Plate Tectonic and Paleogeographic Mapping: State of the Art*

By
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Search and Discovery Article #40312 (2008)
Posted July 7, 2008

*Adapted from oral presentation at AAPG Annual Convention, San Antonio, Texas, April 20-23, 2008

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Abstract

How well do we know the configurations of the continents and ocean basins back through time? How accurate are our interpretations of long-eroded mountain ranges and ancient shallow seas? It has been over 40 years since the plate tectonic revolution; what have we learned? How much do we really know? Where should we be focusing our research efforts? Though there have been incremental improvements in our knowledge, the geological and geophysical datasets upon which these reconstructions are based have not changed much in nearly 20 years ago. There are less than a dozen research groups that produce global plate tectonic and paleogeographic reconstructions. Is there general agreement between these groups concerning plate positions and paleogeography through time? How do the interpretations of each of these groups differ? How do we quantify what we know and what we don't know? Though unanswered questions remain, the advent of GIS technology (ArcGIS 9.2 from ESRI) has made it easier to gather the data needed to tackle the remaining questions. Plate tectonic and paleogeographic mapping is now an important tool that is helping the oil industry better understand the formation and development of hydrocarbon systems in frontier areas. Paleogeographic maps are the foundation upon which sophisticated climate models are being run to predict the spatial and temporal distribution of source rocks and reservoir rocks. The newest generation of paleogeographic maps include 3D digital elevation models (PaleoDEMs) that model past changes in bathymetry and topography. This talk will 1) present snap shots from the PaleoAtlas for ArcGIS, a compilation of 50 plate tectonic and paleogeographic reconstructions assembled by the PALEOMAP Project, and 2) will include a 3D computer animation that illustrates plate motions and paleogeographic changes during the last 750 million years.

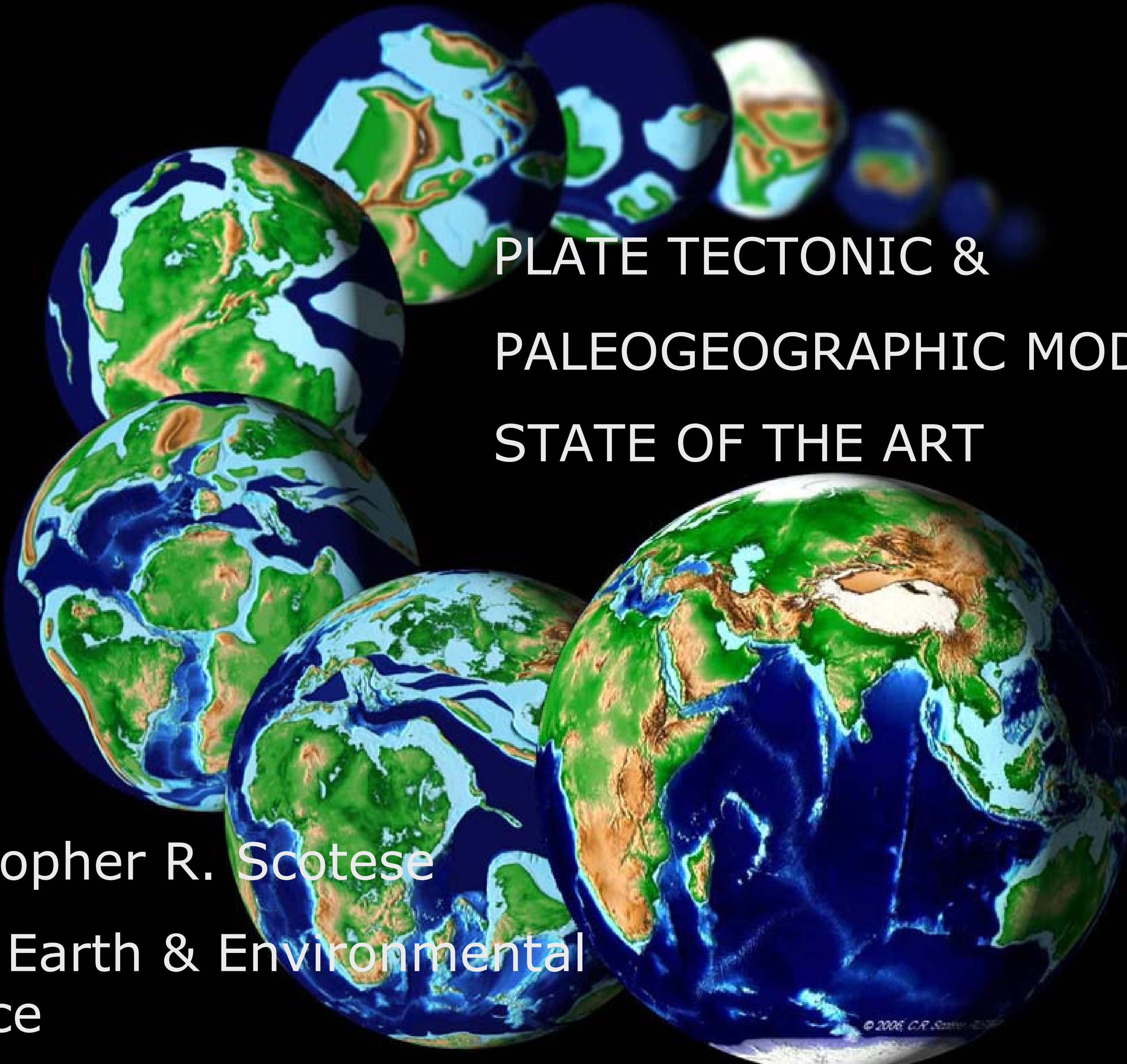

PLATE TECTONIC & PALEOGEOGRAPHIC MODELING: STATE OF THE ART

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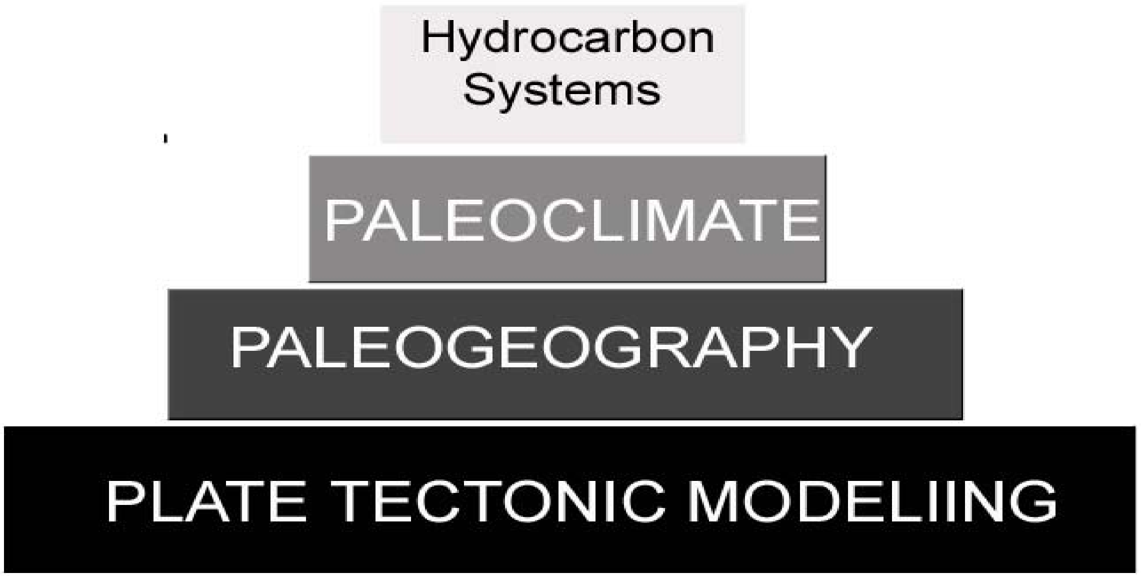
PALEOMAP Project Philosophy

"To use an integrated, multidisciplinary, Earth Systems Science approach to model: plate tectonics, paleogeography, and paleoclimatology in order to better understand the geology in frontier areas and the development of hydrocarbon systems"

PALEOMAP Project Approach



PALEOMAP Project Approach

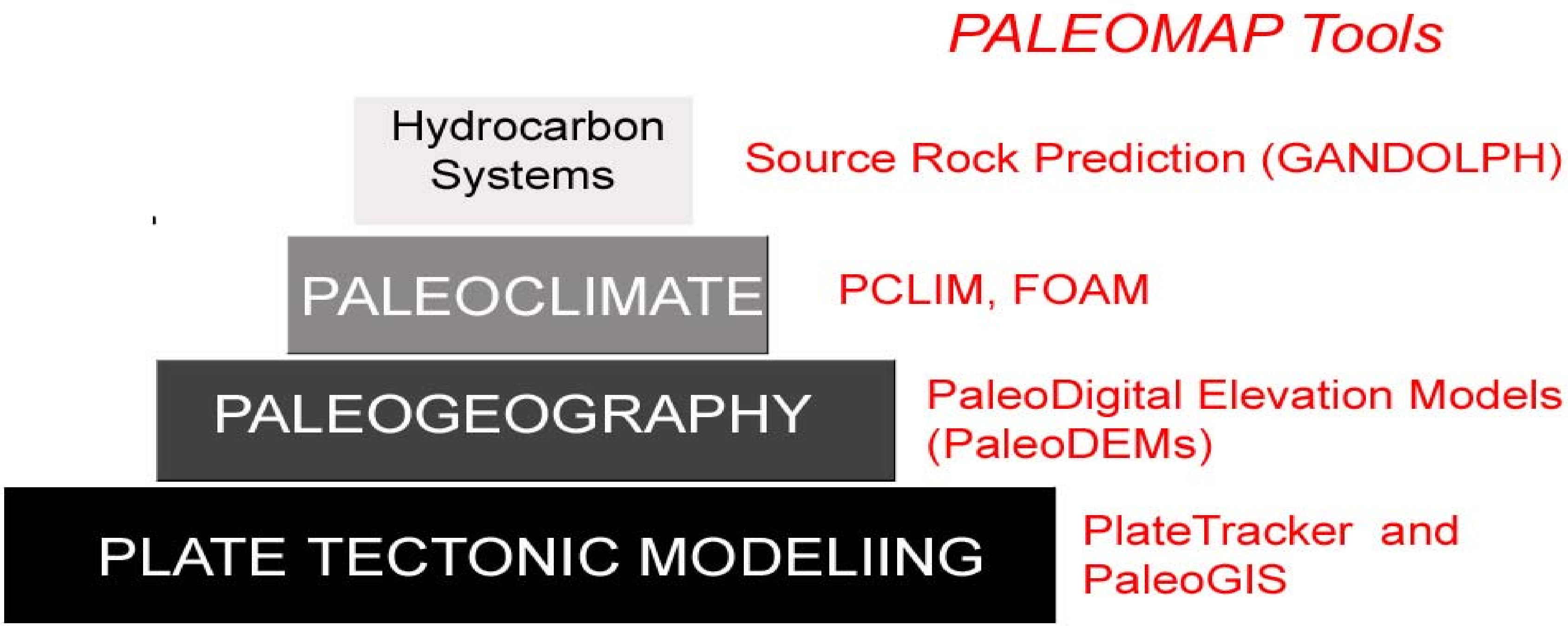
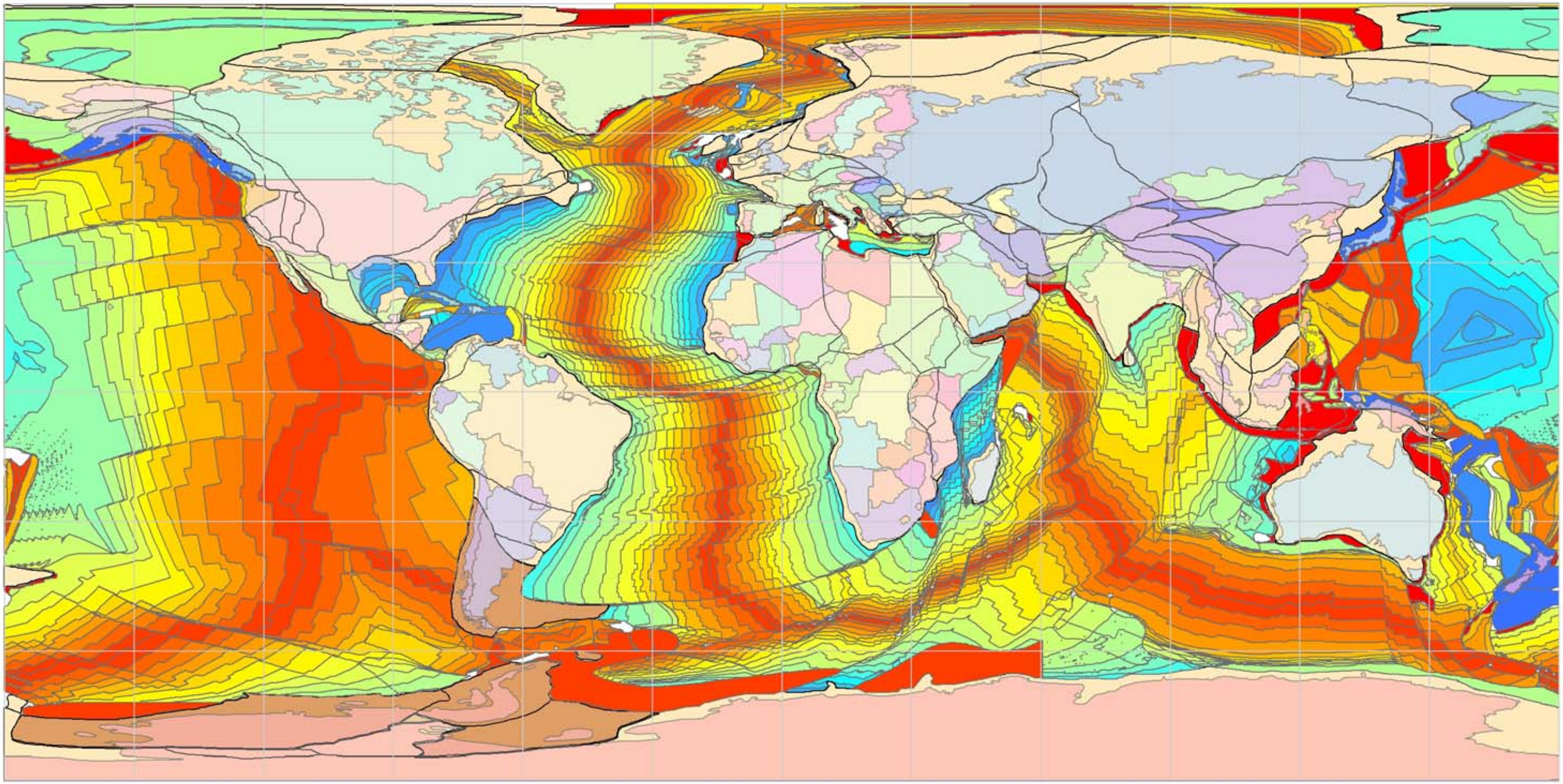
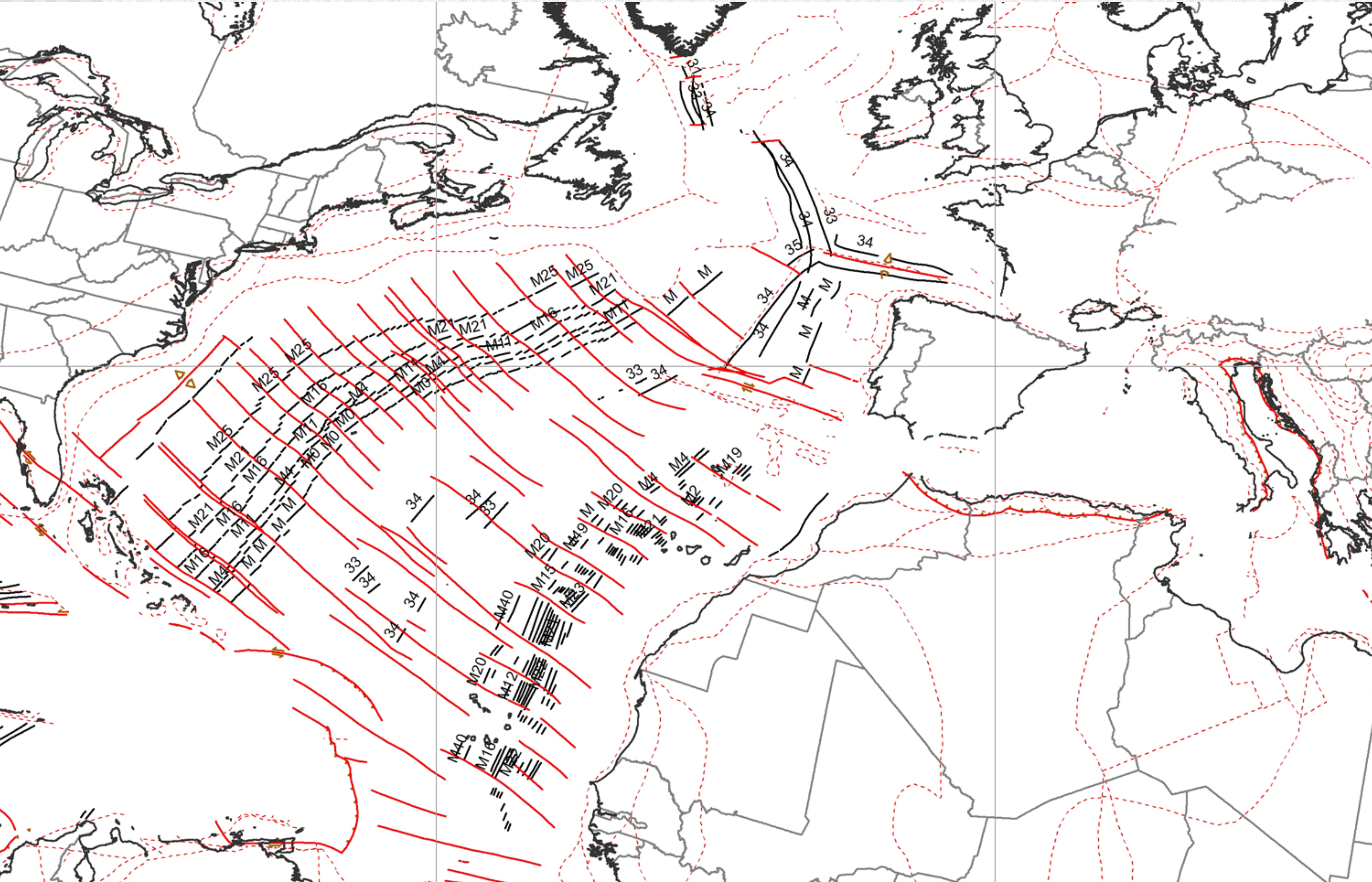


