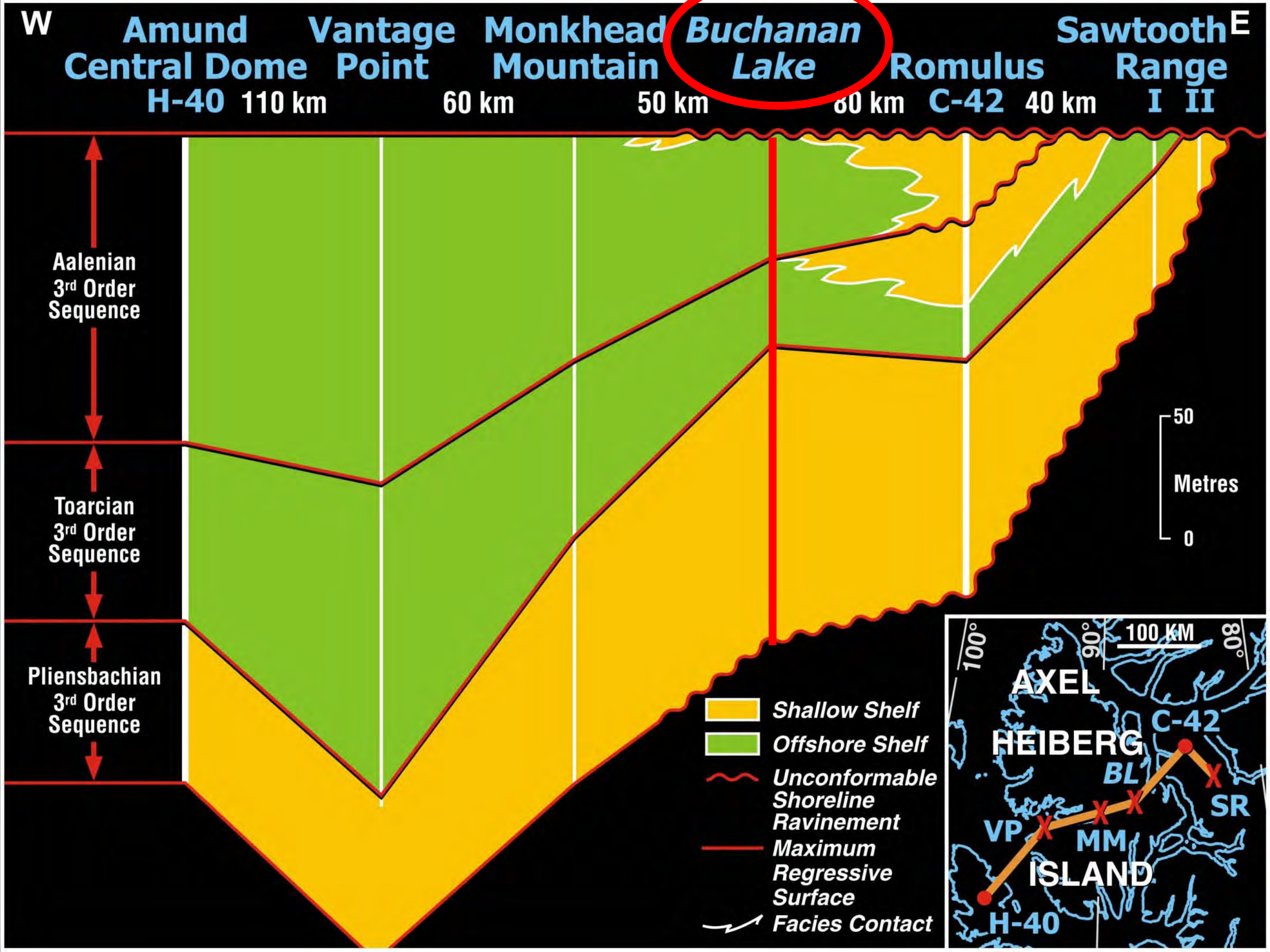
Aalenian Sequence

Toarcian Sequence

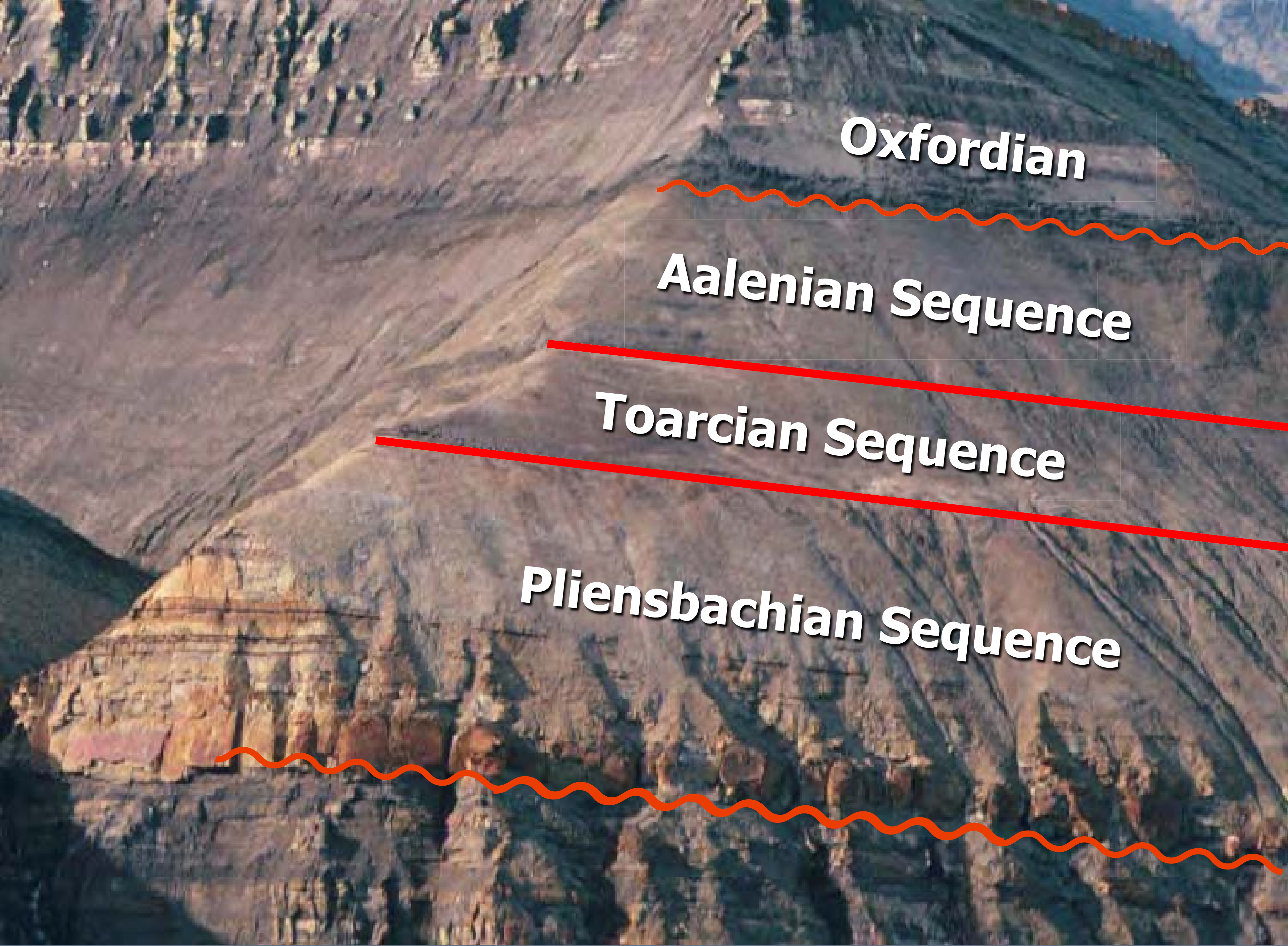
Pliensbachian Sequence



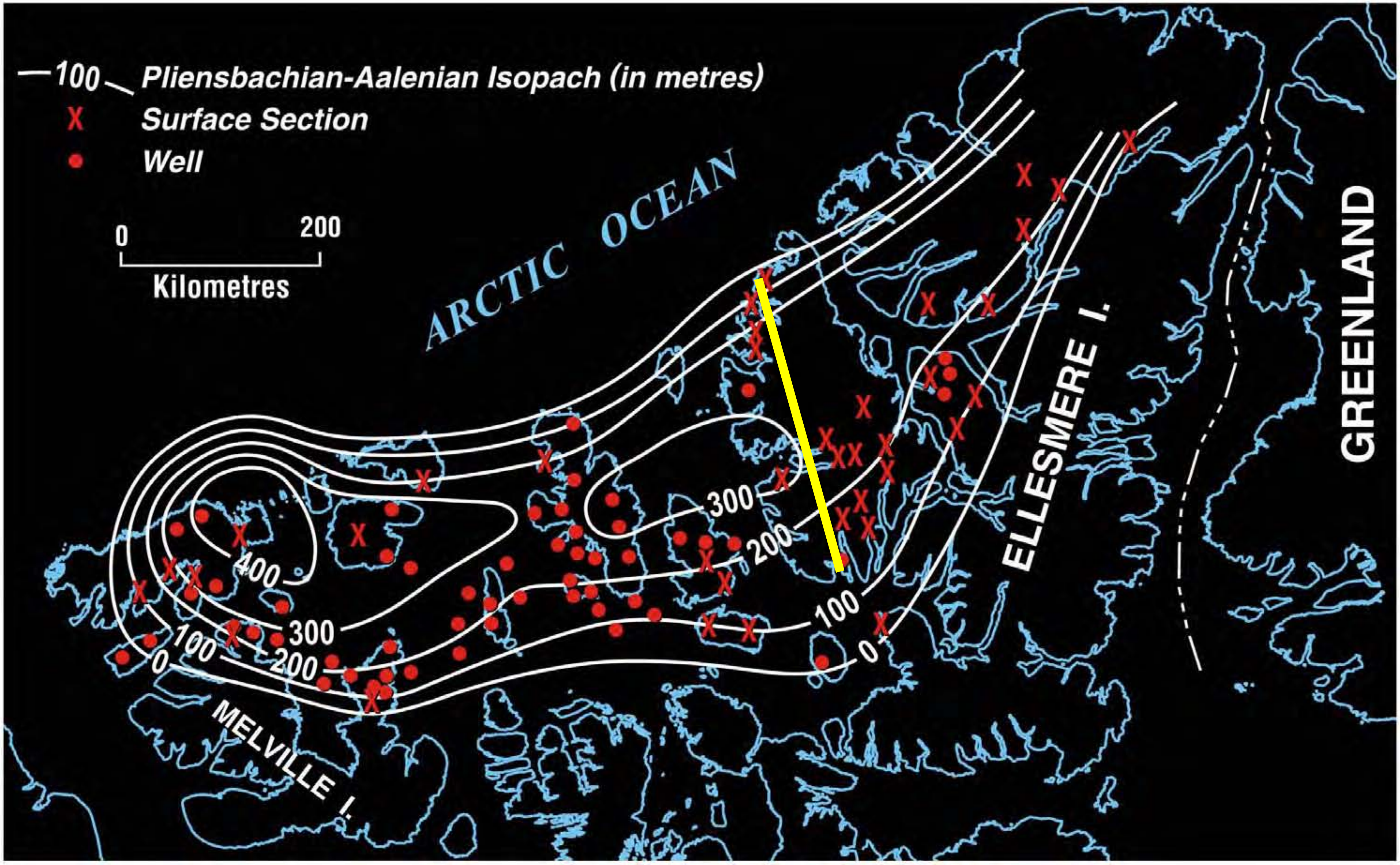
Depot Point Creek, Eastern Axel Heiberg Island



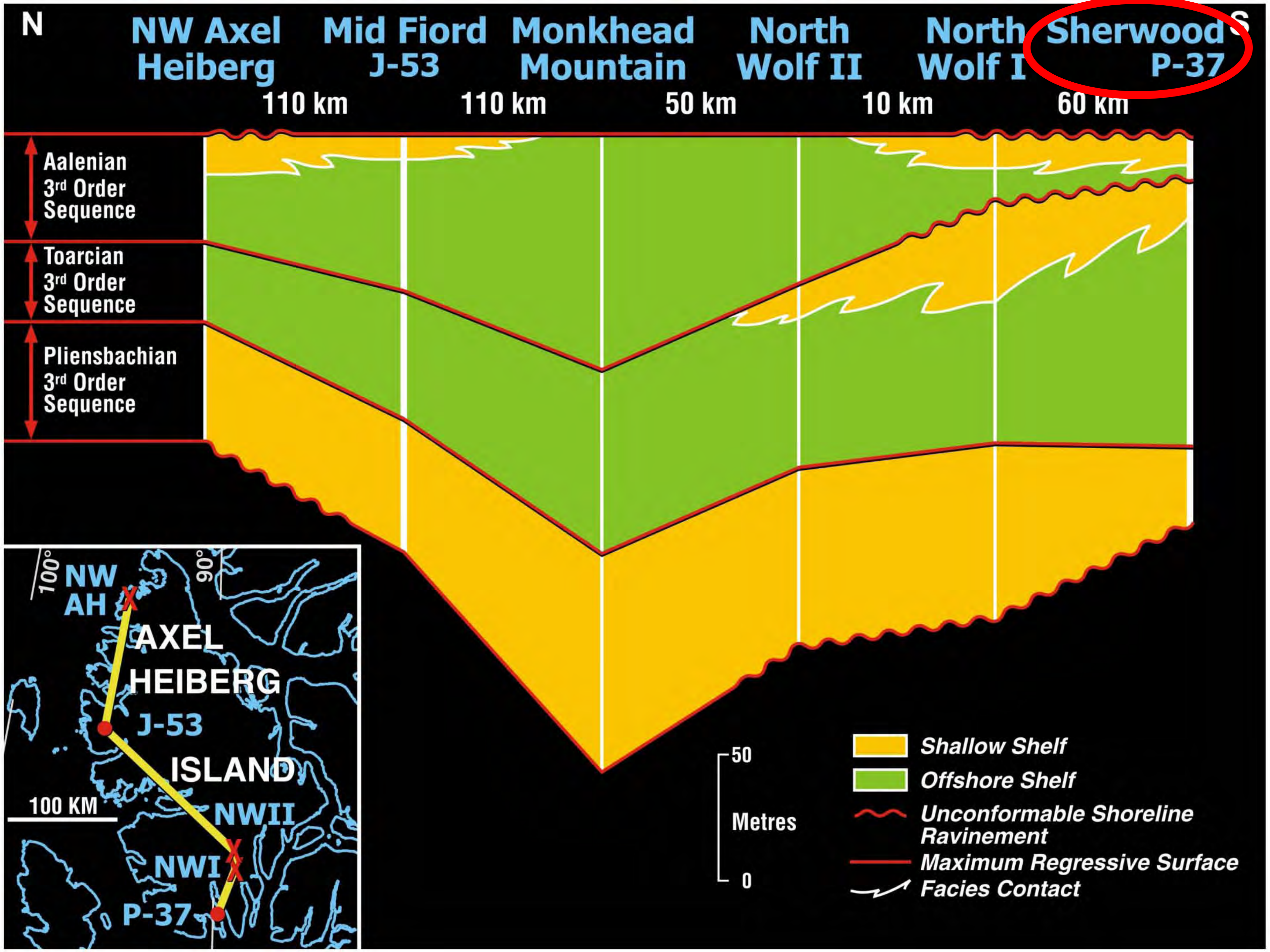
W
Amund Central Dome H-40
110 km
Vantage Point
60 km
Monkhead Mountain
50 km
Buchanan Lake
80 km
Romulus C-42
40 km
Sawtooth Range I II
E
Aalenian 3rd Order Sequence
Toarcian 3rd Order Sequence
Pliensbachian 3rd Order Sequence
50
Metres
0
Shallow Shelf
Offshore Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact
100 KM
100°
90°
80°
AXEL HEIBERG ISLAND
C-42
BL
SR
VP
MM
H-40


Oxfordian
Aalenian Sequence
Toarcian Sequence
Pliensbachian Sequence

Ermine Ridge, west central Axel Heiberg Island

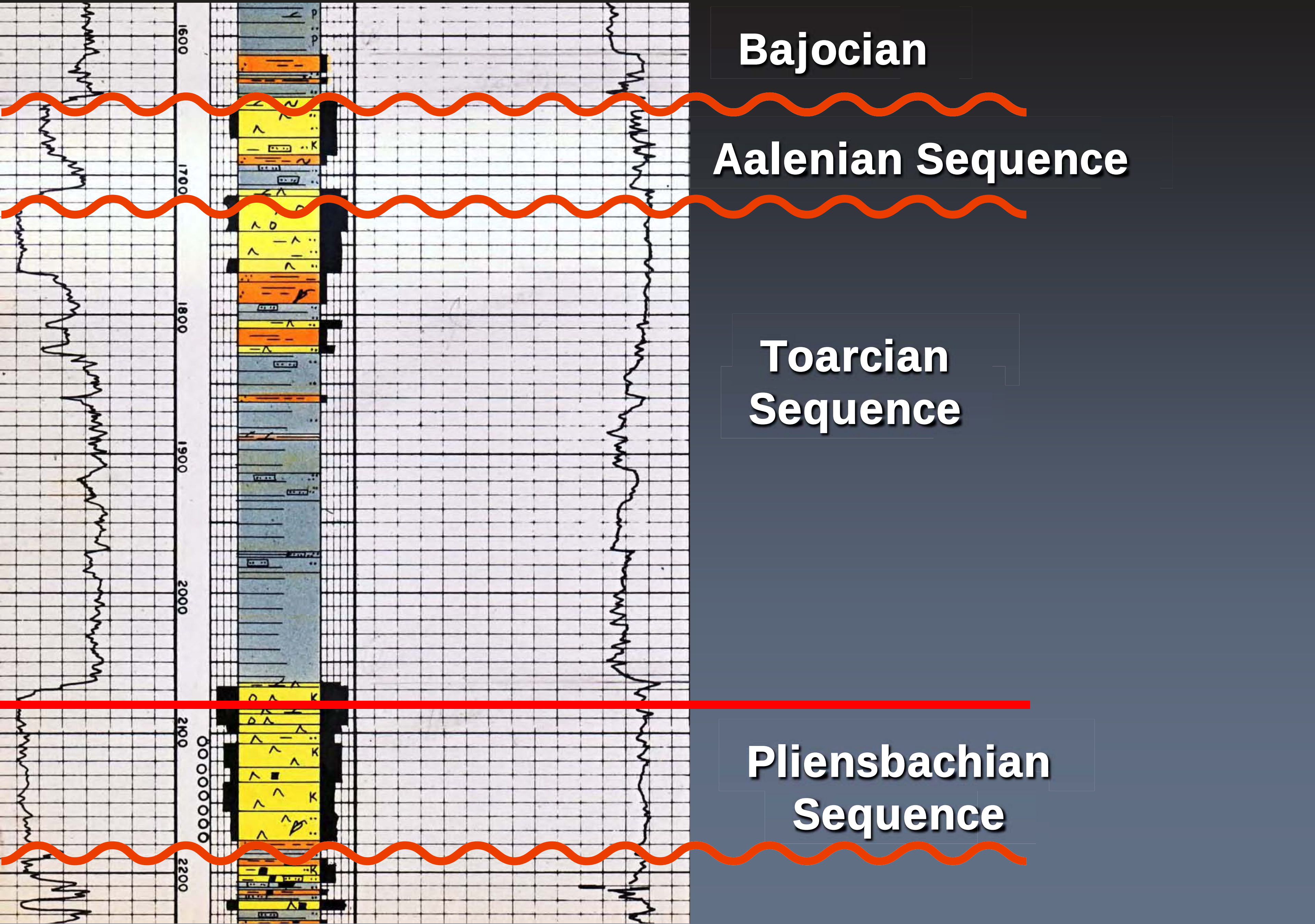


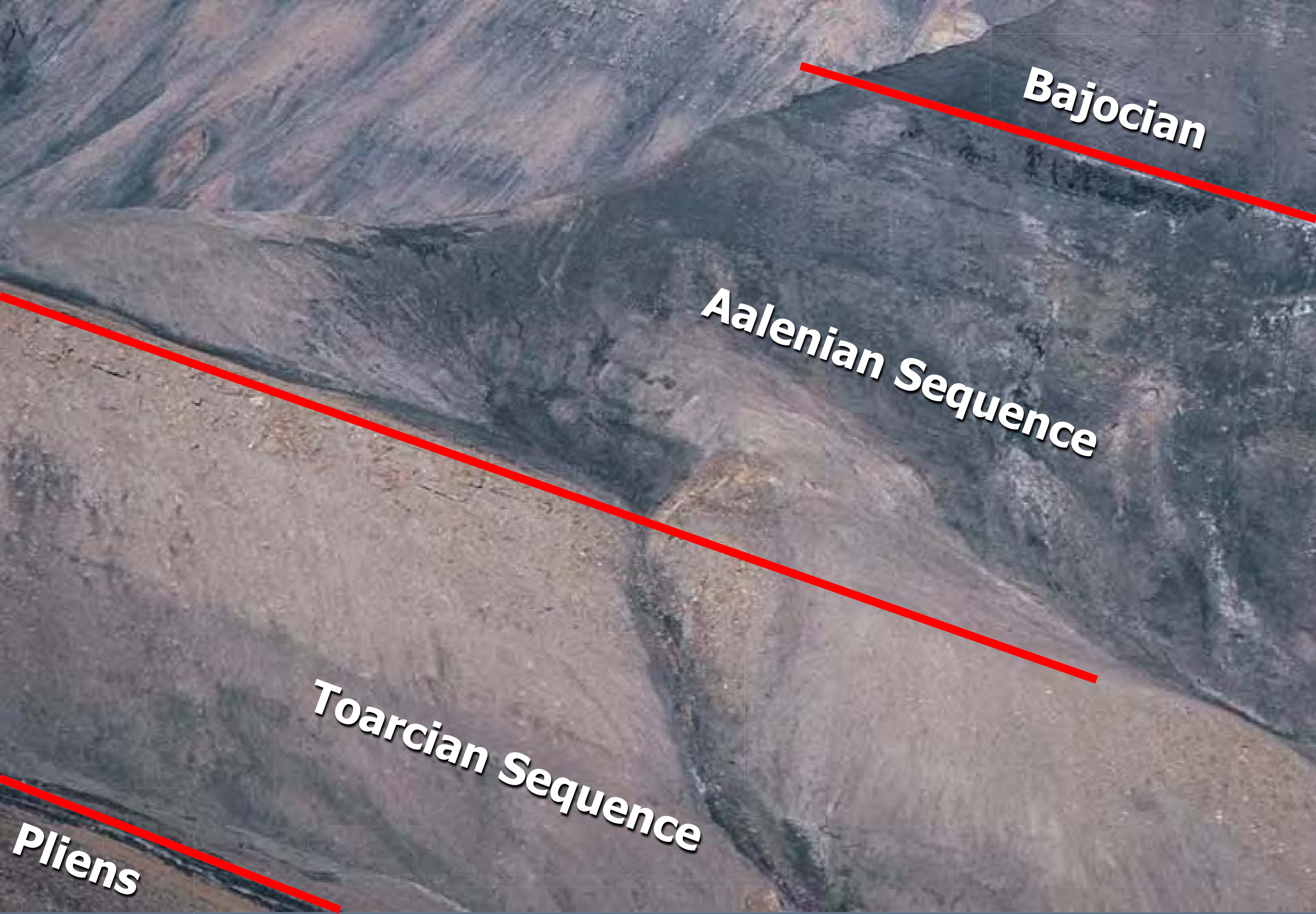
Axel Heiberg Cross Section
Pliensbachian-Aalenian 2nd Order Sequence



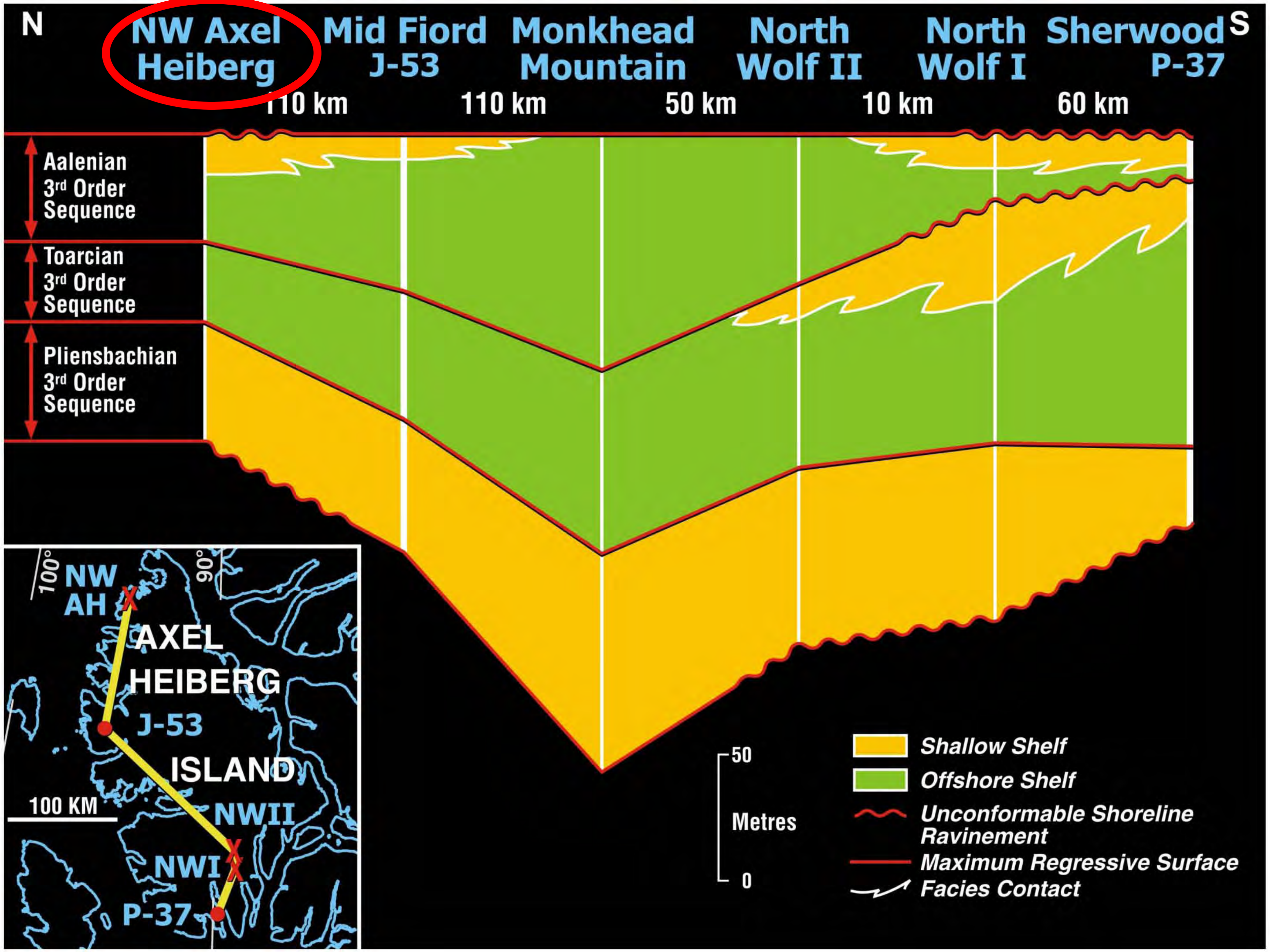
N
S
NW Axel Heiberg
Mid Fiord J-53
Monkhead Mountain
North Wolf II
North Wolf I
Sherwood P-37
110 km
110 km
50 km
10 km
60 km
Aalenian 3rd Order Sequence
Toarcian 3rd Order Sequence
Pliensbachian 3rd Order Sequence
100°
90°
NW AH
AXEL HEIBERG
J-53
ISLAND
100 KM
NWII
NWI
P-37
50
Metres
0
Shallow Shelf
Offshore Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact

