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Paleogeographic Reconstructions of the Circum-Arctic Region since the Late Jurassic*

Christopher R. Scotese[1]

Search and Discovery Article #30193 (2011)
Posted September 30, 2011

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Houston, Texas, April 10-13, 2011. Please refer to related article entitled, "Paleogeographic and Paleoclimatic Atlas" Search and Discovery Article #30192 (2011).

[1]PALEOMAP Project, Arlington, TX (cscotese@gmail.com)

Abstract

We present paleogeographic maps describing the distribution of mountains, lowlands, shallow seas and deep ocean basins in the Circum-Arctic region since the Late Jurassic, with emphases in the Late Mesozoic. These maps are part of a set of 30 paleogeographic reconstructions that describe the development of the Circum-Arctic Region during the last 150-160 my. These paleogeographic maps are based on a plate tectonic model for the Arctic produced by the PALEOMAP Project. This ArcGIS model (PaleoGIS) describes the plate tectonic evolution of the North Atlantic, Eurasia and Makarov basins, Canada Basin, Canadian Cordillera, South-Central Alaska, Northeast Siberia, and the North Pacific. The plate tectonic model provided the framework upon which a 3D digital elevation model was constructed for each time slice. A paleo-digital elevation model (PaleoDEM) is a quantitative description of topographic and bathymetric features that describes the evolution of the seafloor, the tectonic development of island arcs and back-arc basins, the subsidence of lowland areas, and the uplift and erosion of mountain ranges. Each "pixel" in the PaleoDEM represents a 10 km x 10 km square on the map. Vertical resolution is 40 m. Both the plate tectonic model and the paleogeographic maps are important tools for understanding the evolution of sedimentary basins and the development of hydrocarbon systems in the Circum-Arctic Region. The 3D paleogeographic models also provides a framework for further paleoclimatic and paleooceanographic modeling.

Reference

Ziegler, A.M., G. Eshel, P.M. Rees, T.A. Rothfus, D.B. Rowley, and D. Sunderlin, 2003, Tracing the tropics across land and sea; Permian to present, *in* S.K. Donovan, and D.A.T. Harper (eds.) Tropical marine paleoenvironments through time; biodiversity, ecology and evolution: Lethaia, v. 36/3, p. 227-254.

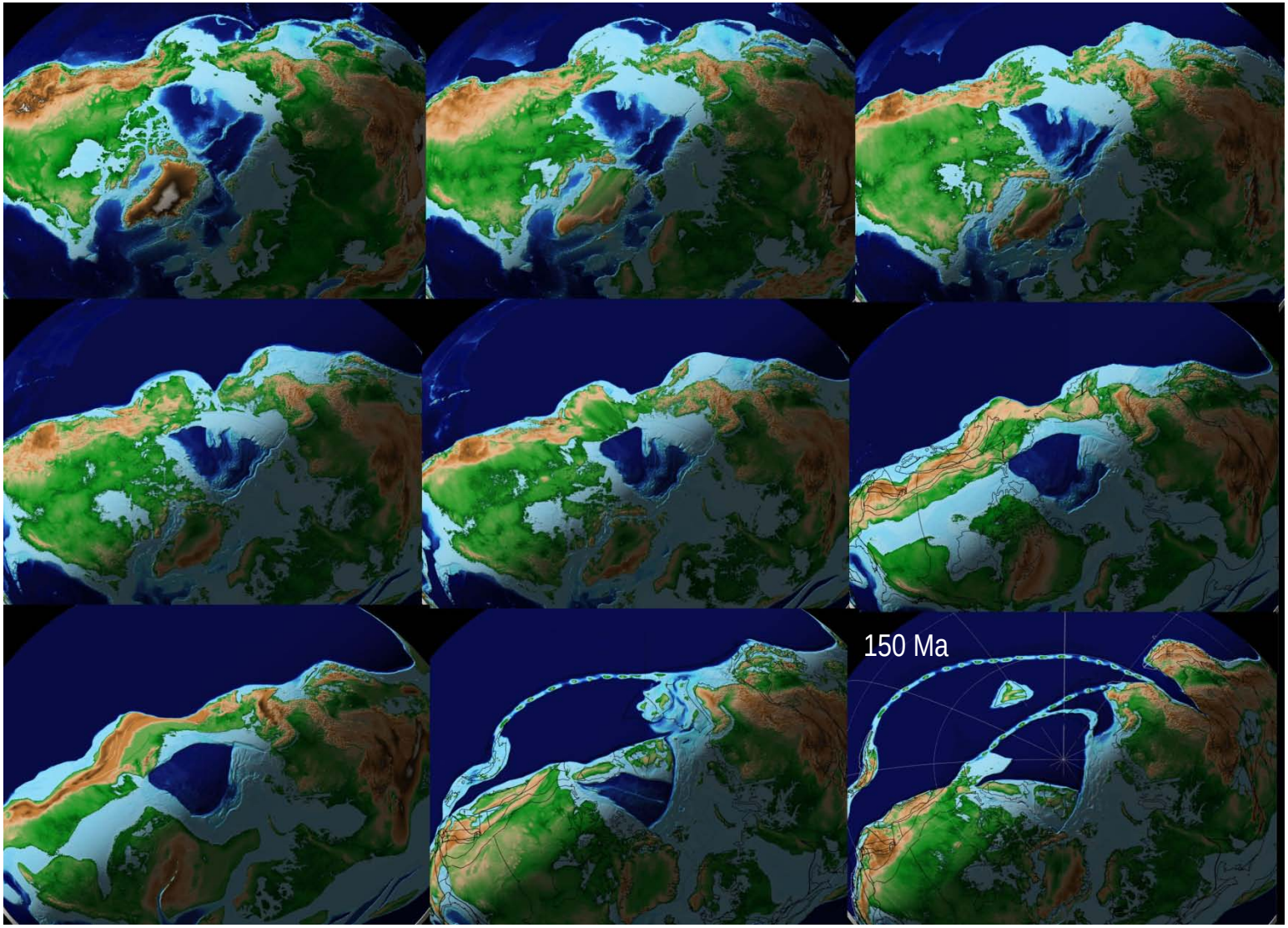
Paleogeographic Reconstructions of the Circum-Arctic Region since the Late Jurassic

- "A Case for an Amerasian Subduction Zone"