PLATE TECTONIC FRAMEWORK

Data Used to Produce Plate Models:

- GPS & Earthquakes (Modern)
- Ocean Floor Fabric (back to 160 Ma)
- Magnetic Picks & LMA (back to 180 Ma)
- Hot Spot Tracks (back to 200 Ma)
- Paleomagnetic APW paths (back to 300 Ma)
- Fossils & Biogeography (back to 600 Ma)
- Single Paleomagnetic Poles (back to 1200 Ma)
- Geologic and Tectonic Interpretation (~2400 Ma)





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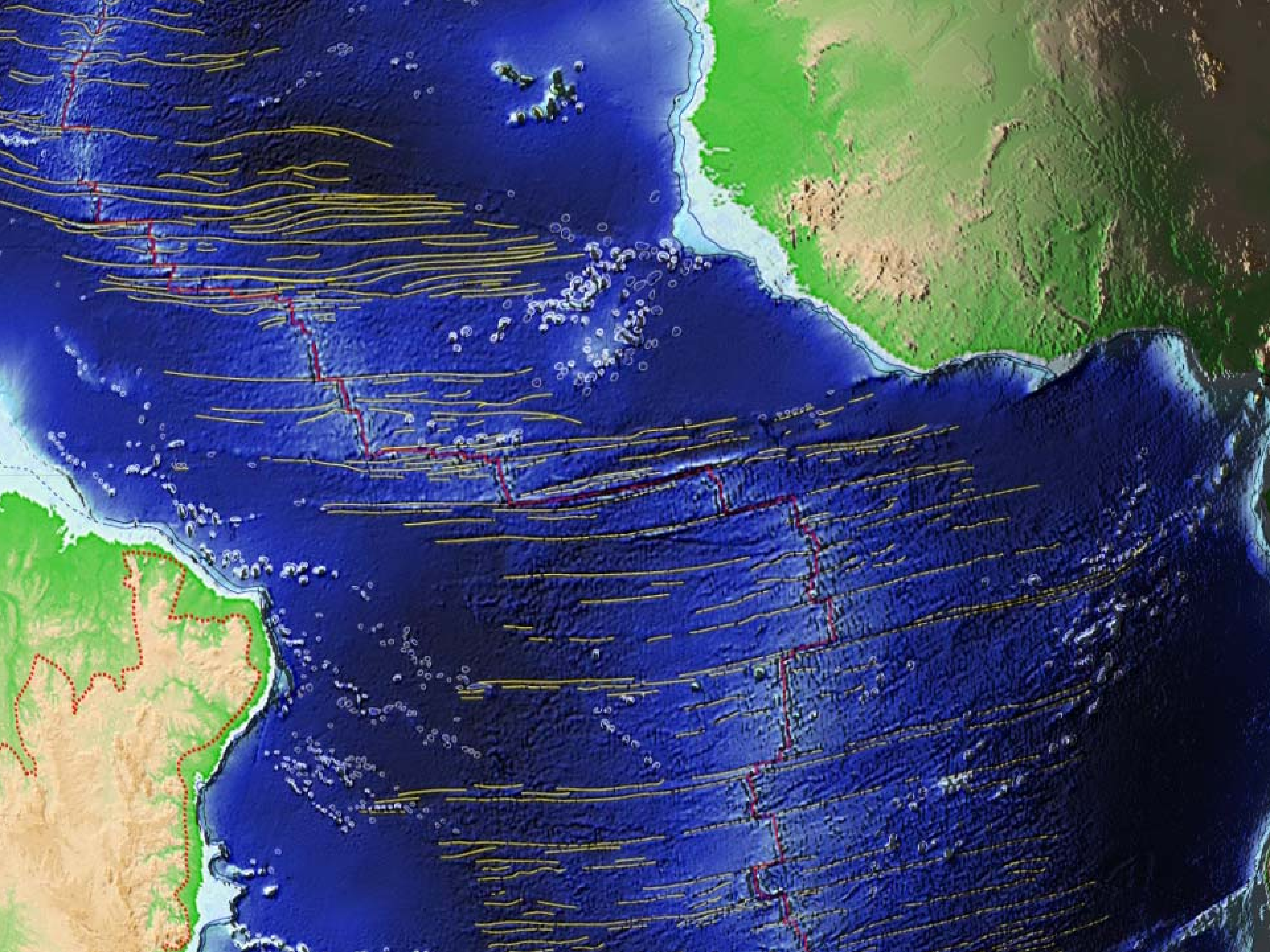
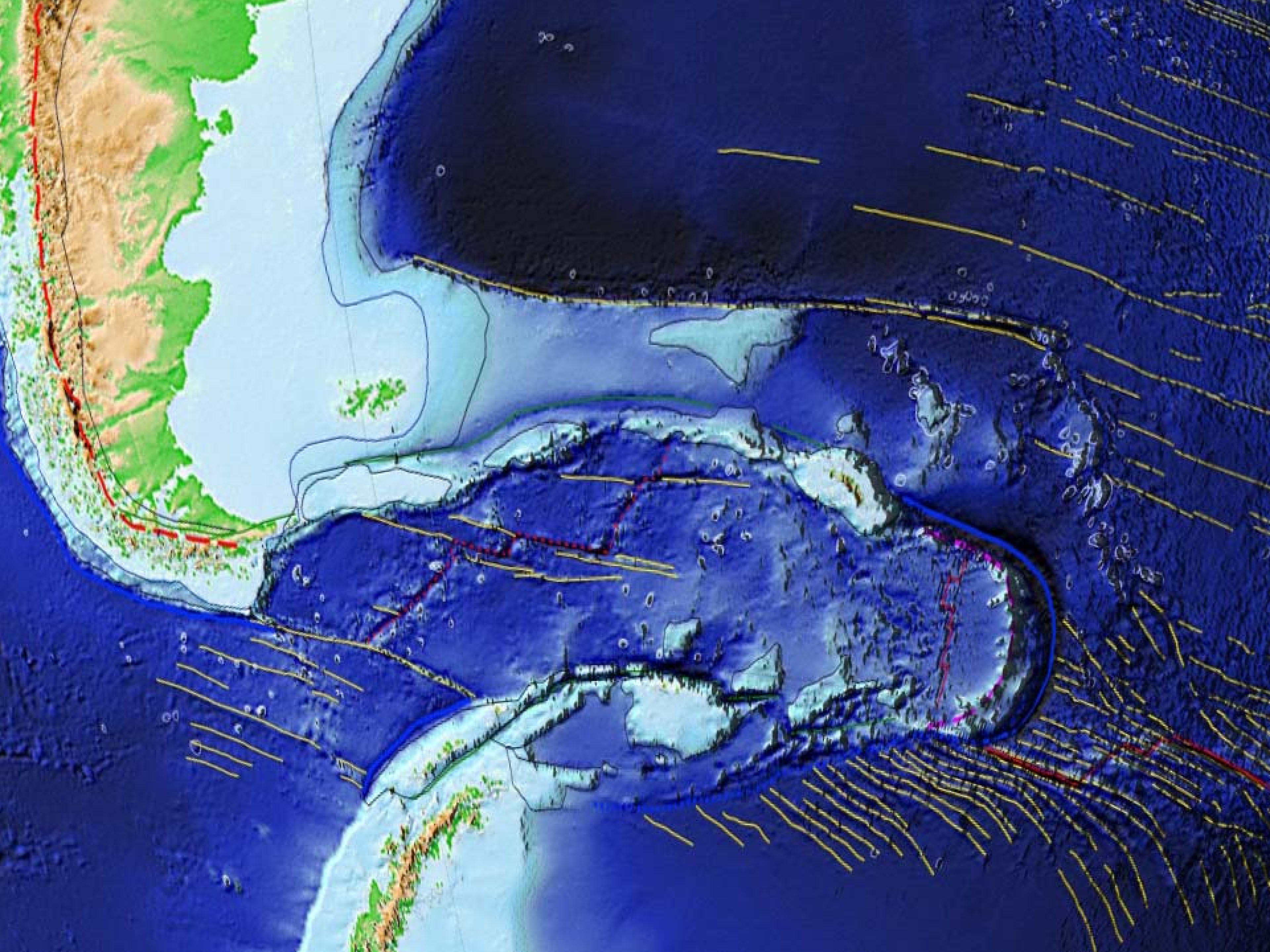
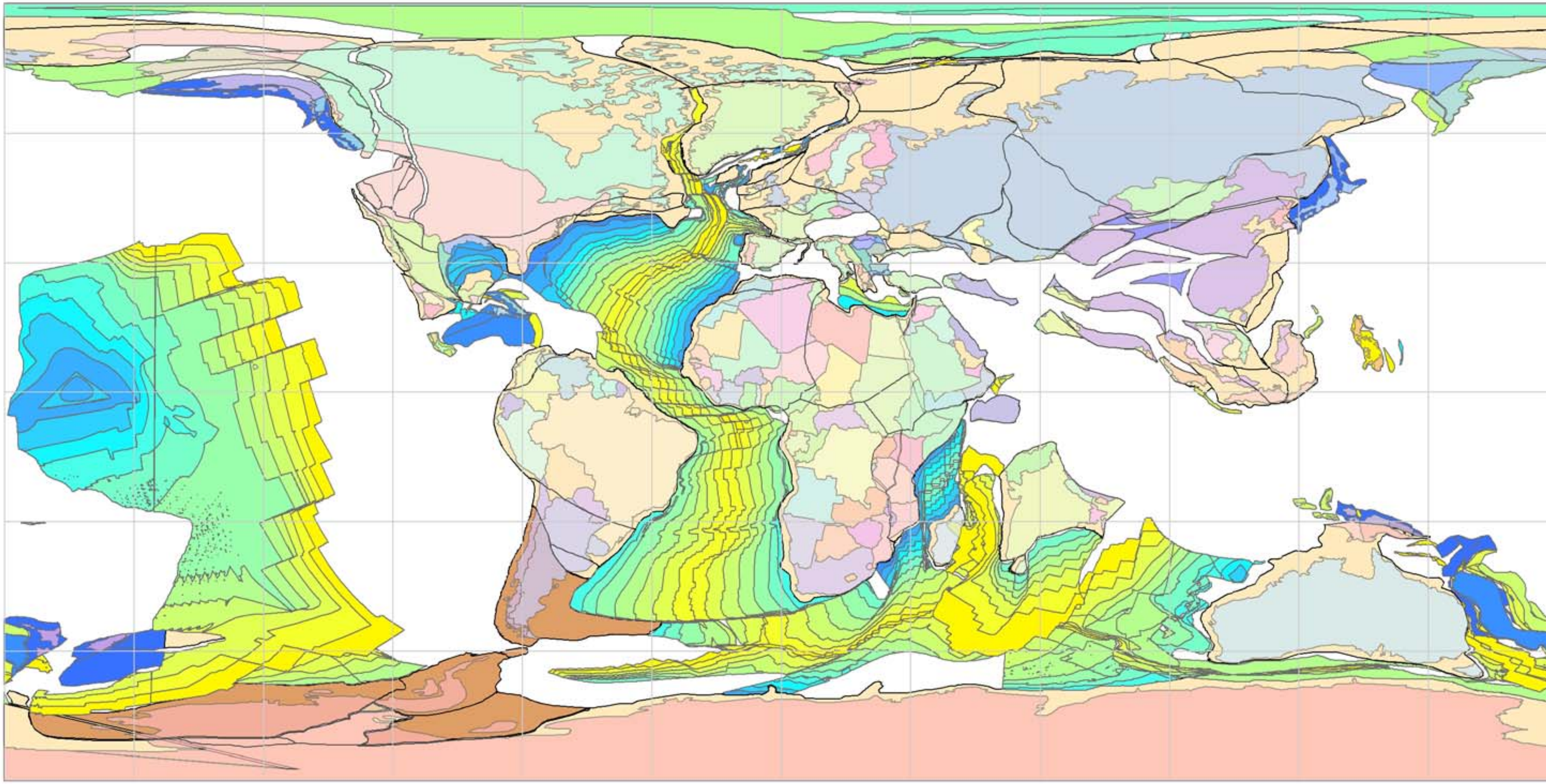