Sherwood P-37

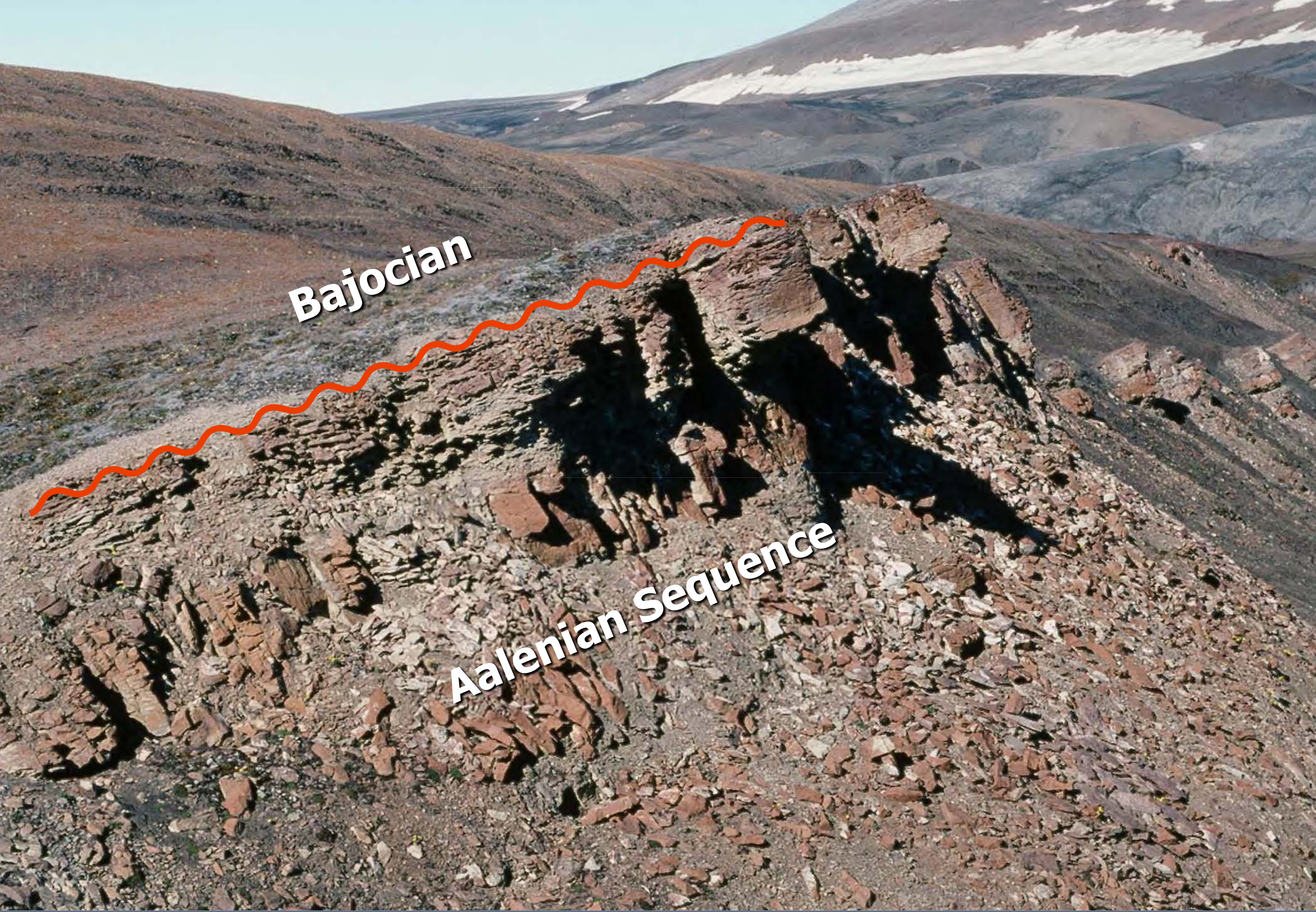




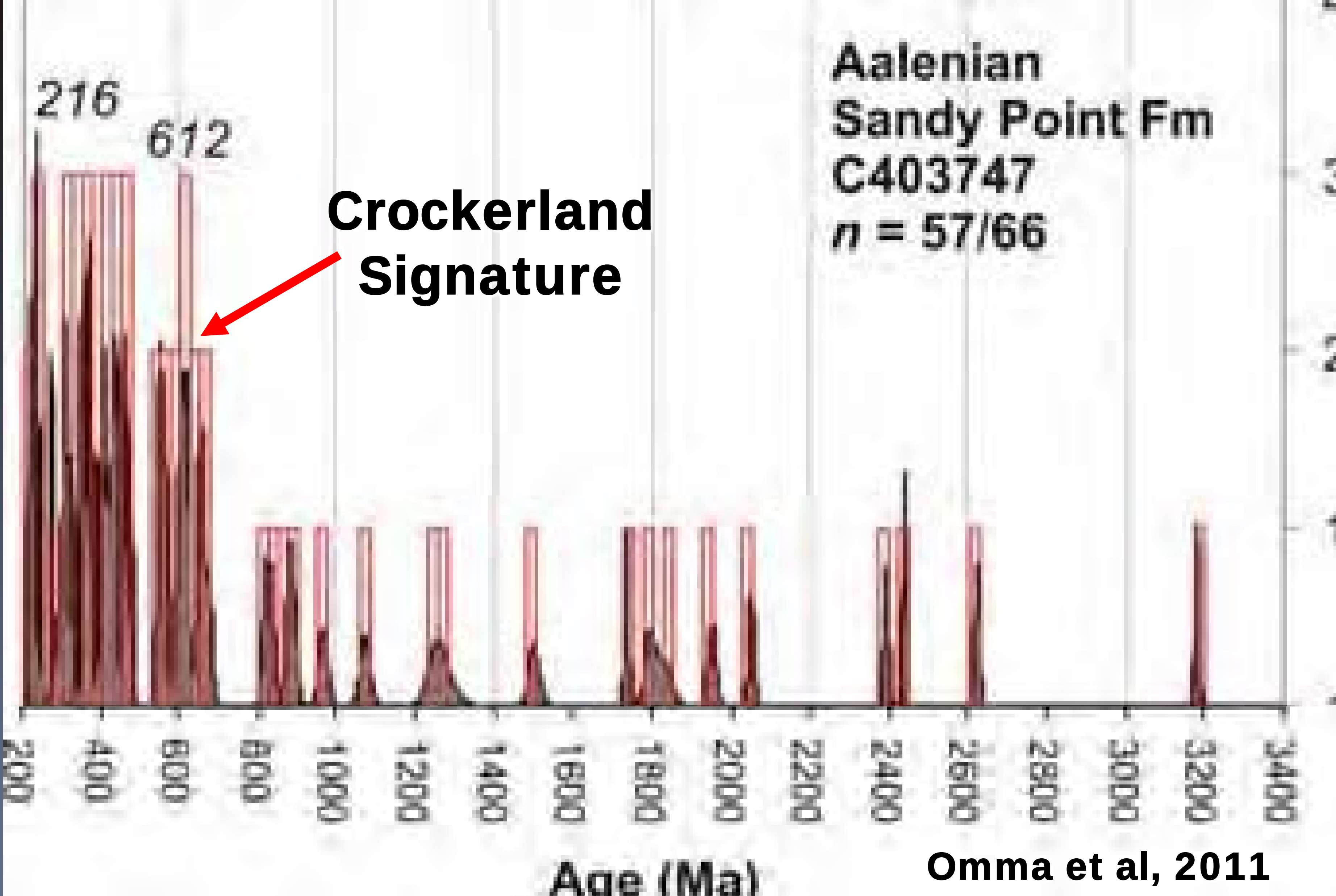
Skaare Fiord, SE Axel Heiberg Island



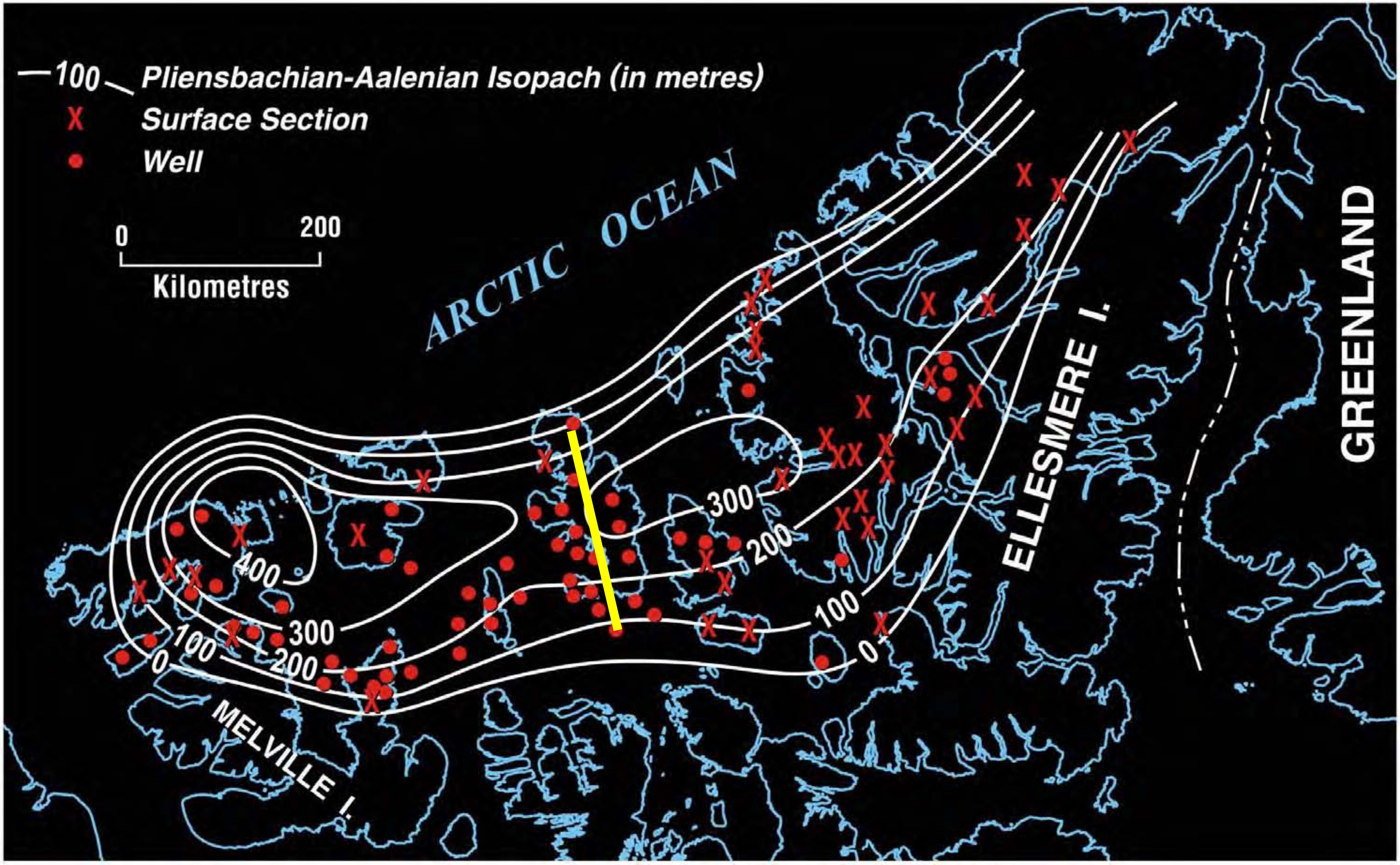
N
S
NW Axel Heiberg
Mid Fiord J-53
Monkhead Mountain
North Wolf II
North Wolf I
Sherwood P-37
110 km
110 km
50 km
10 km
60 km
Aalenian 3rd Order Sequence
Toarcian 3rd Order Sequence
Pliensbachian 3rd Order Sequence
NW AH
AXEL HEIBERG
J-53
ISLAND
NWII
NWI
P-37
100 KM
100°
90°
50
Metres
0
Shallow Shelf
Offshore Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact



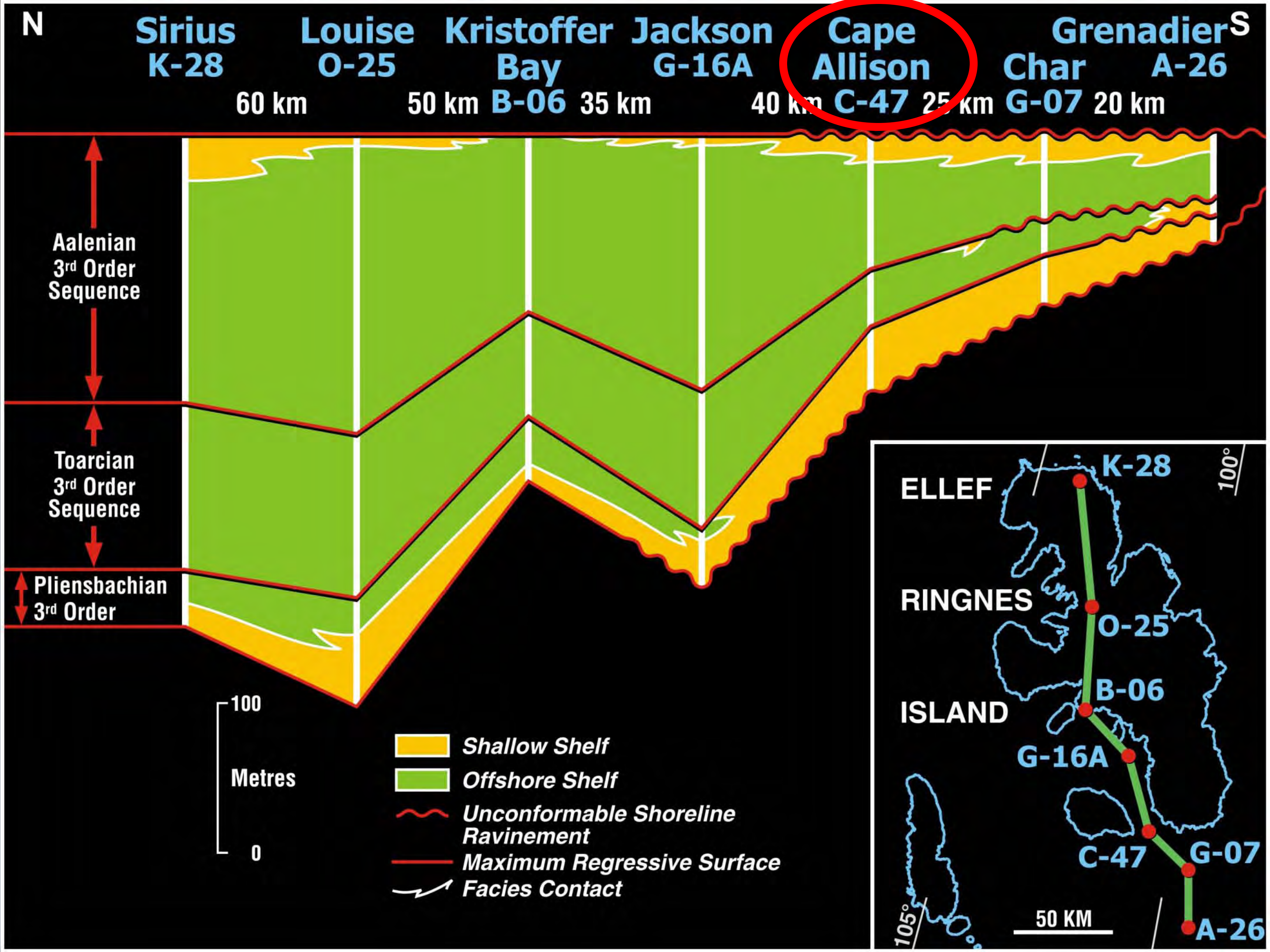
Northwest Axel Heiberg Island



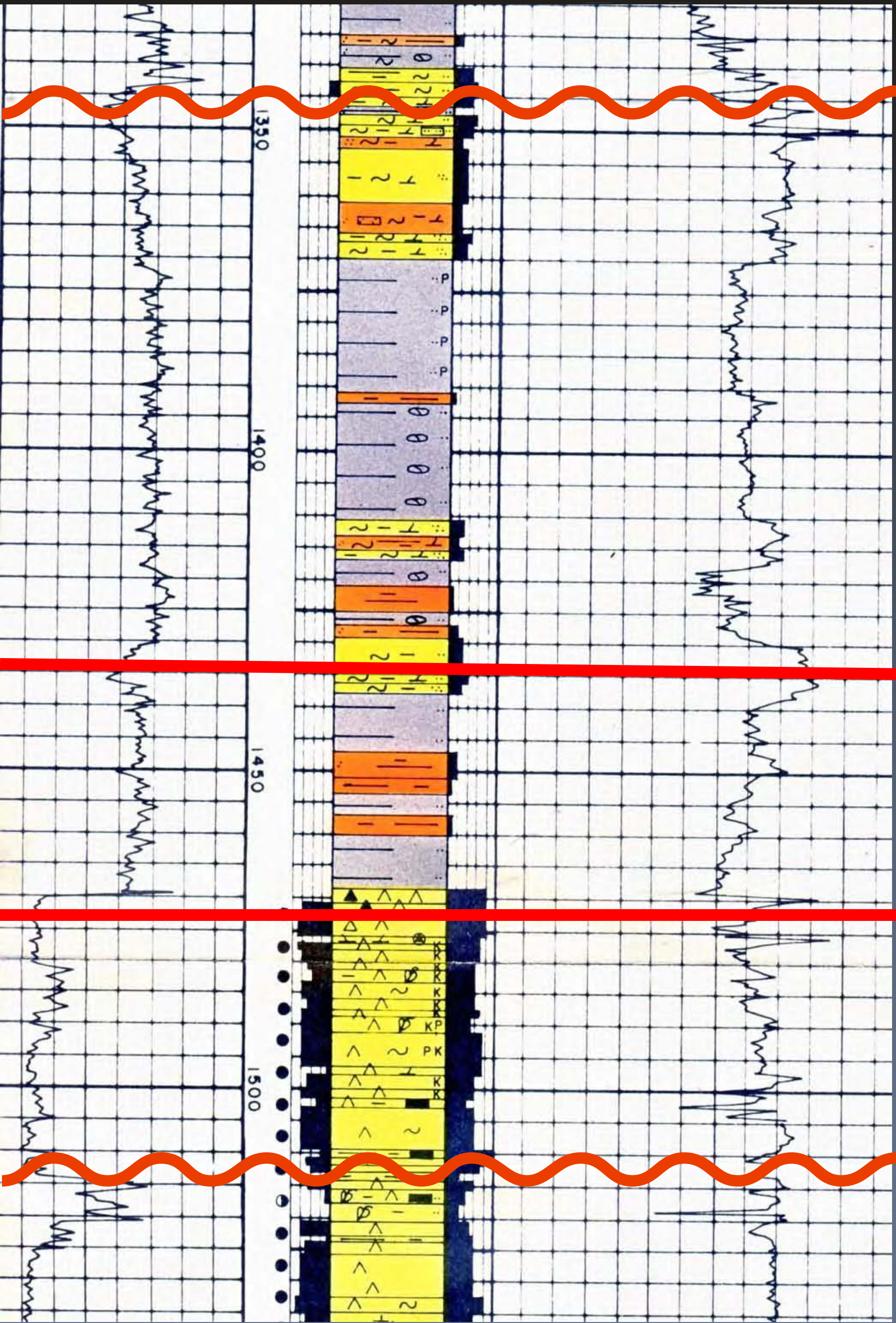
Detrital Zircon Ages, Aalenian Sandstone Northwest Axel Heiberg Island



Ellef Ringnes Cross Section
Pliensbachian-Aalenian 2nd Order Sequence


N
S
Sirius K-28
Louise O-25
Kristoffer Bay B-06
Jackson G-16A
Cape Allison C-47
Char G-07
Grenadier A-26
60 km
50 km
35 km
40 km
25 km
20 km
Aalenian 3rd Order Sequence
Toarcian 3rd Order Sequence
Pliensbachian 3rd Order
100
Metres
0
Shallow Shelf
Offshore Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact
ELLEF
RINGNES
ISLAND
K-28
O-25
B-06
G-16A
C-47
G-07
A-26
100°
105°
50 KM