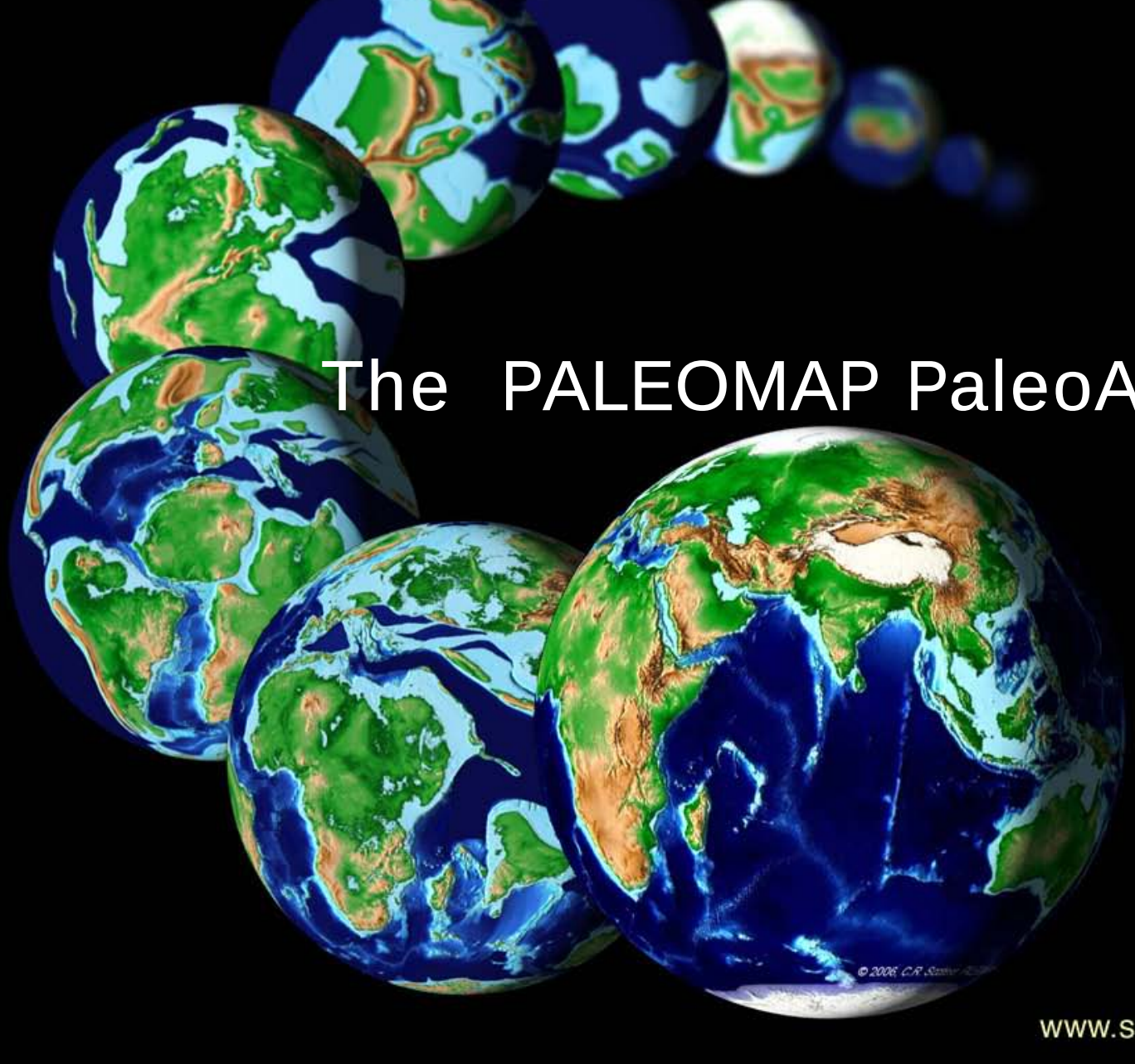
Christopher R. Scotese

PALEOMAP Project, Arlington, Texas

16 Paleogeographic Reconstructions from the Late Jurassic to the Recent



The PALEOMAP PaleoAtlas



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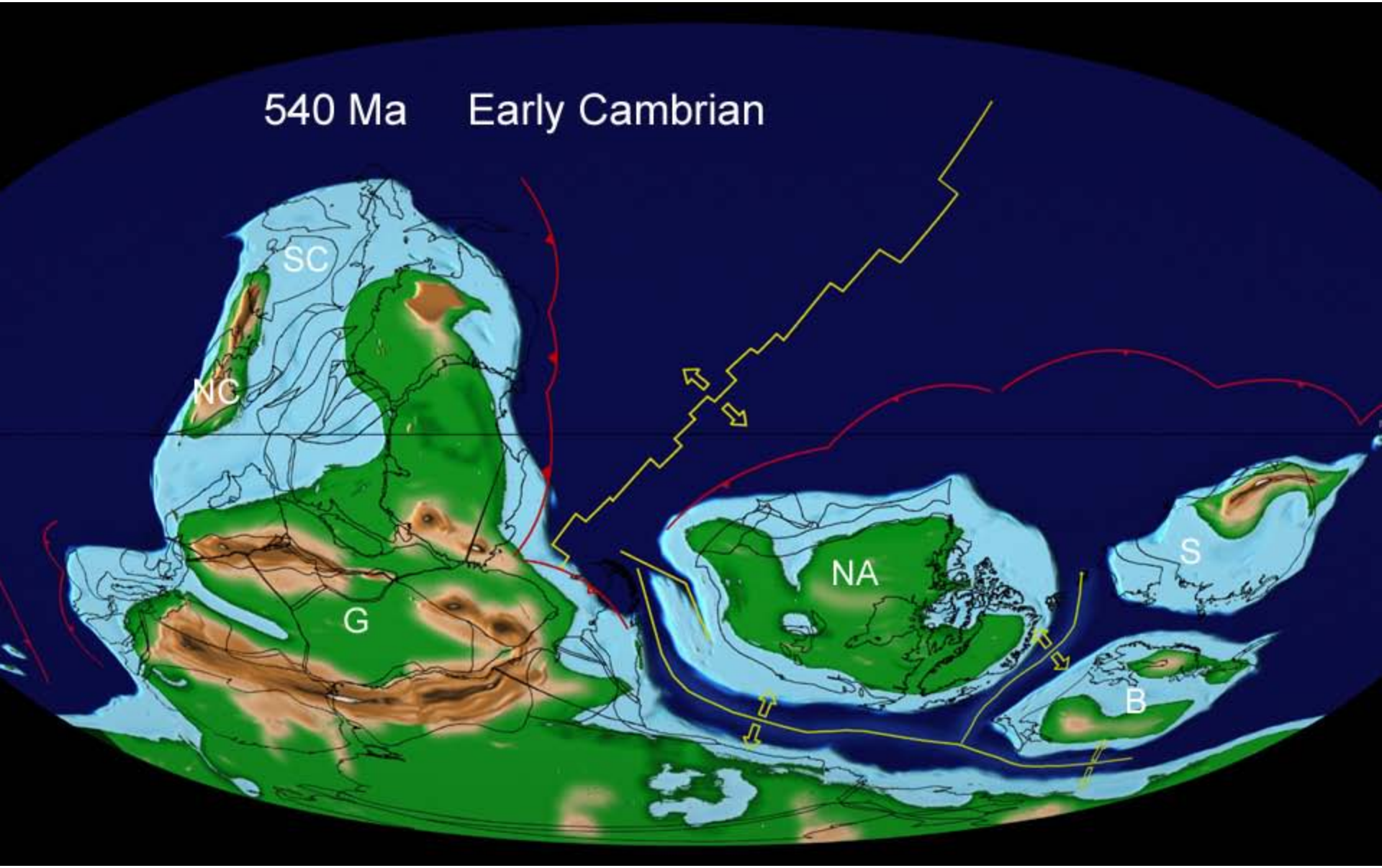
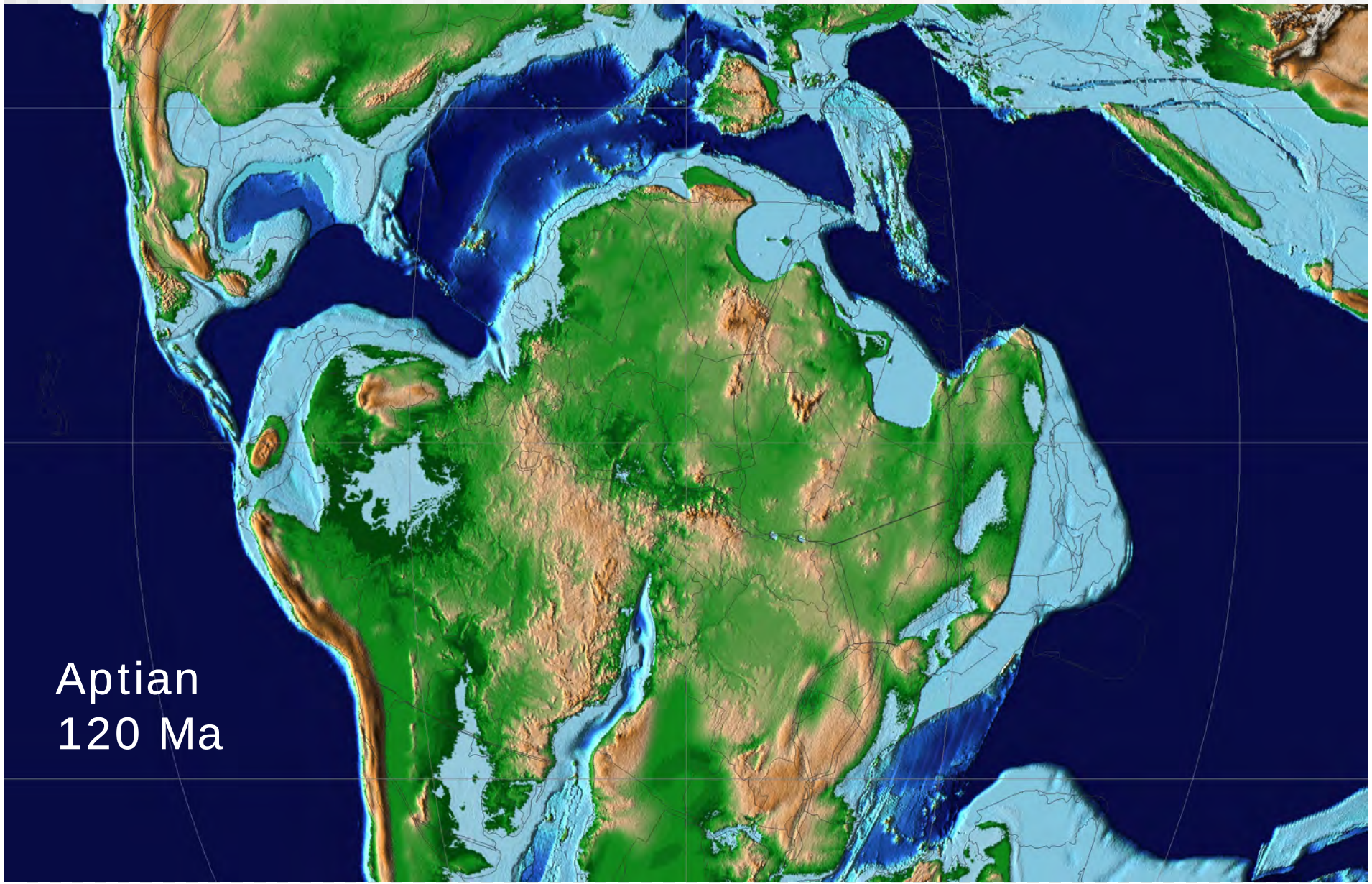
PALEOMAP PaleoAtlas Time Intervals

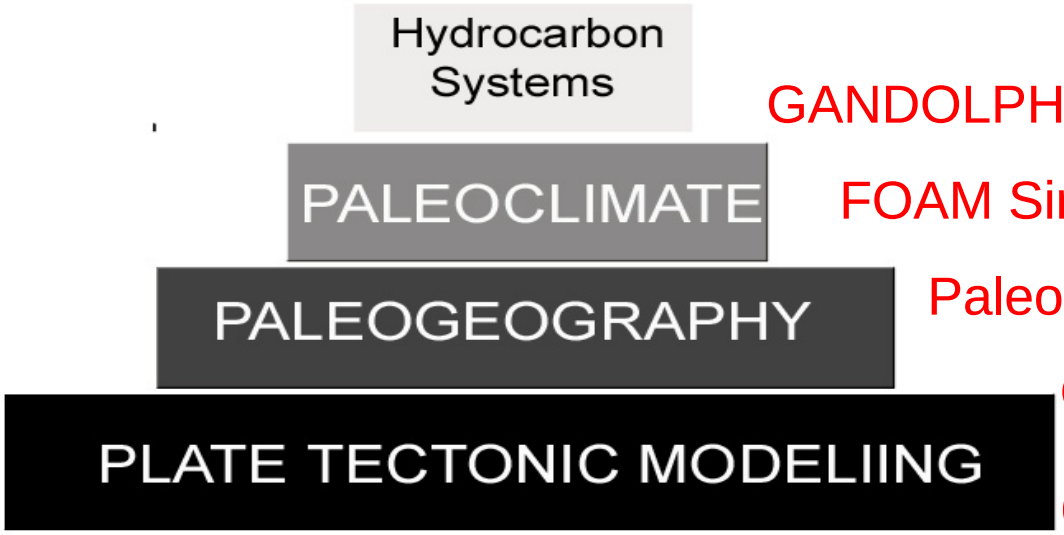
- Cenozoic 10
- Cretaceous 8
- Jurassic 6
- Triassic 4
- Late Paleozoic 12
- Early Paleozoic 10
- Neoproterozoic 3


540 Ma Early Cambrian
SC
NC
G
NA
S
B

High Resolution Paleogeography



PALEOMAP Project Approach



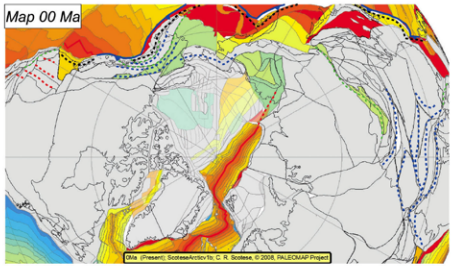
GANDOLPH Source Rock Project

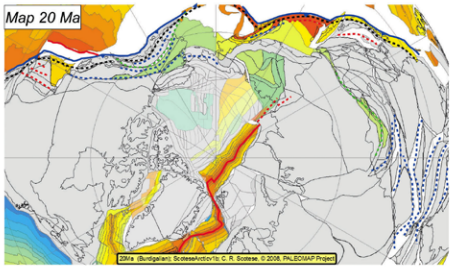
FOAM Simulations (19/53)

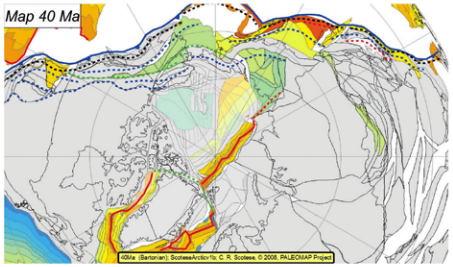
PaleoDEMs (+50)

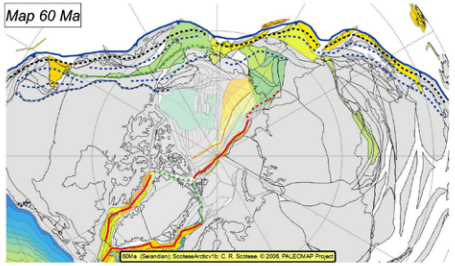
Global Plate Model

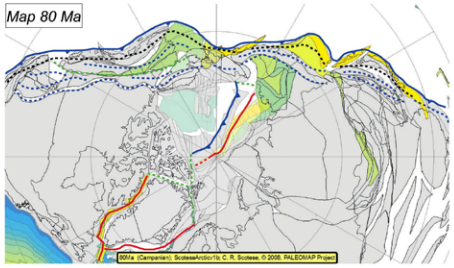
(PaleoGIS)

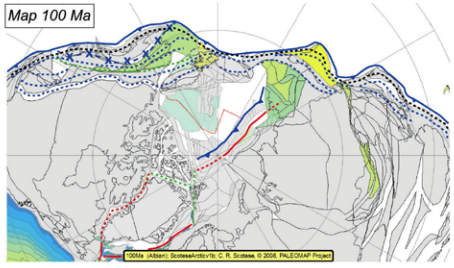


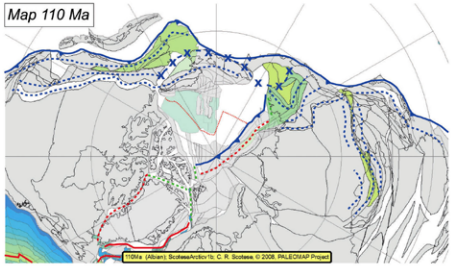


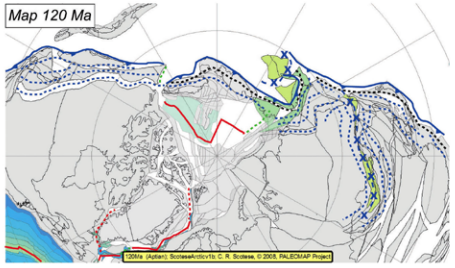


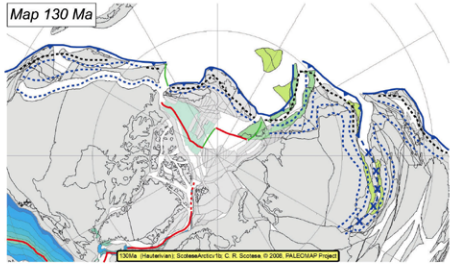


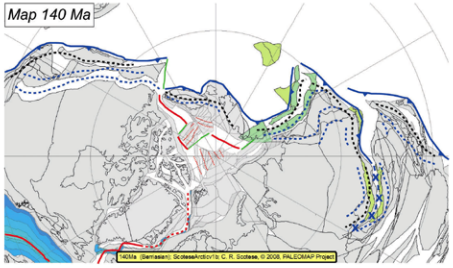


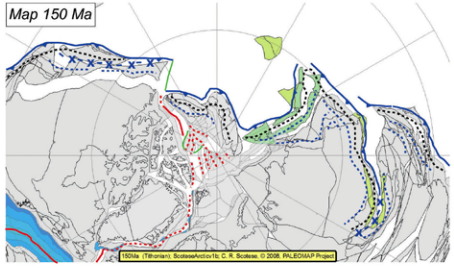


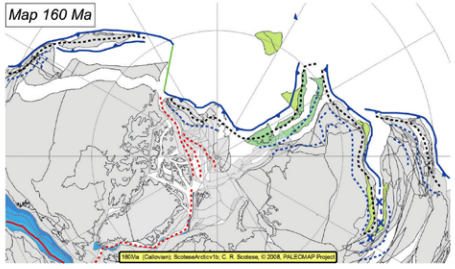


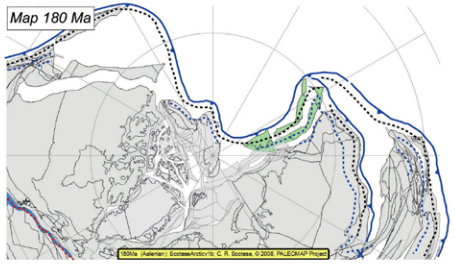


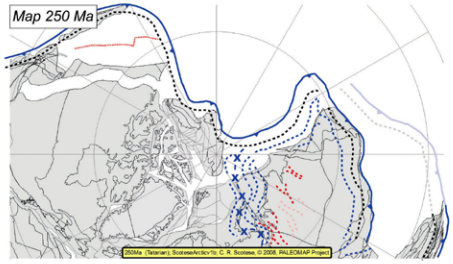


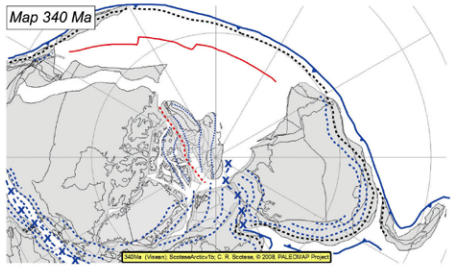


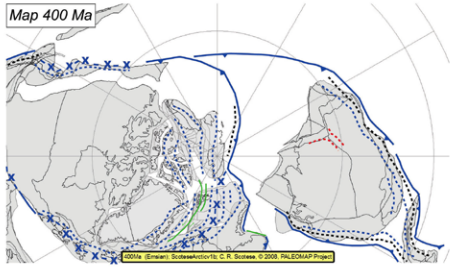


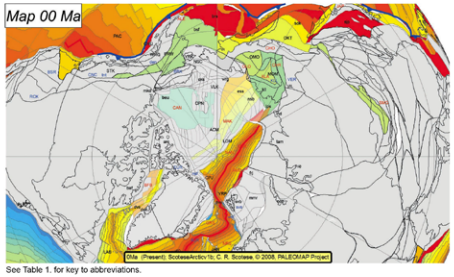












See Table 1. for key to abbreviations.