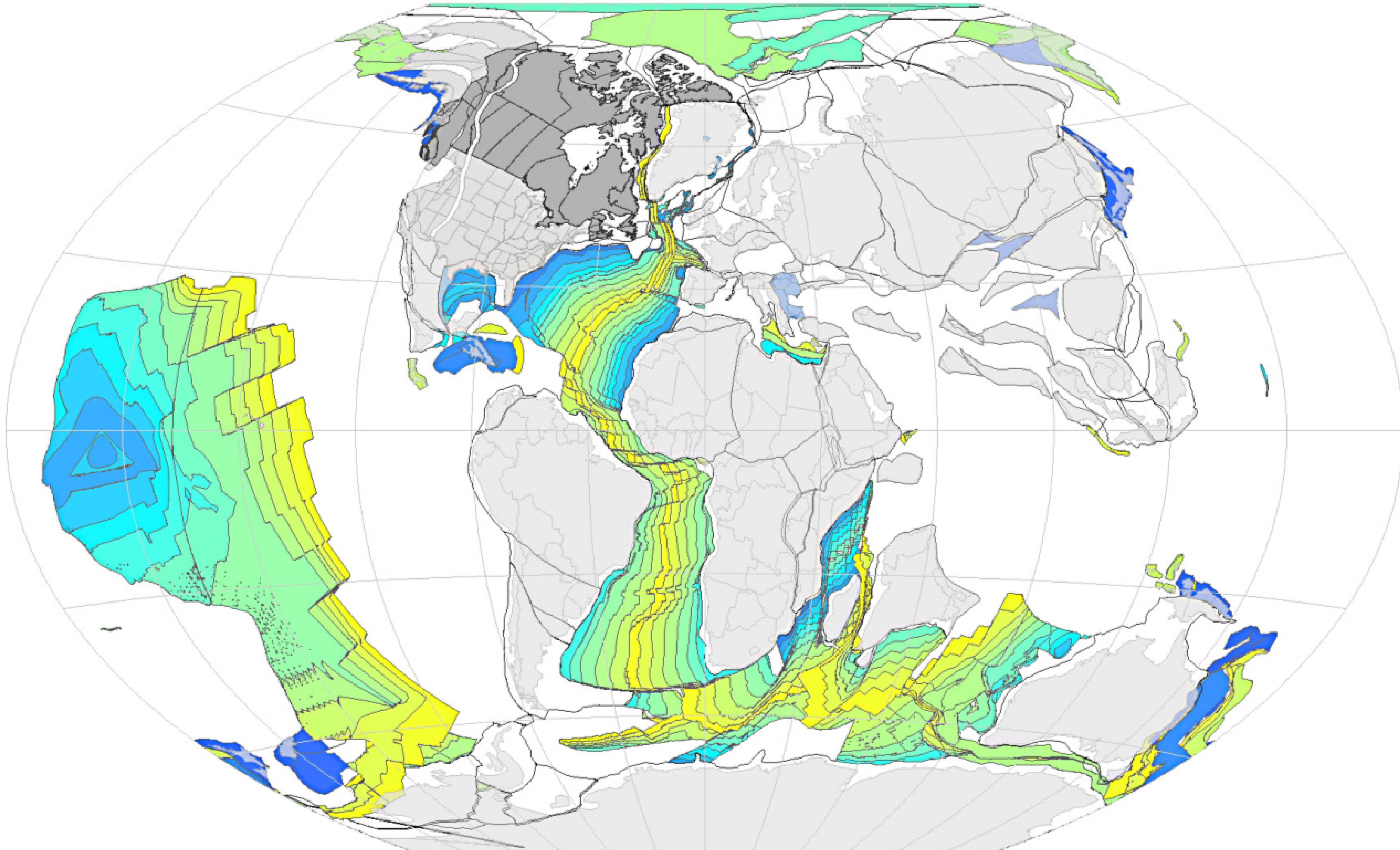
LEGEND

- mid-ocean ridge / oceanic rift
- extinct MOR/oceanic rift
- trench
- extinct trench
- oceanic island arc
- extinct oceanic island arc
- continental volcanic arc
- extinct continental volcanic arc
- oceanic fracture zone
- fold and thrust belt
- continental fragment
- continental strike-slip fault
- shelf break
- slope/rise
- guyot & seamount