Cape Allison C-47

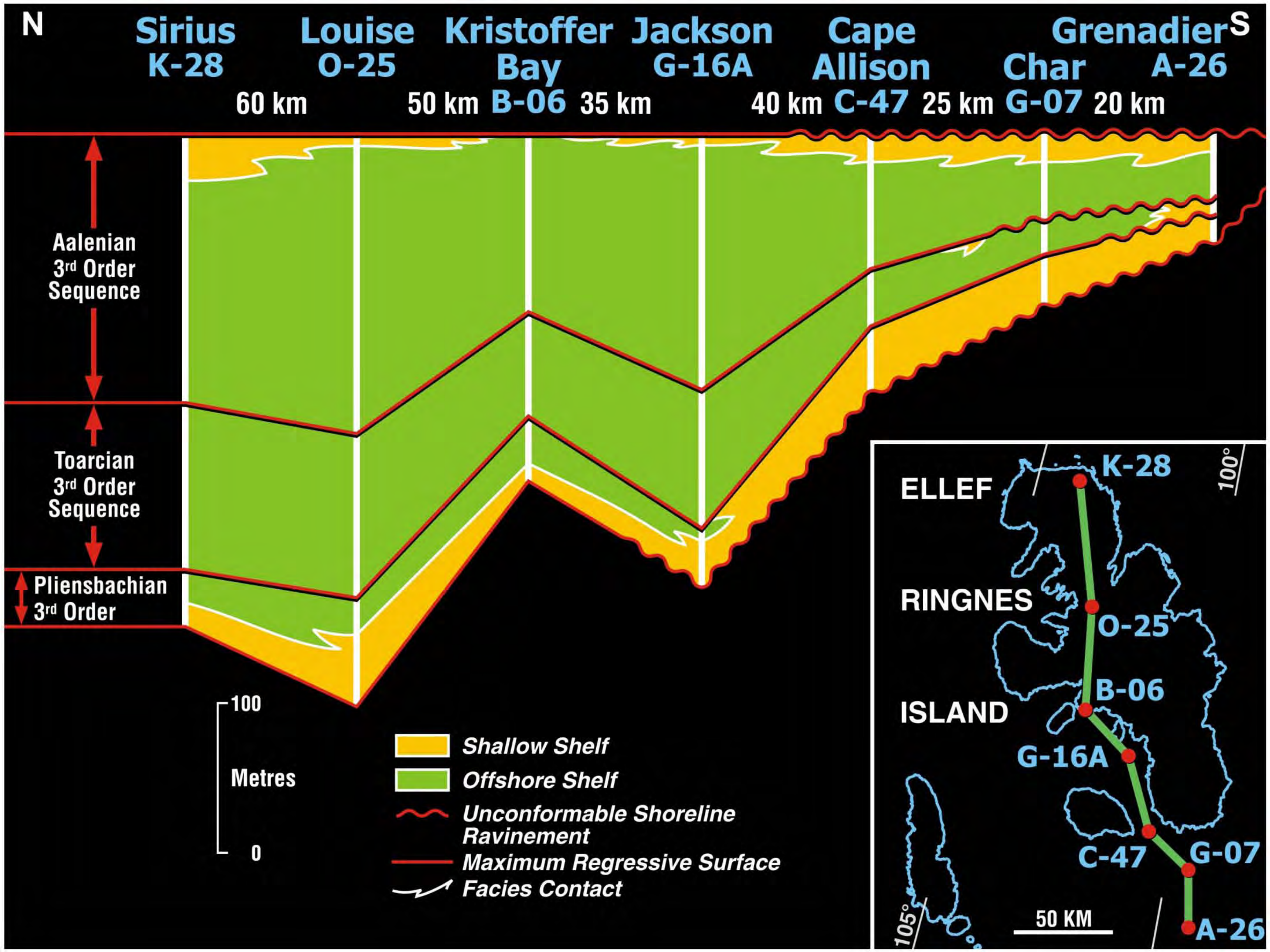


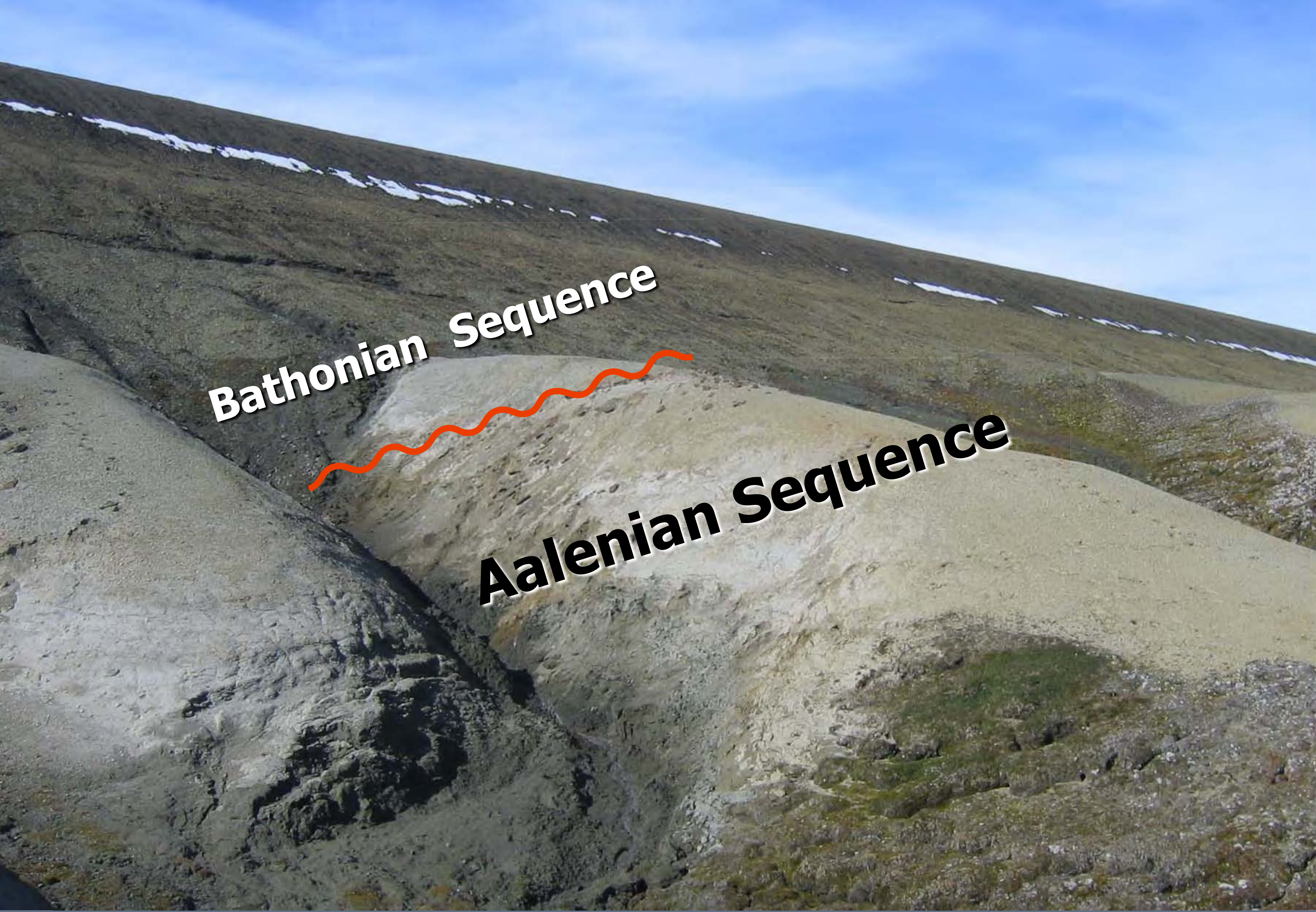
Bajocian Sequence

Aalenian Sequence

Toarcian Sequence

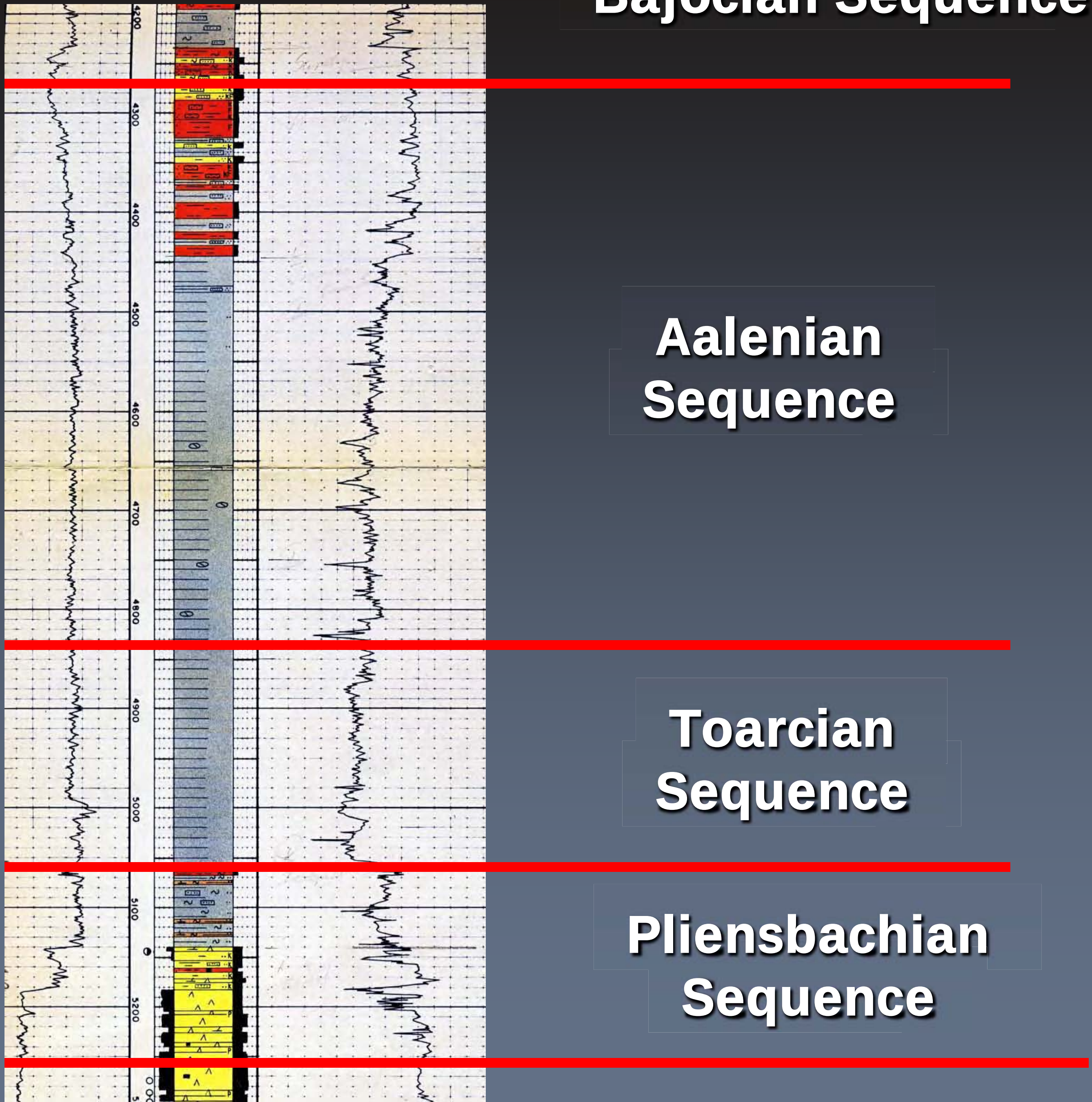
Pliensbachian Sequence

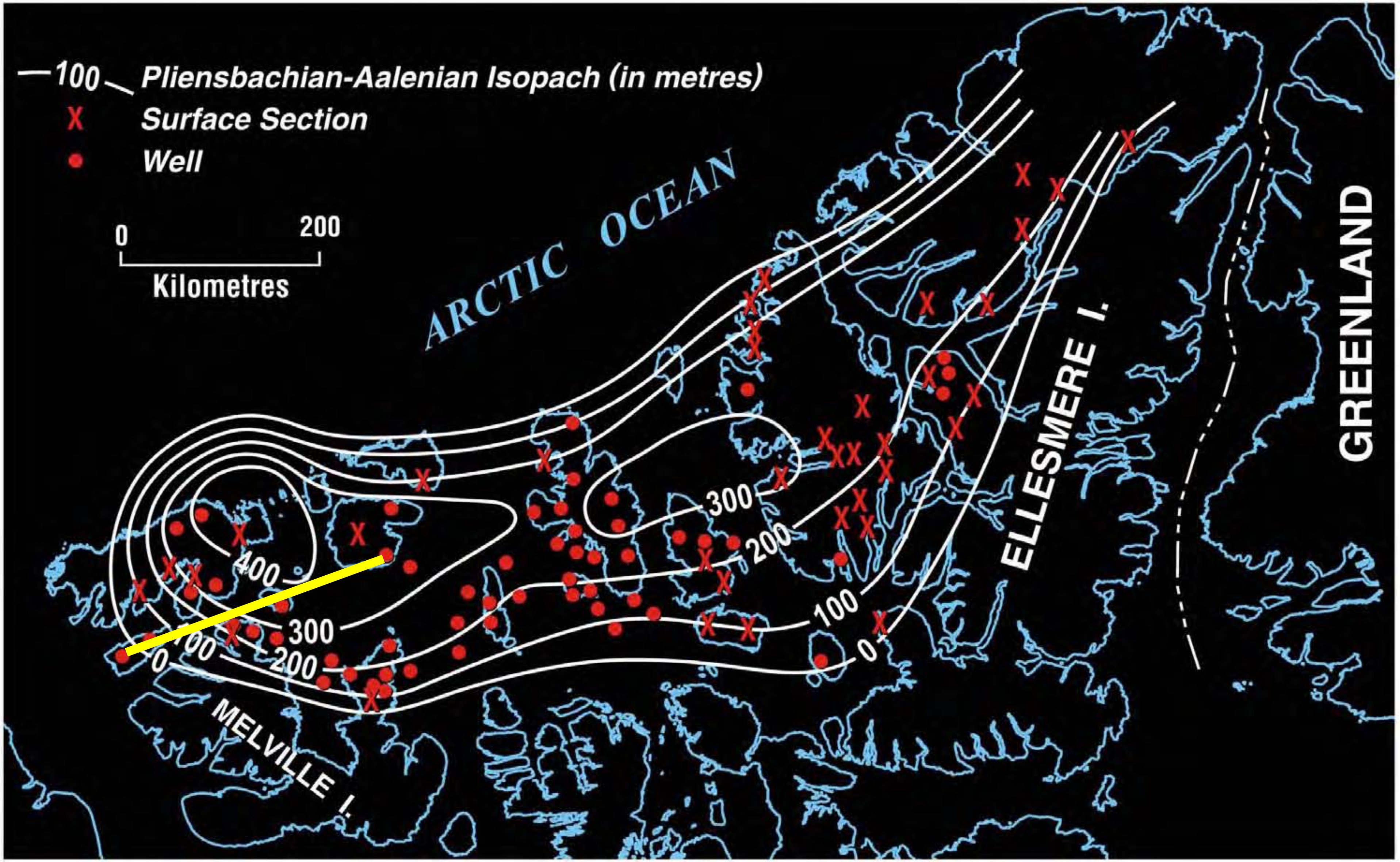

N
S
Sirius K-28
Louise O-25
Kristoffer Bay B-06
Jackson G-16A
Cape Allison C-47
Char G-07
Grenadier A-26
60 km
50 km
35 km
40 km
25 km
20 km
Aalenian 3rd Order Sequence
Toarcian 3rd Order Sequence
Pliensbachian 3rd Order
100
Metres
0
Shallow Shelf
Offshore Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact
ELLEF
RINGNES
ISLAND
K-28
O-25
B-06
G-16A
C-47
G-07
A-26
100°
105°
50 KM



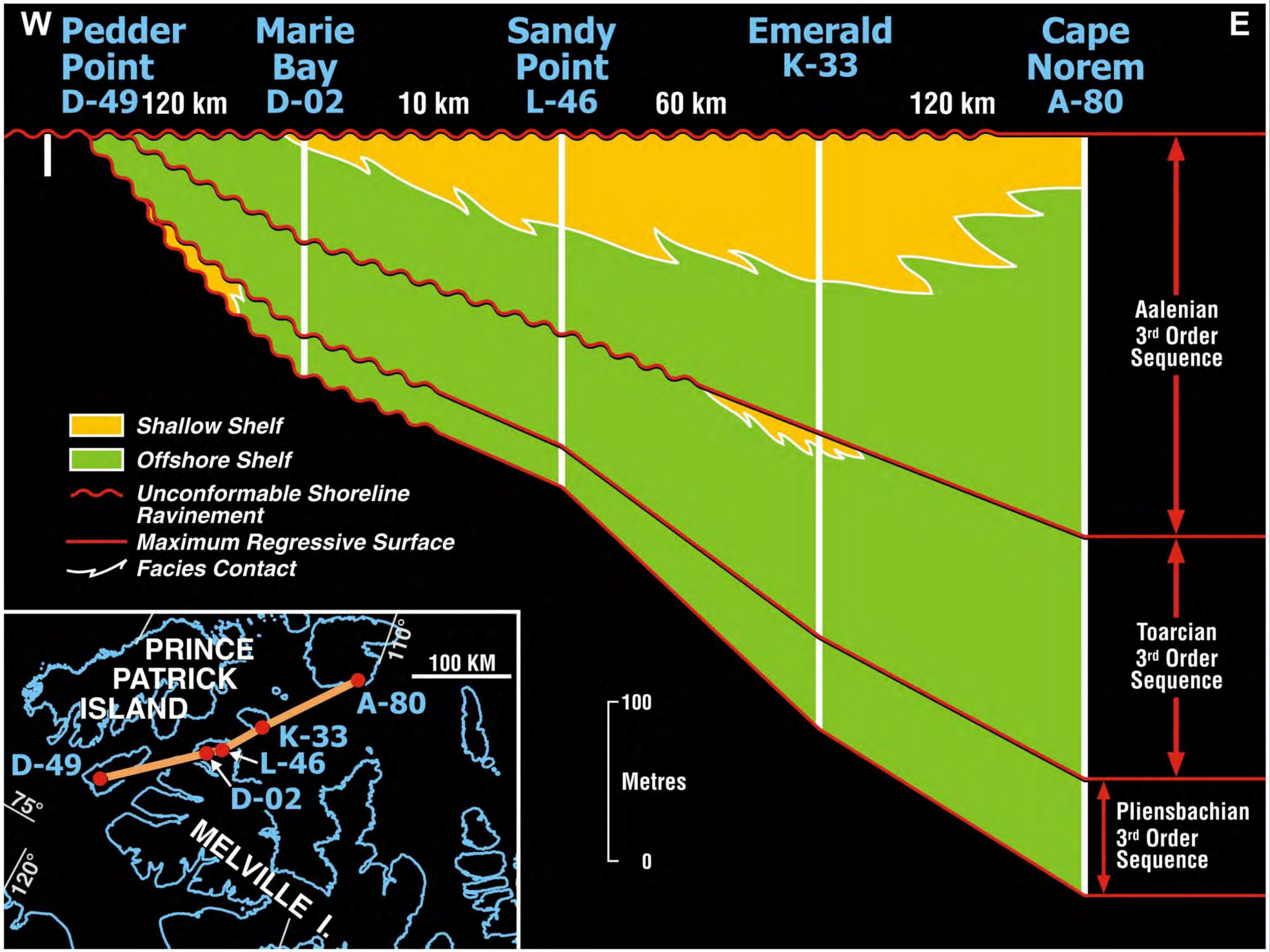
Reindeer Peninsula, NW Ellef Ringnes Island

Mocklin Point D-23



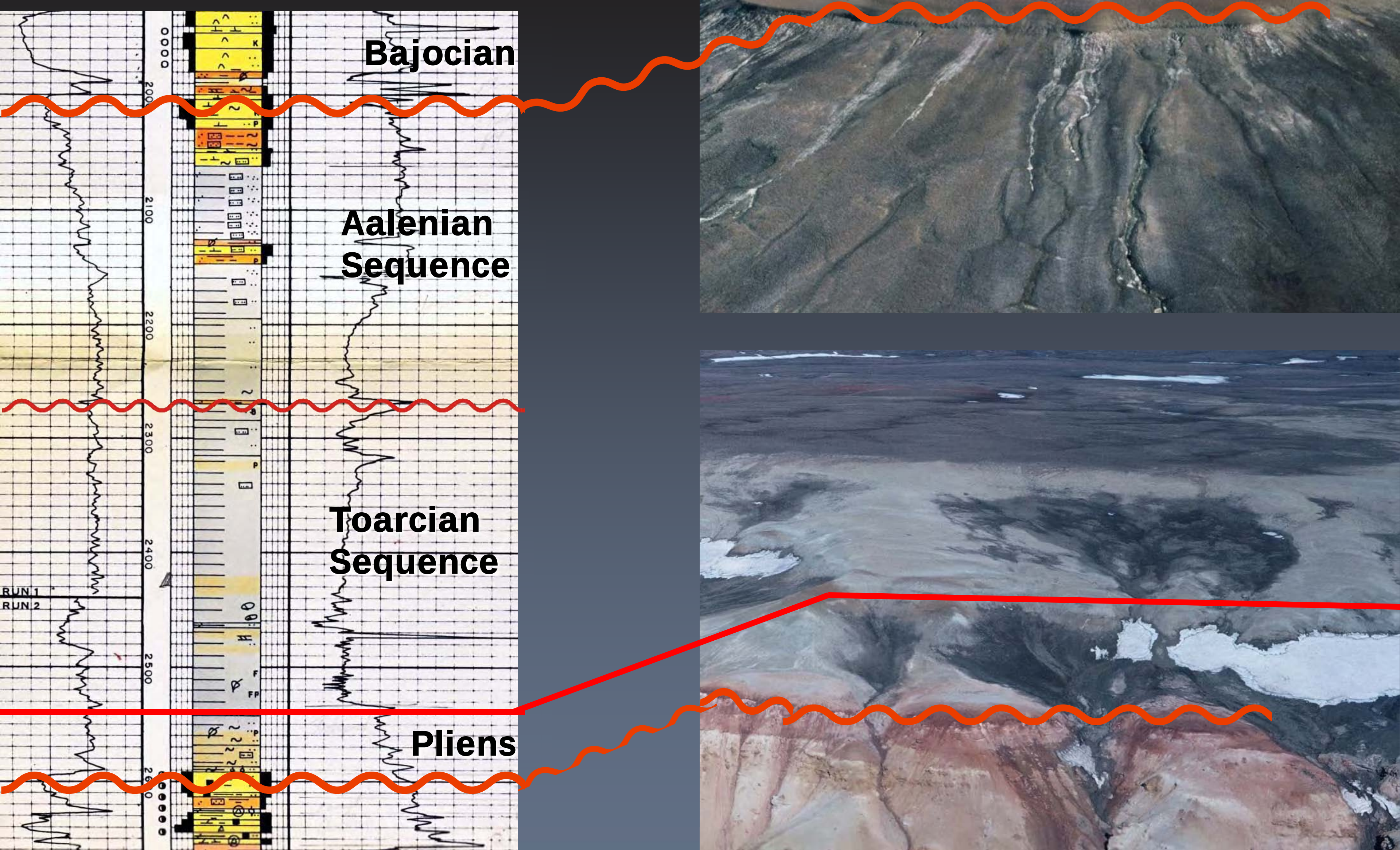


Southwest Basin Cross Section
Pliensbachian-Aalenian 2nd Order Sequence

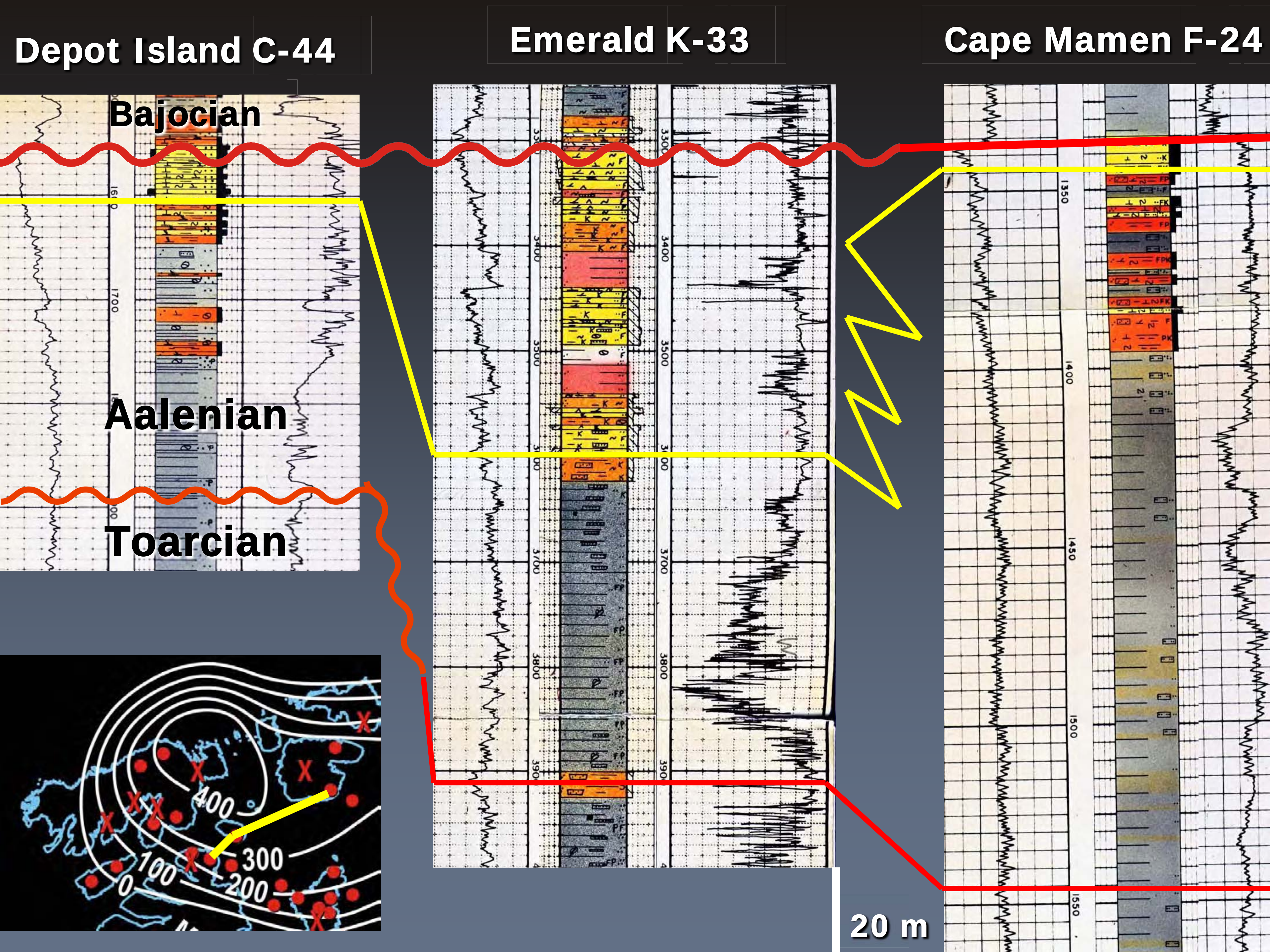


W
E
Pedder Point D-49
120 km
Marie Bay D-02
10 km
Sandy Point L-46
60 km
Emerald K-33
120 km
Cape Norem A-80
Shallow Shelf
Offshore Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact
Aalenian 3rd Order Sequence
Toarcian 3rd Order Sequence
Pliensbachian 3rd Order Sequence
100
Metres
0
PRINCE PATRICK ISLAND
MELVILLE I.
100 KM
110°
75°
120°
D-49
D-02
L-46
K-33
A-80

Grassy I-34



Sproule Peninsula, NW Melville Island


Depot Island C-44
Emerald K-33
Cape Mamen F-24
Bajocian
Aalenian
Toarcian
1600
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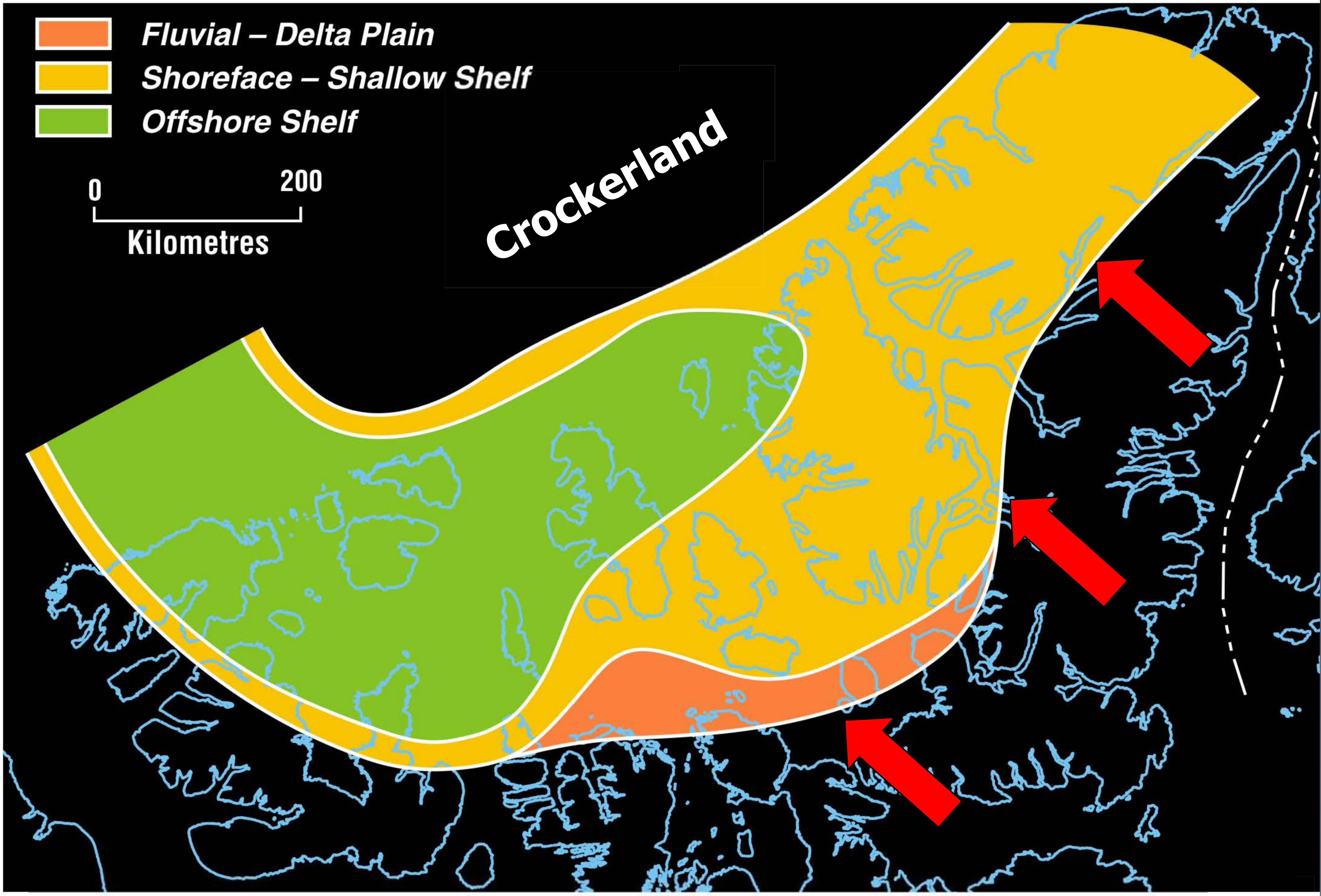
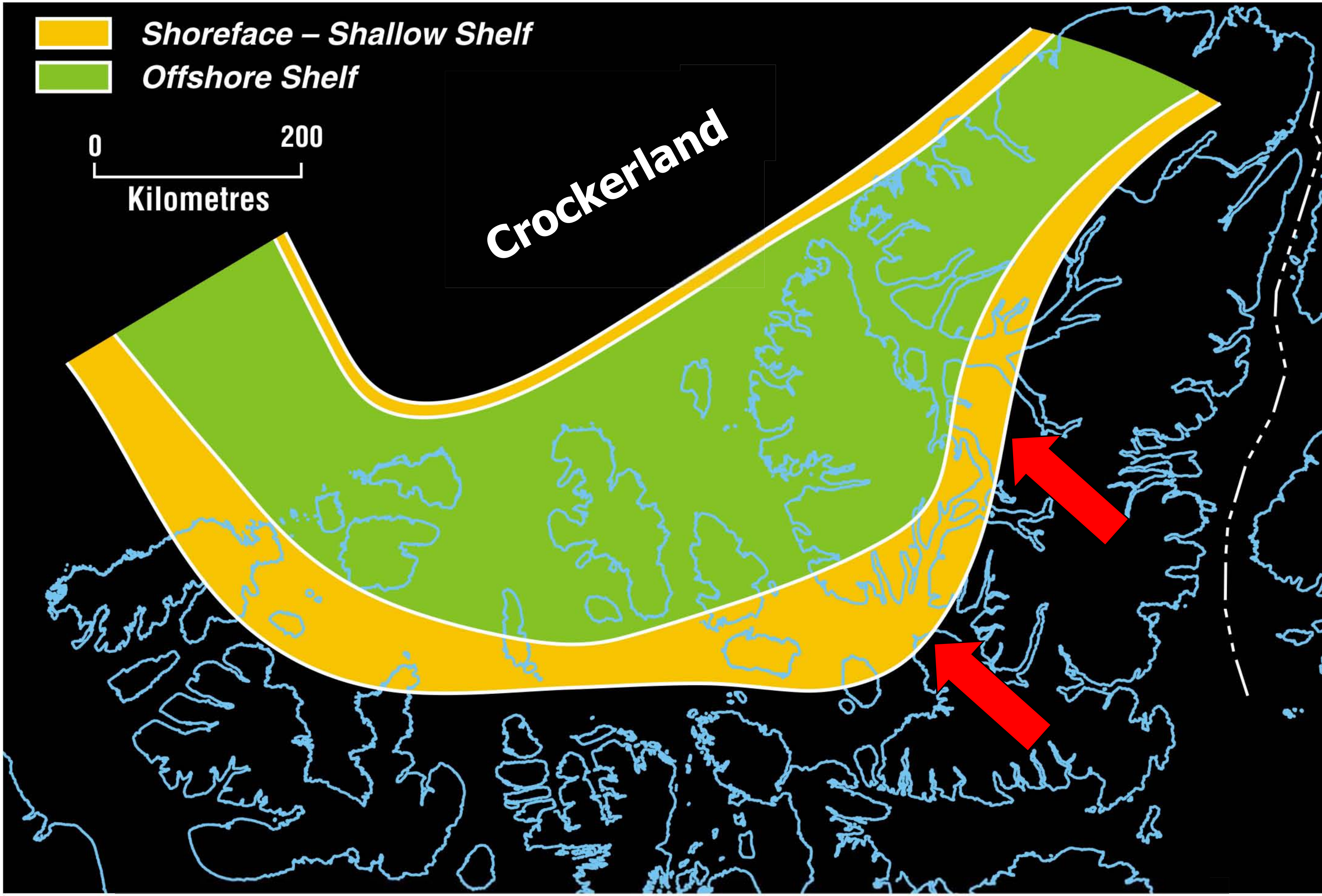
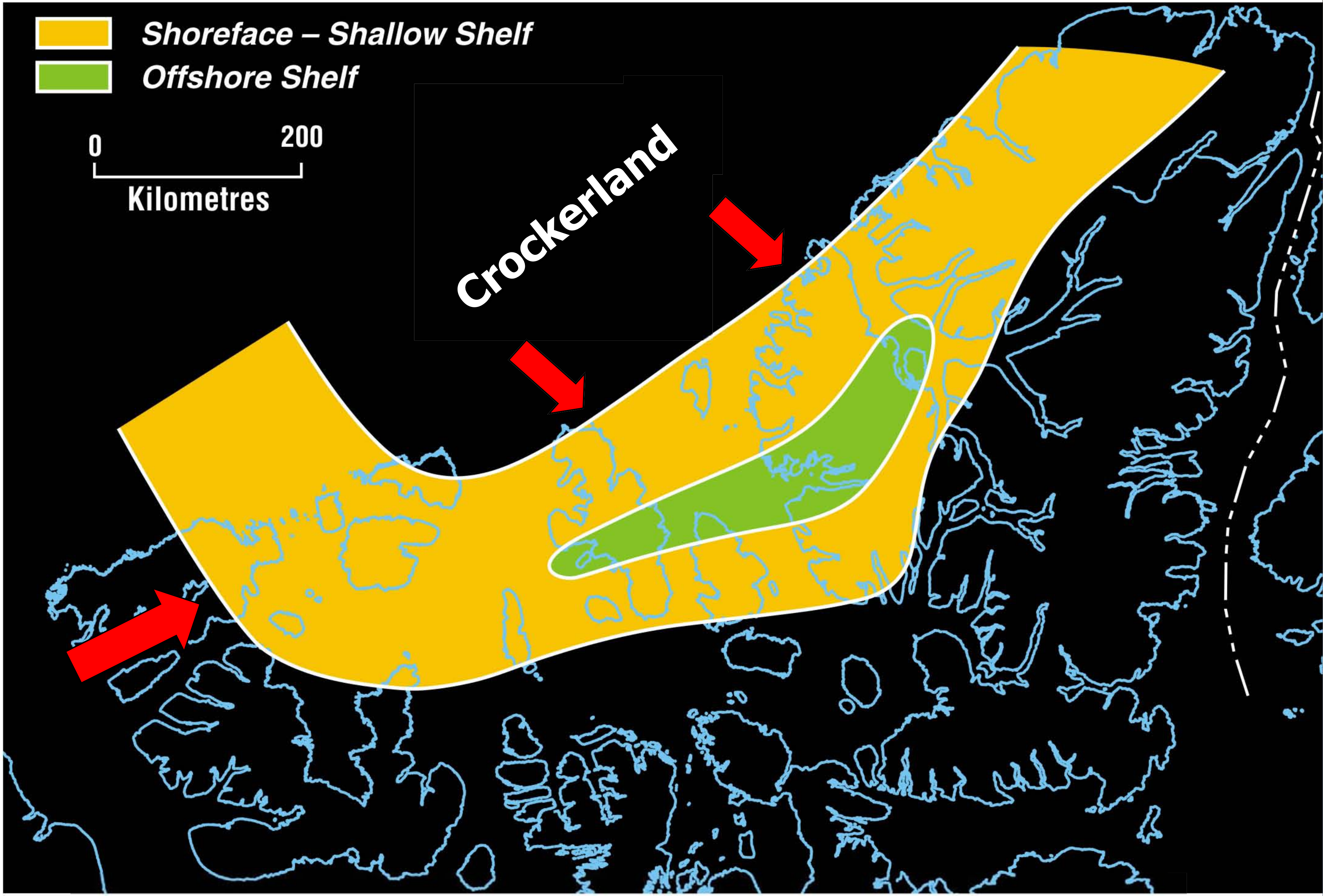