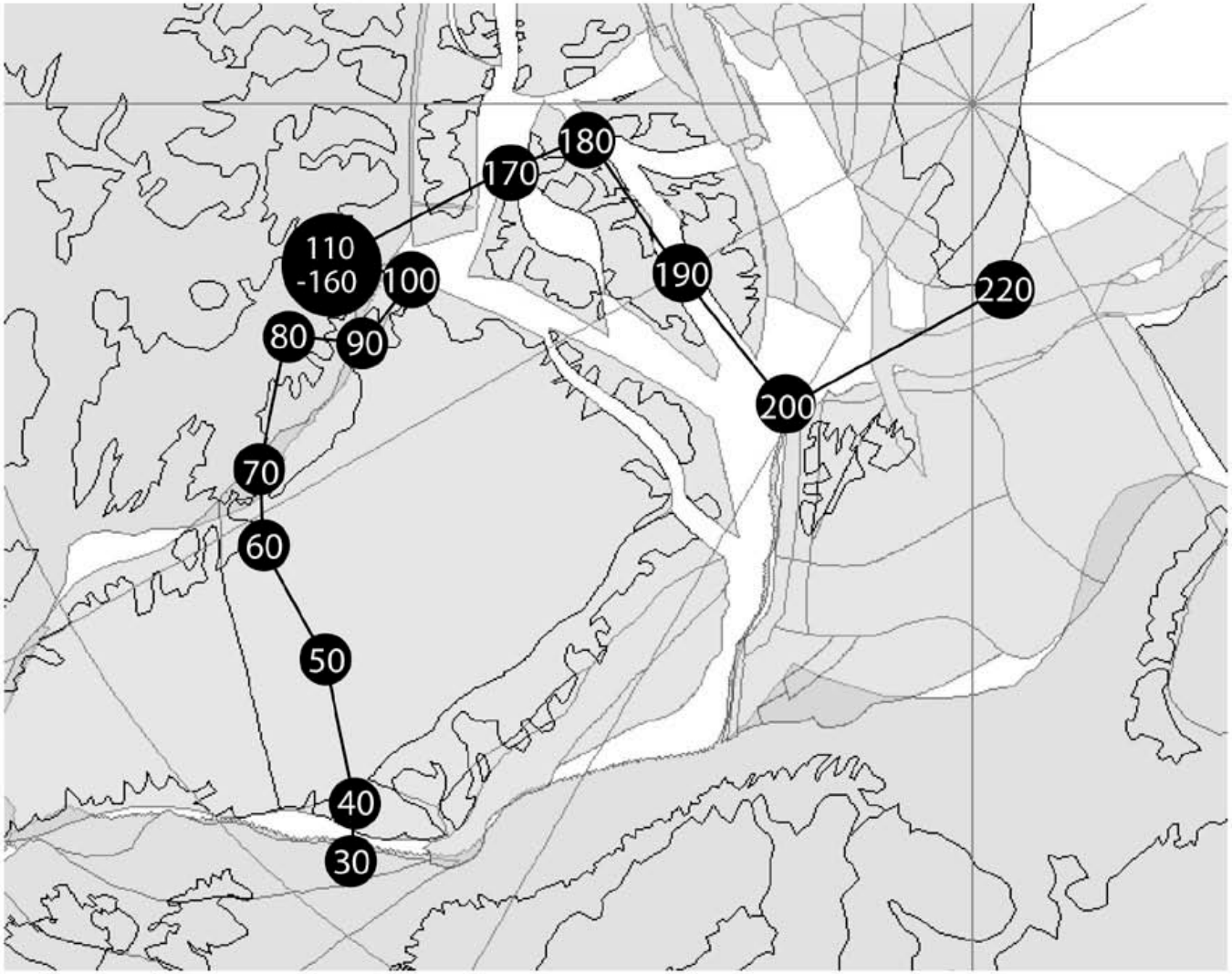
LEGEND

- Subduction Zone
- Volcanic Arc
- Fold & Thrust Belt
- Collision Zone
- Strike-Slip Fault
- Mid-Ocean Ridge
- Continental Rift
- Extinct Rift

Circum-Arctic Plate Tectonic Maps

Christopher R. Scotese
PALEOMAP Project

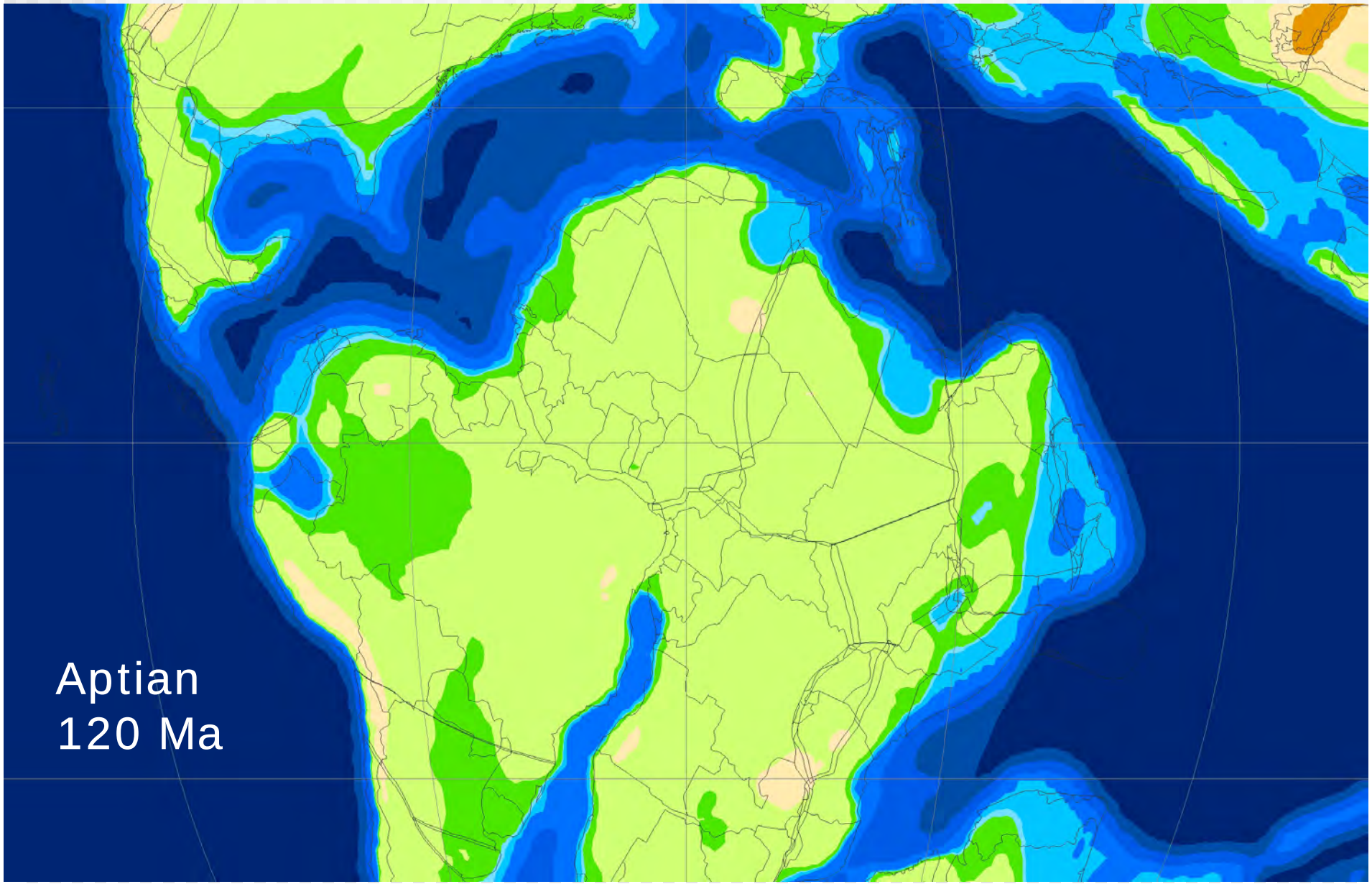
Iceland Hotspot Track



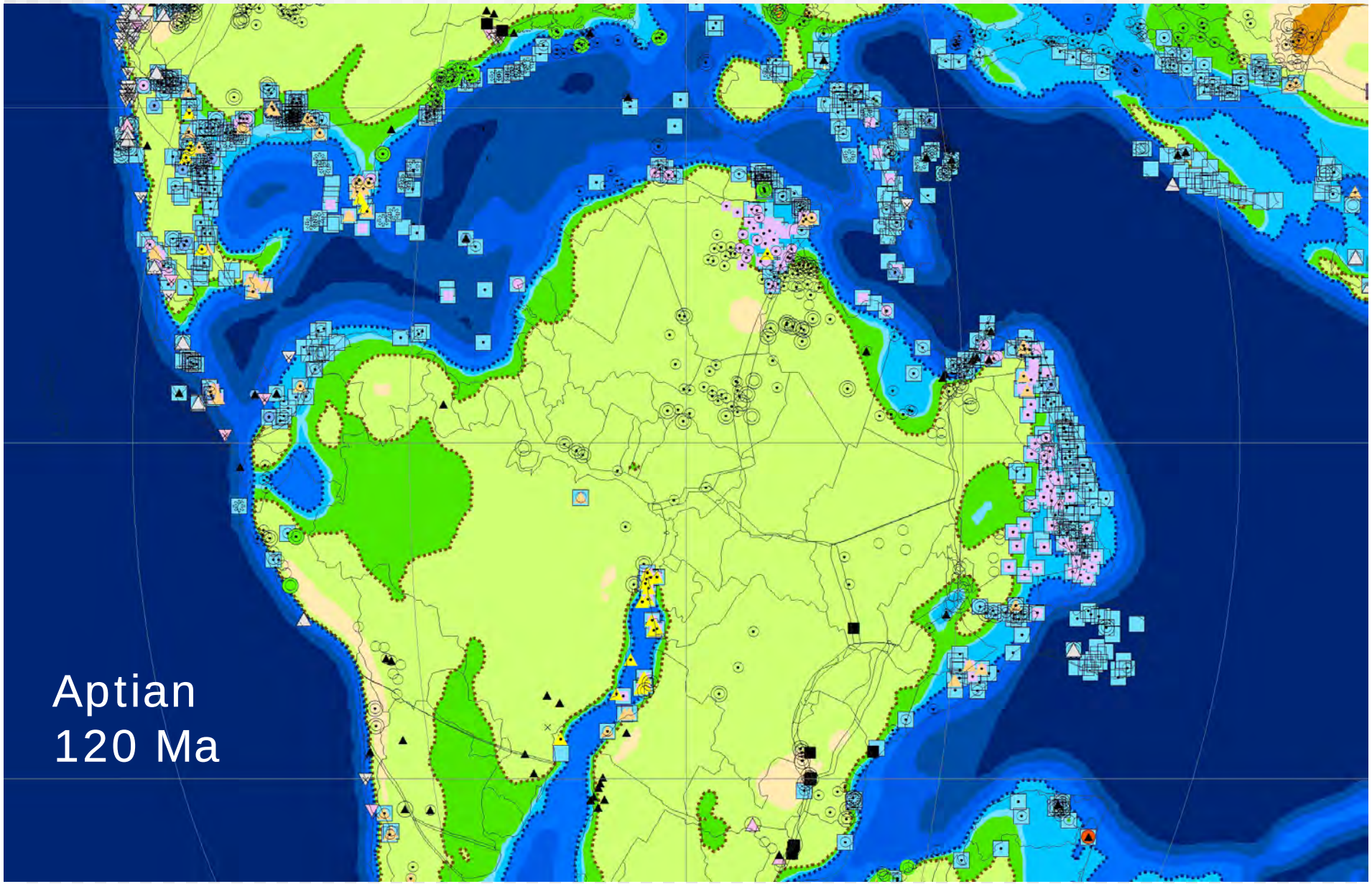
PALEOGEOGRAPHIC RECONSTRUCTIONS

"Interpreting the rock record to map past distribution of lithofacies and environments of deposition."