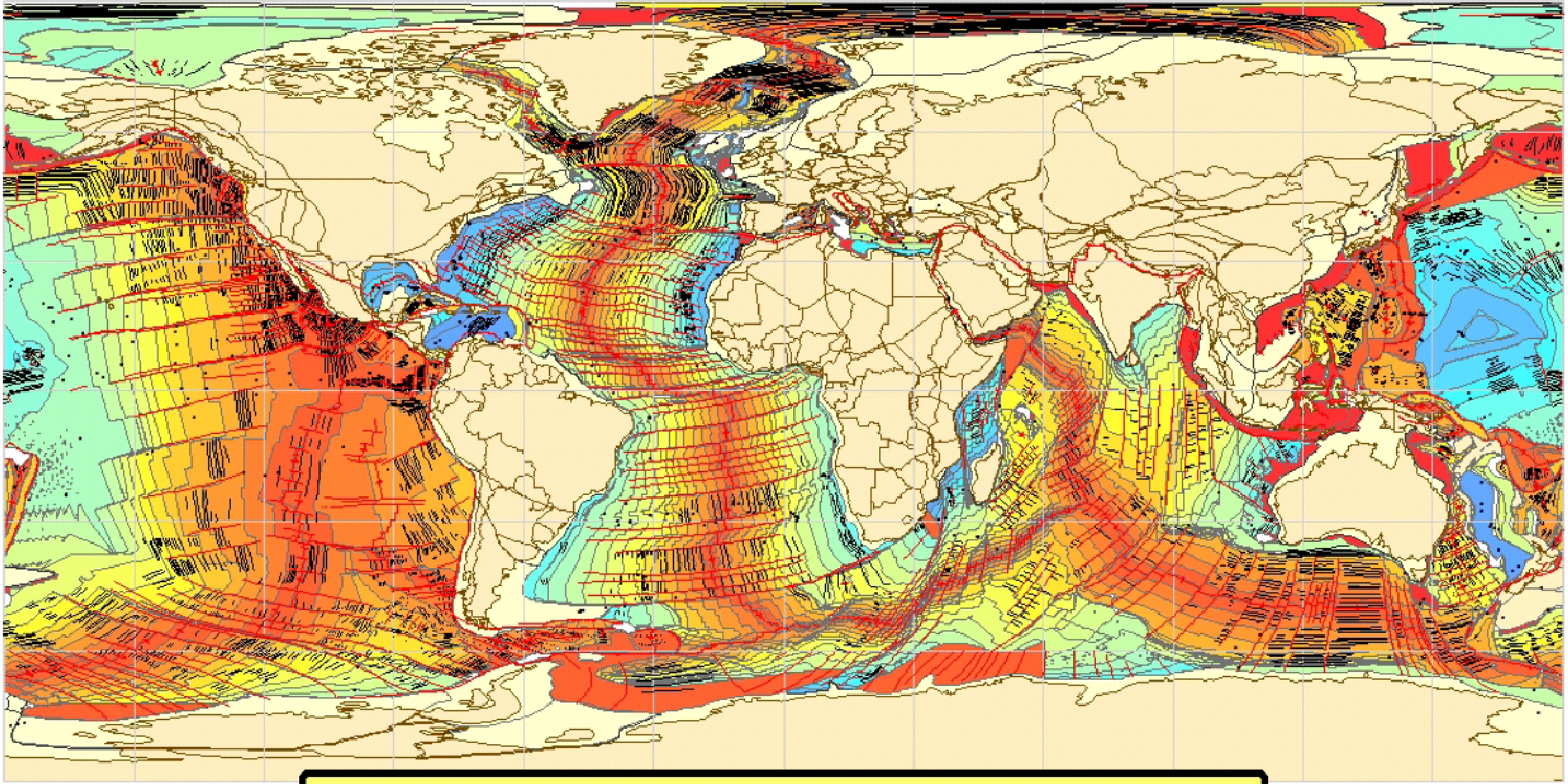




70Ma (Maastrichtian); ScoteseModelv2d; C. R. Scotese, © 2006, PALEOMAP Project



80Ma (Campanian); ScoteseModelv2d.3; C. R. Scotese, © 2006, PALEOMAP Project



0Ma (Present); ScoteseModelv2d3; C. R. Scotese, © 2007, PALEOMAP Project

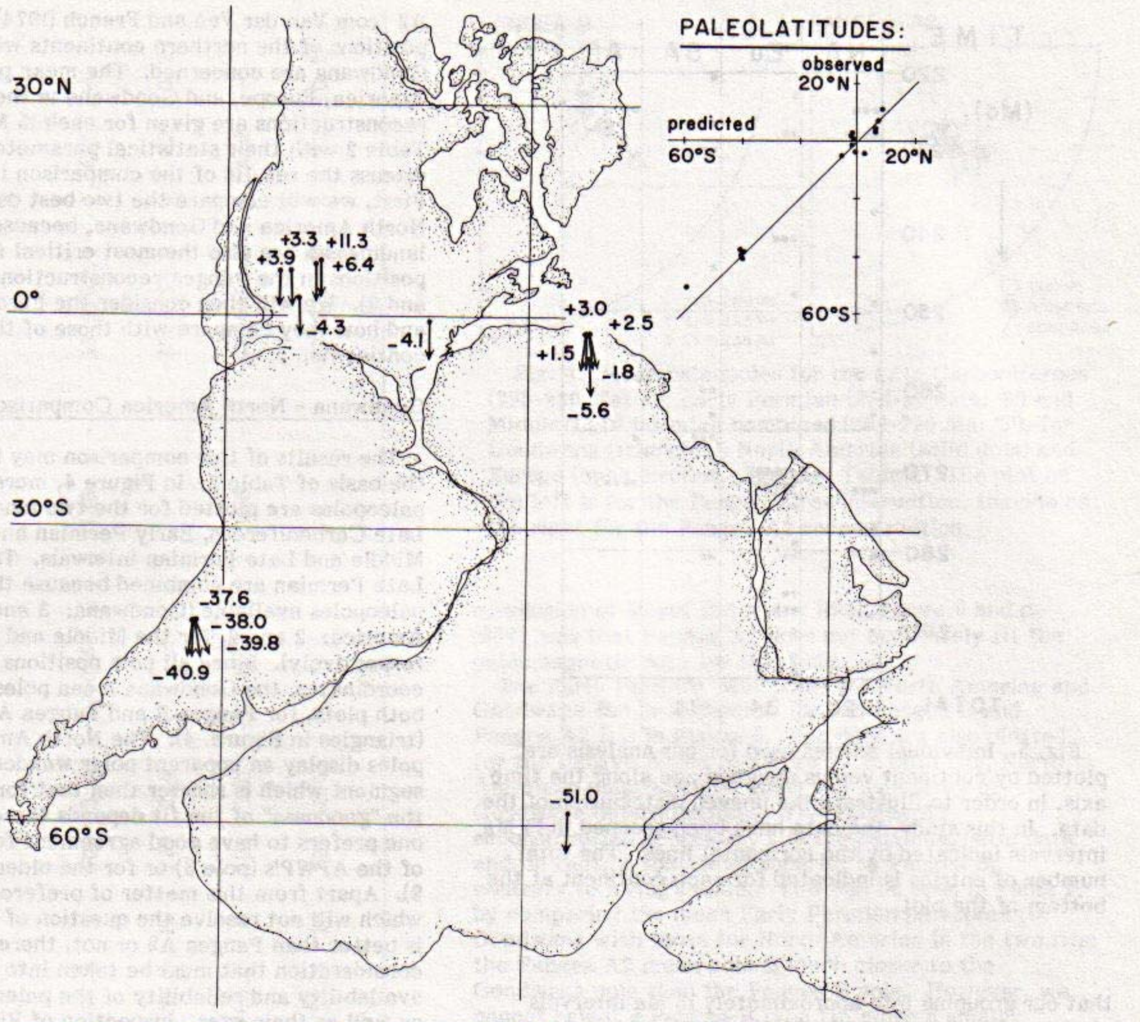
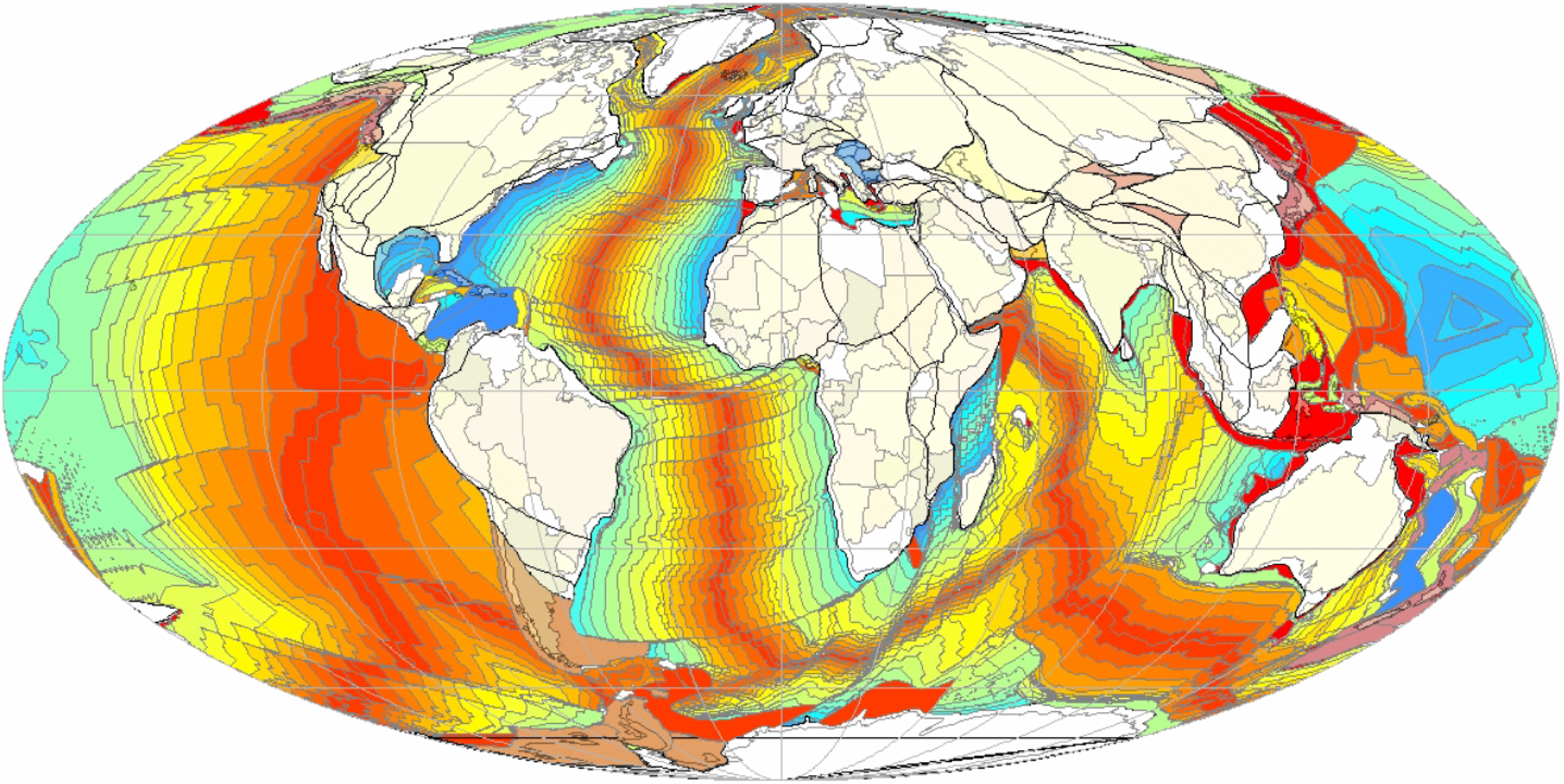


Fig. 2. Pangea reconstruction after Van der Voo and French [1974], herein called Pangea A2, with Early Permian data represented by their declinations (arrows) and paleolatitude values. An overall mean Early Permian pole has been calculated from the data plotted and was used to construct the paleolatitude pattern shown. The inset gives a direct comparison of this pattern ("predictor") with the observed paleolatitudes calculated from the inclination values of each study. Perfect correlation between predictor and observed values would occur along the solid line in this plot.



0Ma (Future, Paleomap Projectv2) © 2006, PALEOMAP Project, C.R. Scotese

Plate Tectonic Modelers

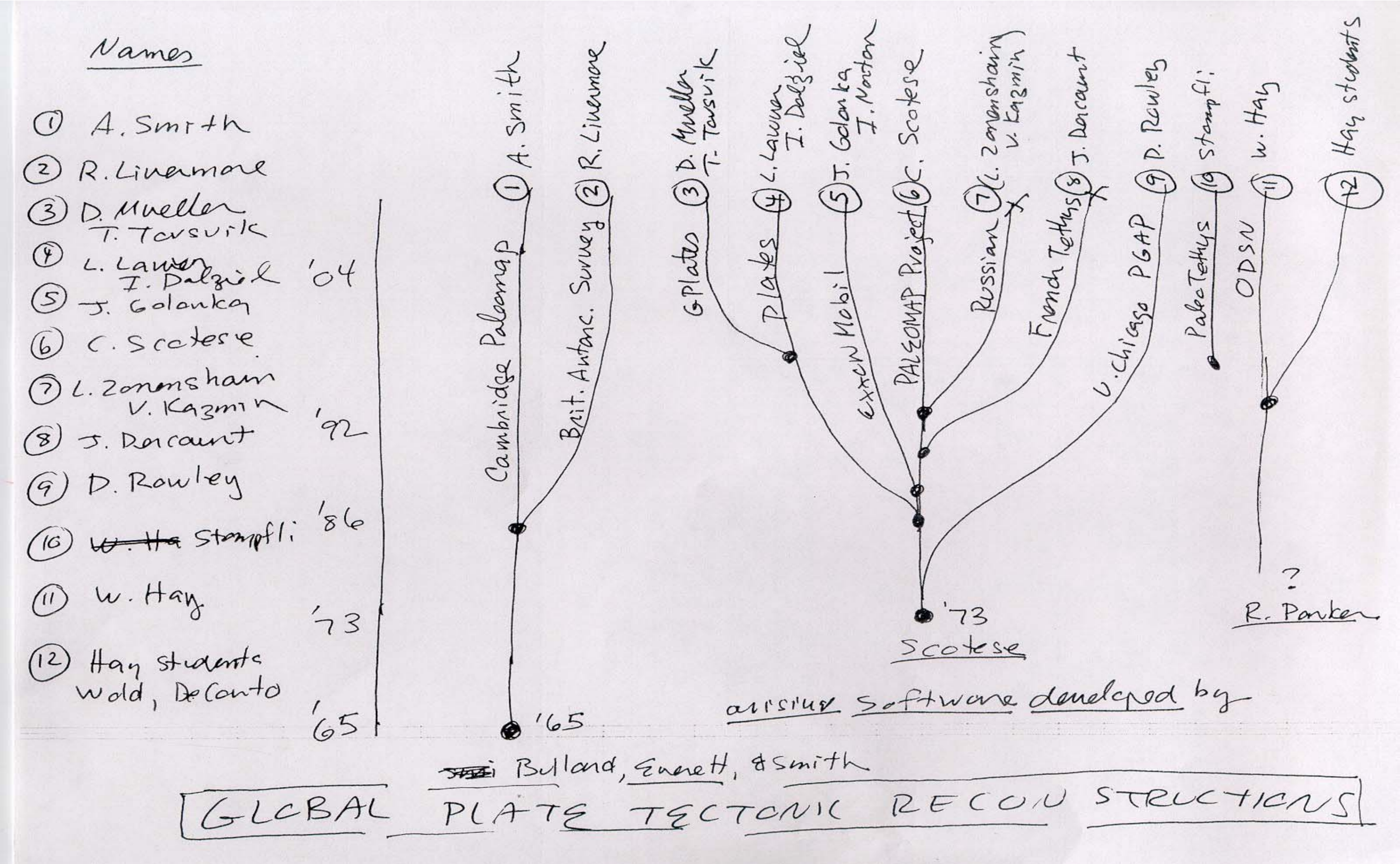


PLATE TECTONIC MODELERS

Alan Smith (Cambridge) 1965

Chris Scotese (PALEOMAP Project) 1973

Bill Hay (ODSN)

David Rowley (U.Chicago) 1984

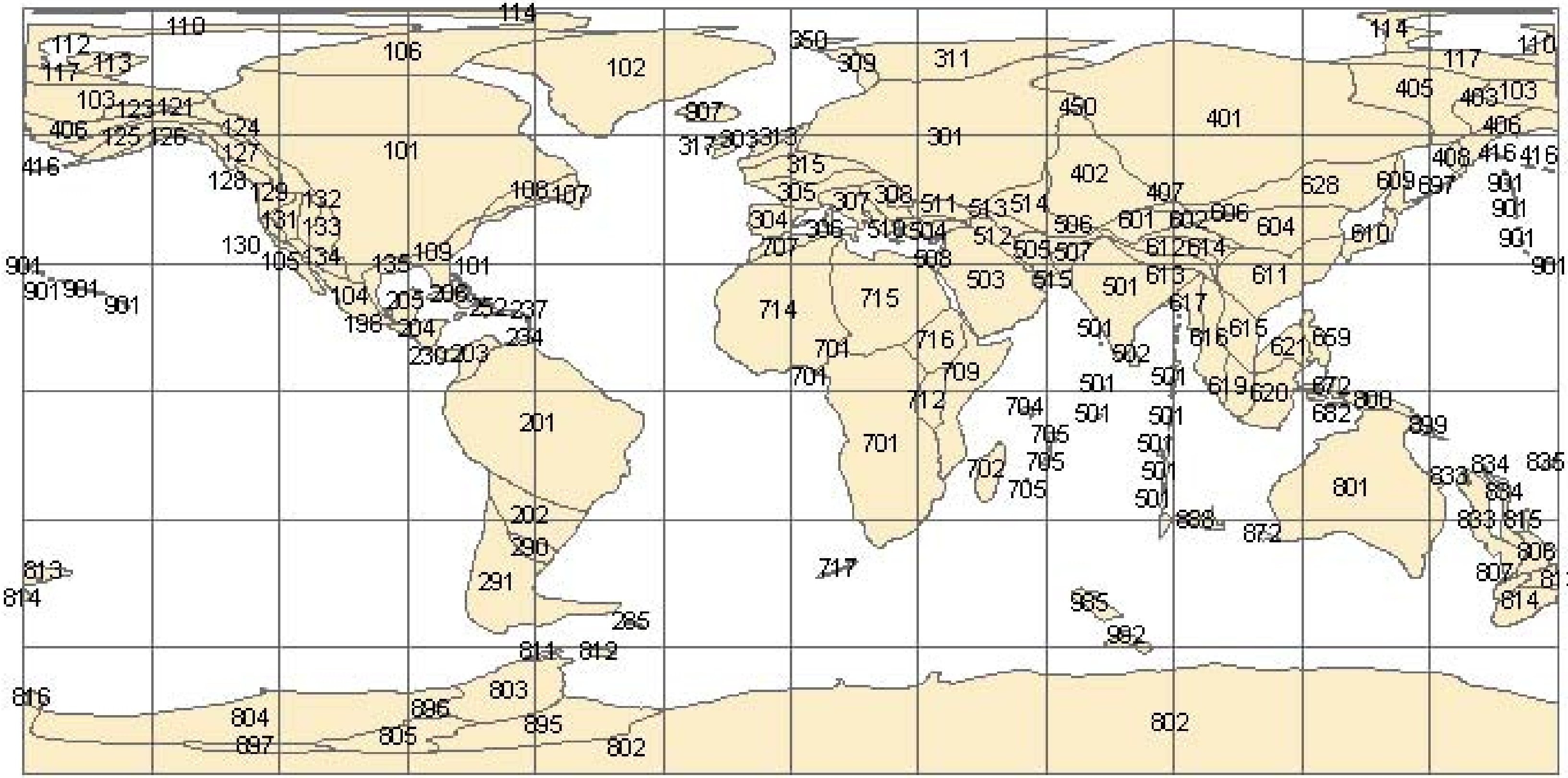
Larry Lawver (PLATES) 1988

Dietmar Mueller (GPLATES) 1990

Bernard Stamplfi (Switzerland)

What Determines the Quality of a Global Plate Model?