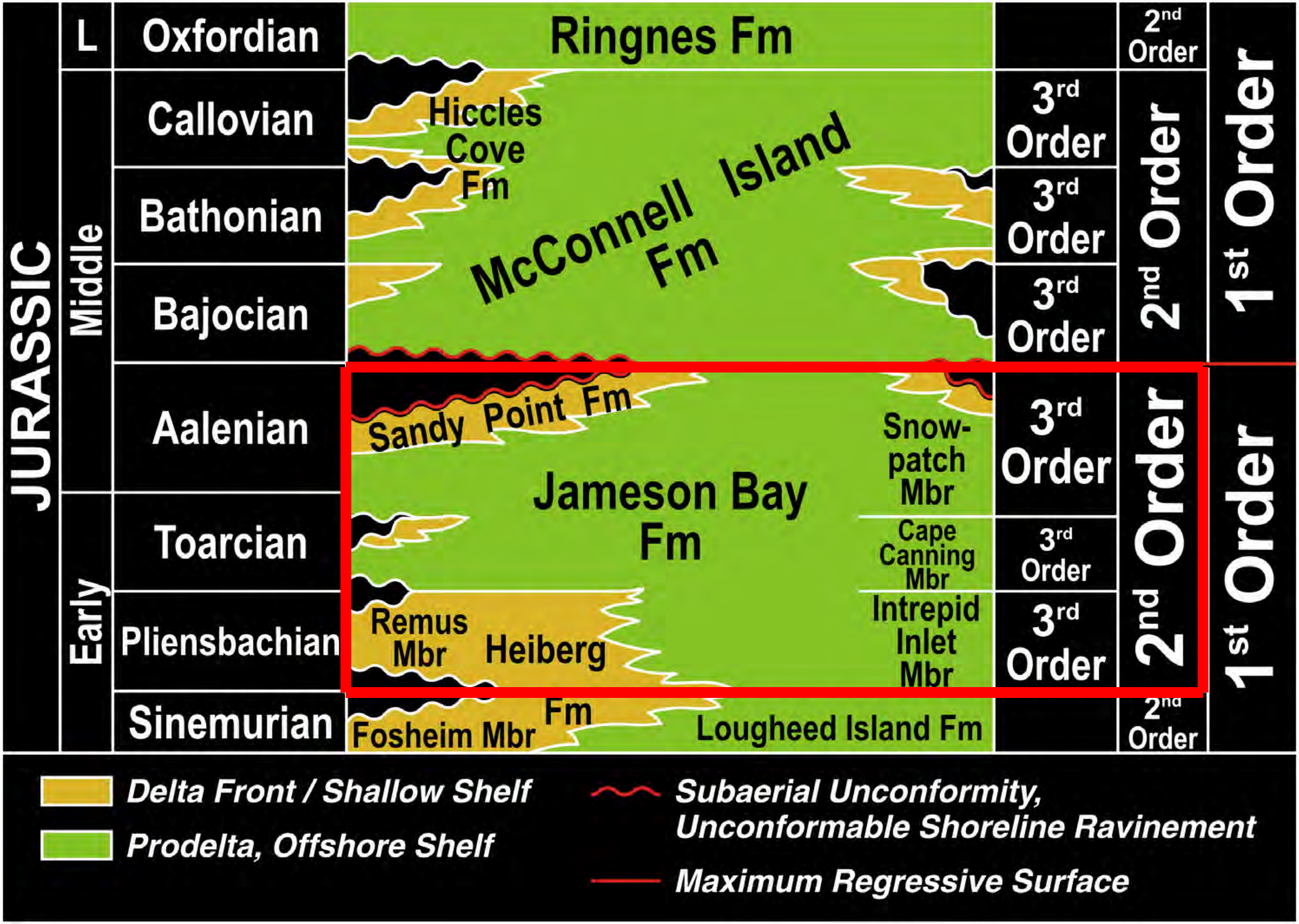
Late Pliensbachian Paleogeography



Late Toarcian Paleogeography



Late Aalenian Paleogeography


JURASSIC
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Middle
Early
Oxfordian
Callovian
Bathonian
Bajocian
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Toarcian
Pliensbachian
Sinemurian
Ringnes Fm
Hiccles Cove Fm
McConnell Island Fm
Sandy Point Fm
Jameson Bay Fm
Snow-patch Mbr
Cape Canning Mbr
Intrepid Inlet Mbr
Remus Mbr
Heiberg Fm
Fosheim Mbr
Lougheed Island Fm
2nd Order
3rd Order
3rd Order
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3rd Order
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1st Order
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Delta Front / Shallow Shelf
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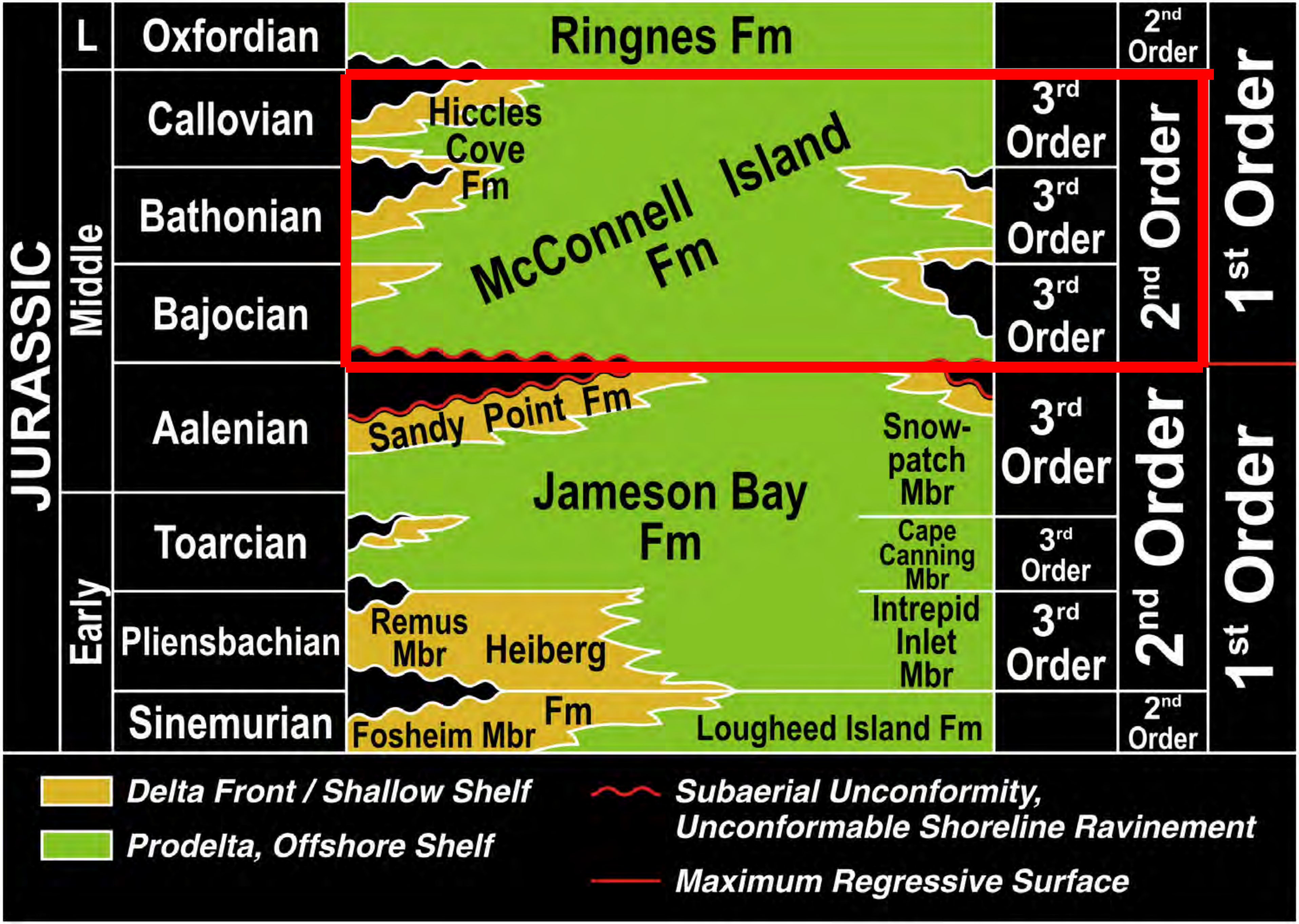
Subaerial Unconformity, Unconformable Shoreline Ravinement
Maximum Regressive Surface


JURASSIC
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Ringnes Fm
Hiccles Cove Fm
McConnell Island Fm
Sandy Point Fm
Snow-patch Mbr
Jameson Bay Fm
Cape Canning Mbr
Intrepid Inlet Mbr
Remus Mbr
Heiberg Fm
Fosheim Mbr
Lougheed Island Fm
2nd Order
3rd Order
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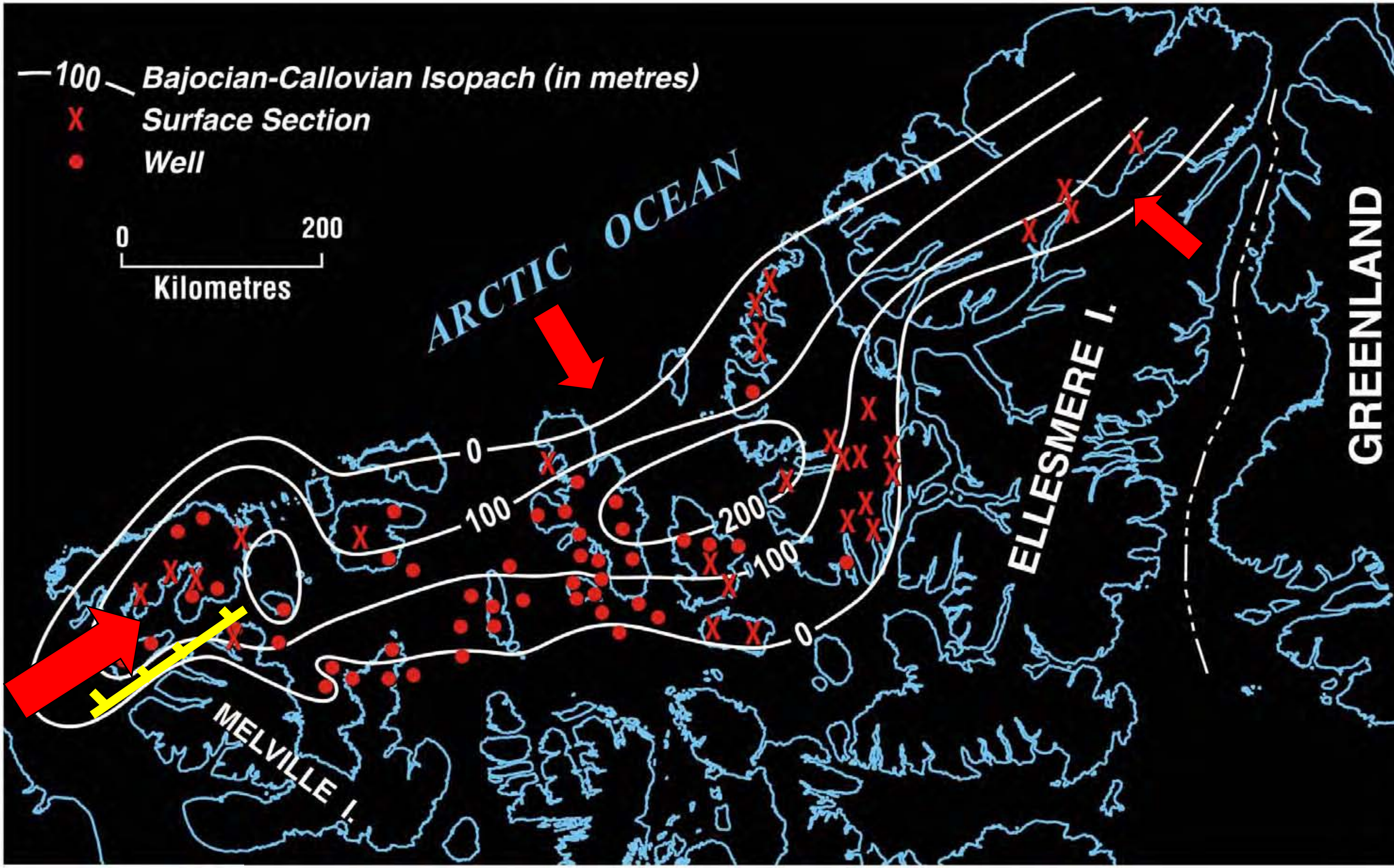
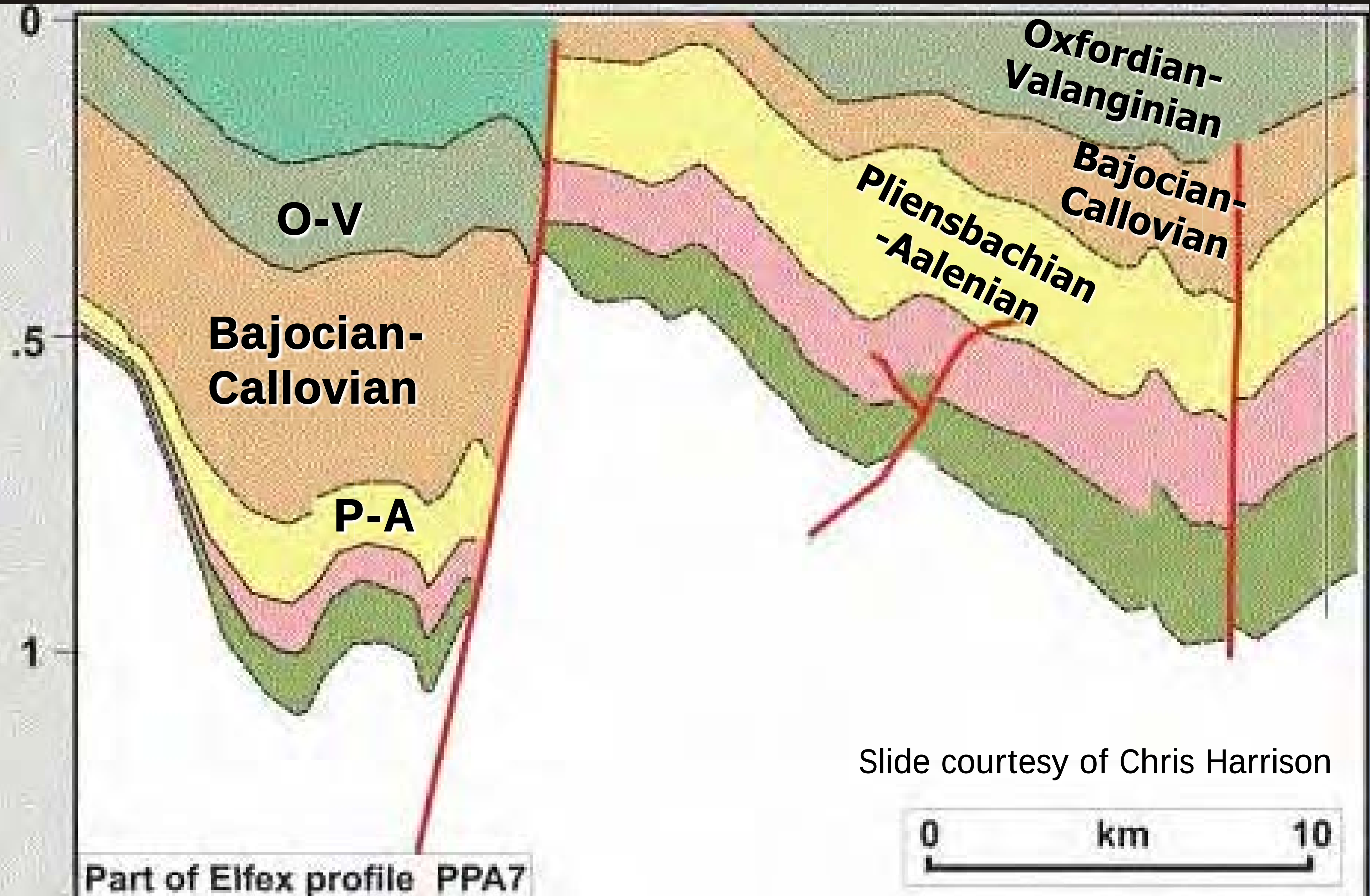
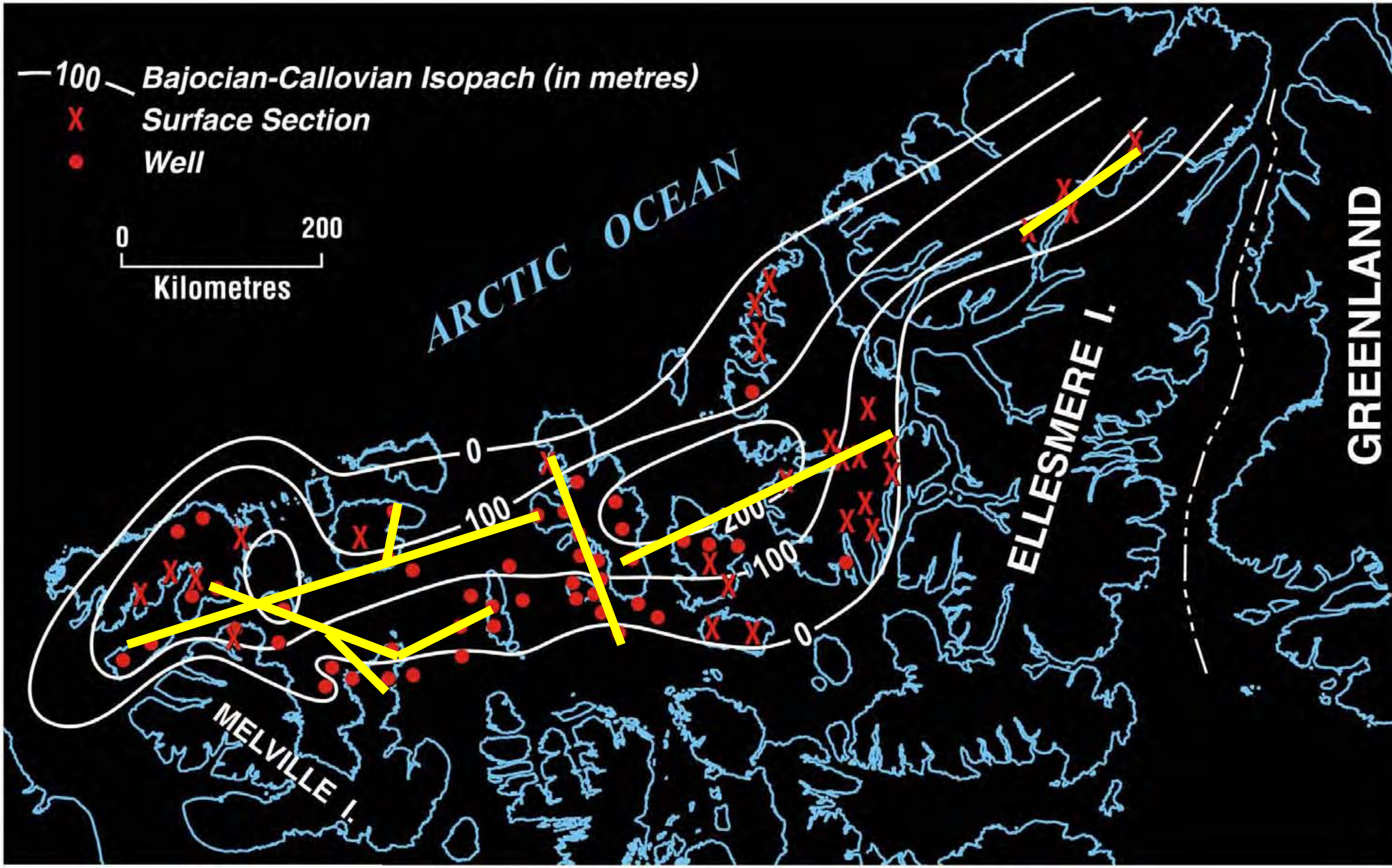


Isopach and Input Centres

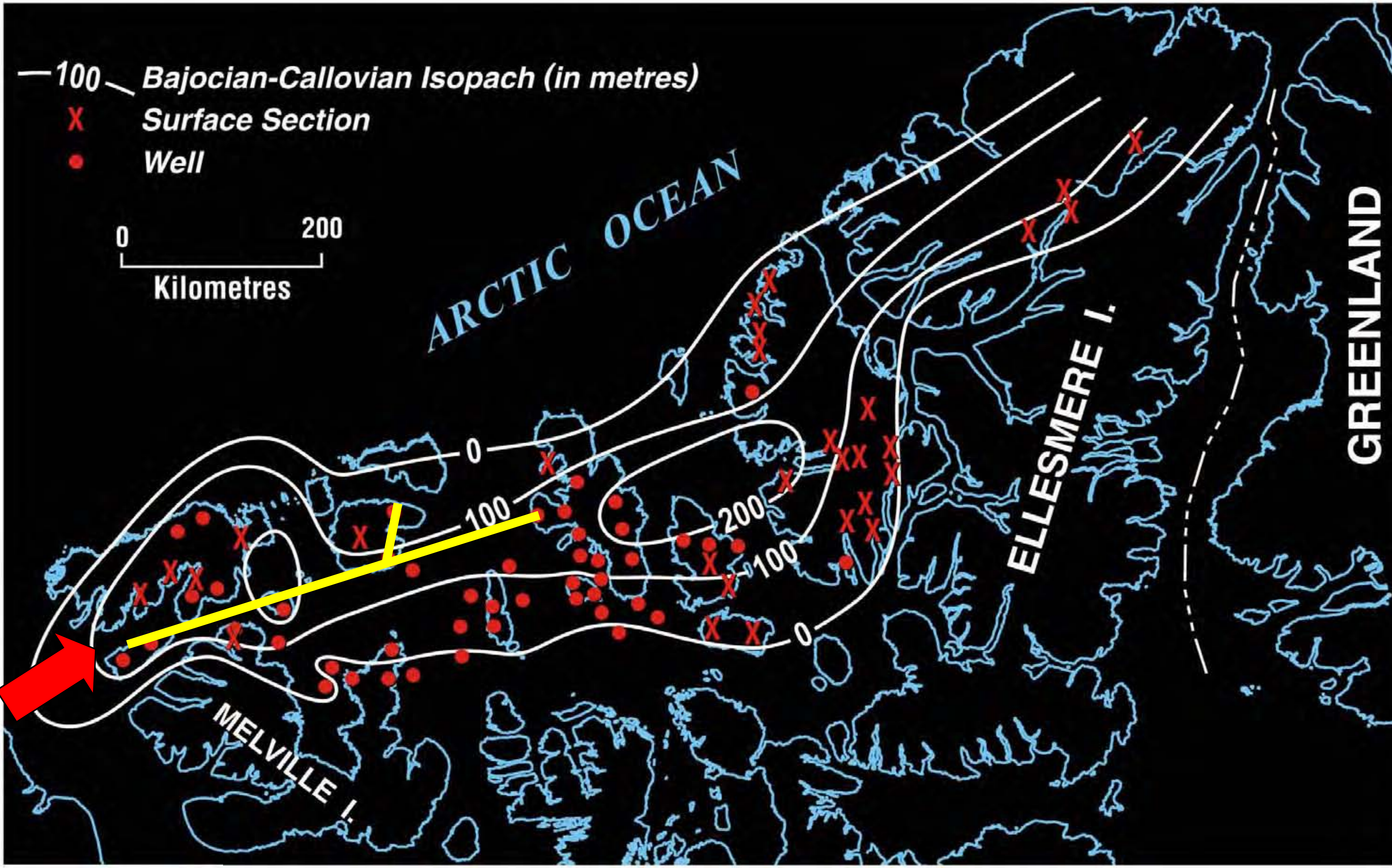
Bajocian - Callovian 2nd Order Sequence



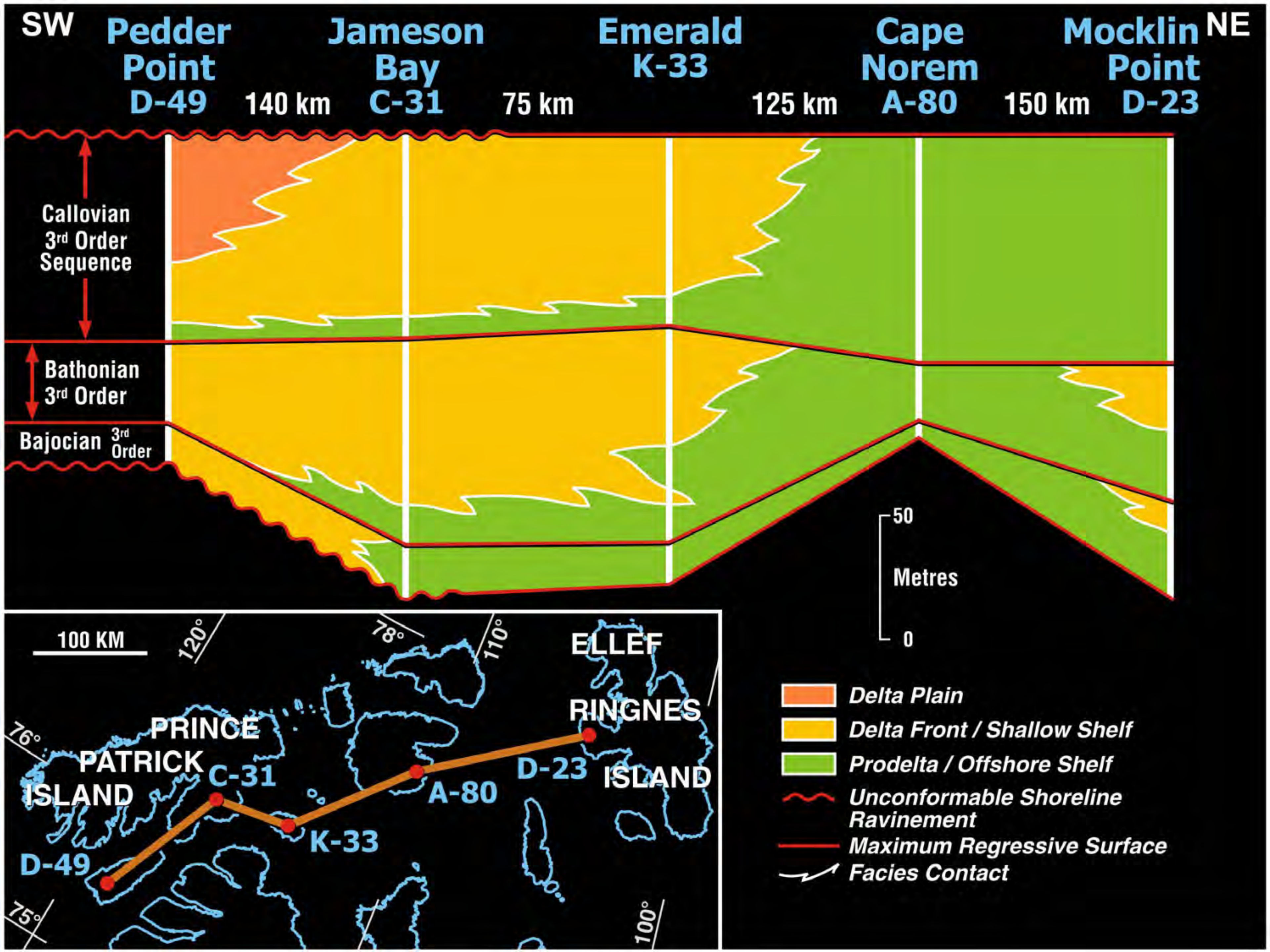
North-South Rifting Began at base Bajocian on Prince Patrick Island



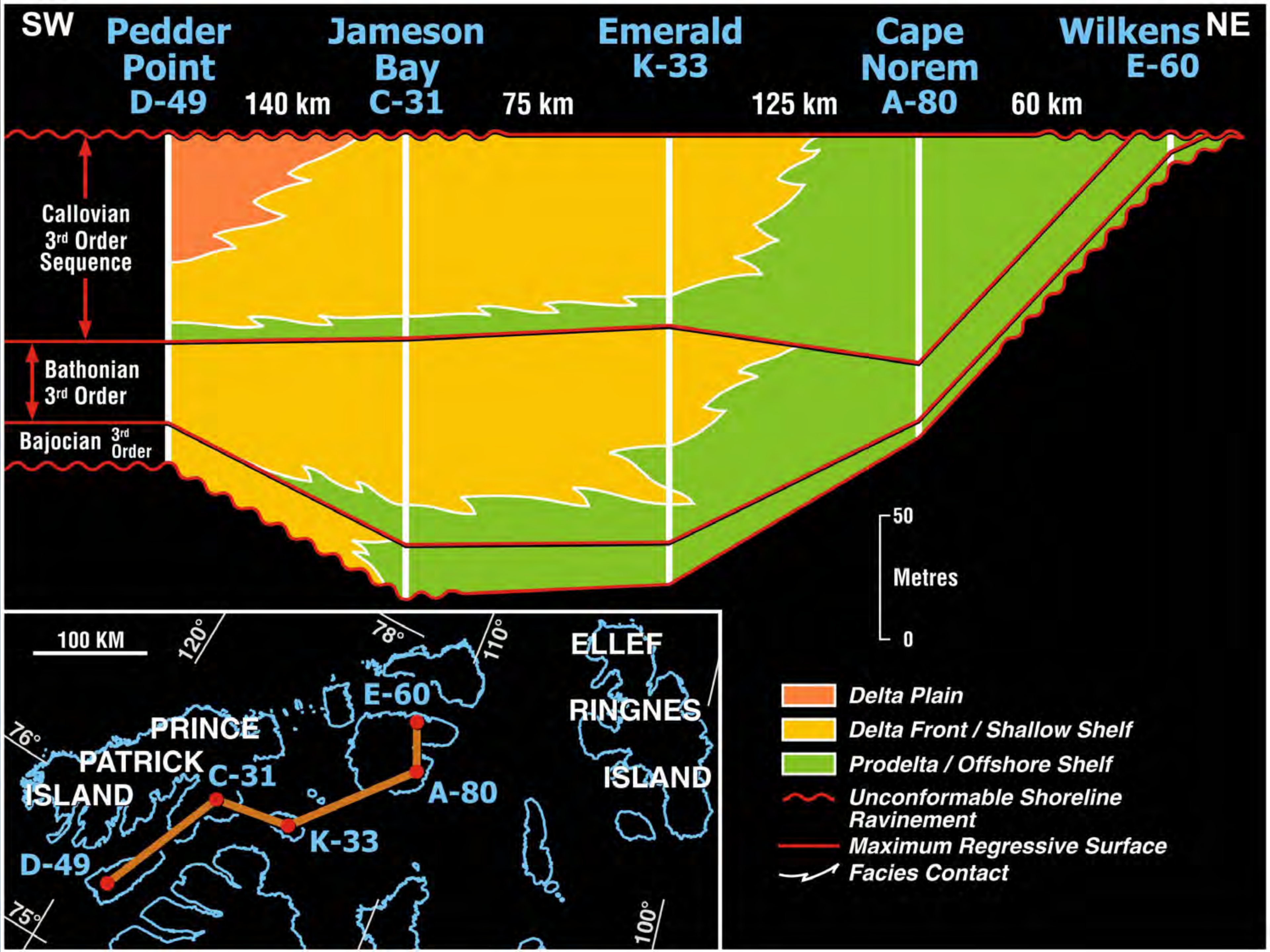
Cross Sections for Bajocian - Callovian 2nd Order Sequence