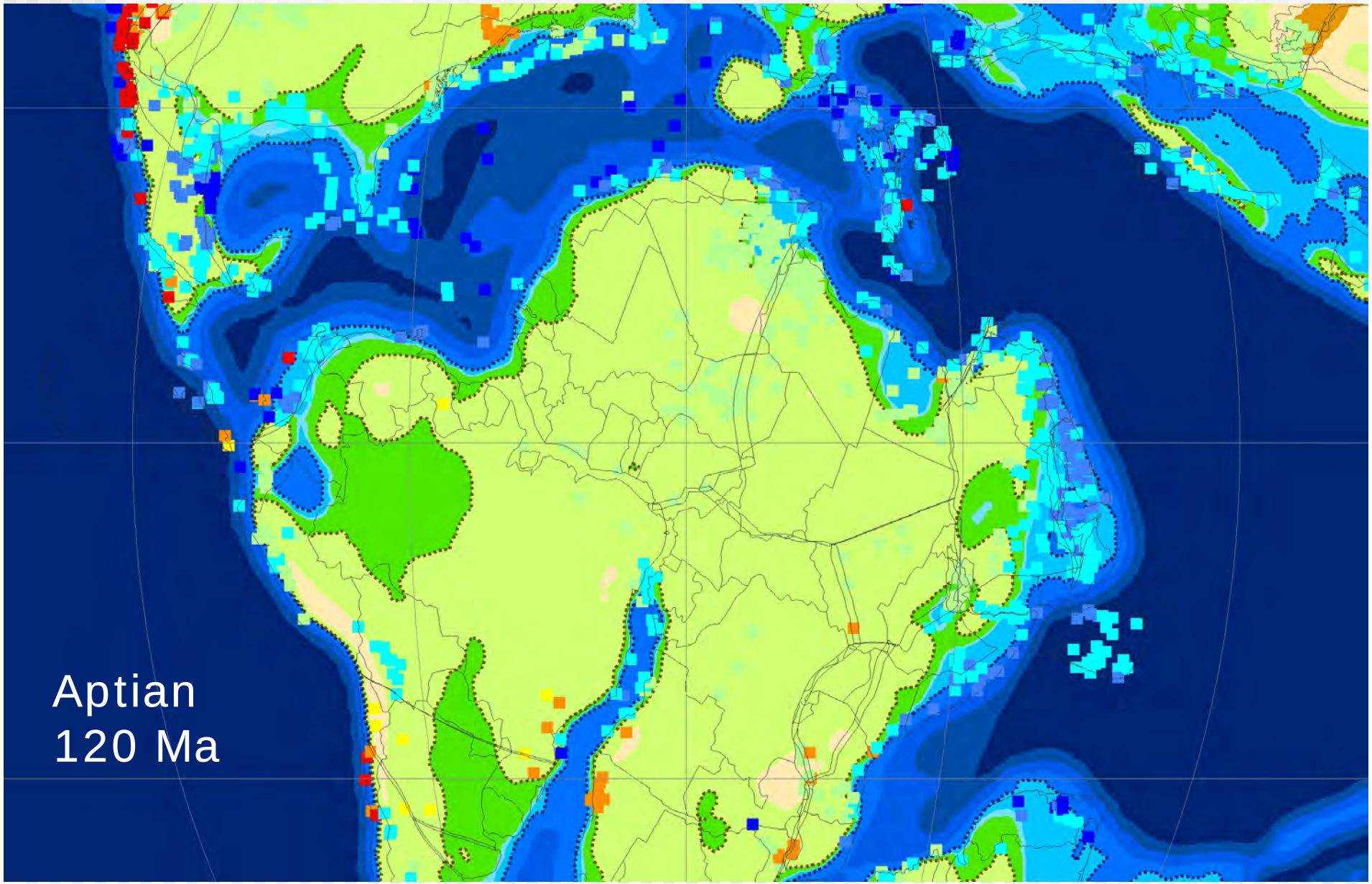
Simplified Paleogeography



Lithofacies (U. Chicago, Ziegler et al., 2003)



Environments of Deposition (Ziegler et al., 2003)



Digital Elevation Model

Resolution of Paleogeographic Maps
Horizontal = .1x.1 degrees
Vertical = 40 m

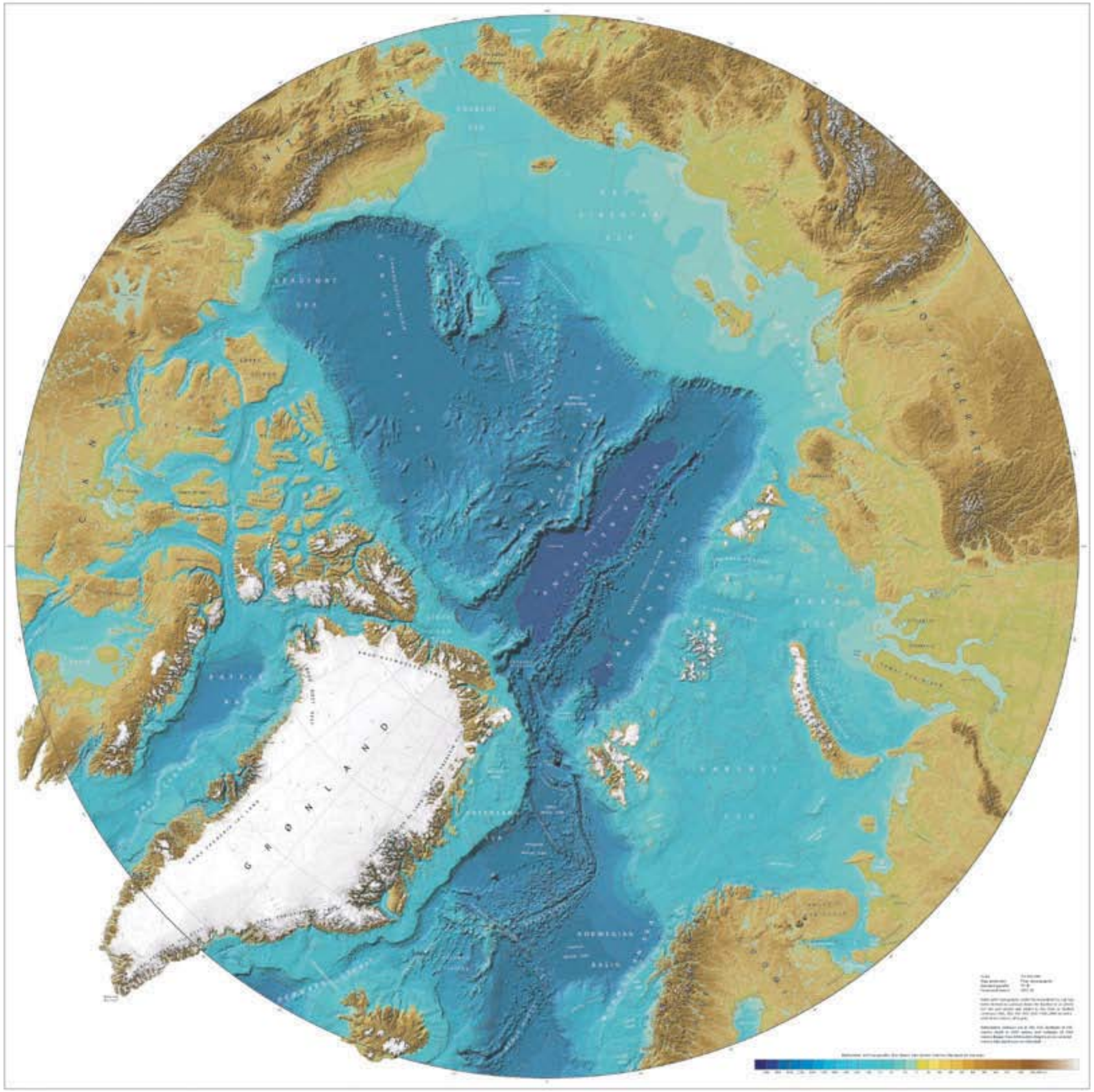
Temporal Resolution
Nearest Sequence Boundary and Maximum Flooding Surface
Lithological Data - Stage

Let’s Go Back to the Tectonic Model

Evolution of the Amerasian Basin

The Key to the Arctic is the Amerasian Basin (Canada Basin + Makarov + Chukchi)

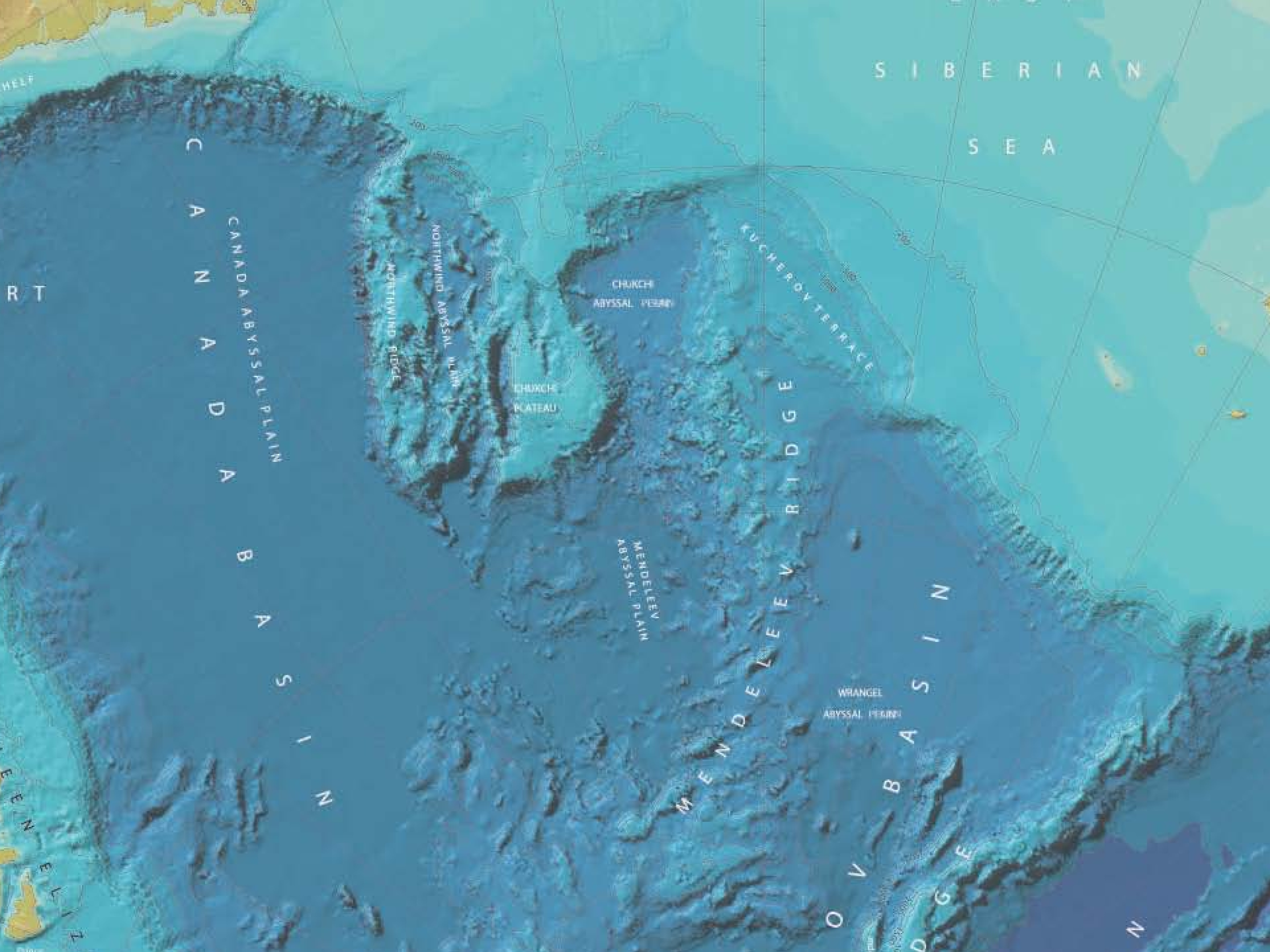
- To Solve Problem of Amerasian Basin, you must first solve:
  - North Atlantic, Labrador Sea, Eurasian Basin
  - North American Cordillera
  - NE Asia
  - Paleozoic History of Laurentia, Baltica, Siberia, and Kazakhstania