- Input Data (shared by all groups)
- Technology (GIS)
- Methodology
  - Plate Polygons
  - Global Rotation Model



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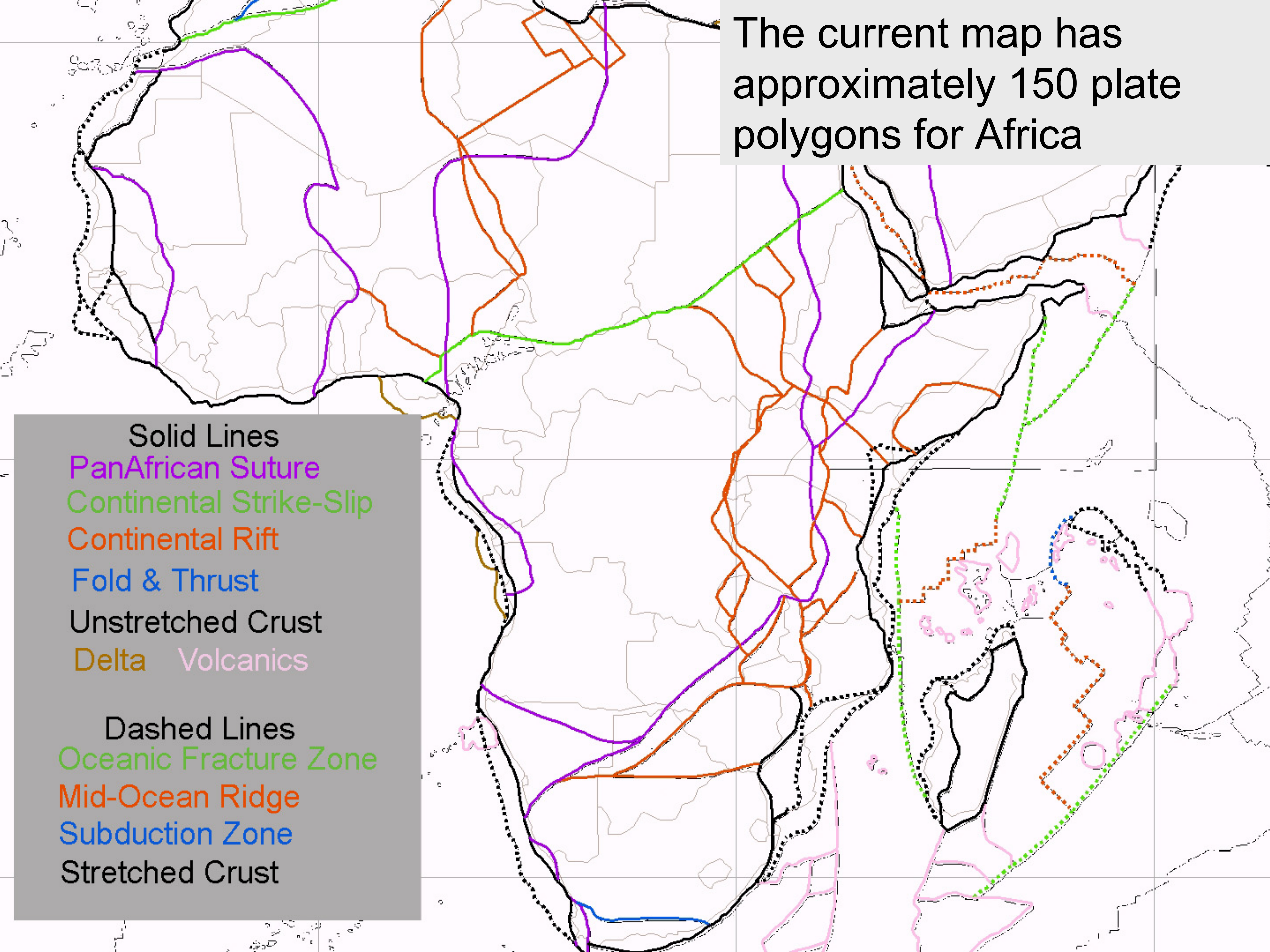
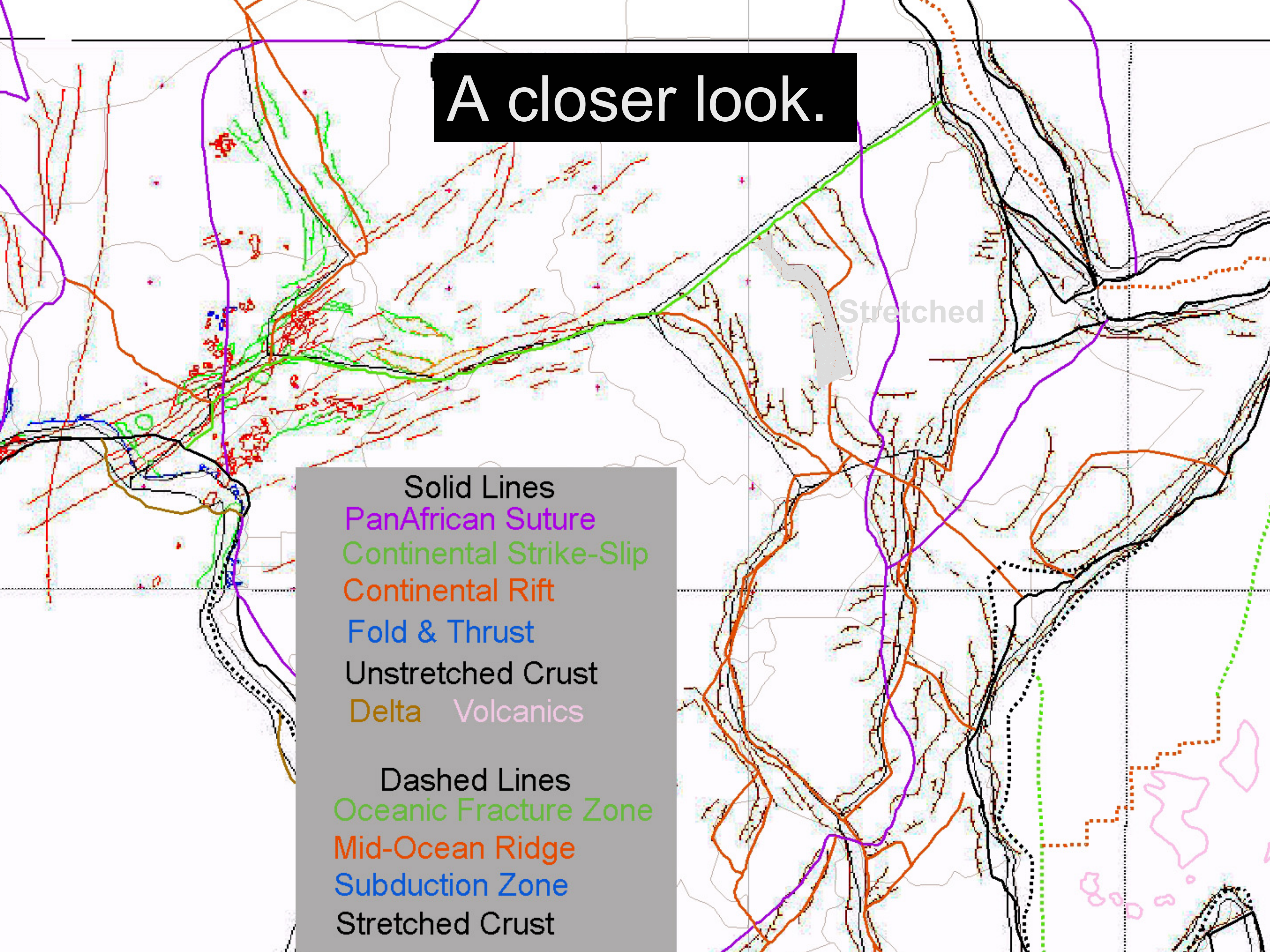
The current map has approximately 150 plate polygons for Africa



A closer look.

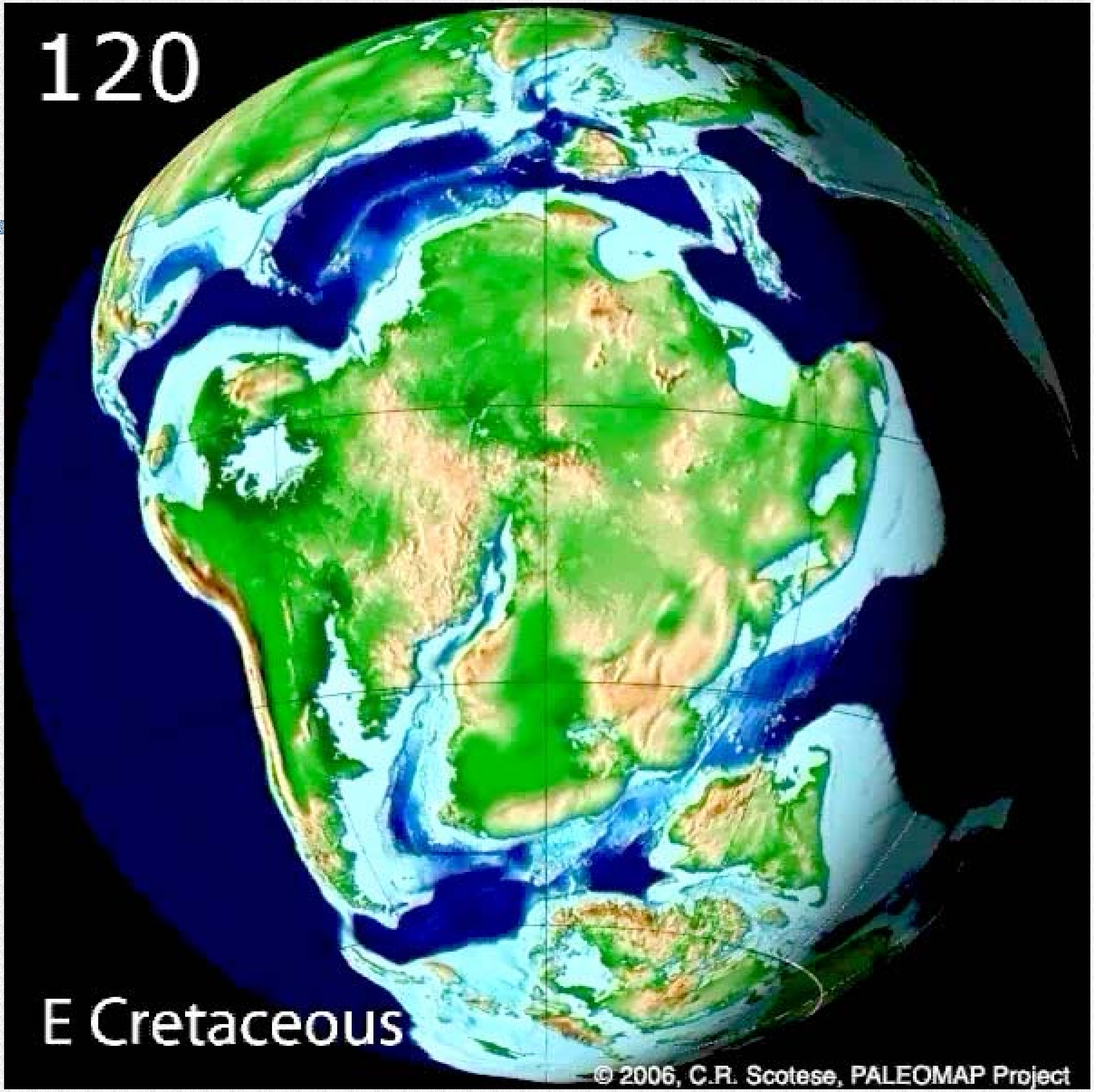


USING GIS

- GIS technology can be used to produce plate tectonic reconstructions
    - PlateTracker for ArcGIS (PALEOMAP)
    - PaleoGIS for ArcGIS (Rothwell Group)

PALEOGEOGRAPHIC RECONSTRUCTIONS

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


120
E Cretaceous
© 2006, C.R. Scotese, PALEOMAP Project

PALEOGEOGRAPHERS

Peter Ziegler (formerly Shell) traditional

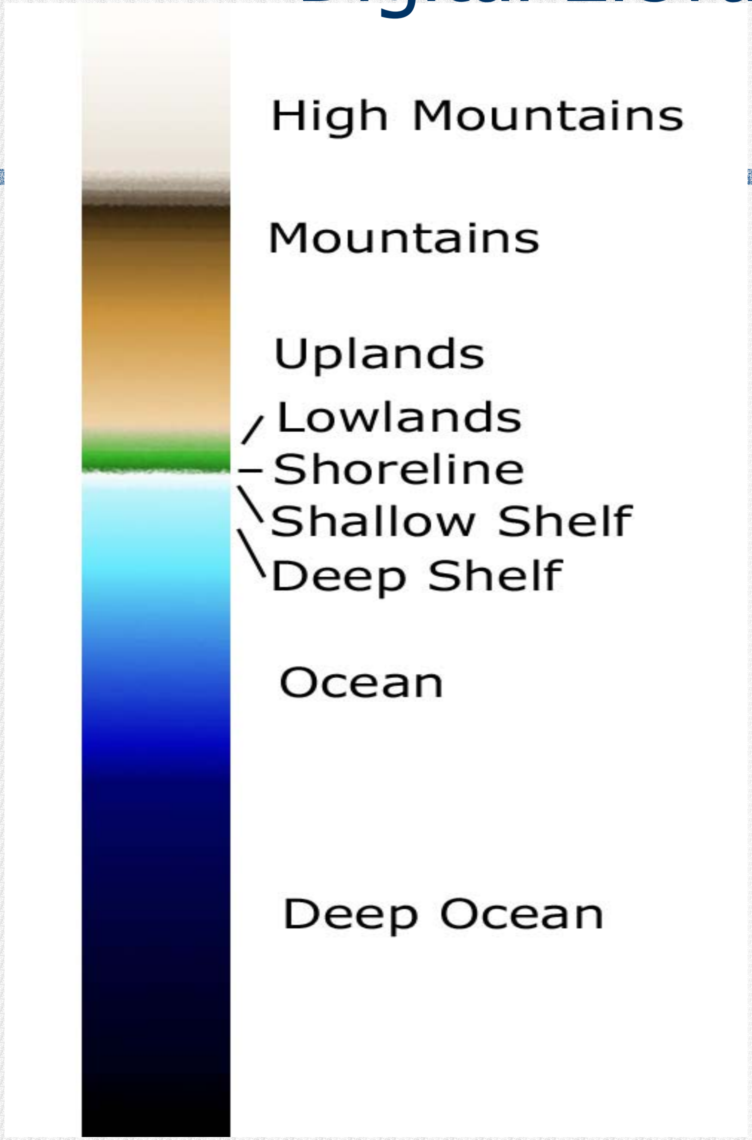
Fred Ziegler (formerly U.Chicago) traditional