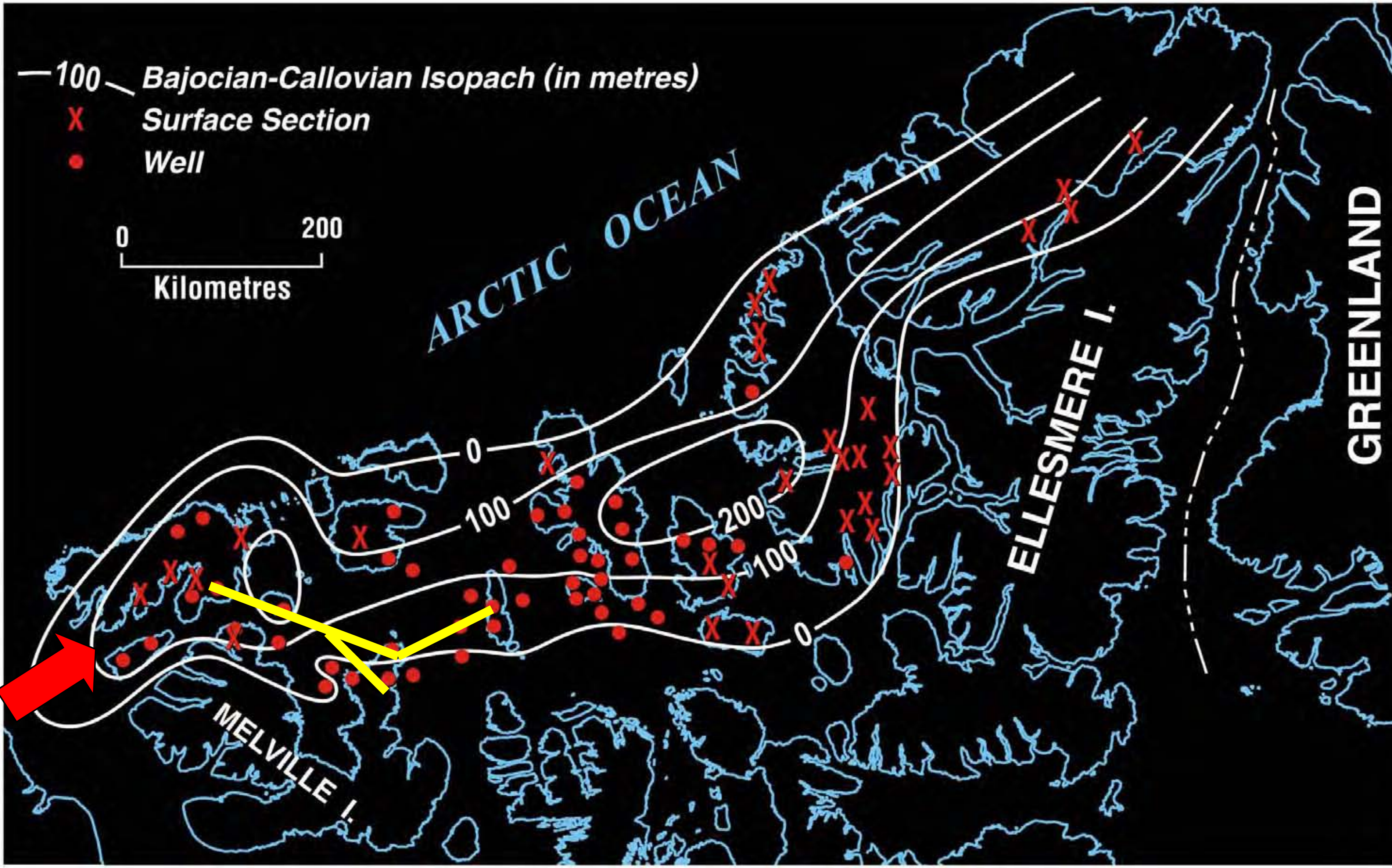


Southwestern Cross Section
Bajocian - Callovian 2nd Order Sequence

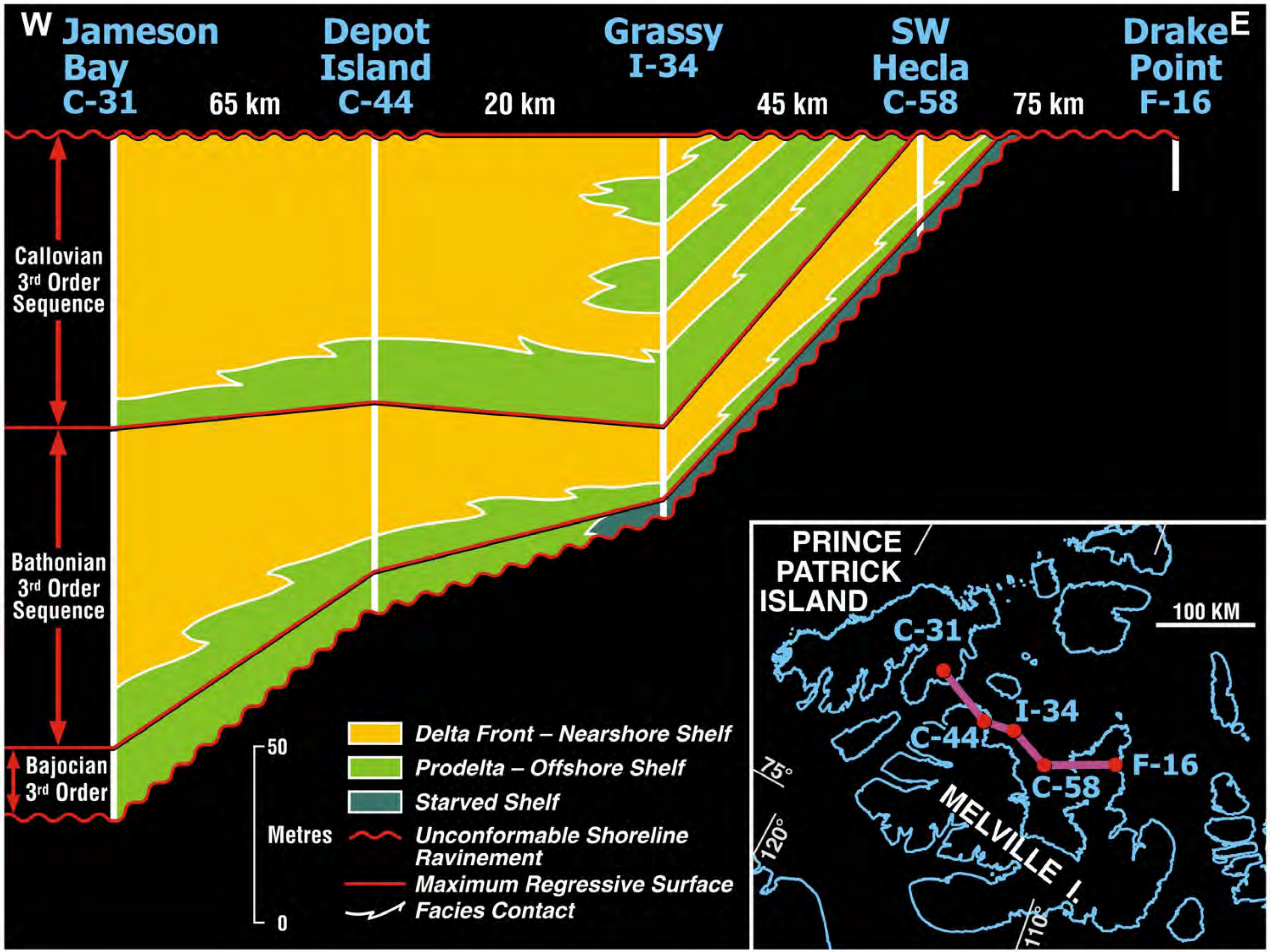


SW
Pedder Point D-49
140 km
Jameson Bay C-31
75 km
Emerald K-33
125 km
Cape Norem A-80
150 km
Mocklin Point D-23
NE
Callovian 3rd Order Sequence
Bathonian 3rd Order
Bajocian 3rd Order
50
Metres
0
100 KM
120°
78°
110°
ELLEF RINGNES ISLAND
PRINCE PATRICK ISLAND
76°
75°
100°
C-31
K-33
A-80
D-23
D-49
Delta Plain
Delta Front / Shallow Shelf
Prodelta / Offshore Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact

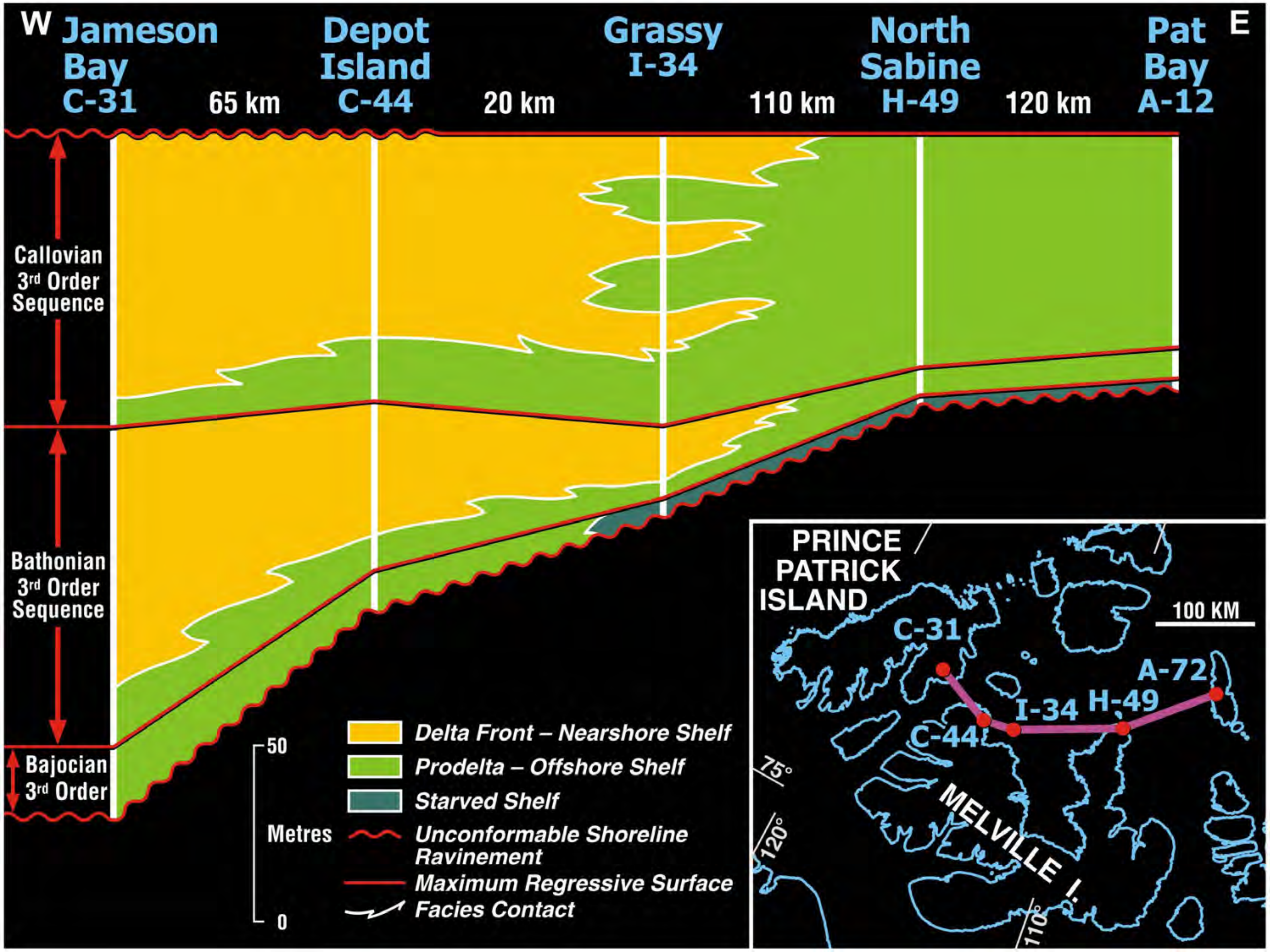

SW
Pedder Point D-49
140 km
Jameson Bay C-31
75 km
Emerald K-33
125 km
Cape Norem A-80
60 km
Wilkens E-60
NE
Callovian 3rd Order Sequence
Bathonian 3rd Order
Bajocian 3rd Order
50
Metres
0
100 KM
120°
78°
110°
76°
75°
100°
ELLEF RINGNES ISLAND
PRINCE PATRICK ISLAND
E-60
C-31
A-80
K-33
D-49
Delta Plain
Delta Front / Shallow Shelf
Prodelta / Offshore Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact

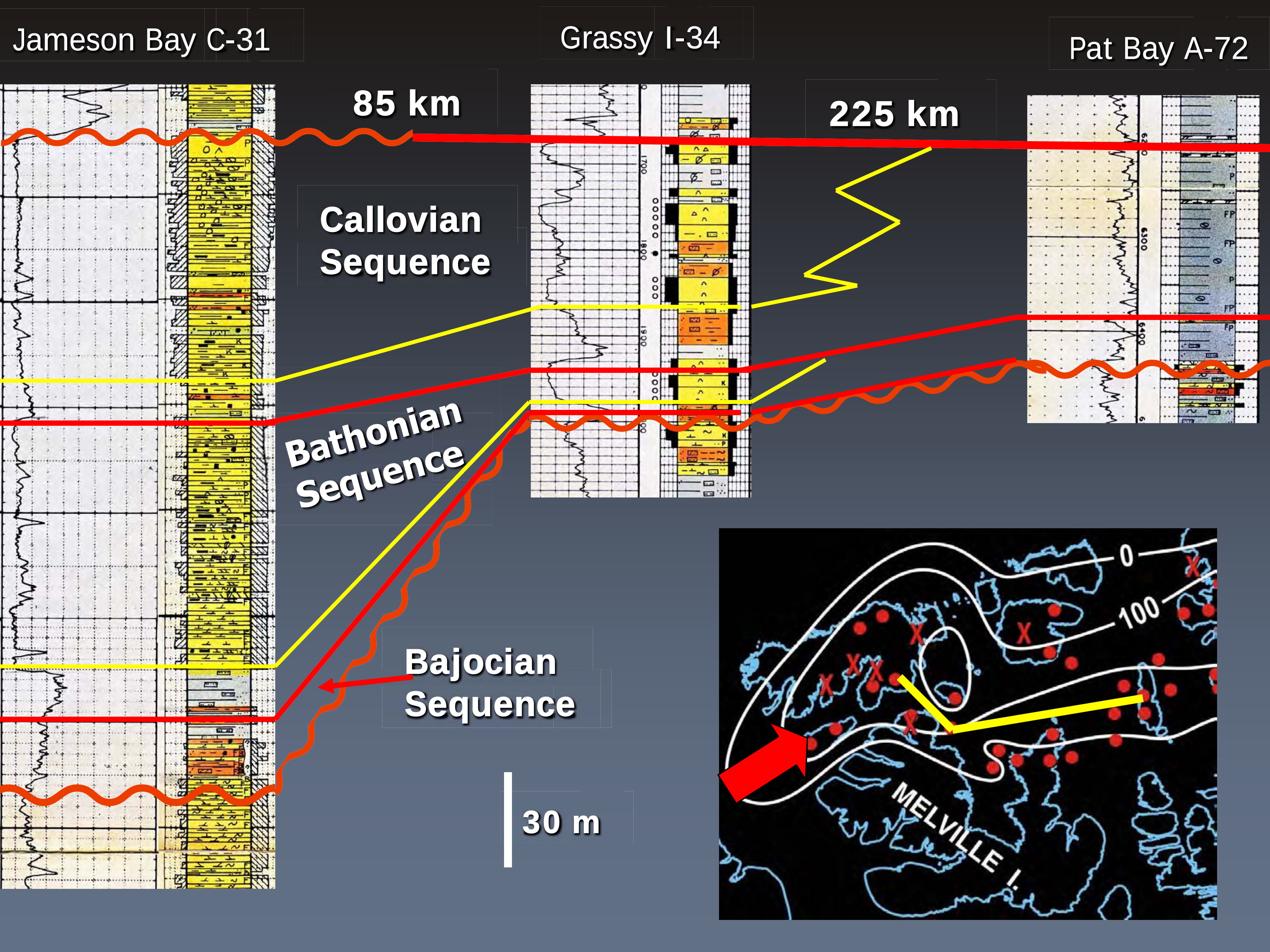


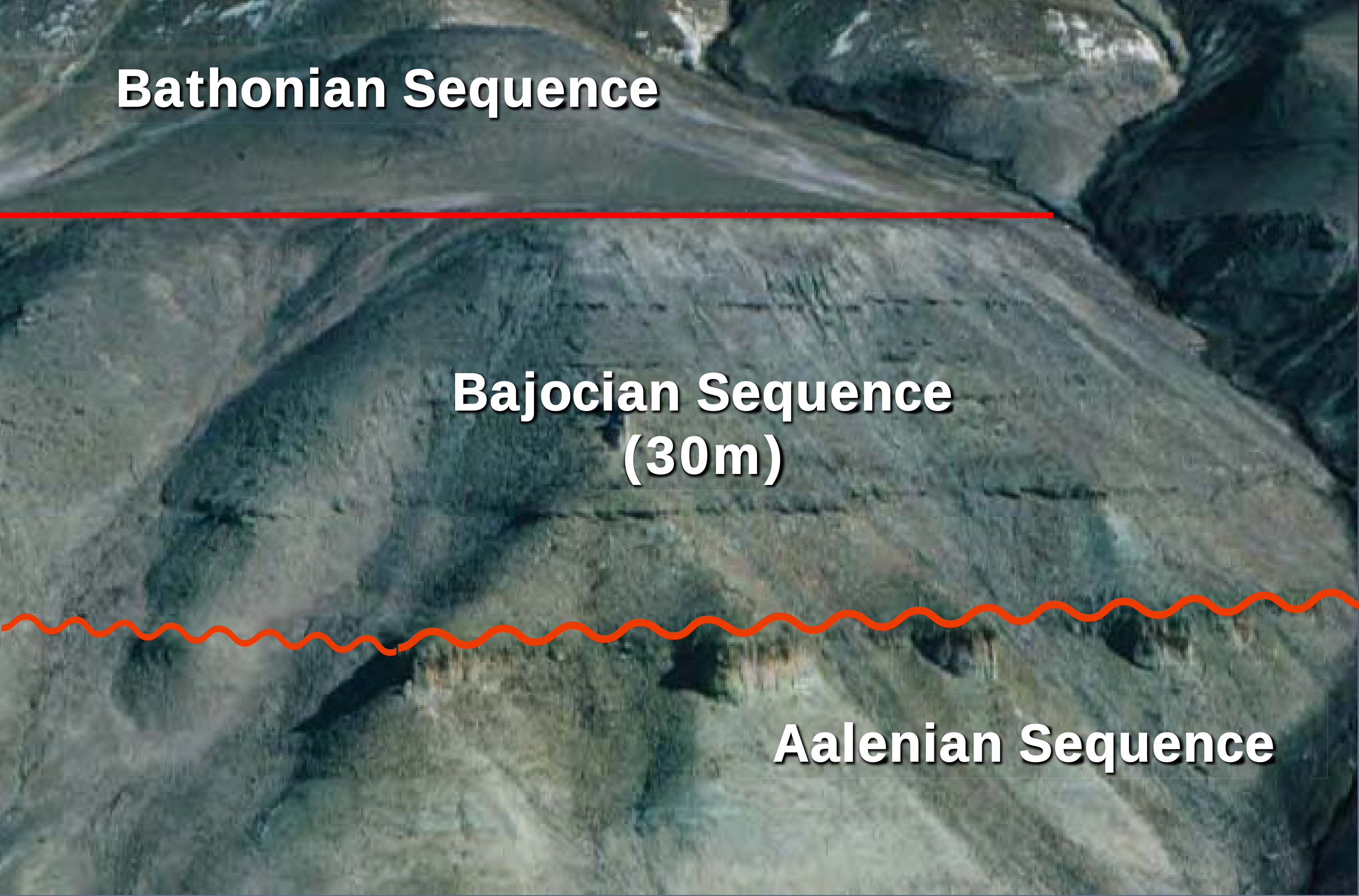
Southwestern Margin Cross Section
Bajocian - Callovian 2nd Order Sequence



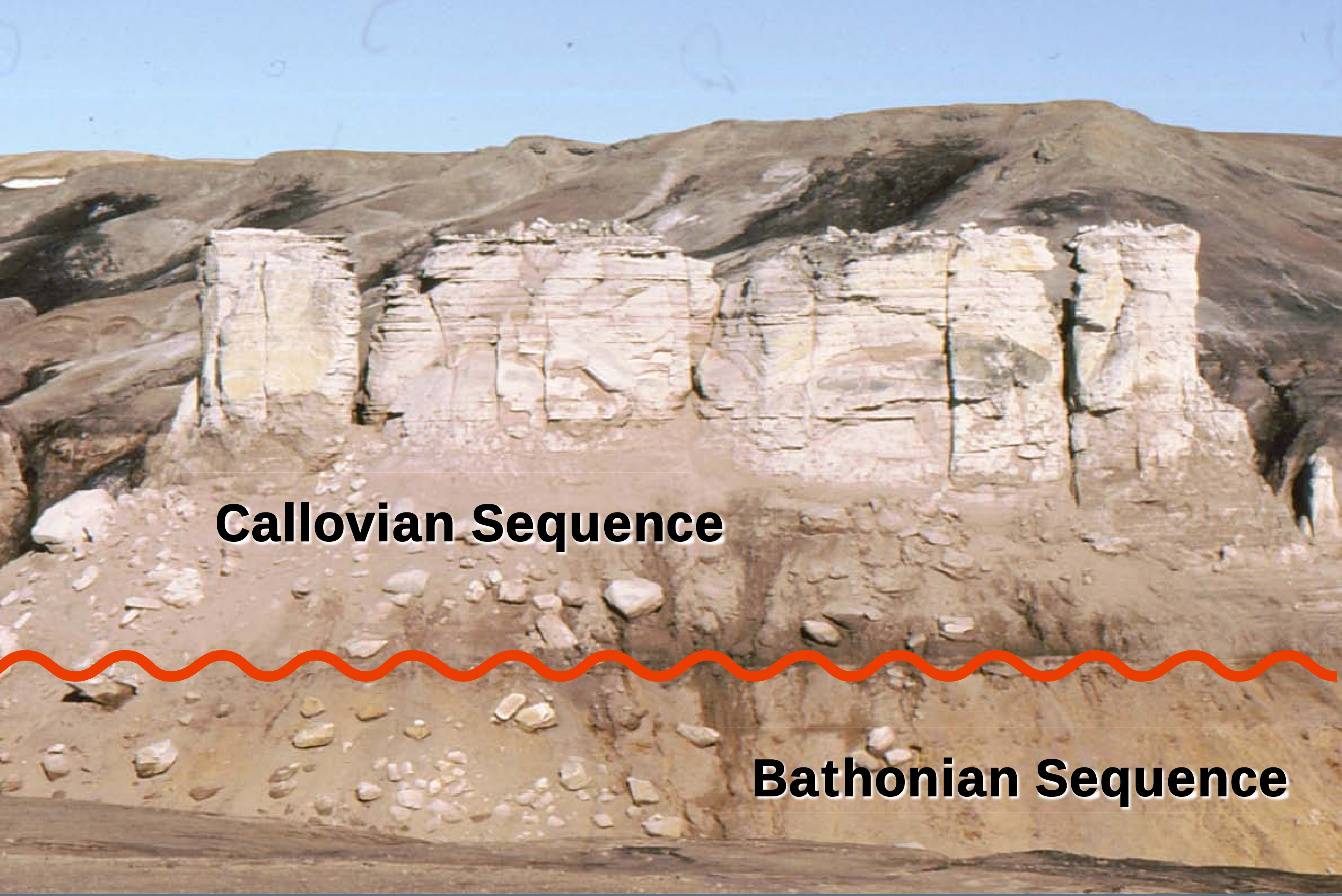
W
Jameson Bay C-31
65 km
Depot Island C-44
20 km
Grassy I-34
45 km
SW Hecla C-58
75 km
Drake Point F-16
E
Callovian 3rd Order Sequence
Bathonian 3rd Order Sequence
Bajocian 3rd Order
50
Metres
0
Delta Front – Nearshore Shelf
Prodelta – Offshore Shelf
Starved Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact
PRINCE PATRICK ISLAND
100 KM
C-31
I-34
C-44
F-16
C-58
MELVILLE I.
75°
120°
110°


W
Jameson Bay C-31
65 km
Depot Island C-44
20 km
Grassy I-34
110 km
North Sabine H-49
120 km
Pat Bay A-12
E
Callovian 3rd Order Sequence
Bathonian 3rd Order Sequence
Bajocian 3rd Order
50
Metres
0
Delta Front – Nearshore Shelf
Prodelta – Offshore Shelf
Starved Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact
PRINCE PATRICK ISLAND
100 KM
C-31
A-72
I-34
H-49
C-44
75°
120°
110°
MELVILLE I.

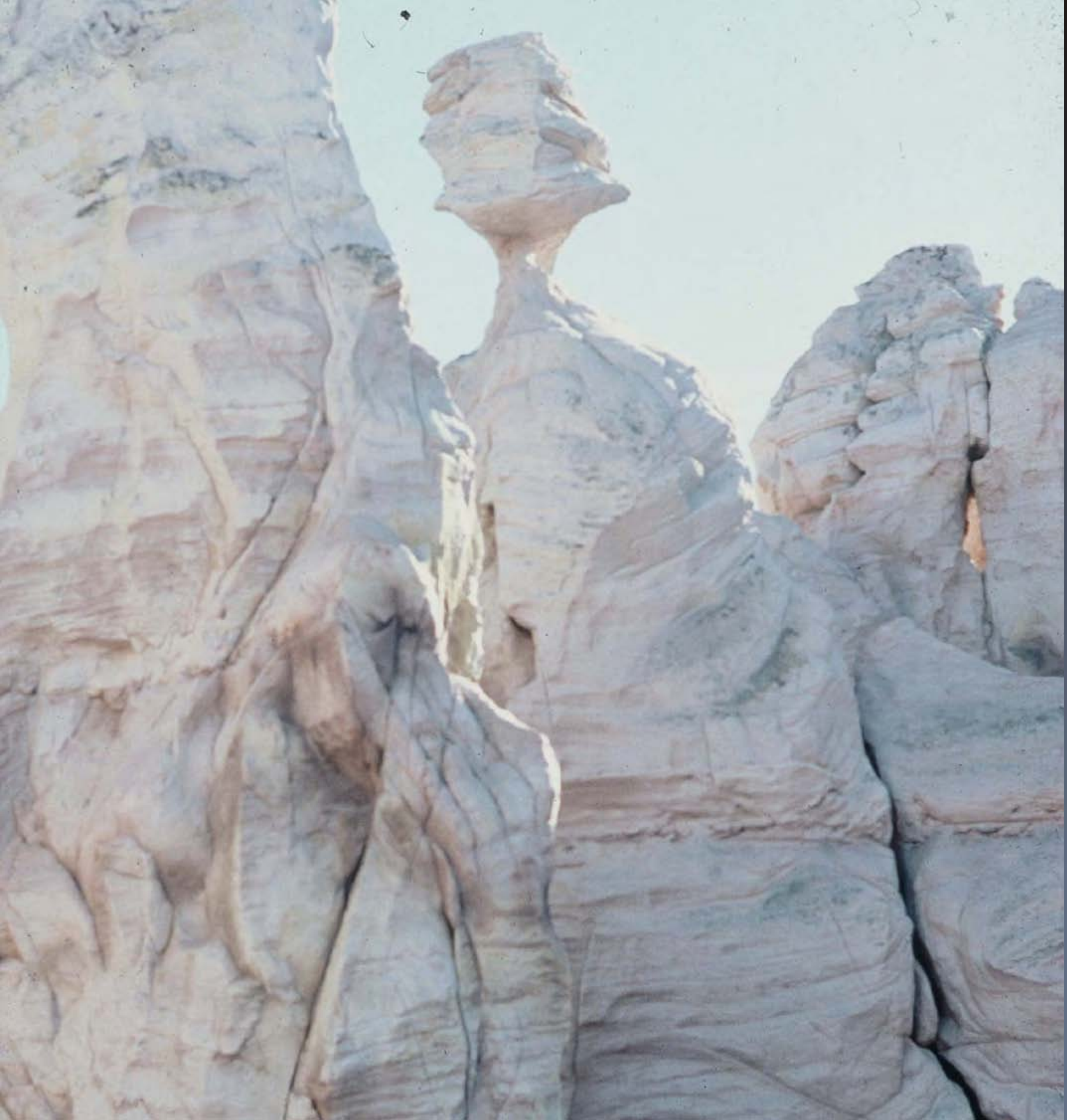

Jameson Bay C-31
Grassy I-34
Pat Bay A-72
85 km
225 km
Callovian Sequence
Bathonian Sequence
Bajocian Sequence
30 m
0
100
MELVILLE I.