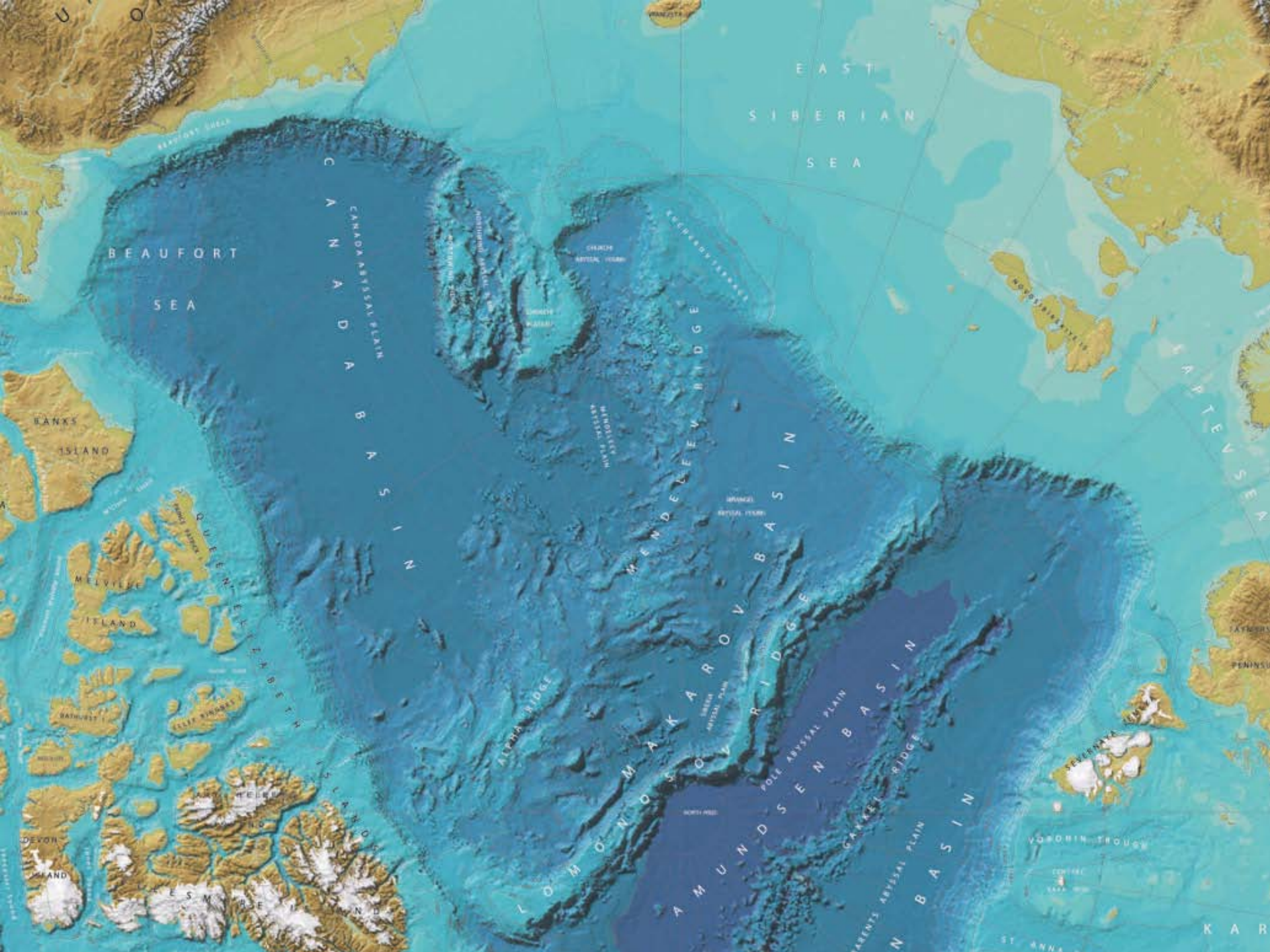


THE INTERNATIONAL BATHYMETRIC CHART OF THE ARCTIC OCEAN (IBCAO)

The Key to the Tectonics of the Amerasian Basin

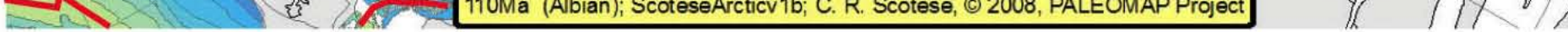
- Two-Part Opening History
- Part 1. 155 Ma (Late Jurassic) – 115 (mid-Cretaceous) Canada Basin Opens
- Part 2. 115 Ma – 65 Ma (mid-Late Cretaceous) Open Makarov – Chukchi Basin.

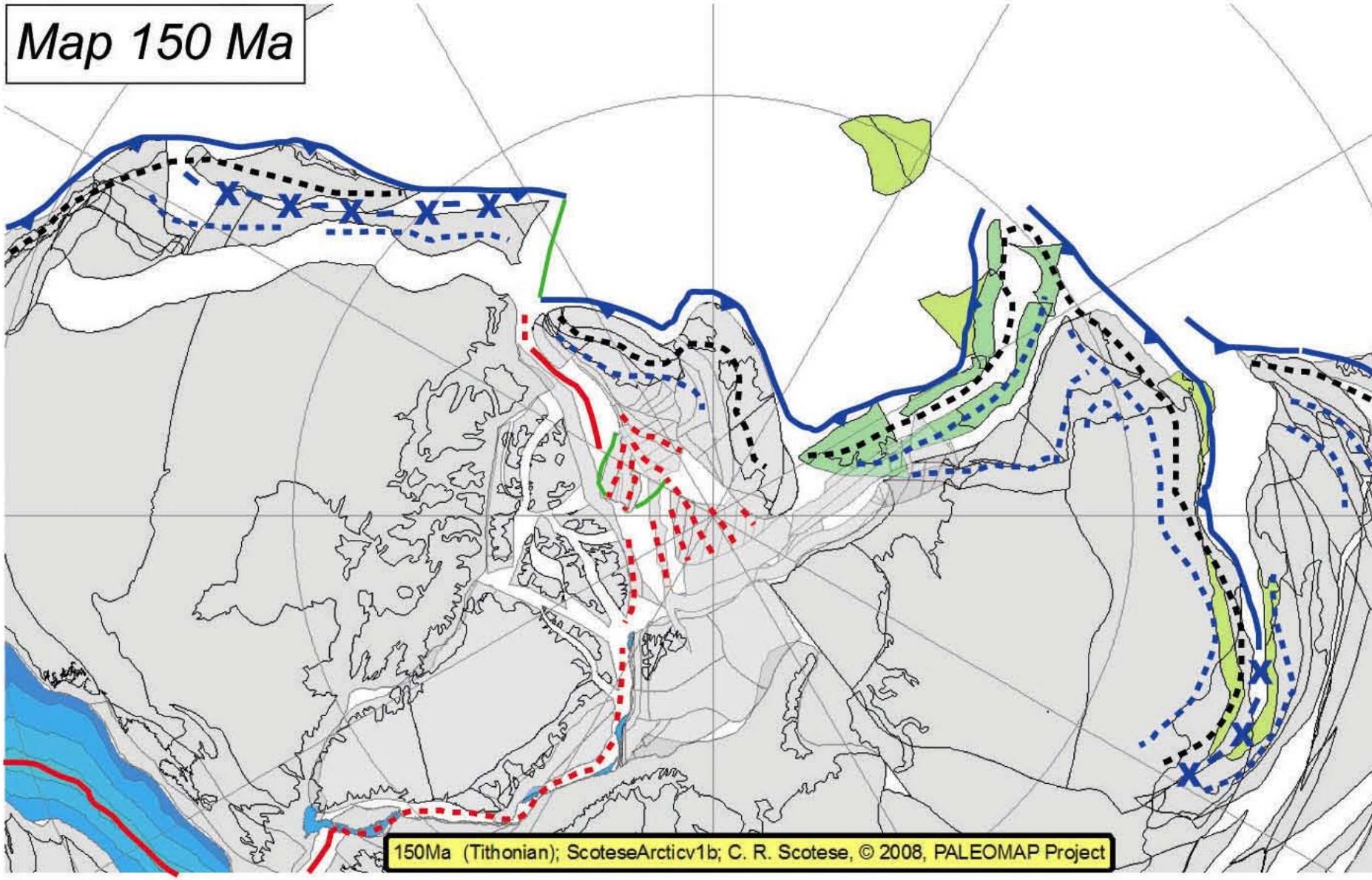

SIBERIAN
SEA
CANADA BASIN
CANADA ABYSSAL PLAIN
NORTHWIND ABYSSAL PLAIN
NORTHWIND RIDGE
CHUKCHI PLATEAU
CHUKCHI ABYSSAL PLAIN
KUCHEROV TERRACE
MENDELEEV RIDGE
MENDELEEV ABYSSAL PLAIN
WRANGEL ABYSSAL PLAIN


EAST
SIBERIAN
SEA
BEAUFORT
SEA
CANADA BASIN
CANADA ABYSSAL PLAIN
MENDELEEV RIDGE
MENDELEEV ABYSSAL PLAIN
CHUKCHI ABYSSAL PLAIN
CHUKCHI PLATEAU
NORTHWIND RIDGE
BANKS
ISLAND
MELVILLE
ISLAND
QUEEN ELIZABETH
ISLANDS
PRINCE PATRICK I.
BATHURST I.
CLELIE RIDGES
ALPHA RIDGE
LOMONOSOV RIDGE
MAKAROV BASIN
AMUNDSEN BASIN
FOGE ABYSSAL PLAIN
GAKKEL RIDGE
NANSEN BASIN
ARCTIC OCEAN
NORTH POLE
SEVERNAYA ZEMLYA
VORONIN TROUGH
PENINSU
KARA
ST ANNA
DEVON
ISLAND
ELLESMERE
ISLAND

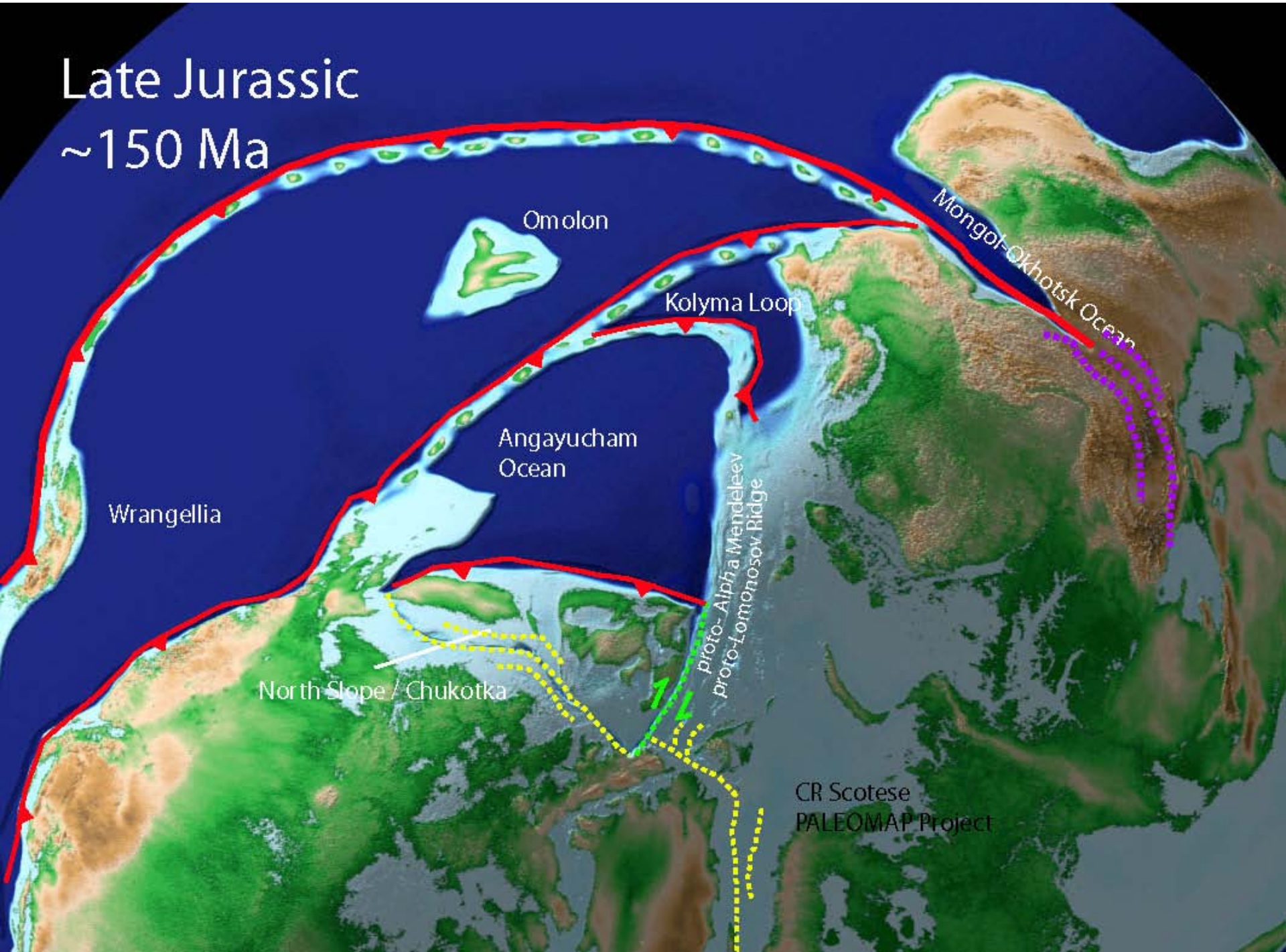
Part 1. Opening of (Greater) Canada Basin

- Opens in latest Jurassic-earliest Cretaceous as a result of northward directed subduction beneath North Slope/Chukotka block
- Essentially a back-arc basin
- Rotation ends when North Slope - Chukotka block collides with central Alaska closing Angayucham Ocean, ~115 Ma – 100 Ma.