Chris Scotese (PALEOMAP) raster PaleoDEM

Ron Blakey (Northern Arizona U.) digital art

Paul Markwick (Getech) PaleoDEM from contours

Digital Elevation Model

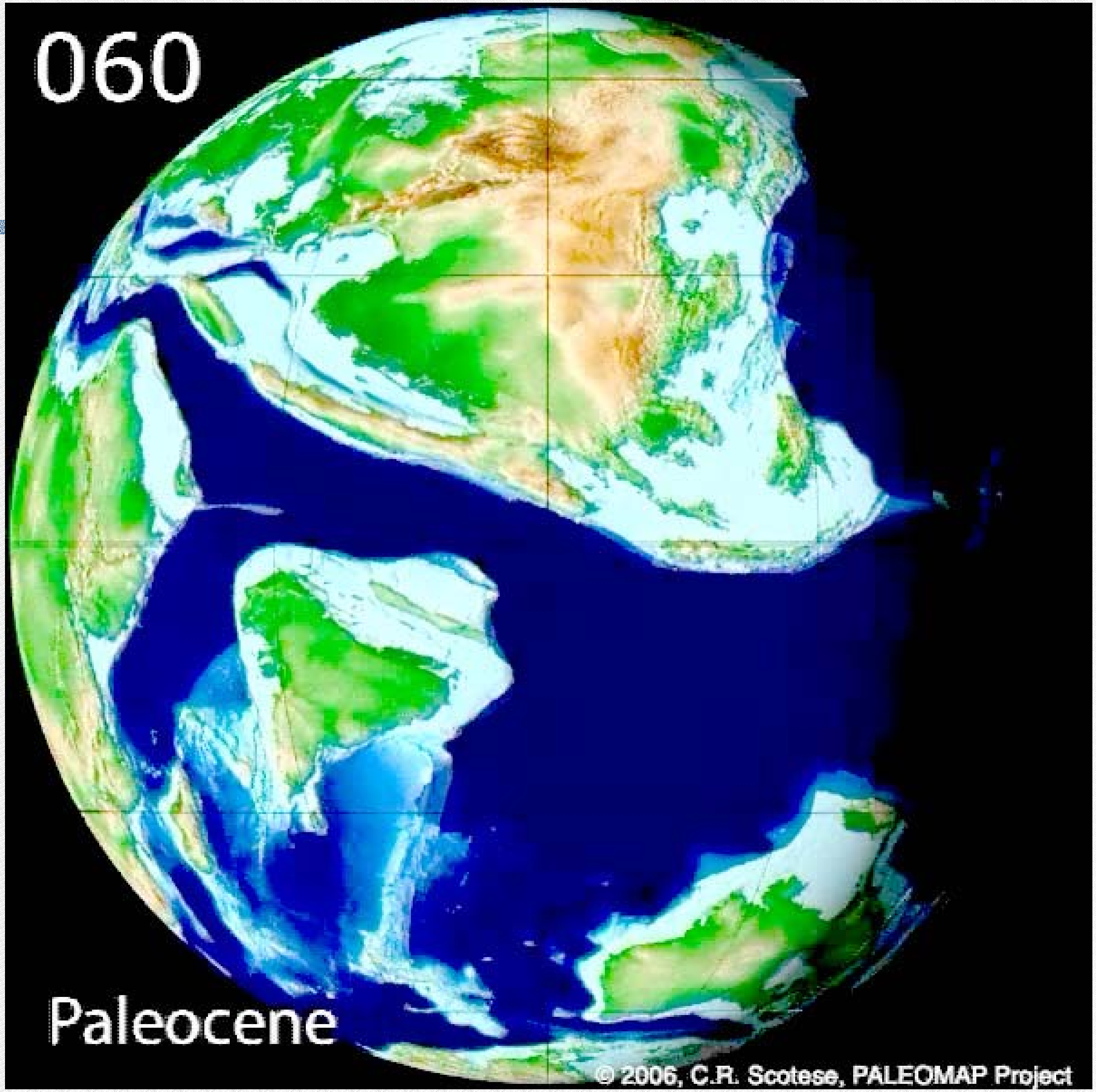


Resolution of Paleogeographic Maps

Horizontal = .1x.1 degrees
Vertical = 40 m

Temporal Resolution

Nearest Sequence Boundary and Maximum Flooding Surface
Lithological Data - Stage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Paleocene
© 2006, C.R. Scotese, PALEOMAP Project

PALEOMAP PaleoAtlas Time Slices

- Cenozoic 8
- Cretaceous 8
- Jurassic 6
- Triassic 4
- Late Paleozoic 11
- Early Paleozoic 8
- Late Precambrian 3
- *Done: 48 of 48/+50 Planned*

Thanks to PALEOMAP Project Sponsors

- Shell 2002
- Anadarko 2003
- BHP 2003
- Chevron 2003
- KerrMcGee 2003
- Oxy 2003
- Total 2003
- Petrobras 2004
- Pioneer 2004
- ExxonMobil 2004
- Marathon 2004
- BP 2005
- Hydro 2005
- Woodside 2005
- Cobalt Int 2006
- ENI 2007
- Devon 2006
- (Petronas 2008)

Plate Tectonic and Paleogeography

Present-day to 540 million years ago

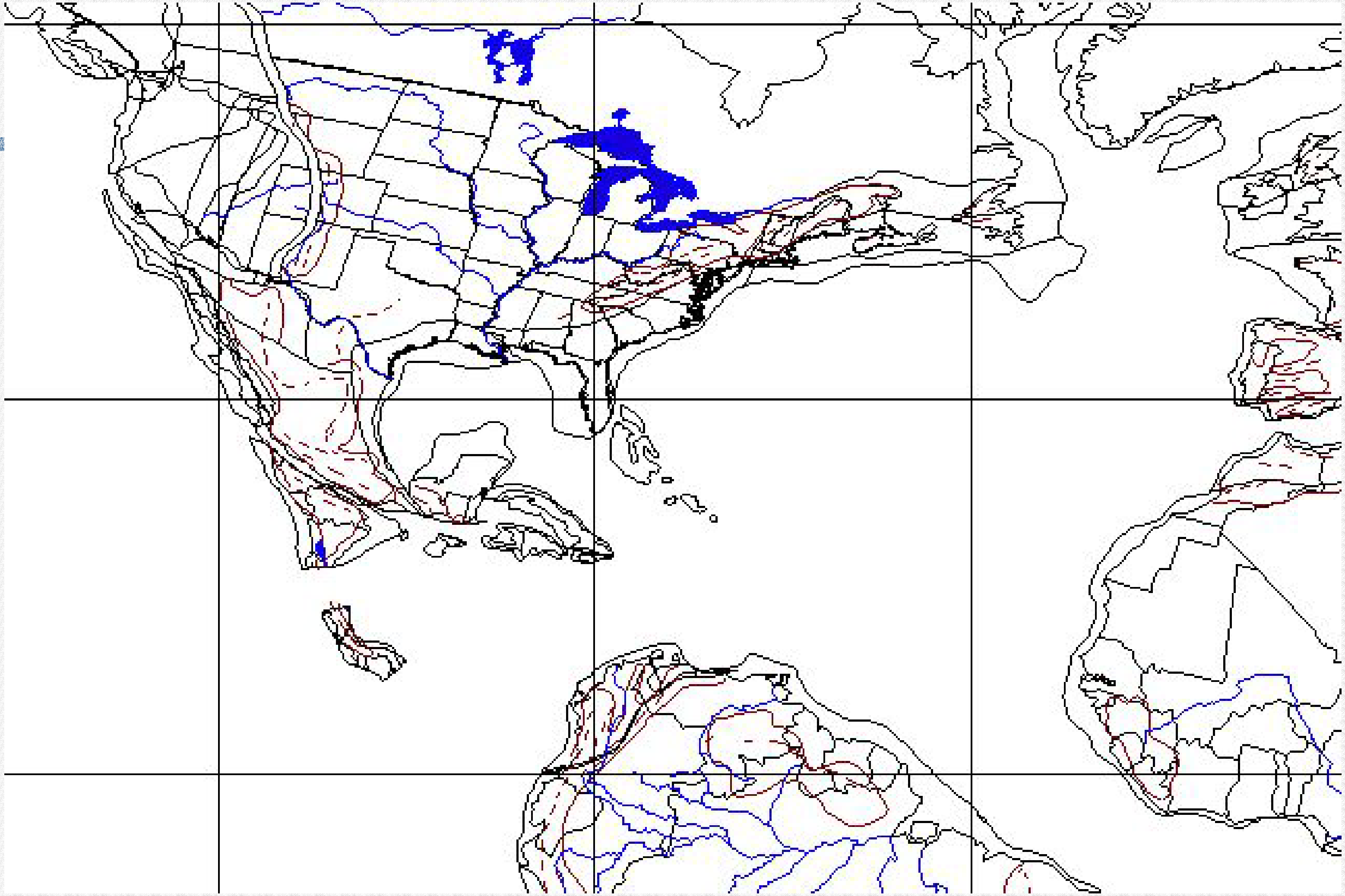
by

Christopher R. Scotese, PALEOMAP Project

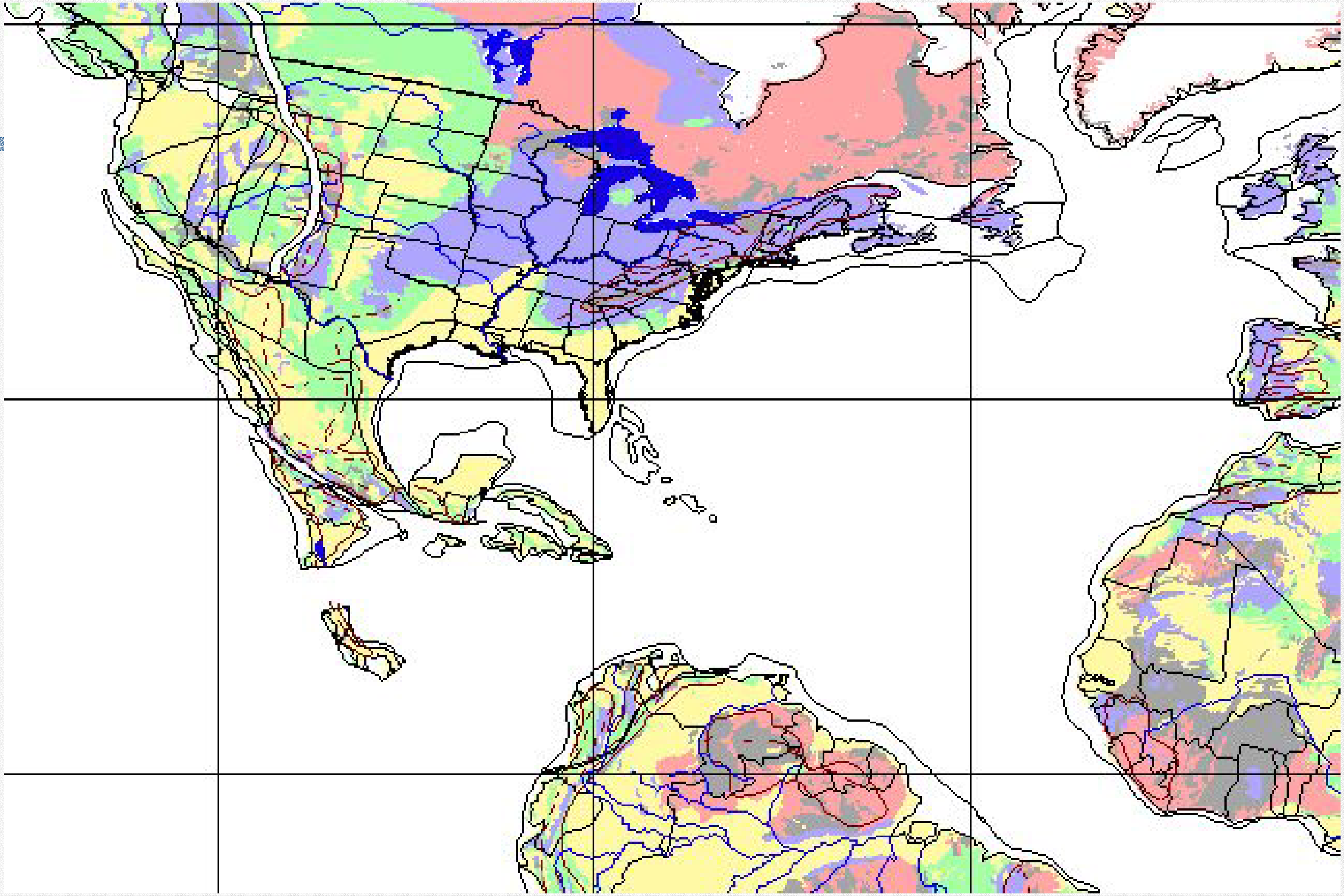
USING GIS

- GIS technology can be used to add layers to paleogeographic reconstructions
- Construct 3D models of paleogeography
- Analyze 3D models , e.g. River Drainage Systems