Intrepid Inlet, Prince Patrick Island

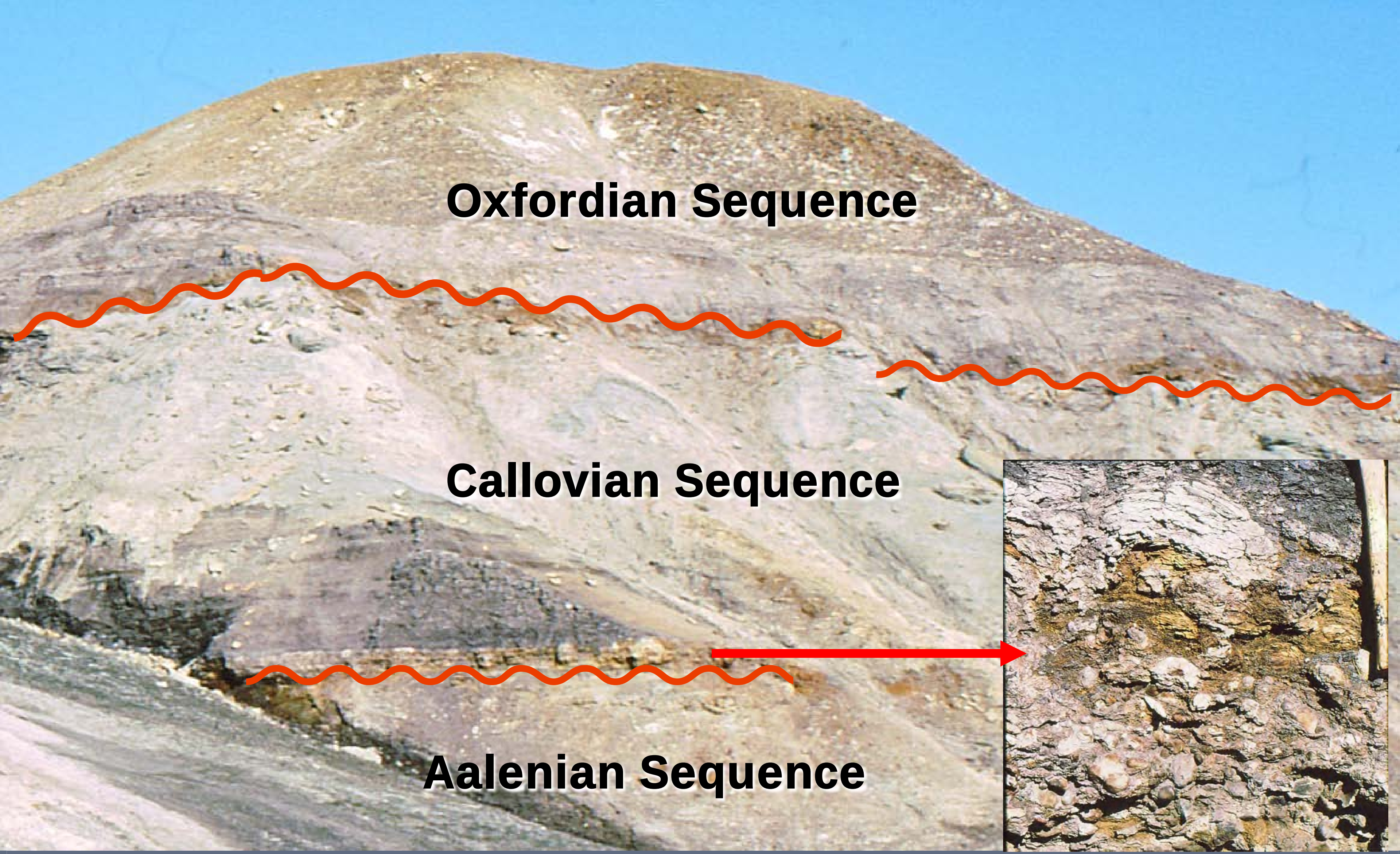


Sproule Peninsula, Northwest Melville Island

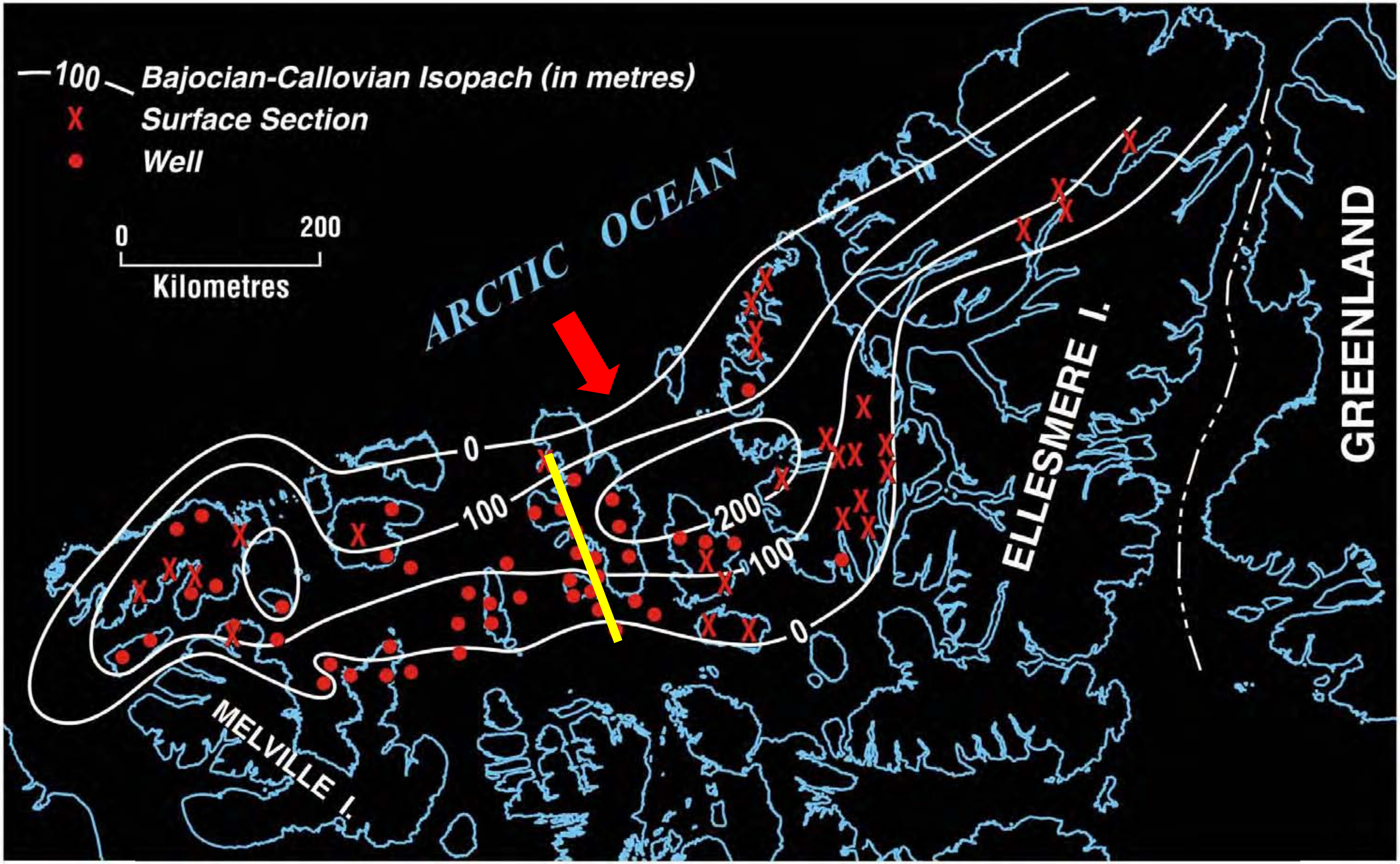


Hoodoo of delta front sandstone, Callovian Sequence, Sproule Peninsula, NW Melville Island

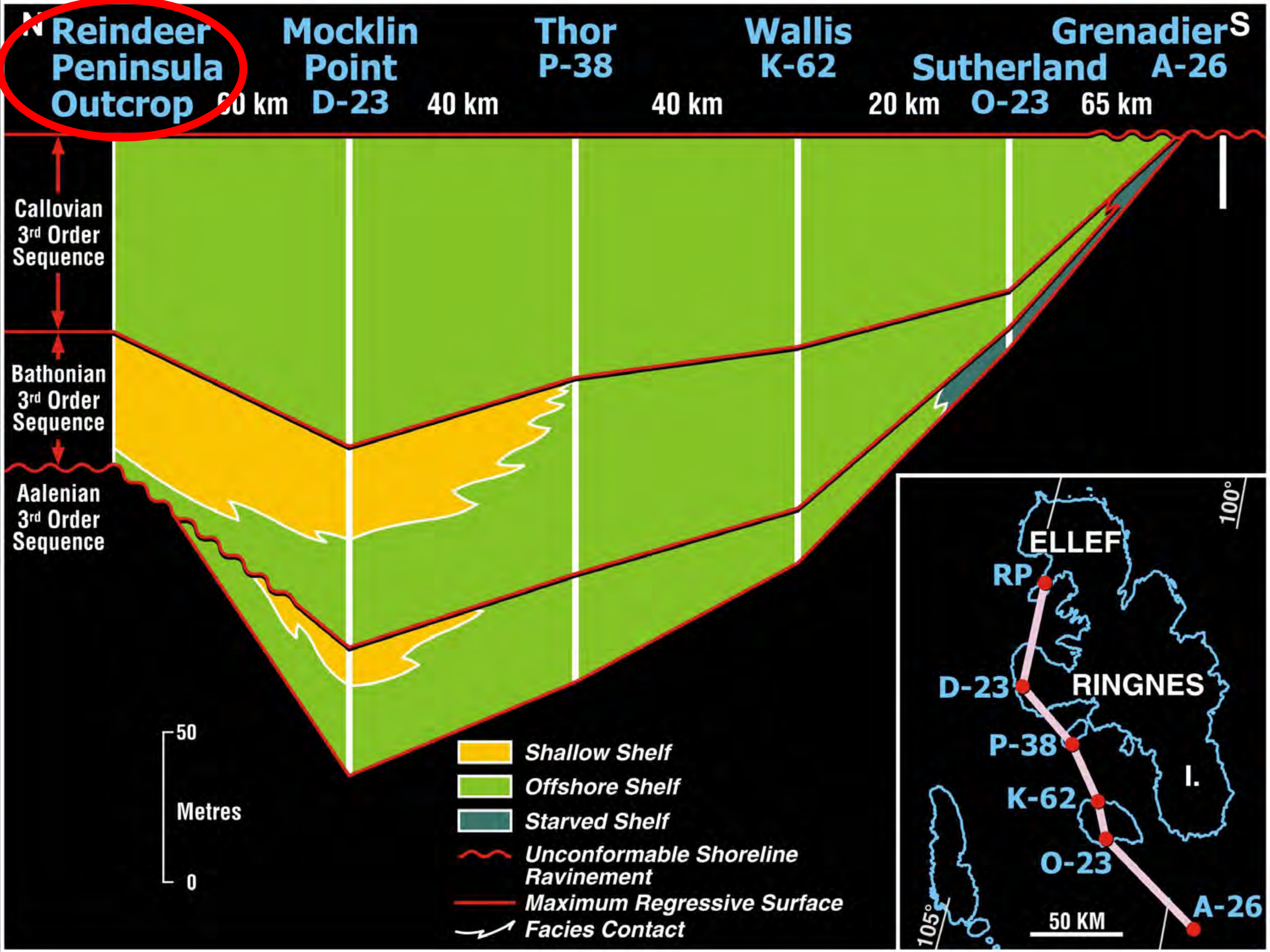
Sproule Peninsula, NW Melville Island



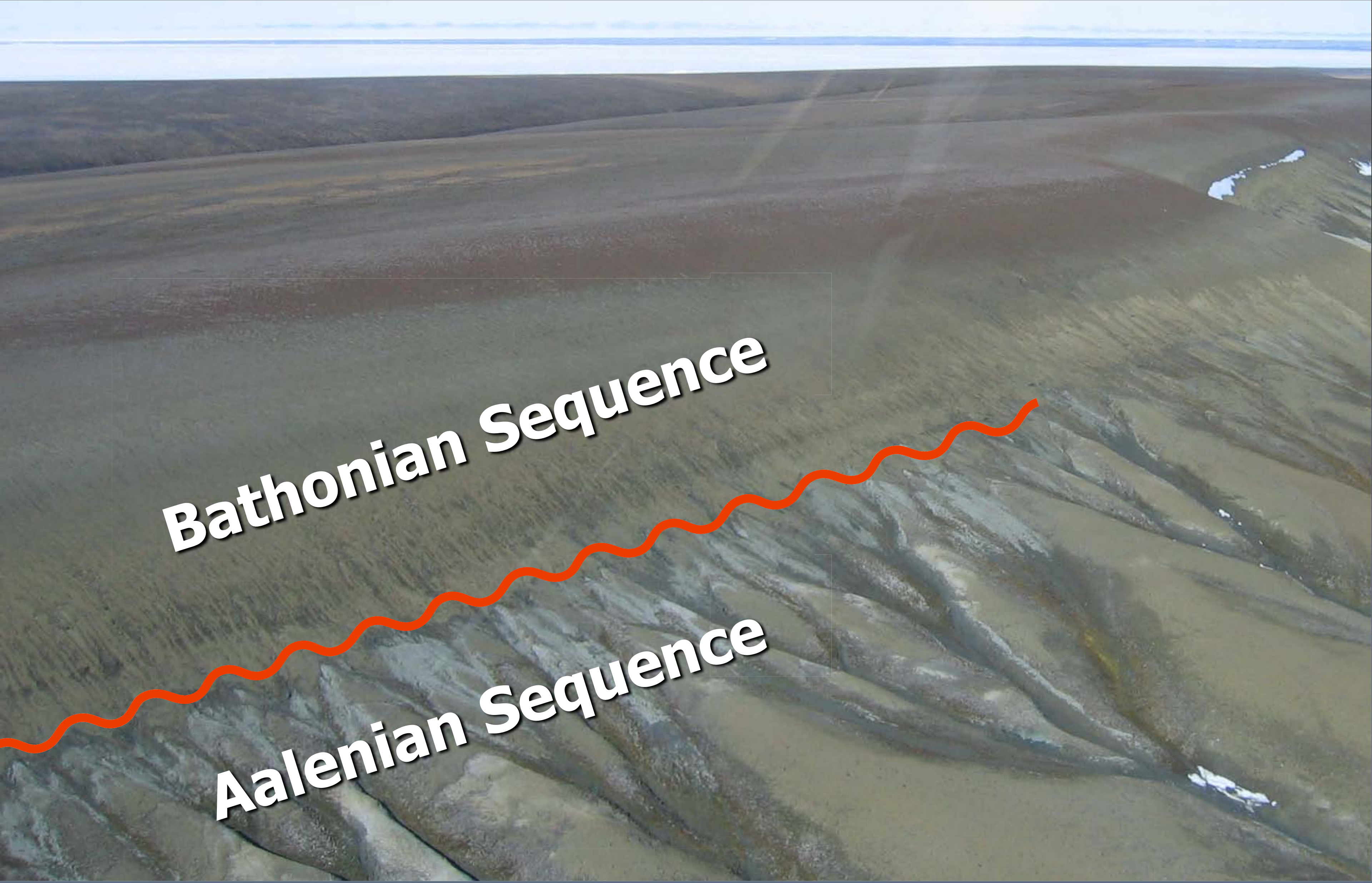
East Kitson River, NW Melville Island



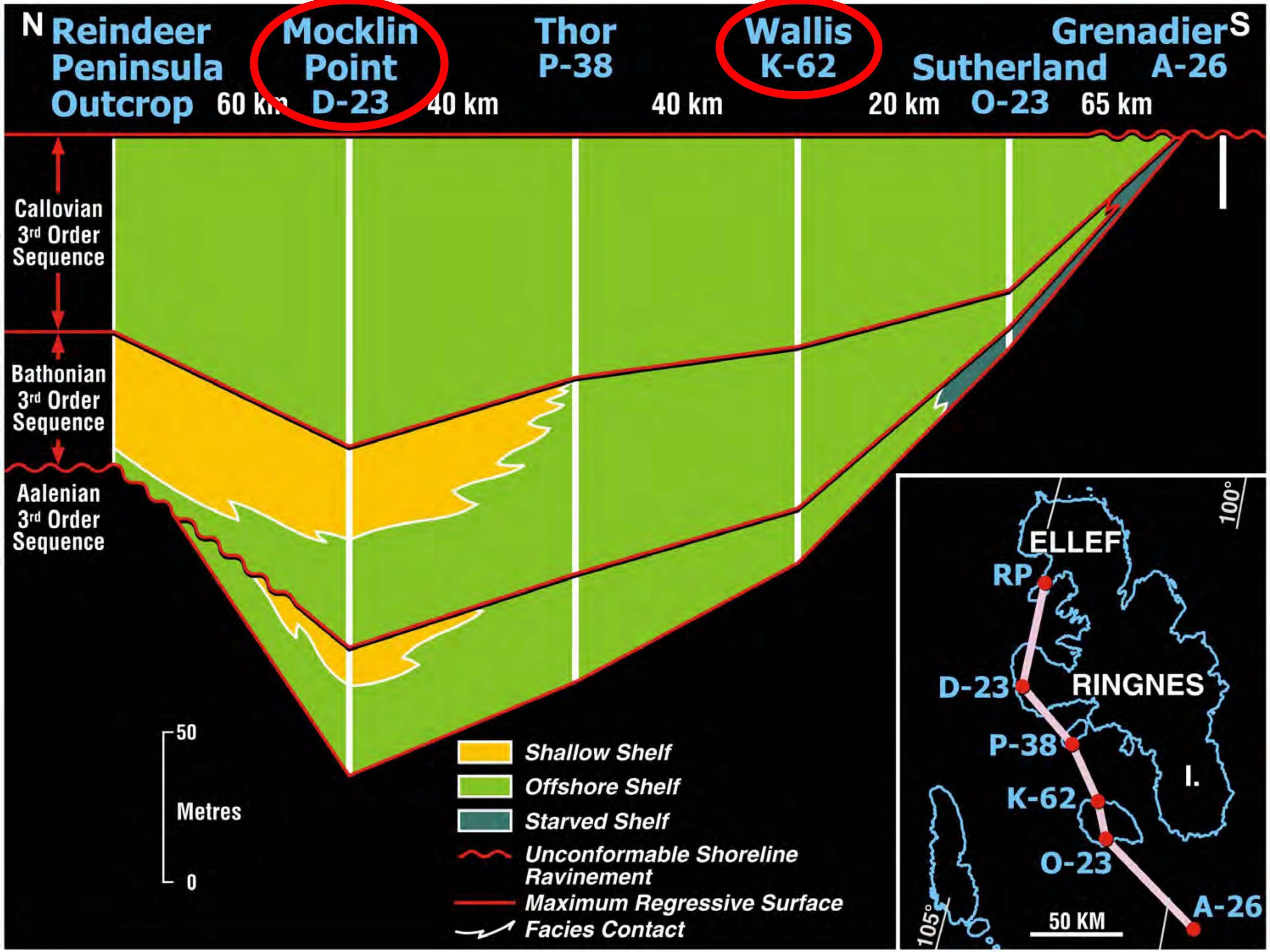
Ellef Ringnes Island Cross Section
Bajocian - Callovian 2nd Order Sequence

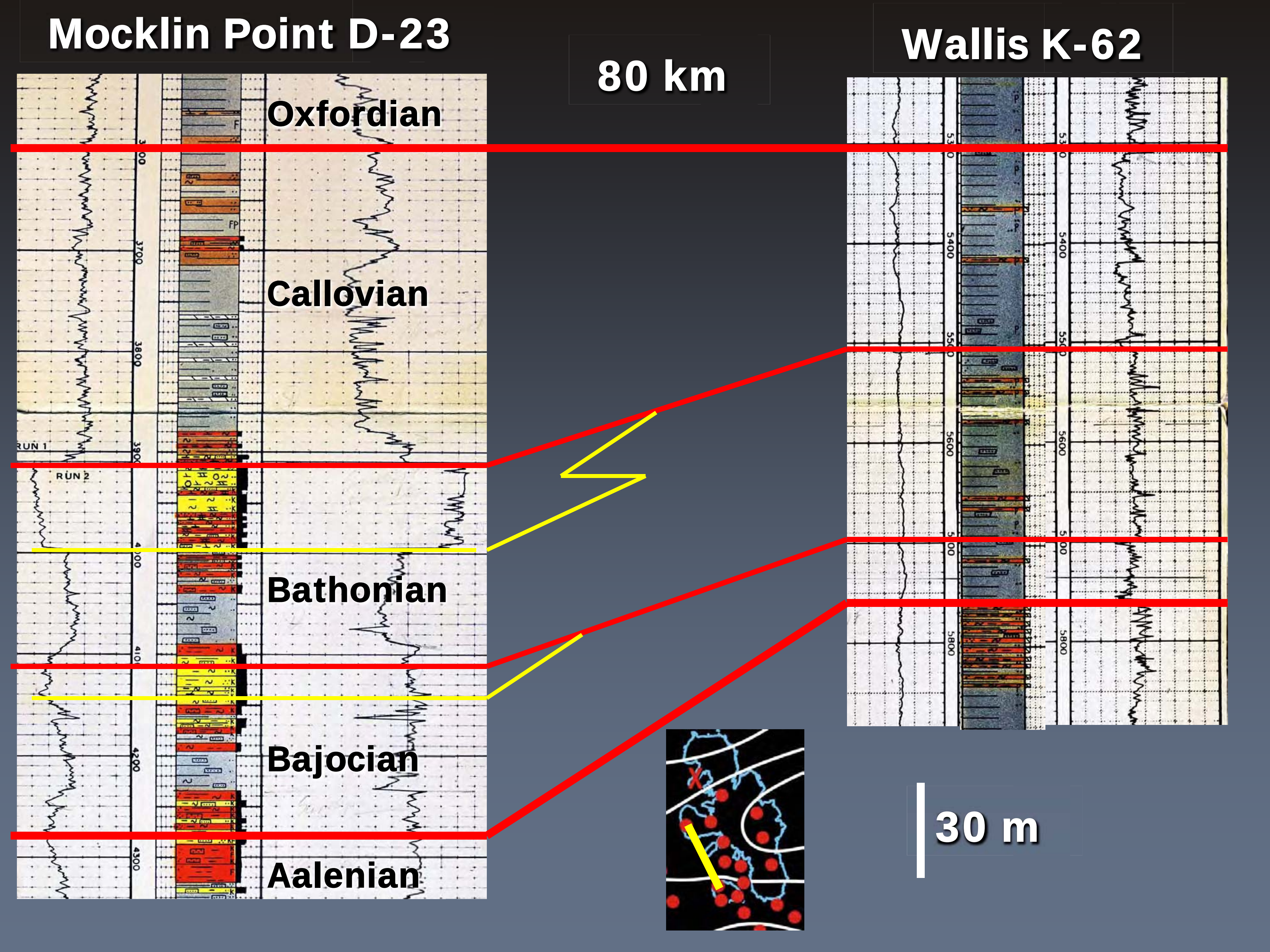


N
Reindeer Peninsula Outcrop
Mocklin Point D-23
Thor P-38
Wallis K-62
Sutherland O-23
Grenadier A-26
S
0 km
40 km
40 km
20 km
65 km
Callovian 3rd Order Sequence
Bathonian 3rd Order Sequence
Aalenian 3rd Order Sequence
50
Metres
0
Shallow Shelf
Offshore Shelf
Starved Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact
ELLEF
RINGNES
I.
RP
D-23
P-38
K-62
O-23
A-26
100°
105°
50 KM

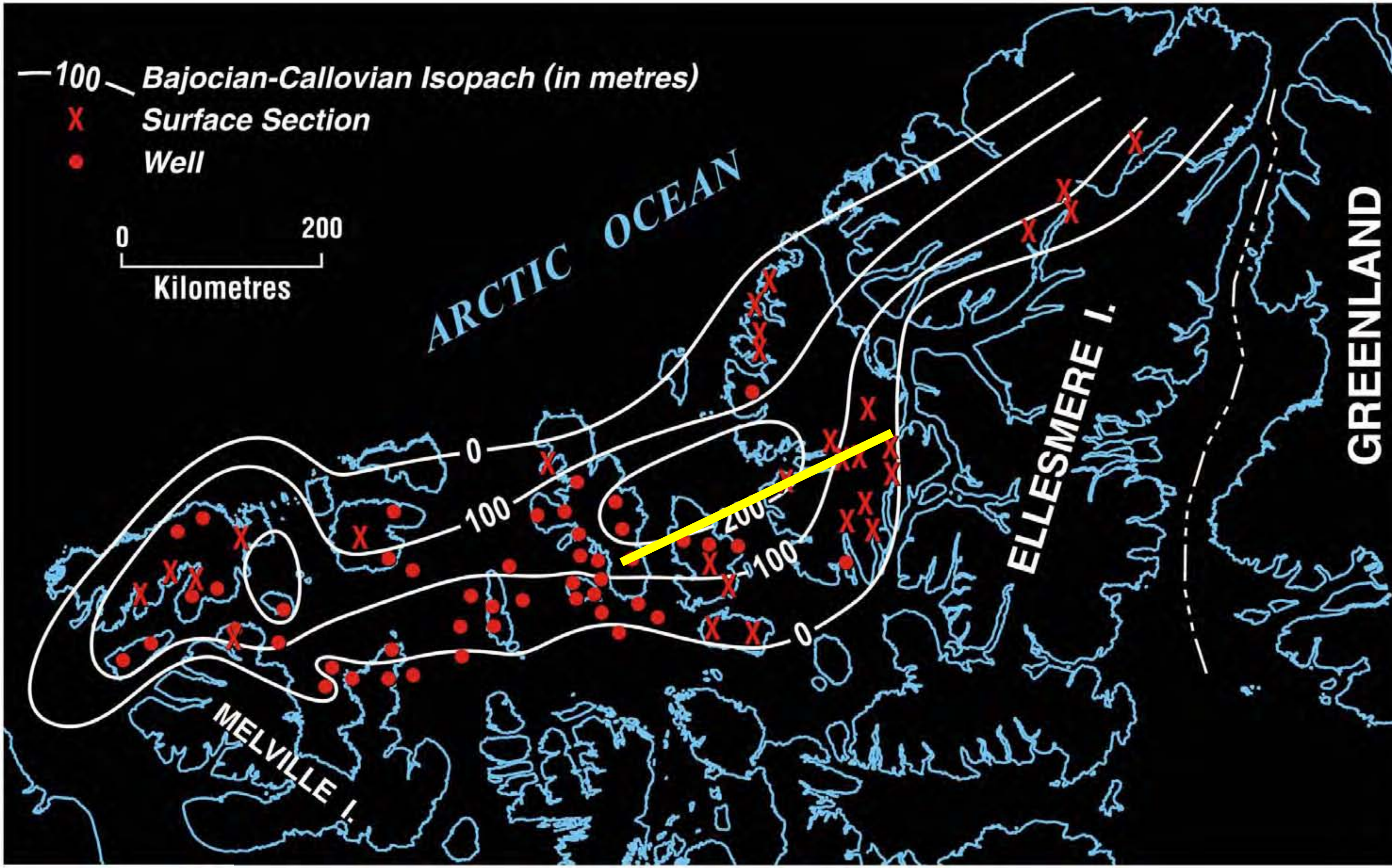


Reindeer Peninsula, NW Ellef Ringnes Island

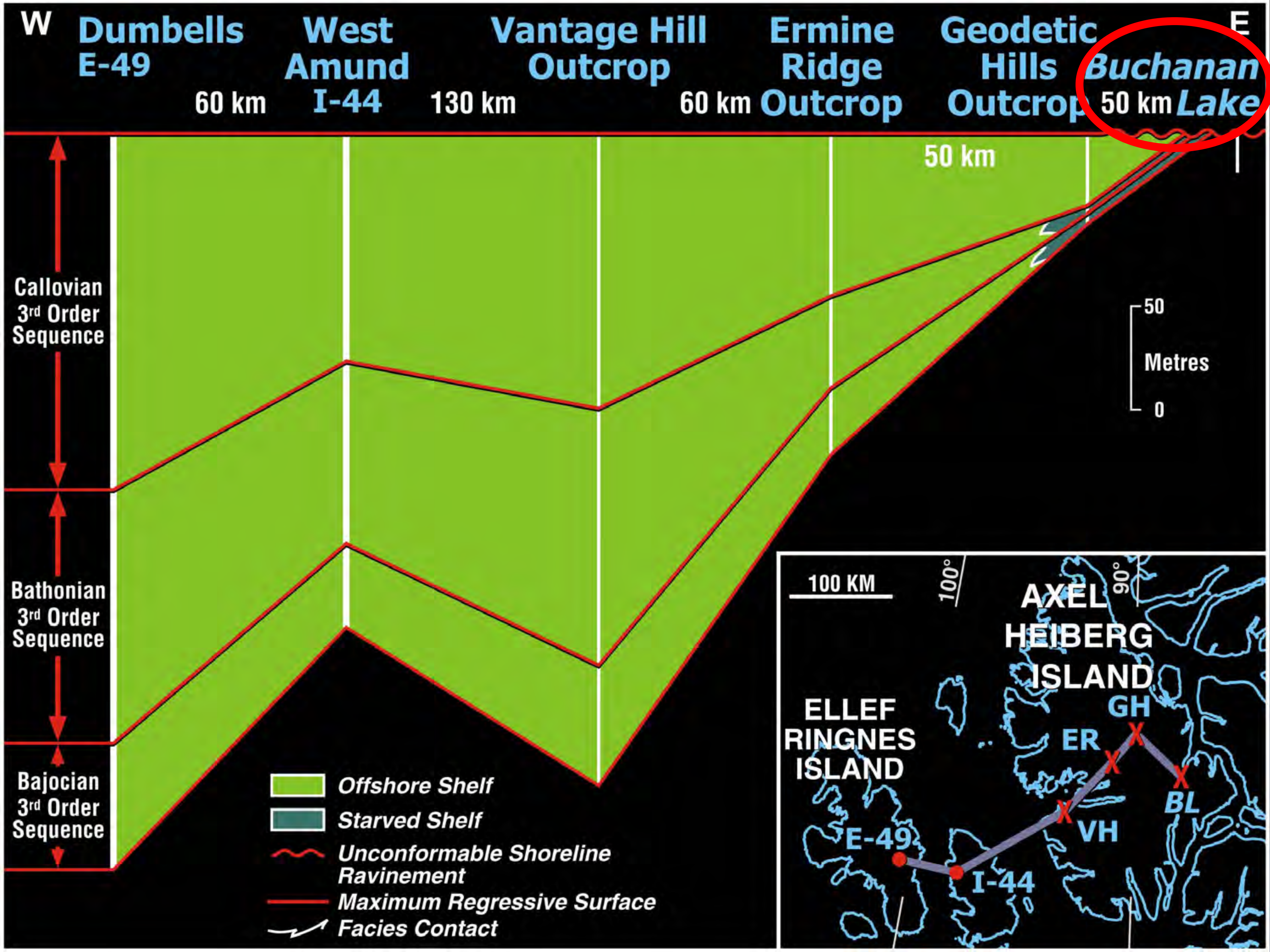

N
Reindeer Peninsula Outcrop
60 km
Mocklin Point D-23
40 km
Thor P-38
40 km
Wallis K-62
20 km
Sutherland O-23
65 km
Grenadier A-26
S
Callovian 3rd Order Sequence
Bathonian 3rd Order Sequence
Aalenian 3rd Order Sequence
50
Metres
0
Shallow Shelf
Offshore Shelf
Starved Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact
ELLEF
RINGNES
I.
RP
D-23
P-38
K-62
O-23
A-26
100°
105°
50 KM