110Ma (Albian); ScoteseArcticv1b; C. R. Scotese, © 2008, PALEOMAP Project

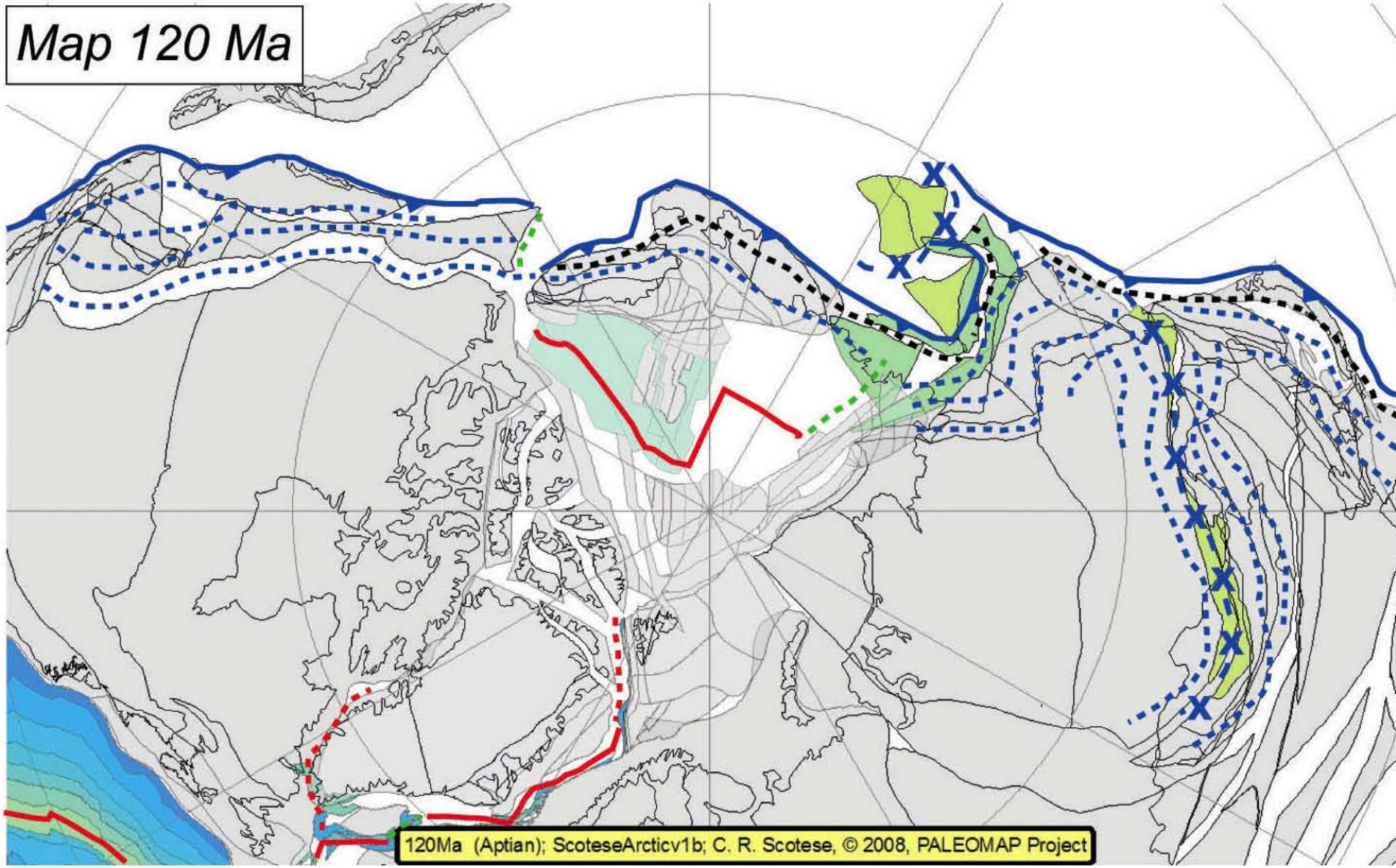

Map 150 Ma
150Ma (Tithonian); ScoteseArcticv1b; C. R. Scotese, © 2008, PALEOMAP Project


Map 340 Ma

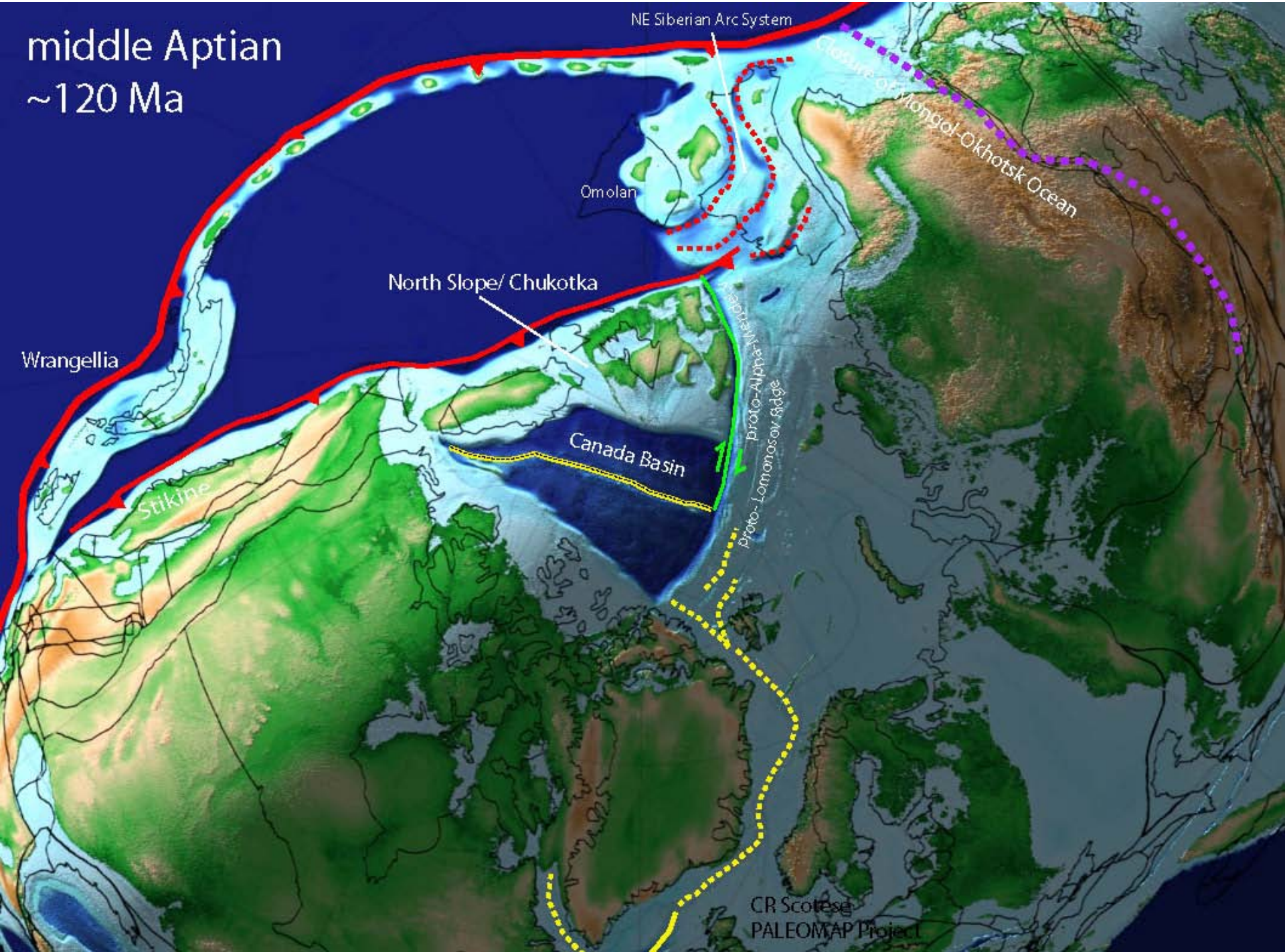

Late Jurassic
~150 Ma
Omolon
Kolyma Loop
Mongol-Okhotsk Ocean
Angayucham
Ocean
Wrangellia
proto-Alpha Mendeleev
proto-Lomonosov Ridge
North Slope / Chukotka
CR Scotese
PALEOMAP Project

60Ma (Selandian); ScoteseArcticv1b; C. R. Scotese, © 2008, PALEOMAP Project

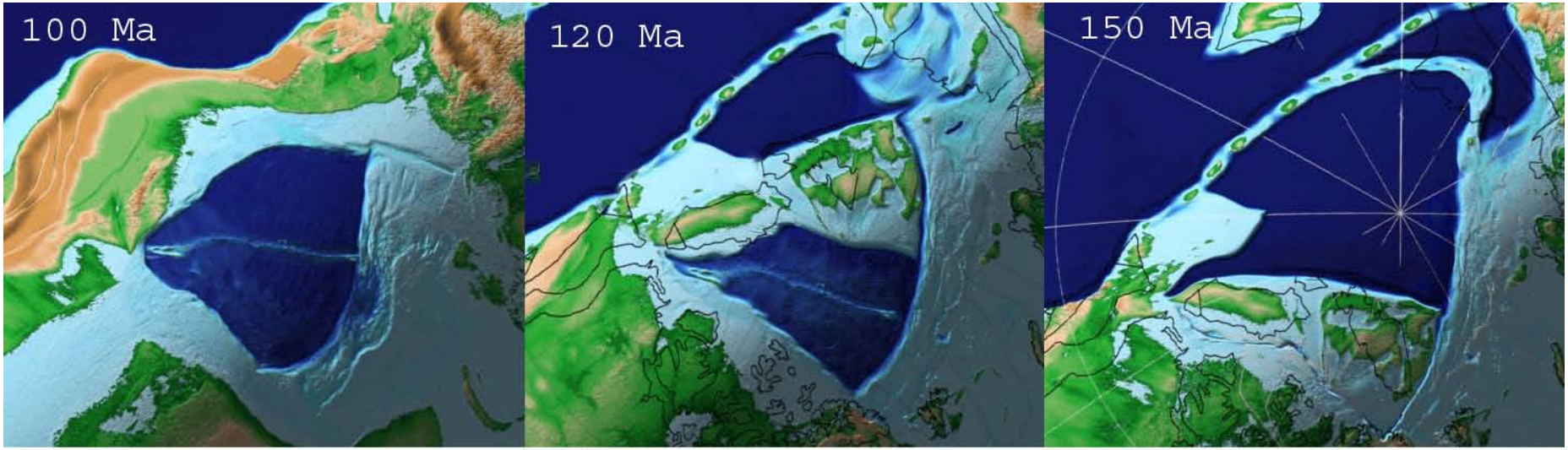
Map 120 Ma



120Ma (Aptian); ScoteseArcticv1b; C. R. Scotese, © 2008, PALEOMAP Project


middle Aptian
~120 Ma
NE Siberian Arc System
Closure of Mongol-Okhotsk Ocean
Omolan
North Slope/ Chukotka
Wrangellia
Canada Basin
proto-Alpha-Mendeleev ridge
proto-Lomonosov ridge
Stikine
CR Scotese
PALEOMAP Project

Part 1. Opening of the (Greater) Canada Basin



Opening of the Amerasian Basin (part 1)