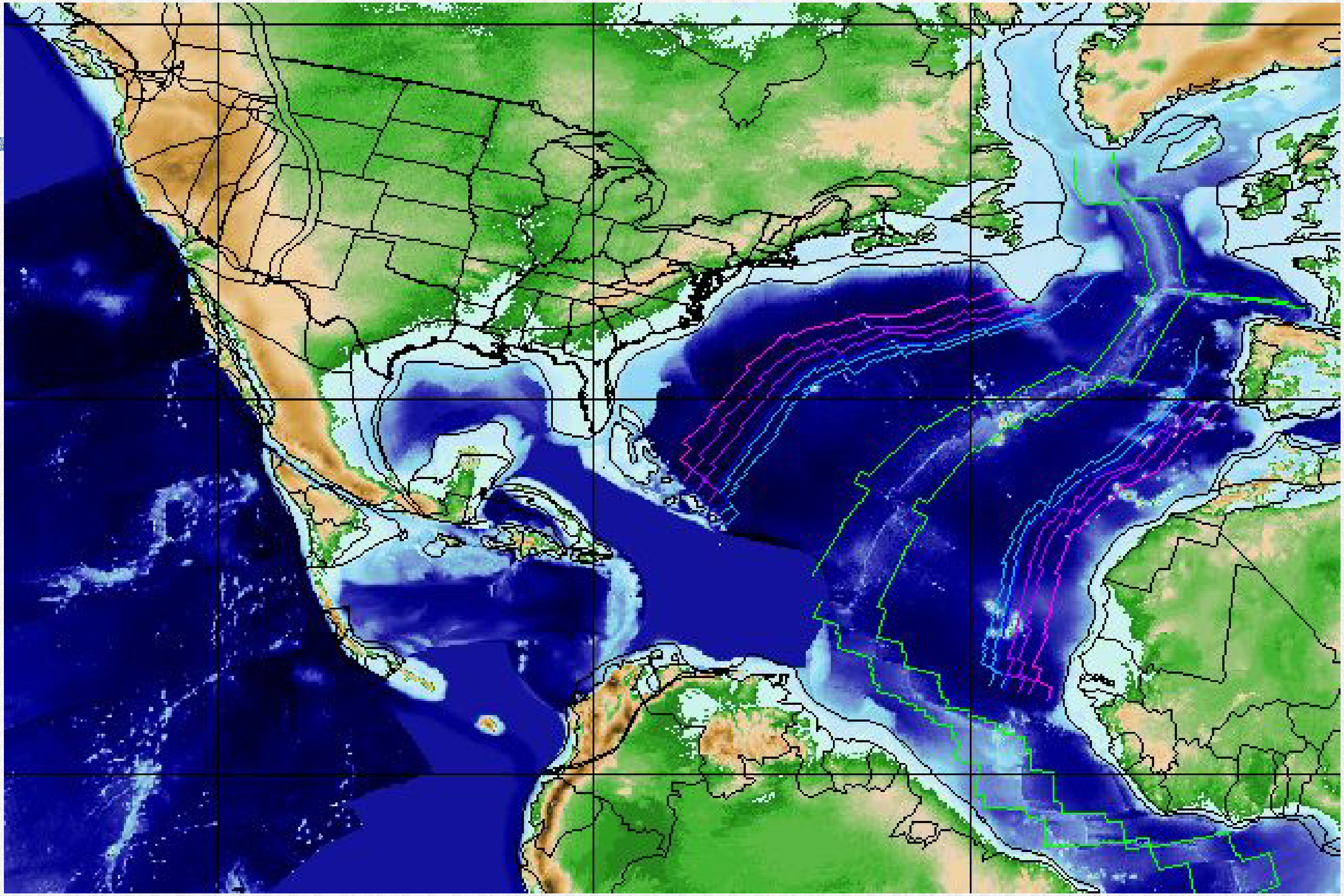
Paleo-Reconstructions

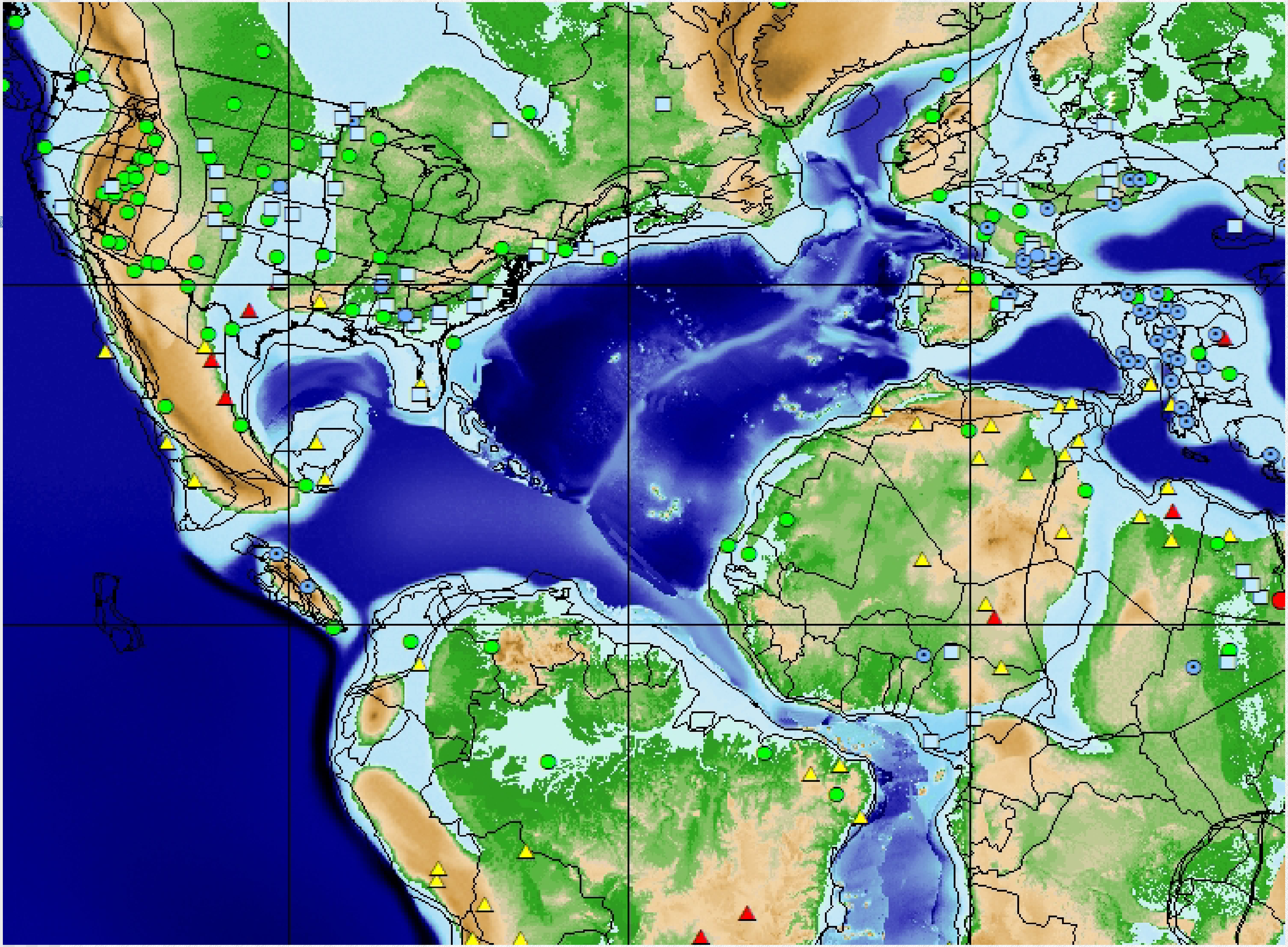


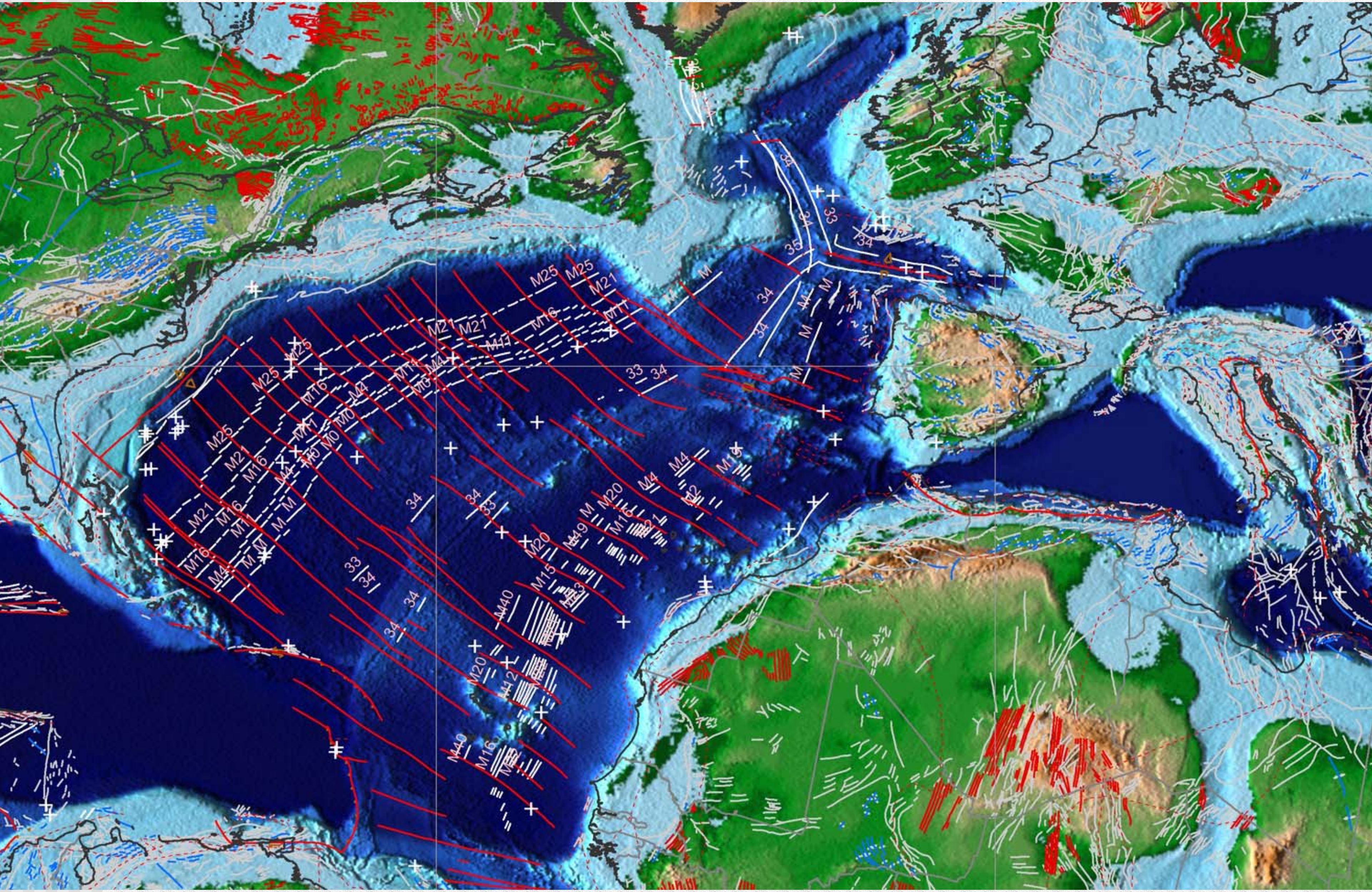
Paleo-Geology



ESH-GIS Paleogeography



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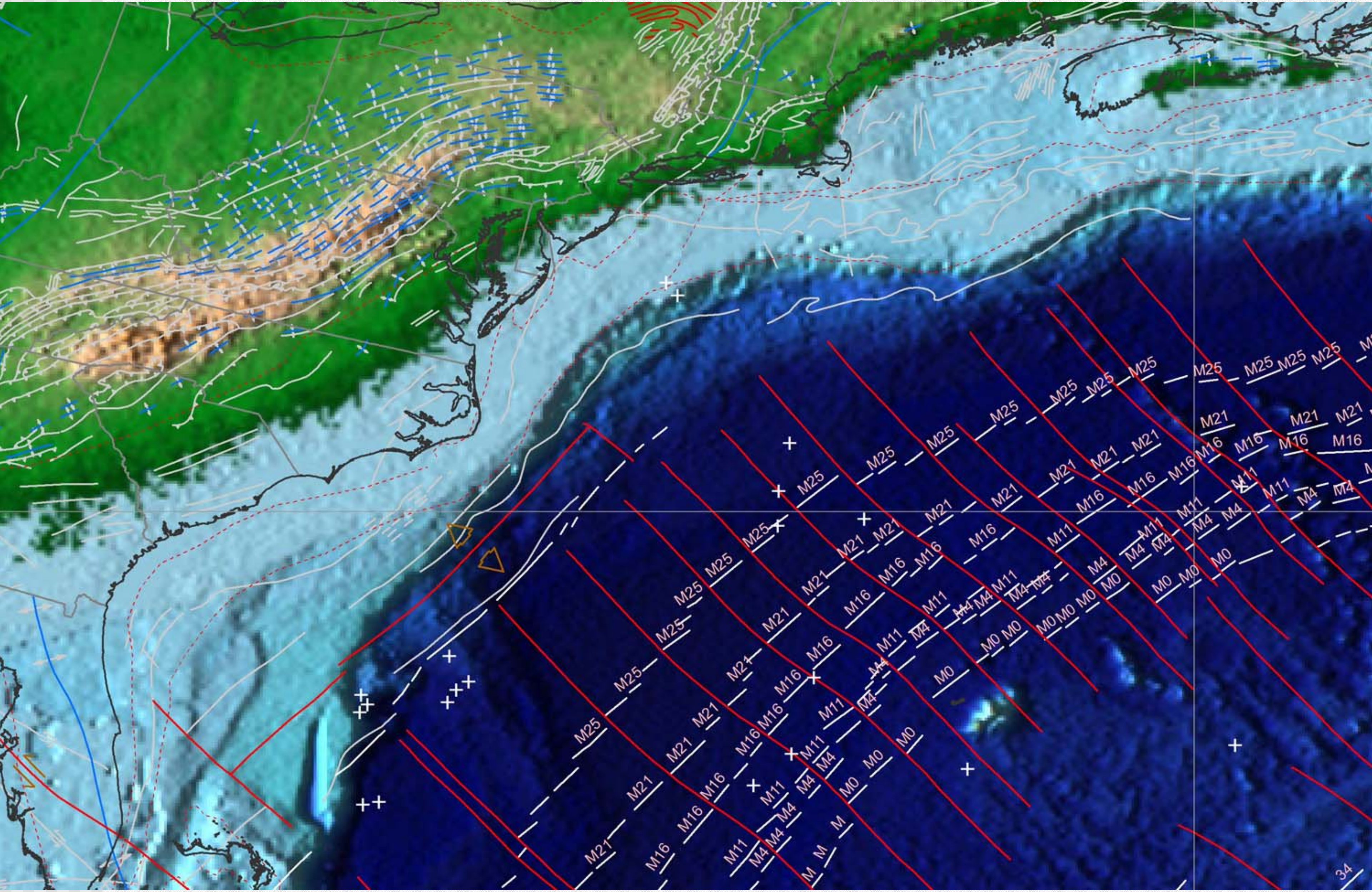
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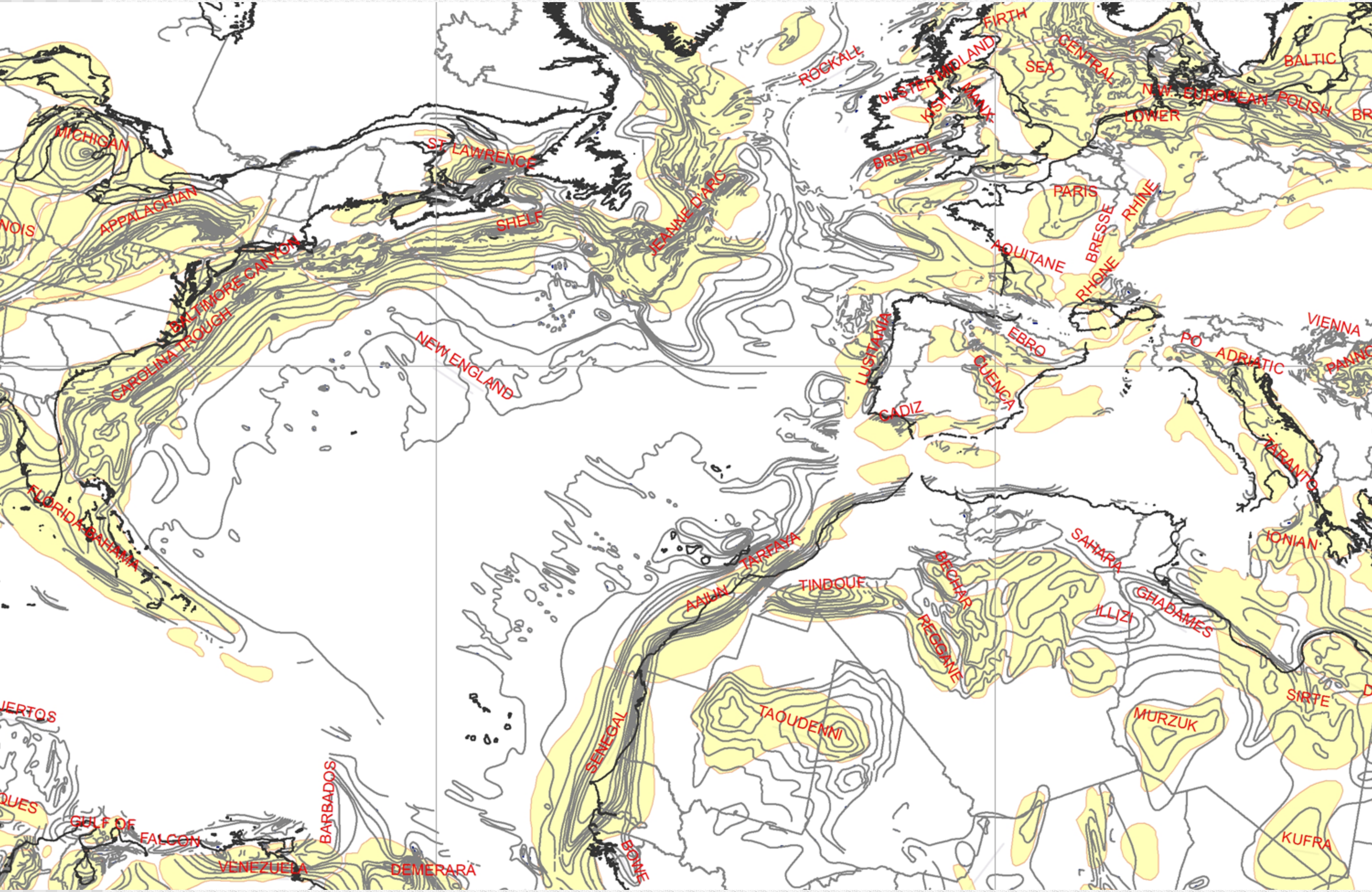

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NW. EUROPEAN