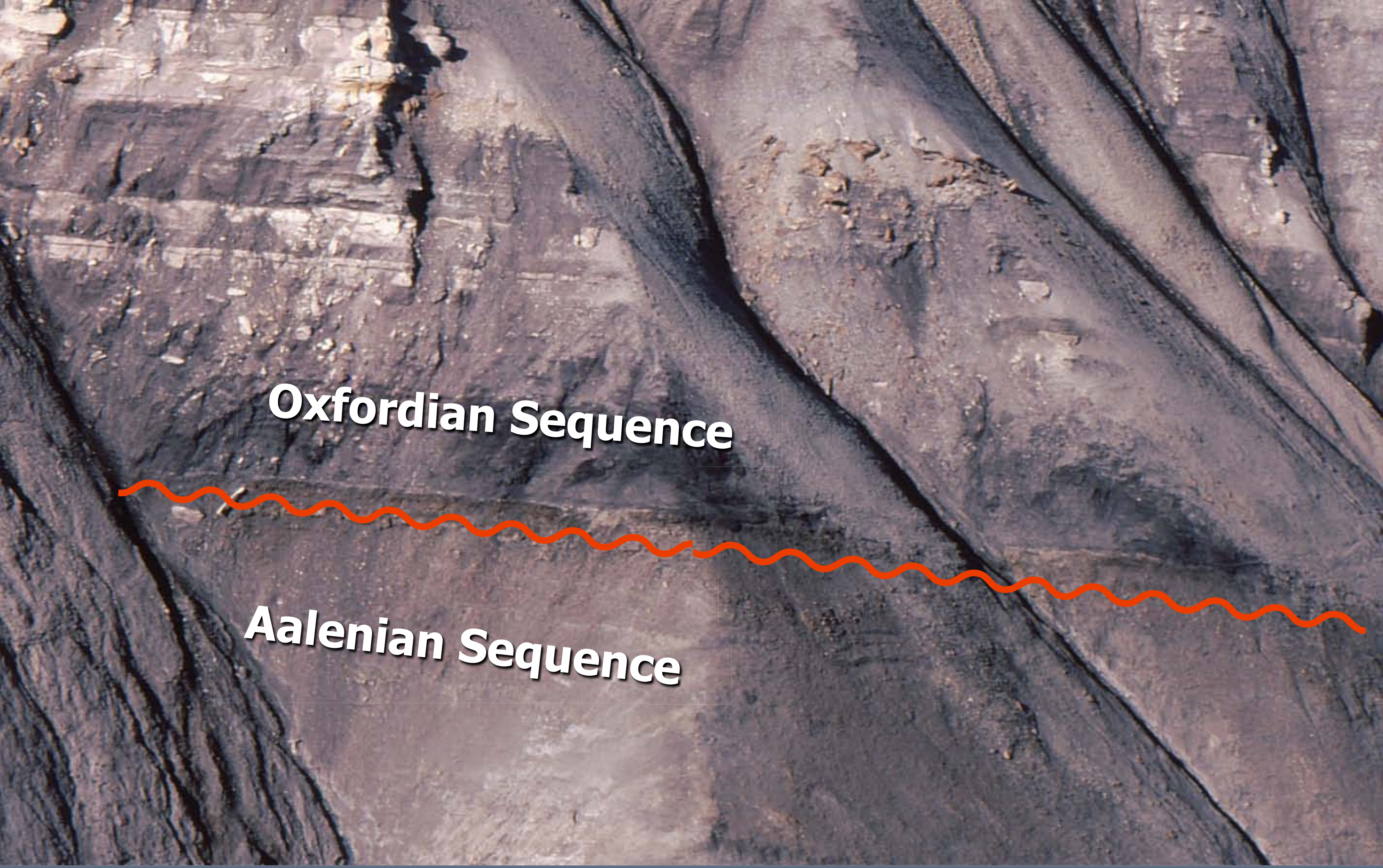
Mocklin Point D-23
80 km
Wallis K-62
Oxfordian
Callovian
Bathonian
Bajocian
Aalenian
RUN 1
RUN 2
3700
3800
4200
4300
5400
5600
5800
30 m



Central Basin Cross Section
Bajocian - Callovian 2nd Order Sequence

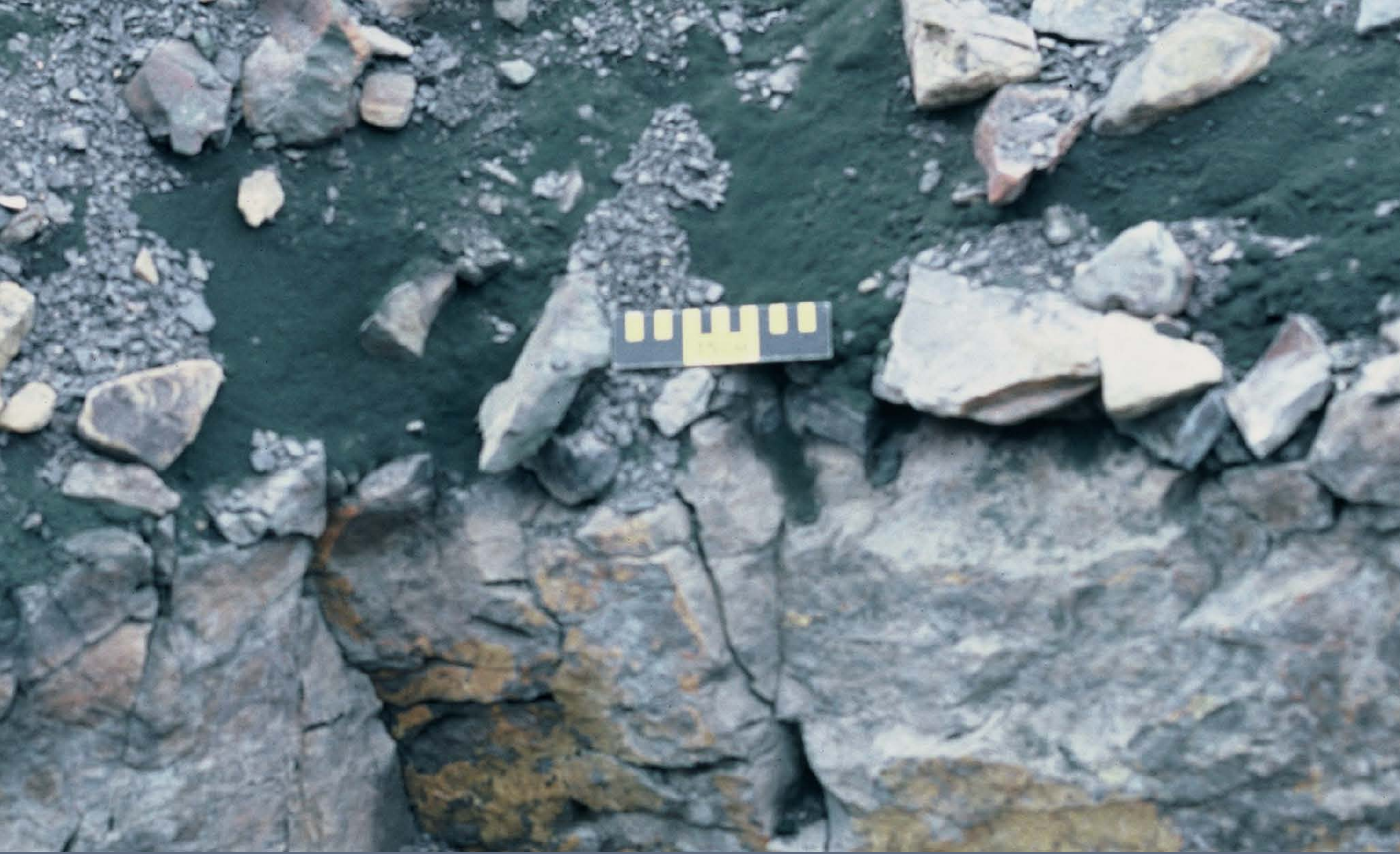


W
E
Dumbells E-49
60 km
West Amund I-44
130 km
Vantage Hill Outcrop
60 km
Ermine Ridge Outcrop
Geodetic Hills Outcrop
50 km
Buchanan Lake
50 km
Callovian 3rd Order Sequence
Bathonian 3rd Order Sequence
Bajocian 3rd Order Sequence
50
Metres
0
Offshore Shelf
Starved Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact
100 KM
100°
90°
AXEL HEIBERG ISLAND
ELLEF RINGNES ISLAND
GH
ER
BL
VH
E-49
I-44

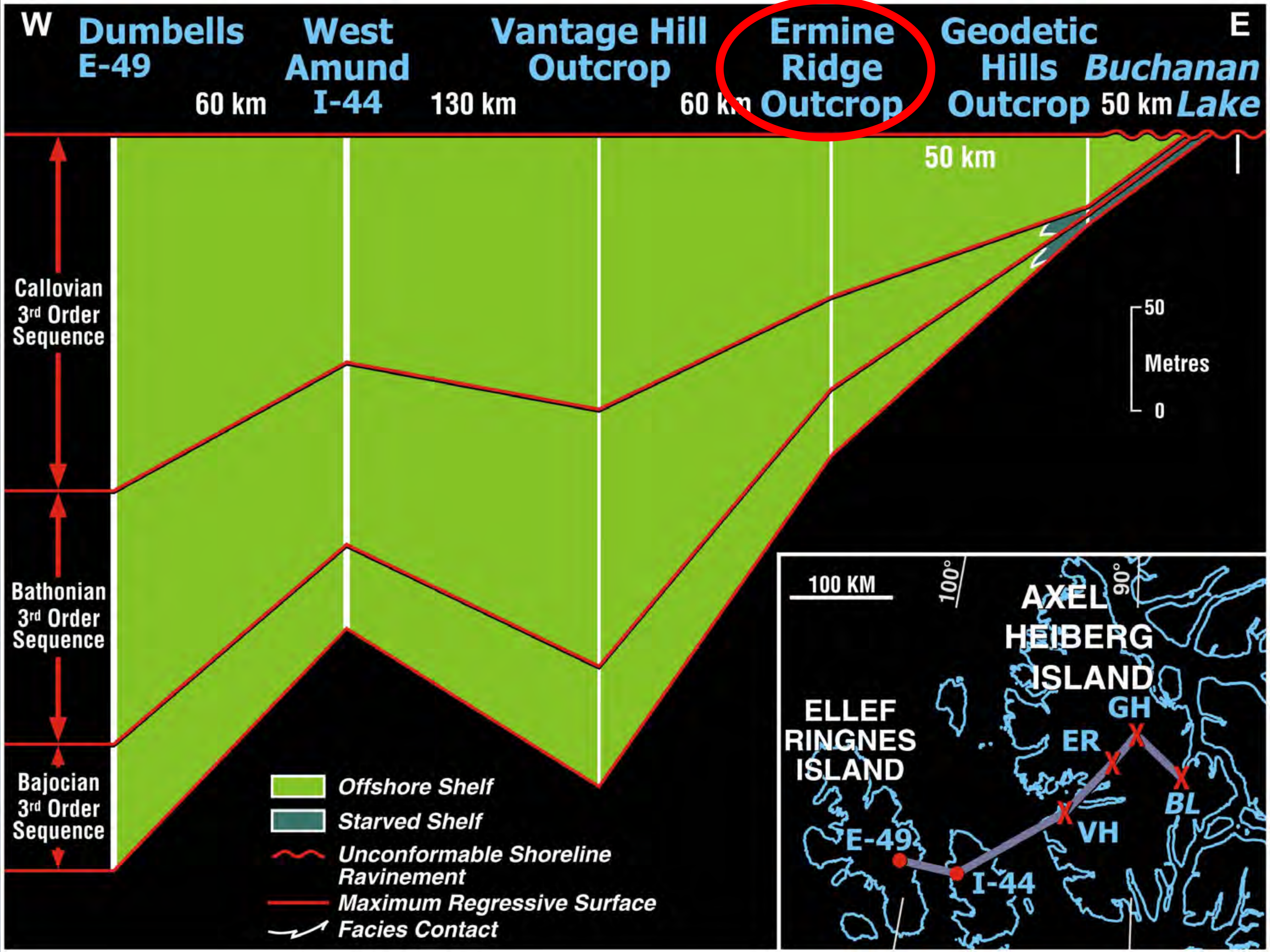


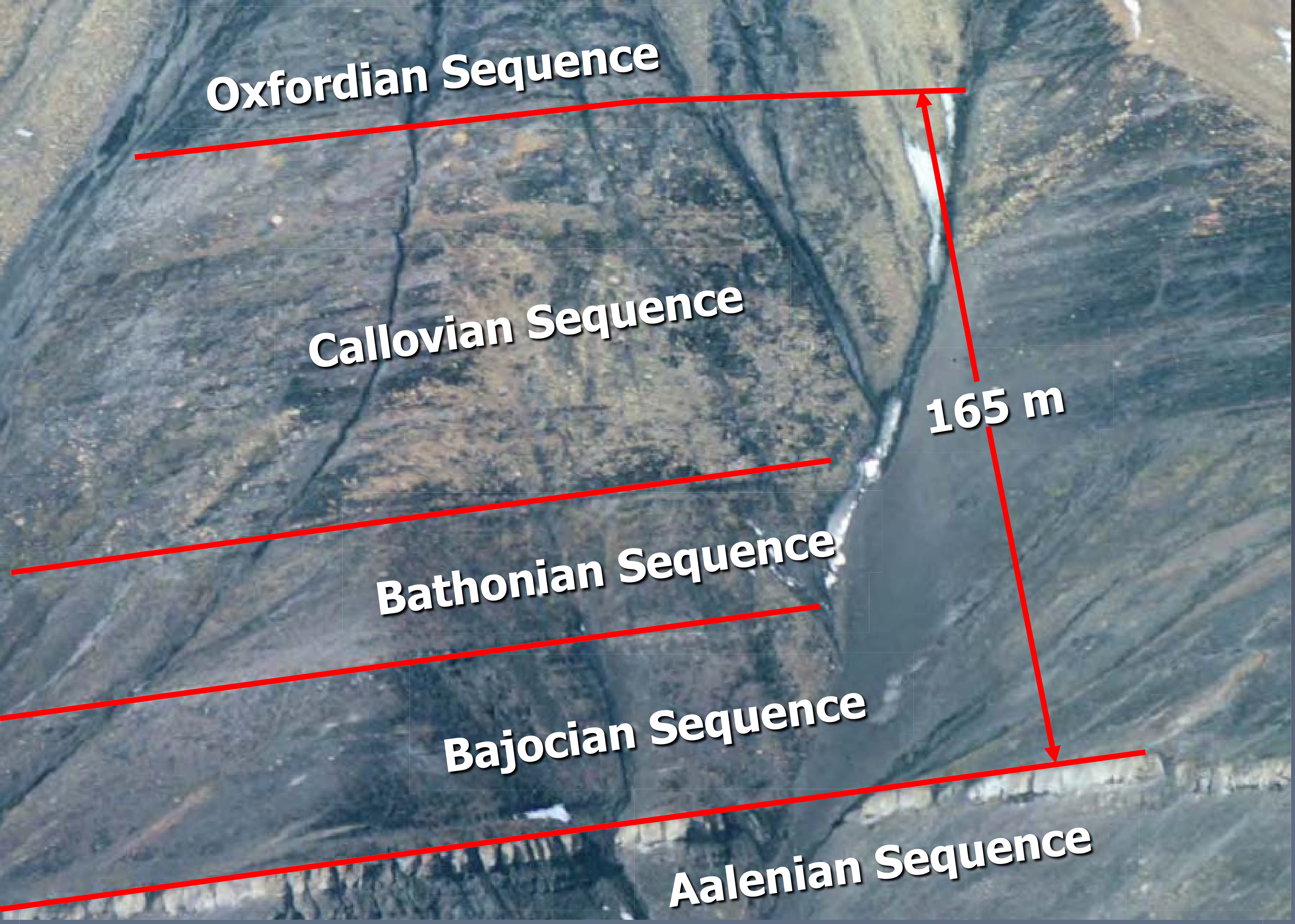
Buchanan Lake, East Central Axel Heiberg Island
Bajocian-Callovian 2nd Order Sequence Eroded

North Wolf Fiord, South Central Axel Heiberg I.

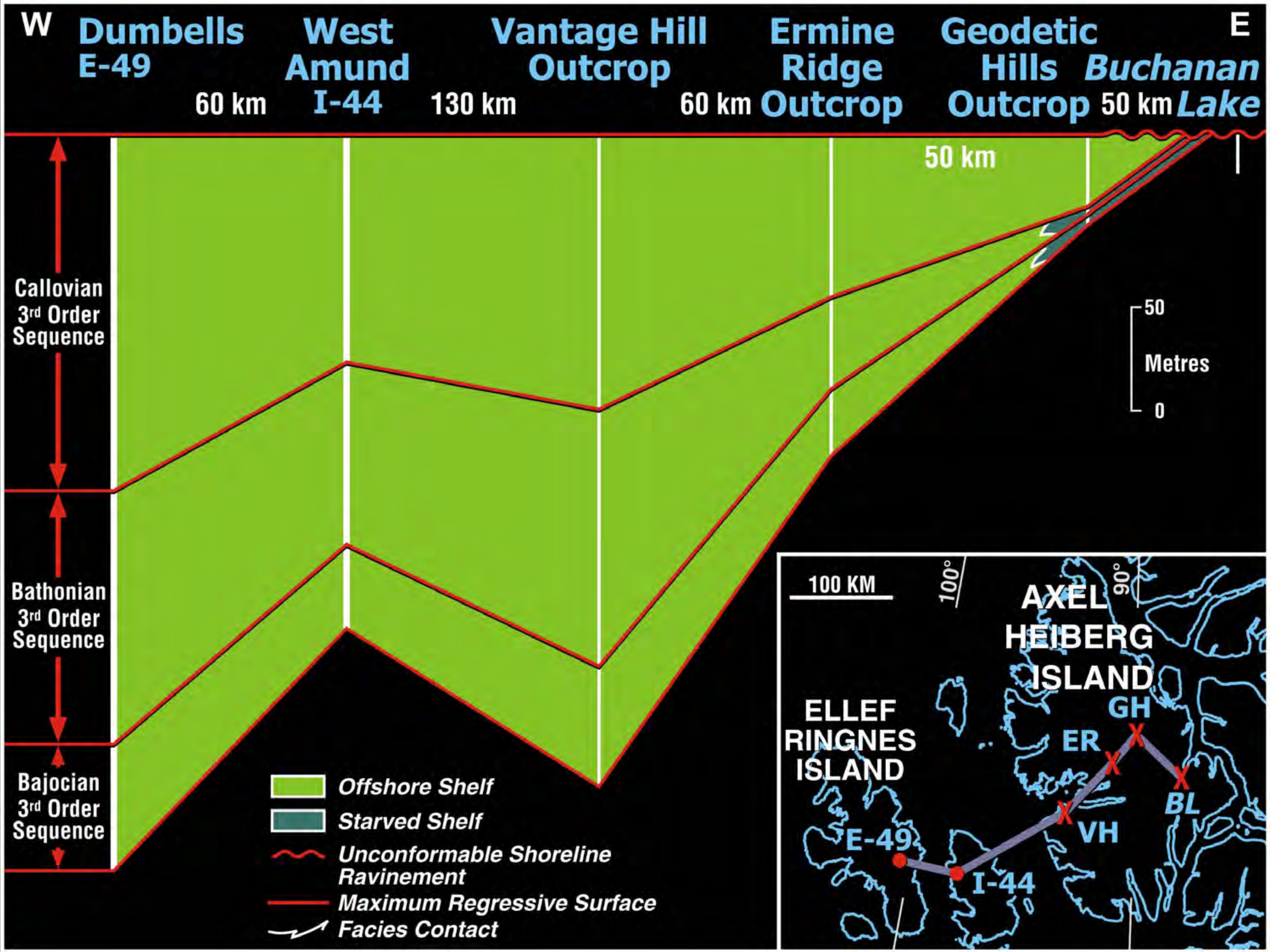


Glauconite Bed at Base of Bajocian-Callovian Sequence, Geodetic Hills, Eastern Axel Heiberg I.

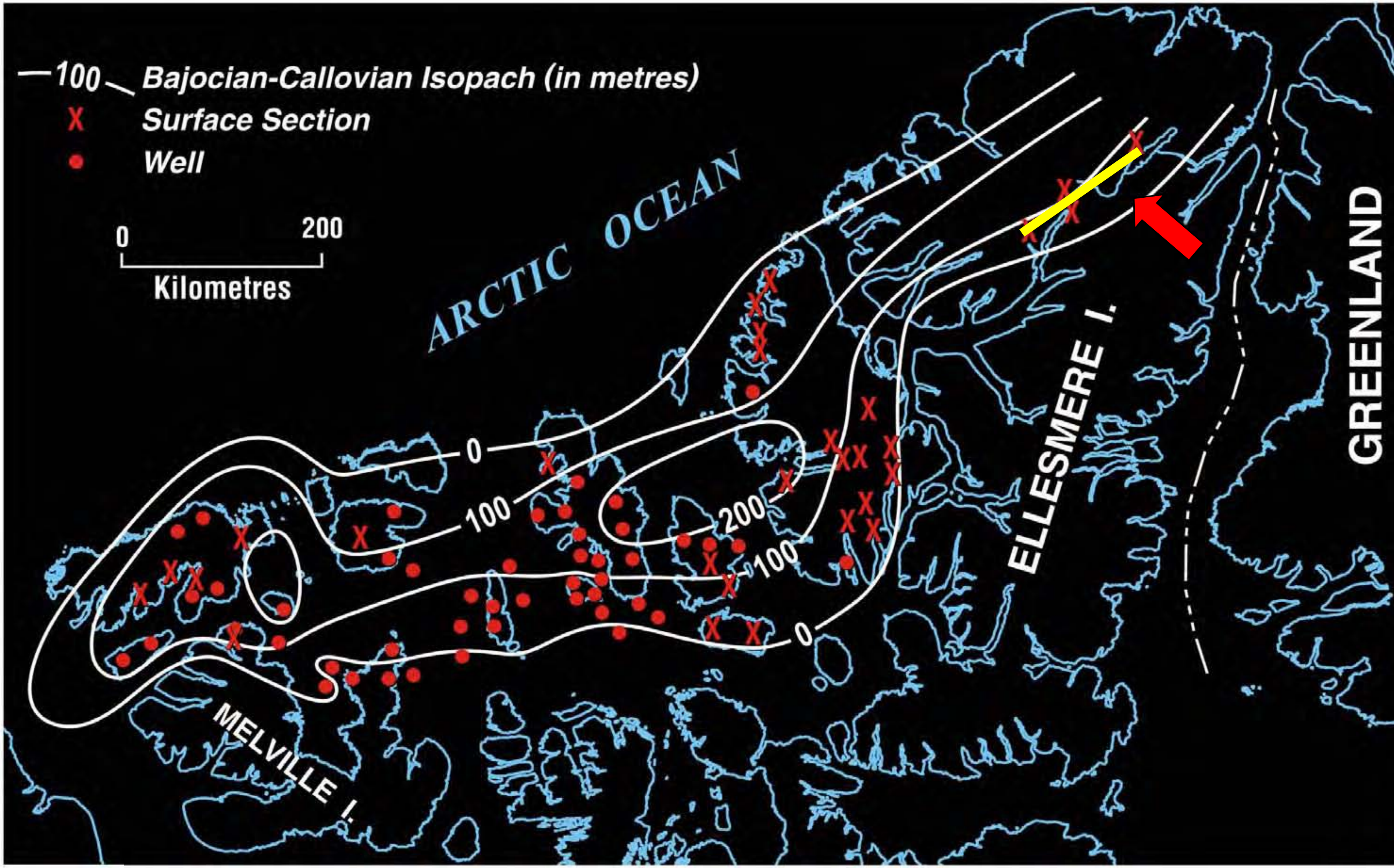

W
Dumbells E-49
60 km
West Amund I-44
130 km
Vantage Hill Outcrop
60 km
Ermine Ridge Outcrop
Geodetic Hills Outcrop
50 km
Buchanan Lake
E
50 km
Callovian 3rd Order Sequence
Bathonian 3rd Order Sequence
Bajocian 3rd Order Sequence
50
Metres
0
Offshore Shelf
Starved Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact
100 KM
100°
90°
AXEL HEIBERG ISLAND
ELLEF RINGNES ISLAND
GH
ER
BL
VH
E-49
I-44



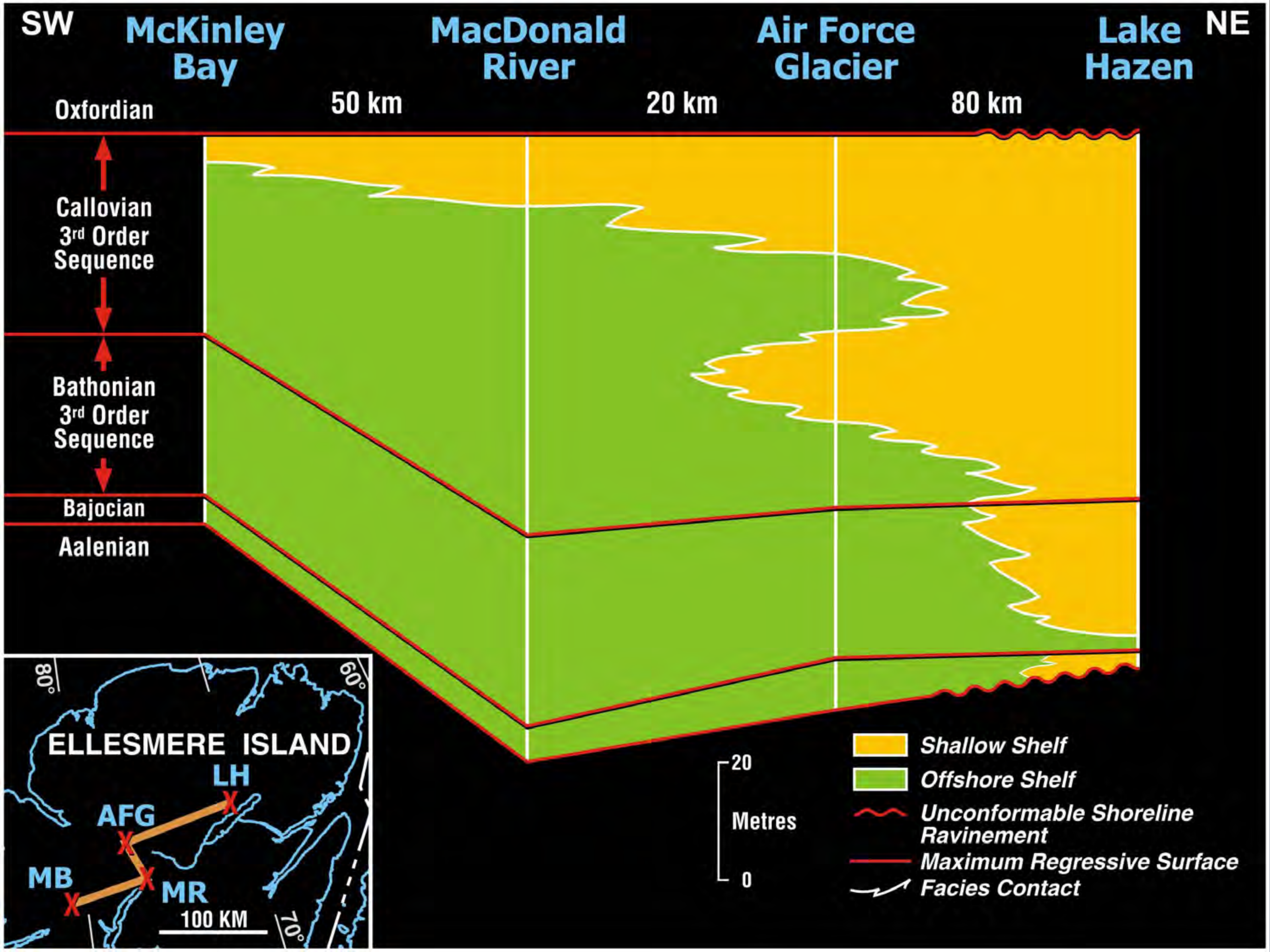
Ermine Ridge, west central Axel Heiberg Island