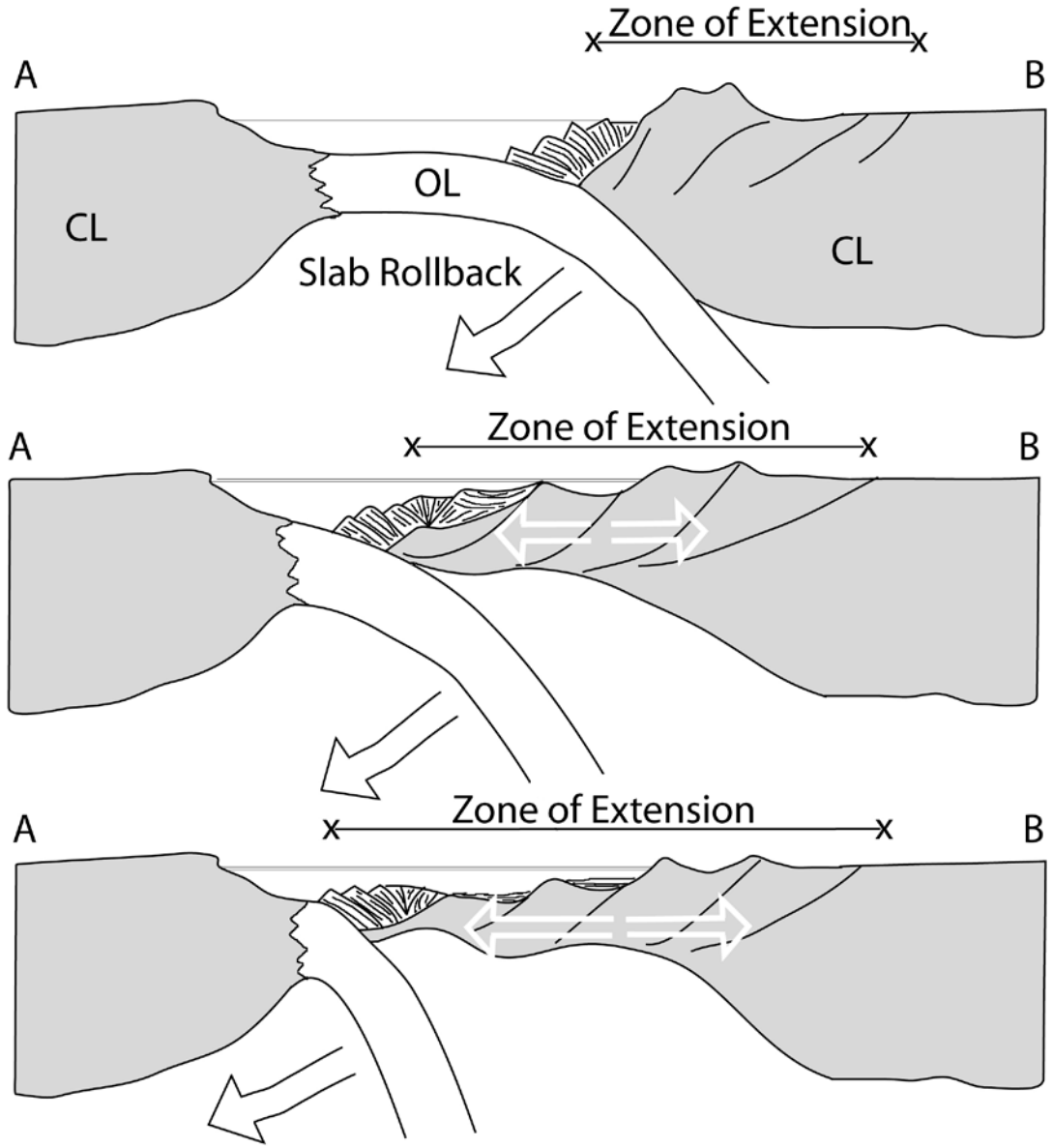
Part 2. Opening of Makarov – Chukchi Basins (mid-Late Cretaceous, ~100 Ma – 65 Ma)

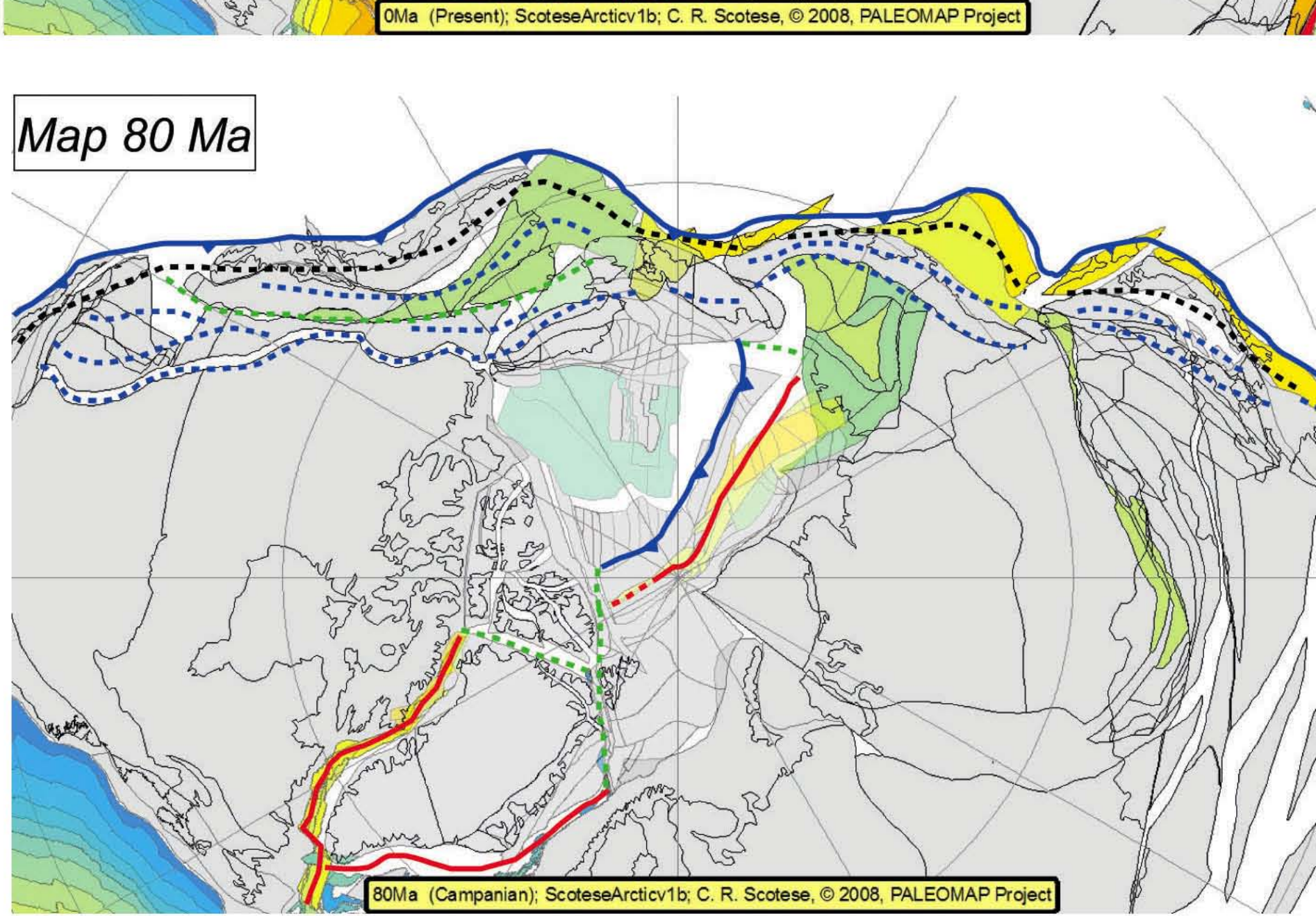
\

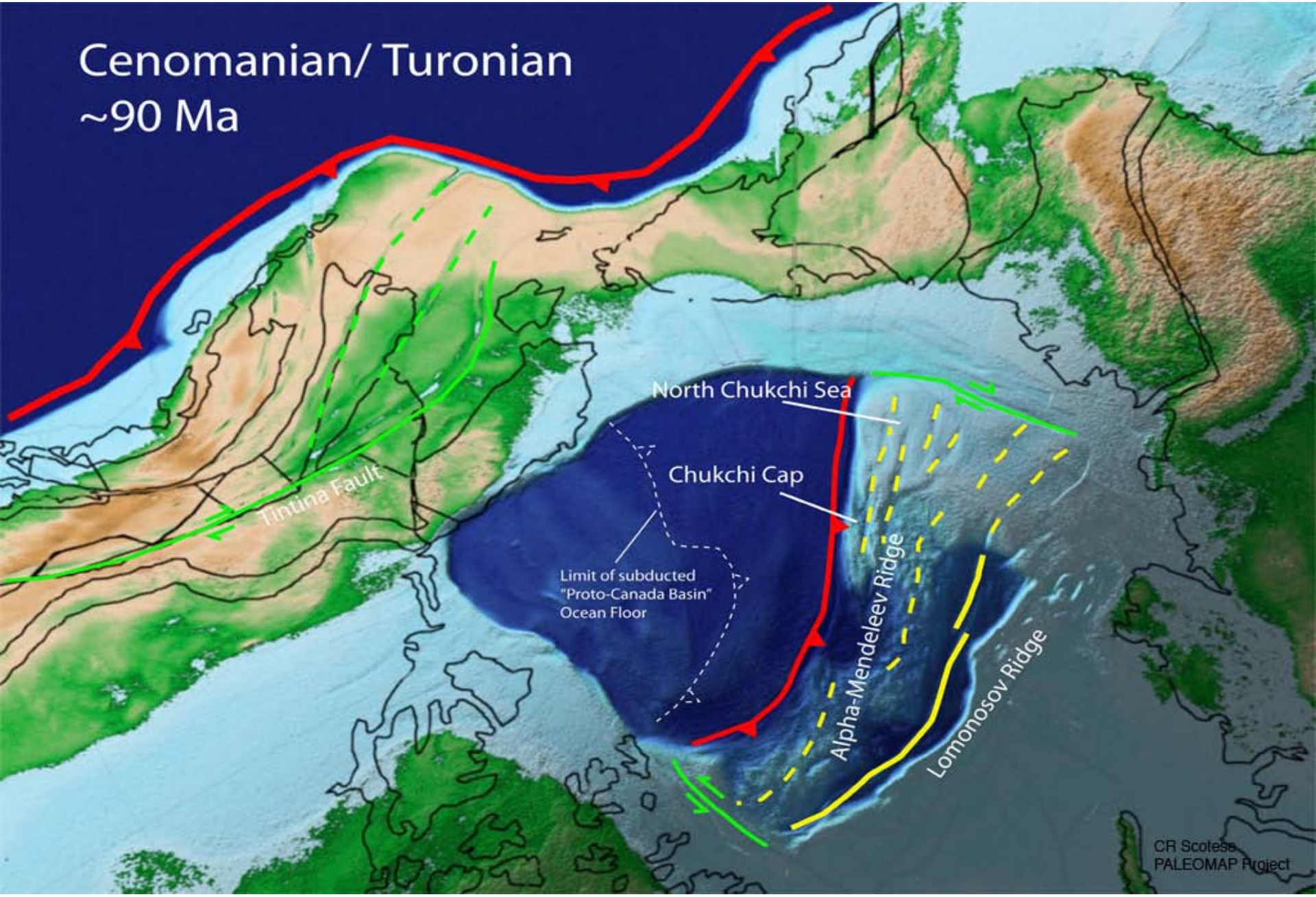
- Alpha –Mendeleev Ridge was originally located adjacent to Lomonsov Ridge
- Subduction beneath Alpha-Mendeleev Ridge resulted in “roll-back” extension (like the Tyrhennian Sea) opening Makarov Basin
- Continued Rollback resulted in extension of Alpha-Mendleev Ridge and Chukchi Plateau
- Subduction ended as a result of “collision” of trench with NW Alaska (Pt. Barrow).