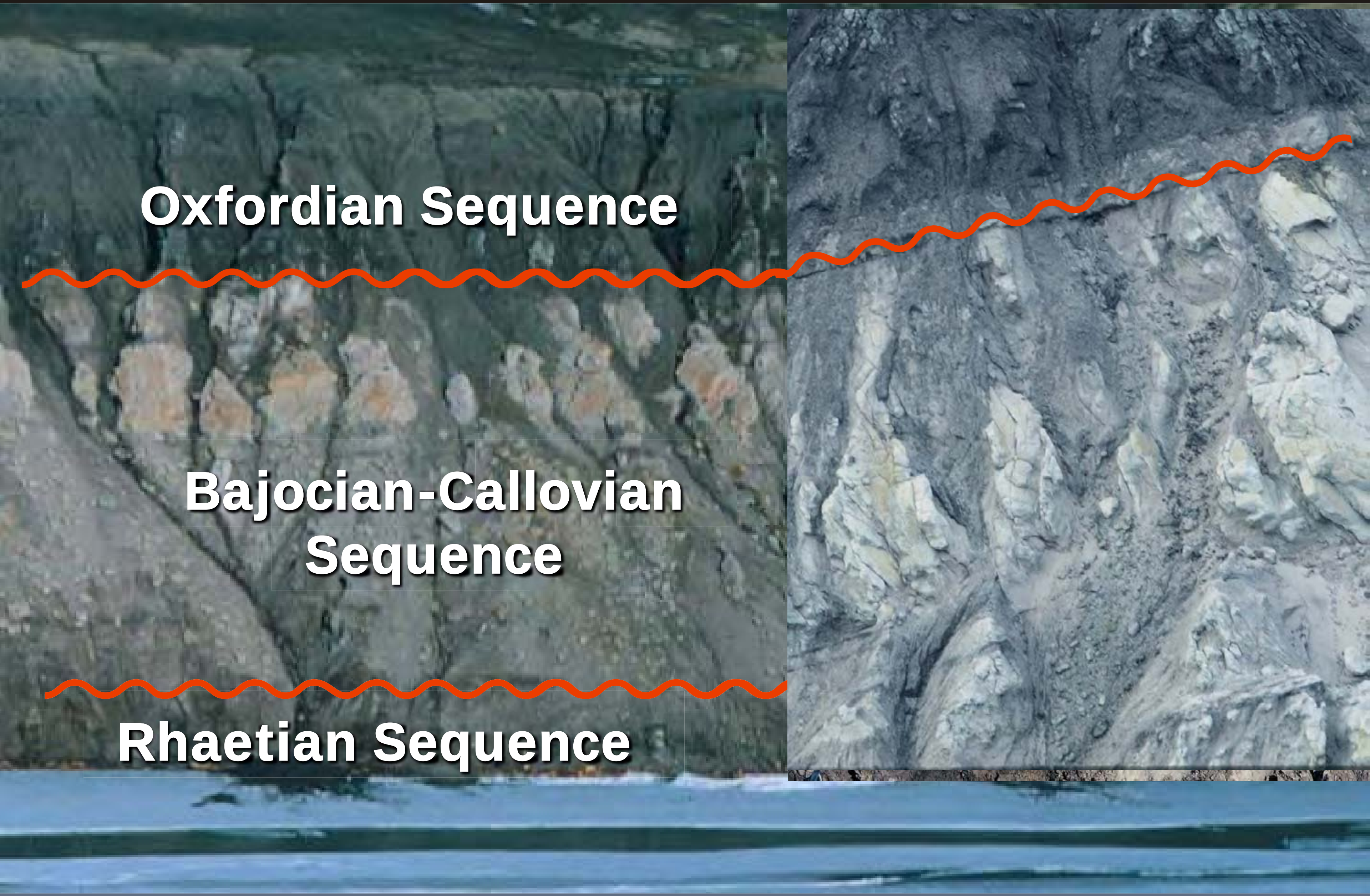


W
Dumbells E-49
60 km
West Amund I-44
130 km
Vantage Hill Outcrop
60 km
Ermine Ridge Outcrop
Geodetic Hills Outcrop
50 km
Buchanan Lake
E
50 km
Callovian 3rd Order Sequence
Bathonian 3rd Order Sequence
Bajocian 3rd Order Sequence
50
Metres
0
Offshore Shelf
Starved Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact
100 KM
100°
90°
AXEL HEIBERG ISLAND
ELLEF RINGNES ISLAND
GH
ER
BL
VH
E-49
I-44



Northeast Ellesmere Cross Section
Bajocian - Callovian 2nd Order Sequence

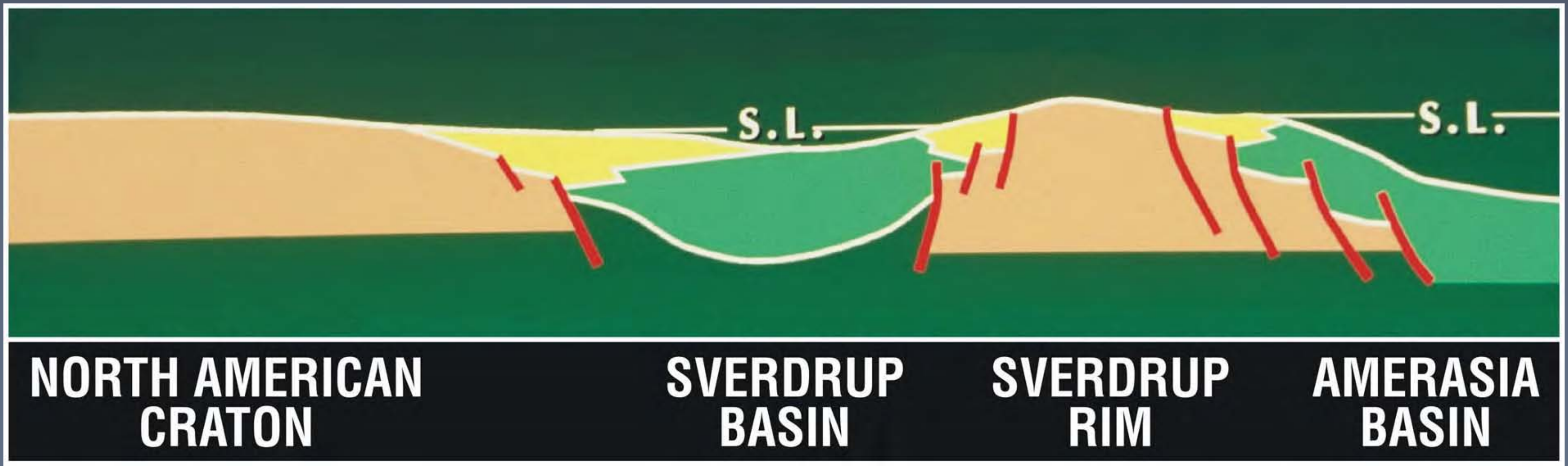

SW
McKinley Bay
MacDonald River
Air Force Glacier
Lake Hazen
NE
Oxfordian
50 km
20 km
80 km
Callovian 3rd Order Sequence
Bathonian 3rd Order Sequence
Bajocian
Aalenian
ELLESMERE ISLAND
80°
60°
70°
LH
AFG
MB
MR
100 KM
20
Metres
0
Shallow Shelf
Offshore Shelf
Unconformable Shoreline Ravinement
Maximum Regressive Surface
Facies Contact

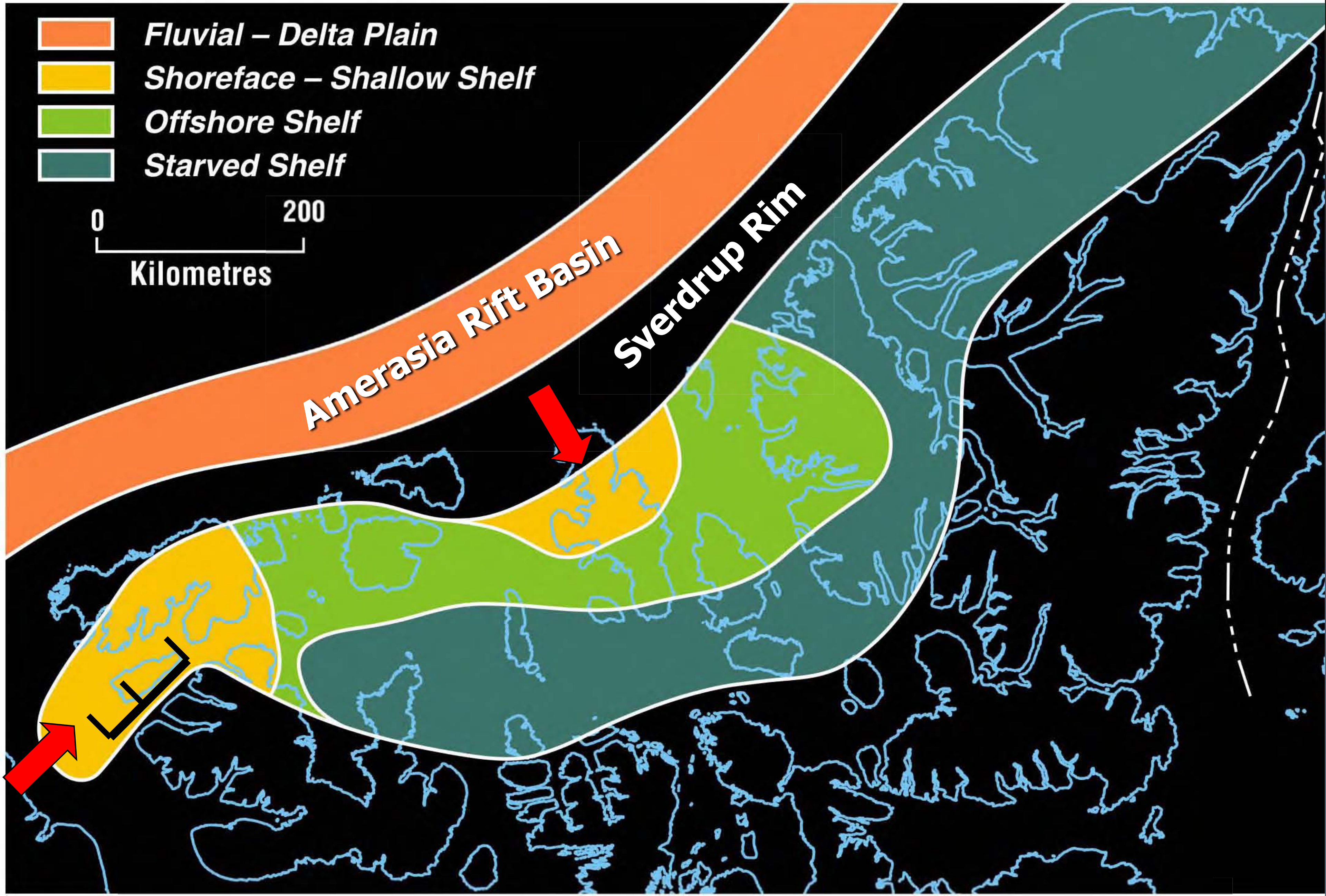


Lake Hazen, Northeast Ellesmere Island

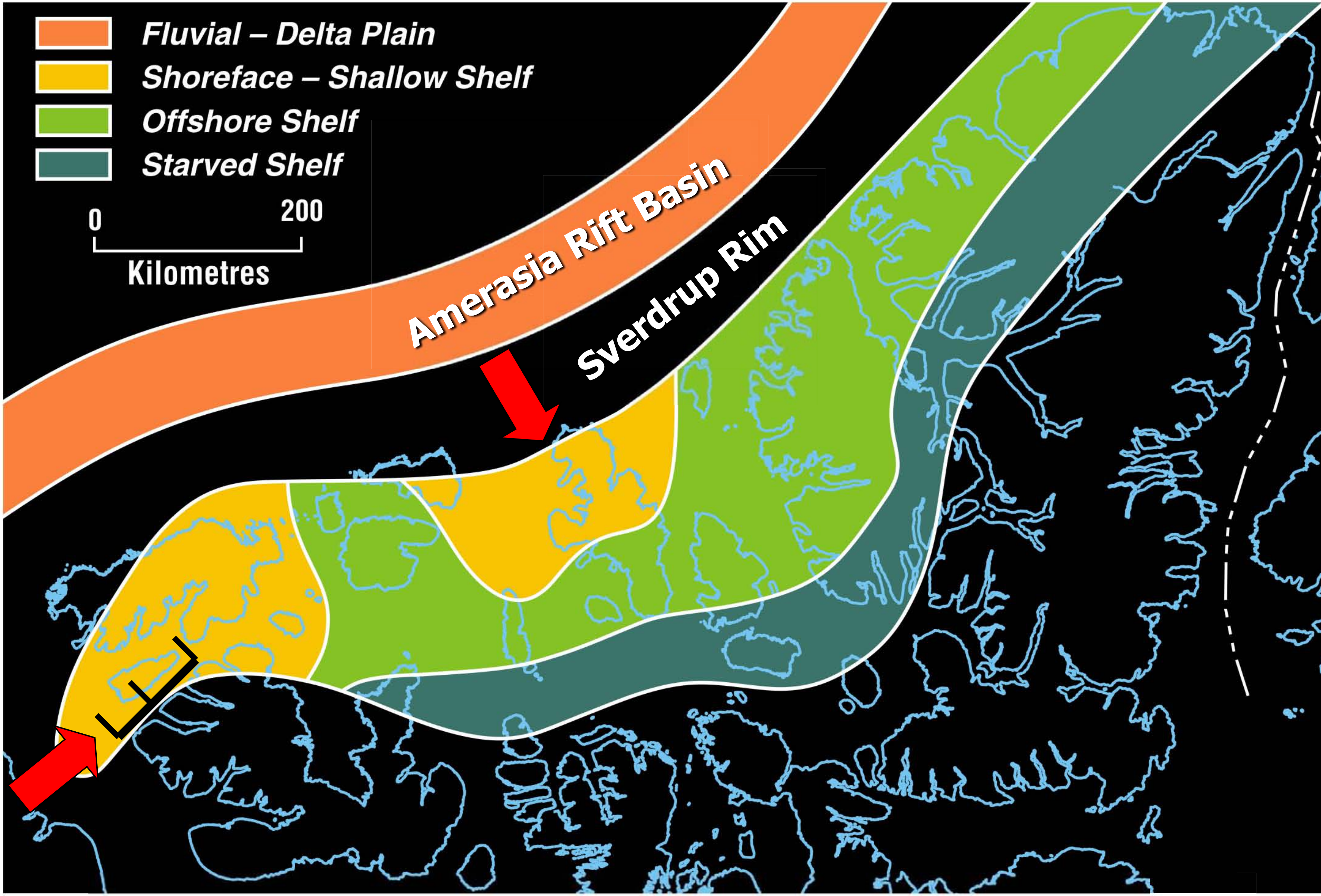
EARLY PERMIAN – AALENIAN

BAJOCIAN– CRETACEOUS

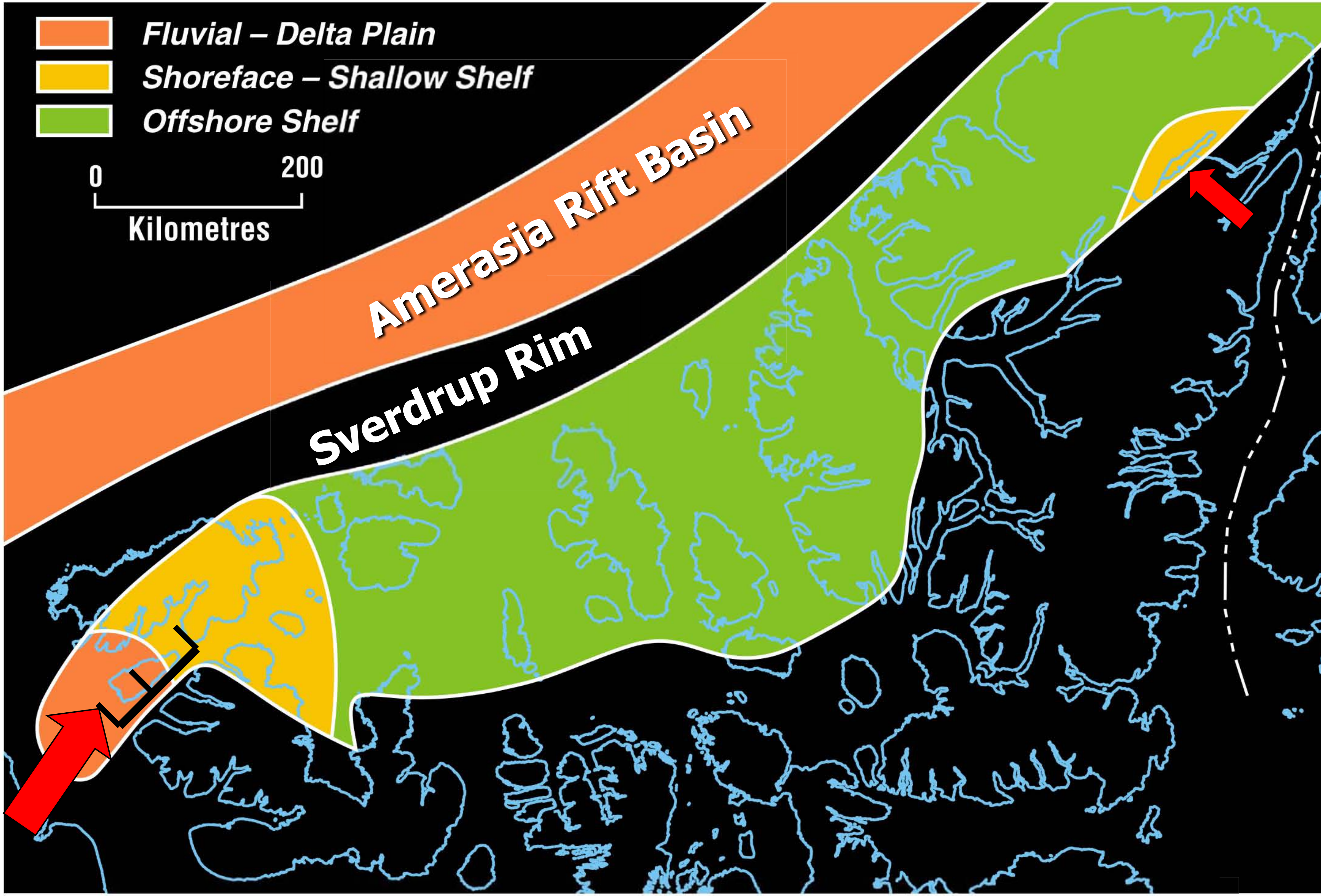




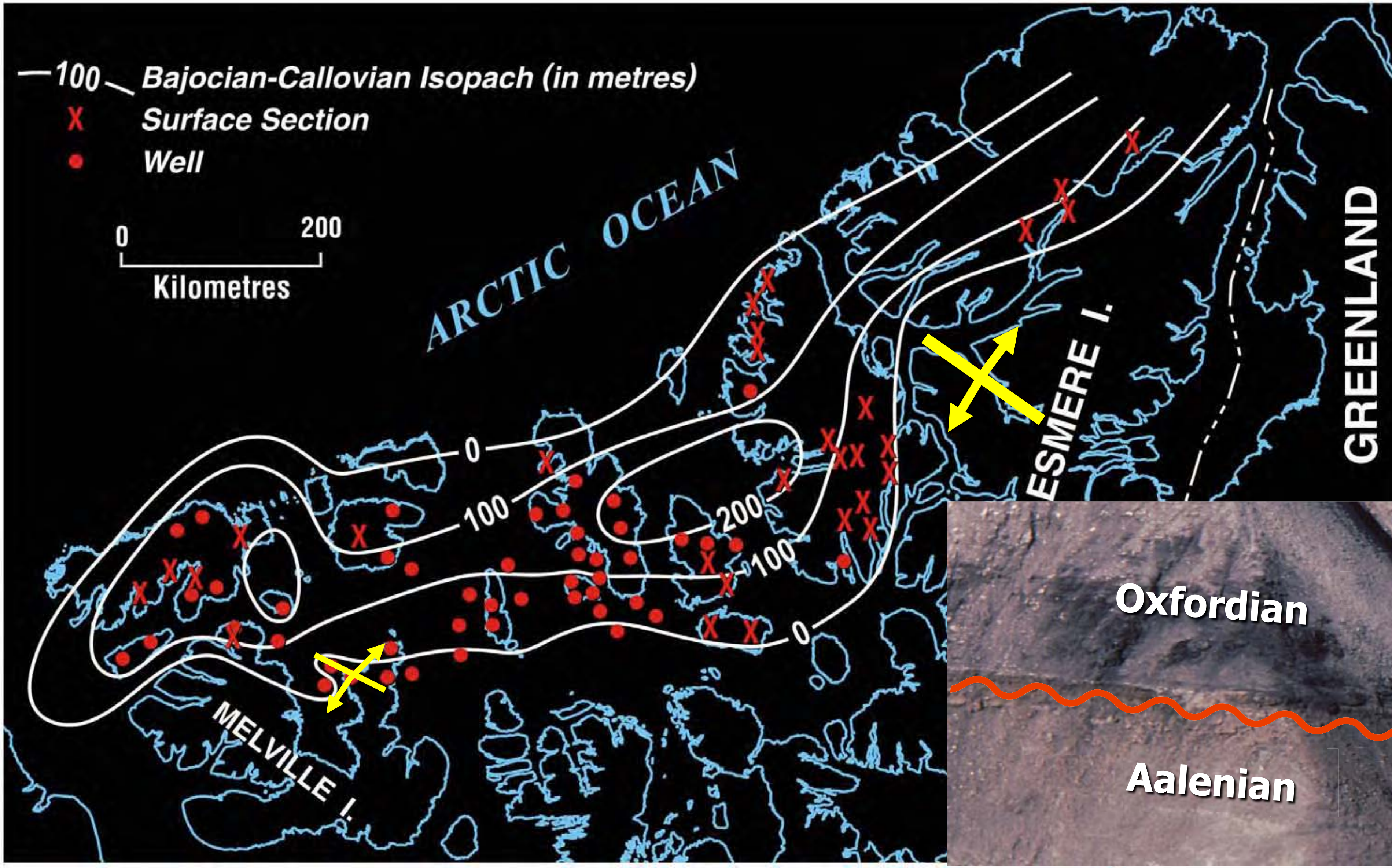
Late Bajocian Paleogeography



Late Bathonian Paleogeography



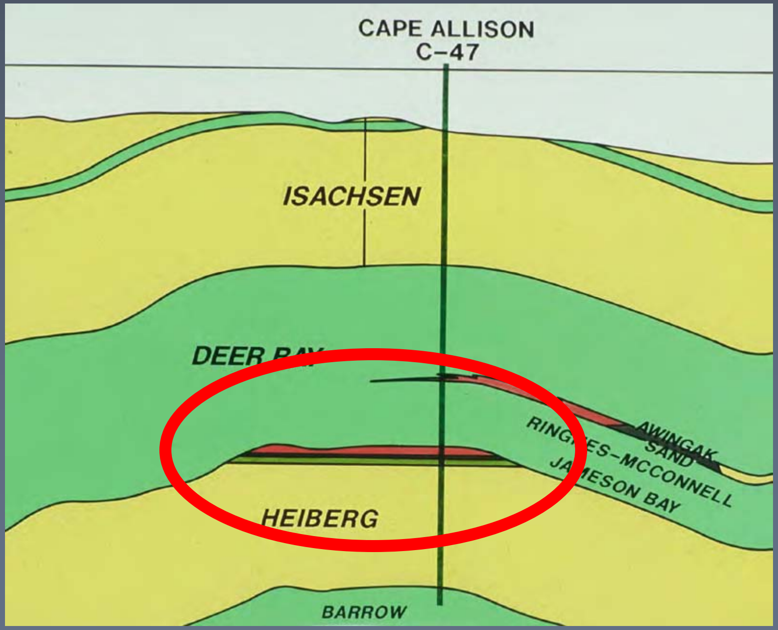
Late Callovian Paleogeography



Base Oxfordian Tectonic Unconformity

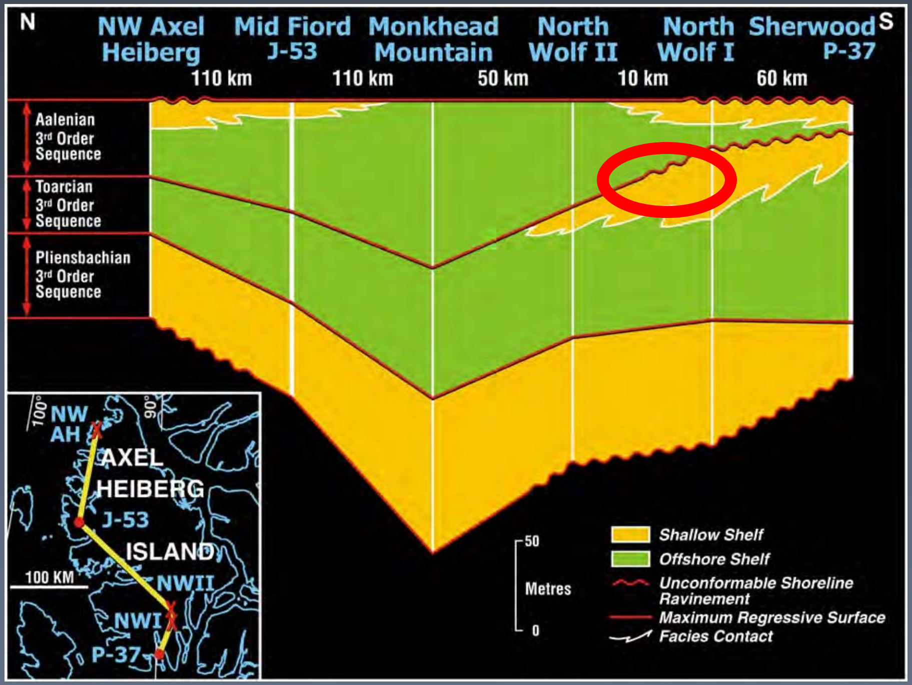
Petroleum Prospects

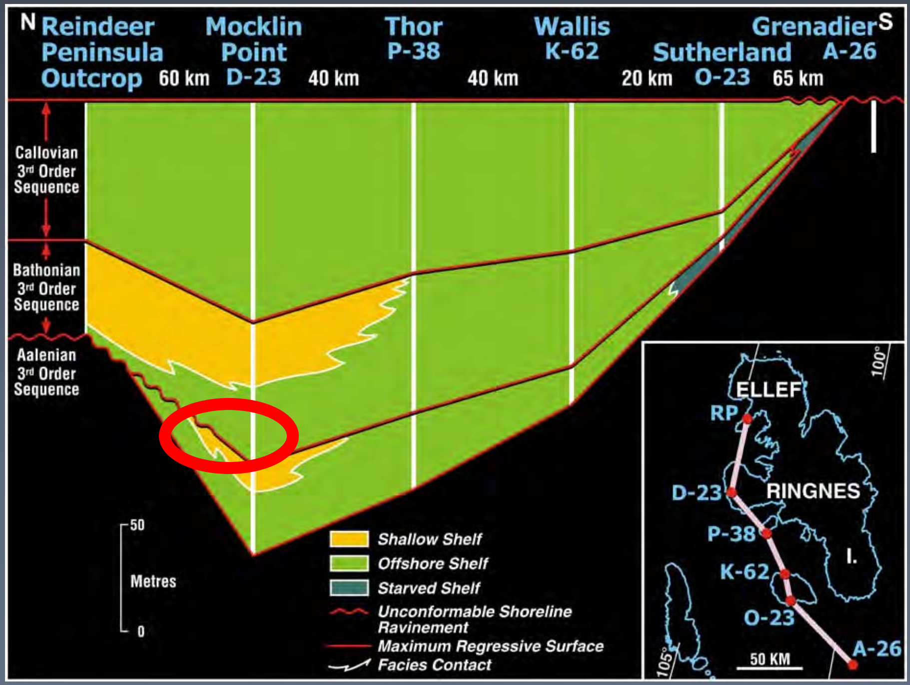
- Pliensbachian sandstones are major reservoirs in gas fields on Ellef Ringnes Island with the Toarcian shale being an effective seal.



Petroleum Prospects

- Toarcian to Callovian sandstone units are potential targets where they pinchout updip.





Conclusions

- The Pliensbachian to Callovian succession comprises two 2nd order sequences which are separated by a 1st order boundary of earliest Bajocian age.
- Each 2nd order sequence contains three third order sequences which approximate Jurassic stages.

Conclusions

- The beginning of the Pliensbachian – Aalenian 2nd order sequence is characterized by a greatly reduced sediment influx.

- The main sediment source area for the Pliensbachian to Aalenian sequence was the craton to the east and south. Crockerland also contributed sediment in the Aalenian.

Conclusions

- The 1st order sequence boundary at near base Bajocian is characterized by the start of rifting of the Amerasia Basin and by a greatly reduced sediment influx.
- The main sediment source area for the Bajocian to Callovian 2nd order sequence was the Sverdrup Rim.

Conclusions

- The current data strongly support the interpretation that the start of rifting for the Amerasia Ocean Basin began in latest Aalenian-earliest Bajocian.
- Structural/stratigraphic traps involving pinchouts of porous sandstone units on the flanks of highs offer the best potential petroleum accumulations.

Thanks to my employer, Geological Survey of Canada, for Continued Support

Thanks to

Dave Sargent for Slide Preparation

Thank you for your kind attention

Time for a drink!