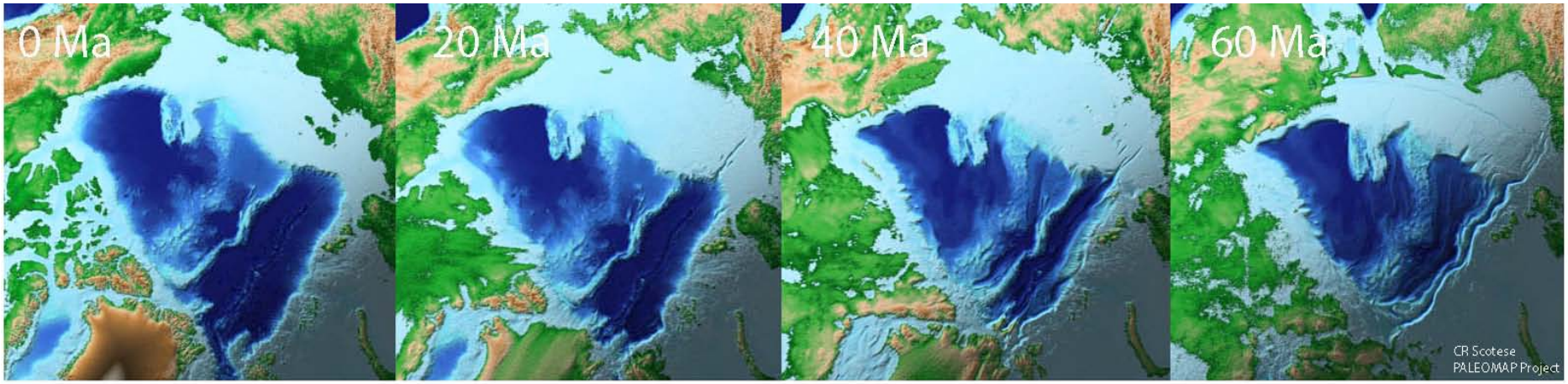
Two Styles of Subduction

- "Conveyor Belt"
  - Active
  - Fast (8 – 10 cm/yr)
  - MOR- coupled
  - Effect on Adjacent Continent: Compression
  - Lots of Volcanism
  - Long-lived (10's – 100's my)
  - Length of subducted slab:
  - 5,000 – >10,000 km
  - Examples: Circum-Pacific "Ring of Fire", Tethyan Margin
- "Roll-Back"
  - Passive
  - Slow (2-5 cm/yr ?)
  - No Ridge, landlocked
  - Effect on Adjacent Continent: Extension
  - Almost no Volcanism
  - Length of subducted slab: 100's - < 2000 km
  - Short –lived (10's my)
  - Tyrhennian Sea, Pannonian Basin, Amerasian Basin

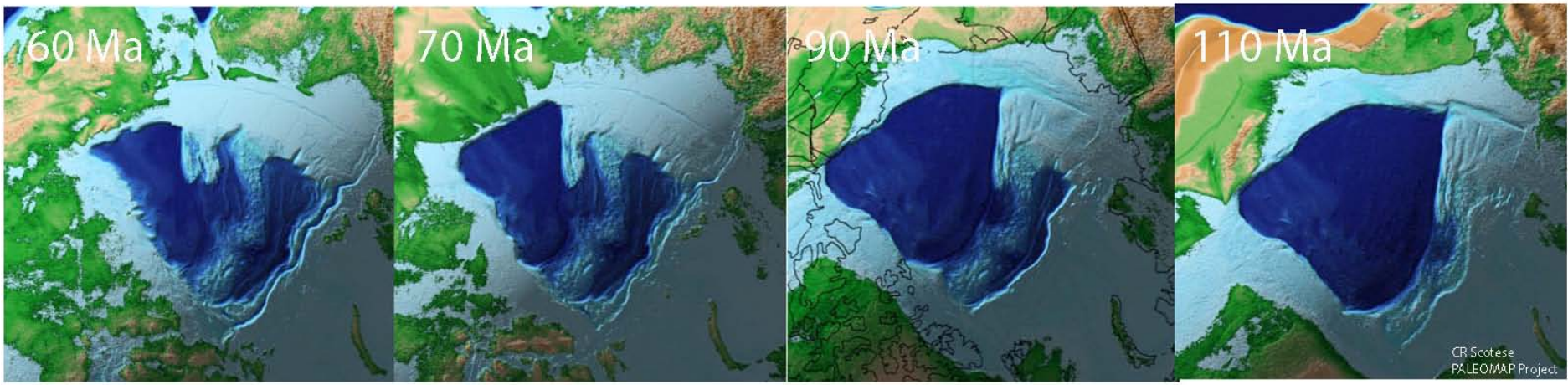

Zone of Extension
A
B
CL
OL
CL
Slab Rollback
Zone of Extension
A
B
Zone of Extension
A
B


Map 80 Ma
0Ma (Present); ScoteseArcticv1b; C. R. Scotese, © 2008, PALEOMAP Project
80Ma (Campanian); ScoteseArcticv1b; C. R. Scotese, © 2008, PALEOMAP Project


Cenomanian/ Turonian
~90 Ma
North Chukchi Sea
Chukchi Cap
Tintina Fault
Limit of subducted
"Proto-Canada Basin"
Ocean Floor
Alpha-Mendeleev Ridge
Lomonosov Ridge
CR Scotese
PALEOMAP Project



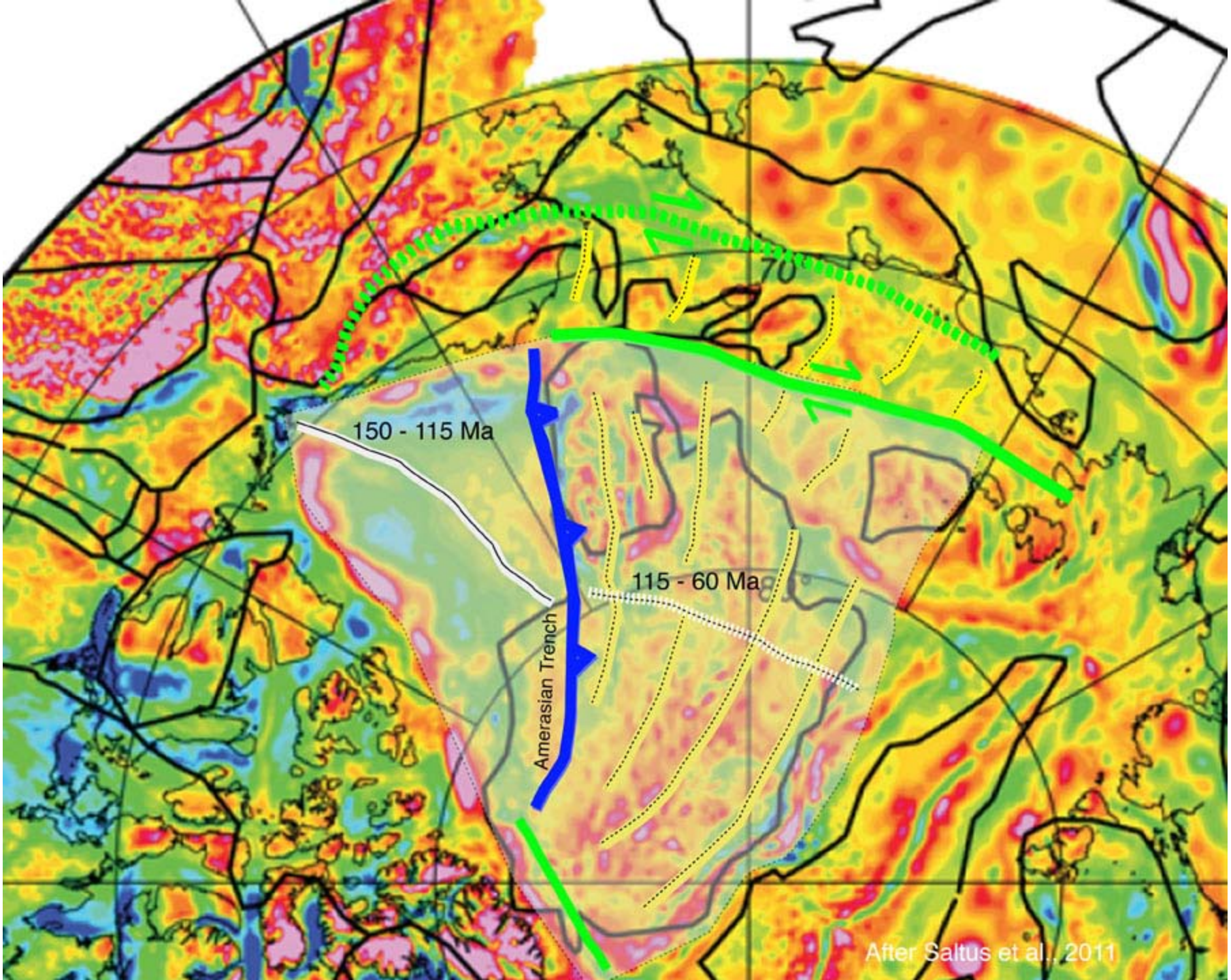
Opening of the Eurasian Basin



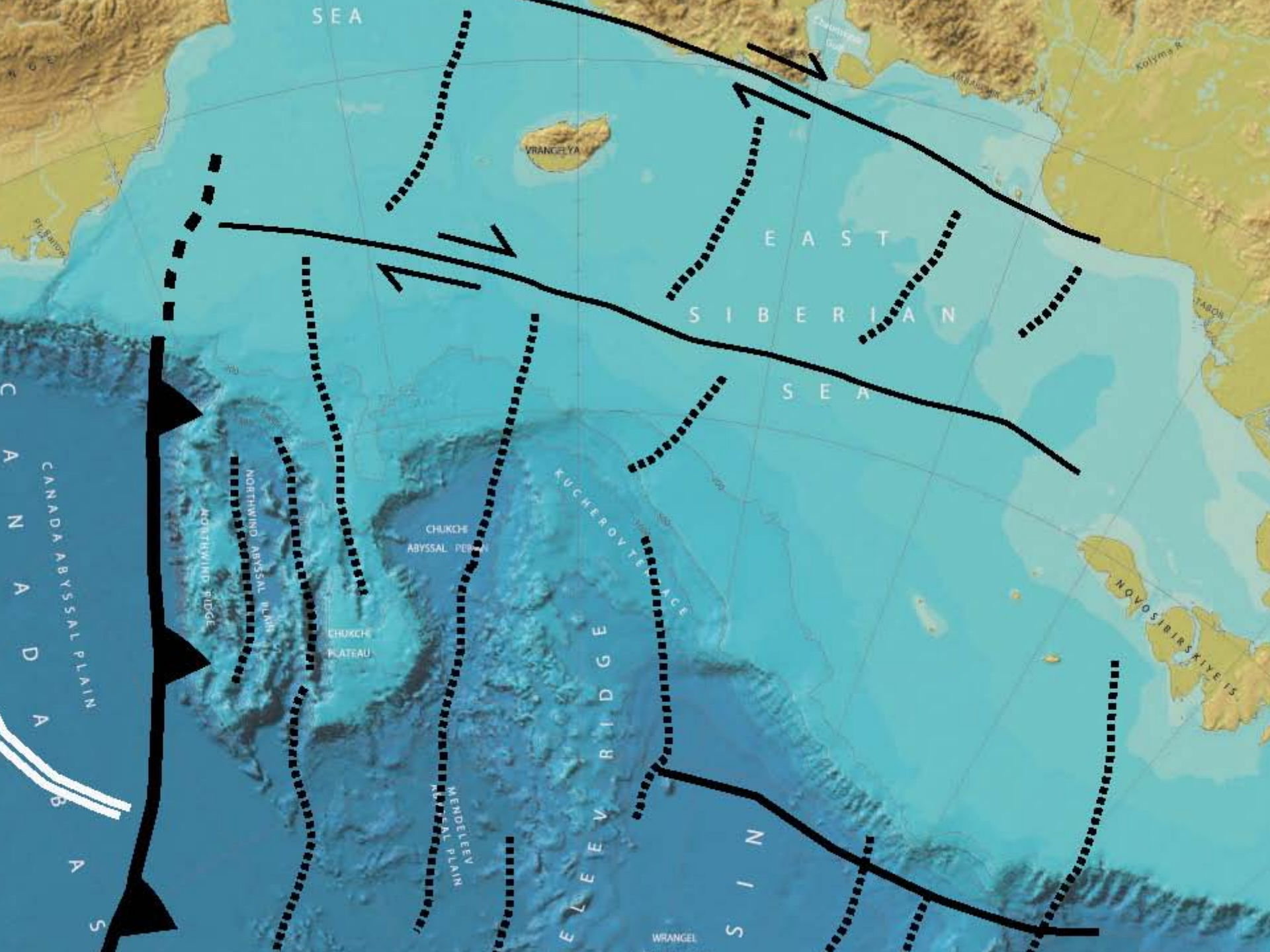
Opening of the Amerasian Basin (part 2)

Evidence and Consequences

- High Arctic Large Igneous Province is the result of excess volcanism due “roll-back” extension.
- There is a major dextral strike-slip boundary beneath the North Chukchi and East Siberia Sea.
- The collision of the Amerasian Trench with NW Alaska (~65 Ma) resulted in Pt. Barrow uplift.


70
150 - 115 Ma
115 - 60 Ma
Amerasian Trench
After Saltus et al., 2011


SEA
VRANGELYA
EAST
SIBERIAN
SEA
CANADA ABYSSAL PLAIN
NORTHWIND RIDGE
NORTHWIND ABYSSAL PLAIN
CHUKCHI
ABYSSAL PLAIN
CHUKCHI
PLATEAU
KUCHEROV TERRACE
MENDELEEV
ABYSSAL PLAIN
MENDELEEV RIDGE
NOVOSIBIRSKIYE IS.
WRANGEL


SEA
VRANGELYA
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MENDELEEV RIDGE
MENDELEEV ABYSSAL PLAIN
NOVOSIBIRSKIYE IS.
WRANGEL

Questions & Conclusions

- OK, so where is this supposed subduction zone?
- Why can’t we “see”it?
- Where is the island arc that goes with it?
- Why did it stop subducting?
- How can we test this hypothesis?