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PARIS
RHINE
BRESSE
AQUITANE
RHONE
BALTIMORE CANYON
CAROLINA TROUGH
NEW ENGLAND
LUSITANIA
EBRO
CUENCA
CADIZ
VIENNA
PO
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TARANTO
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TARFAYA
AAIUN
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BECHAR
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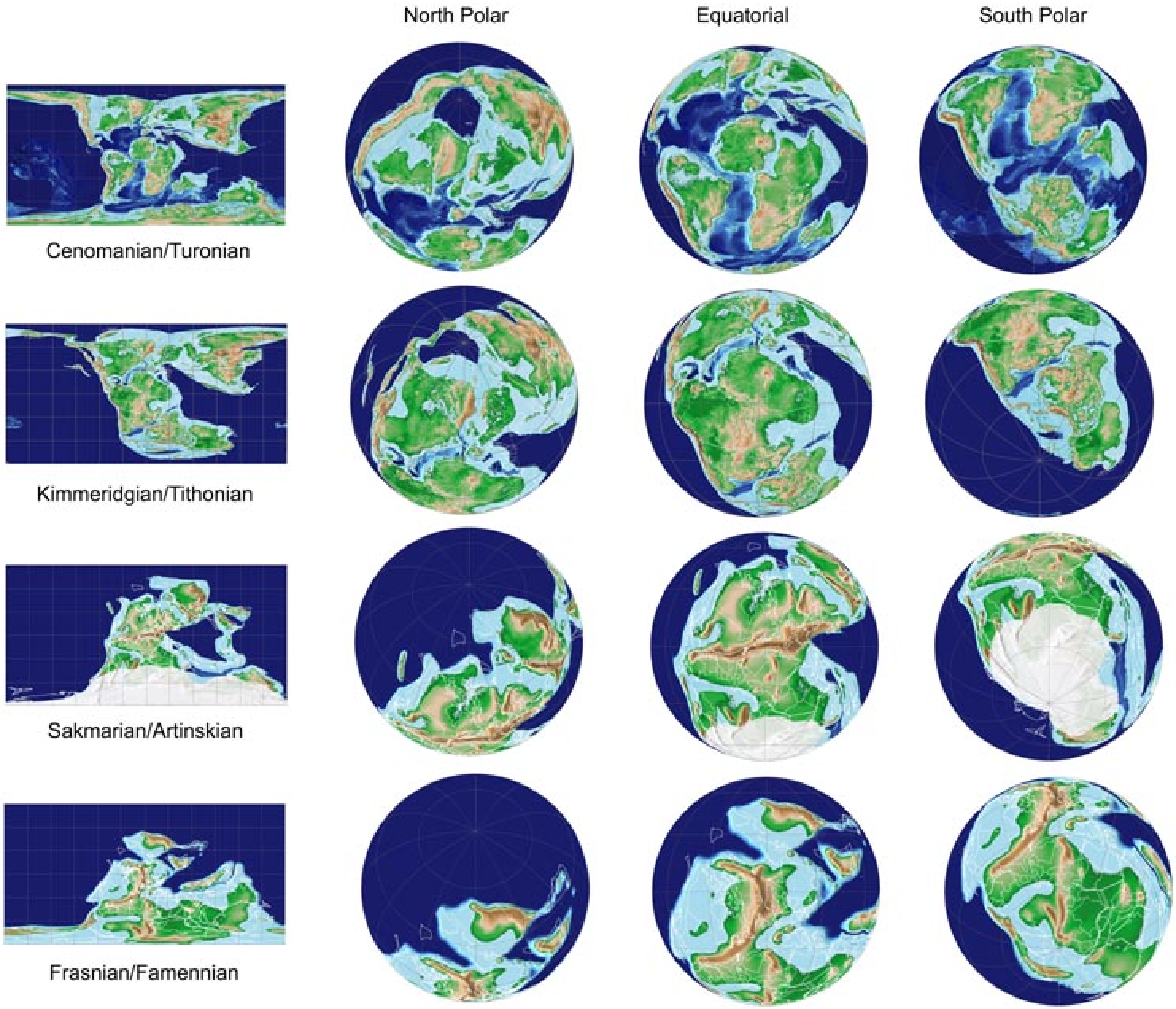
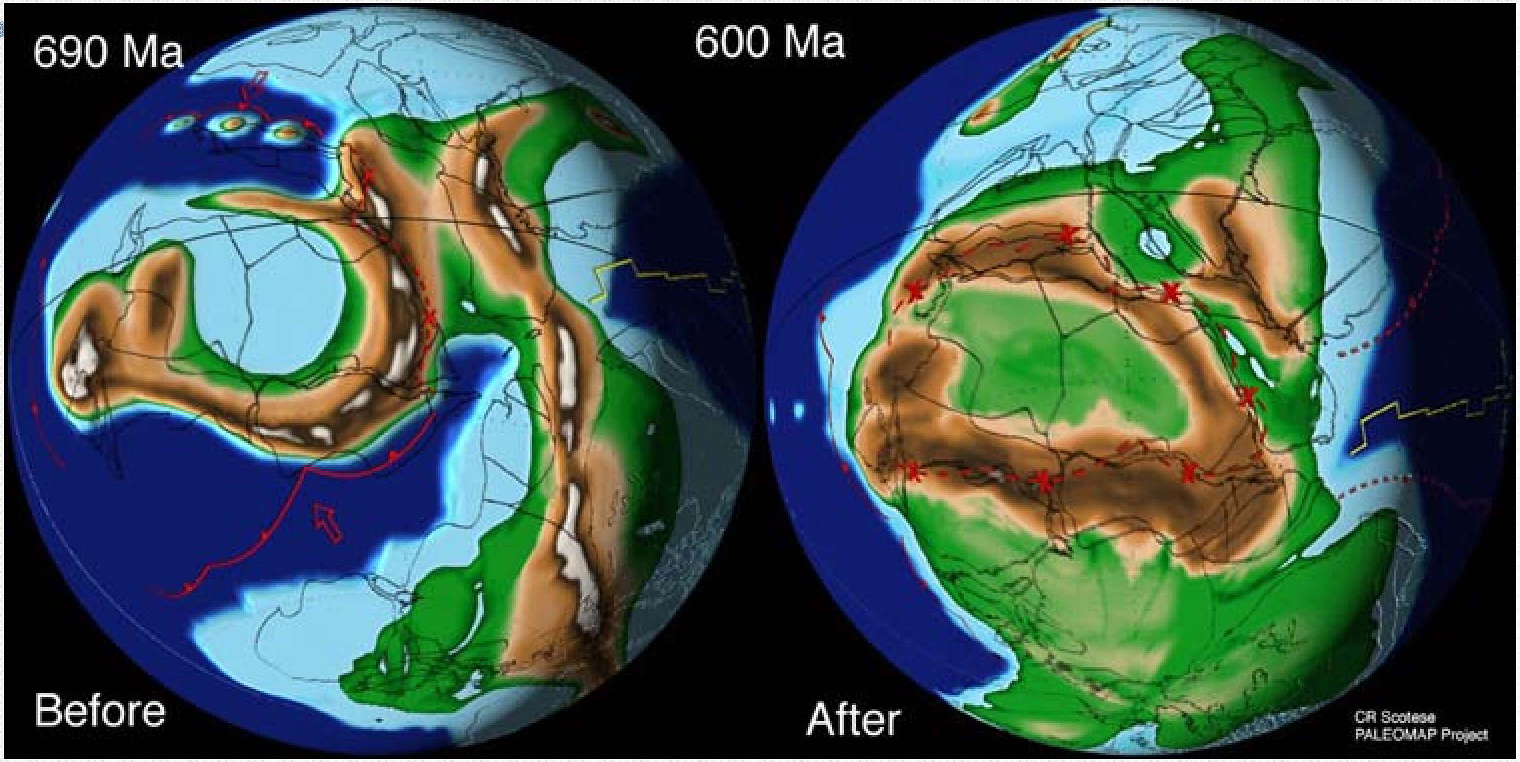
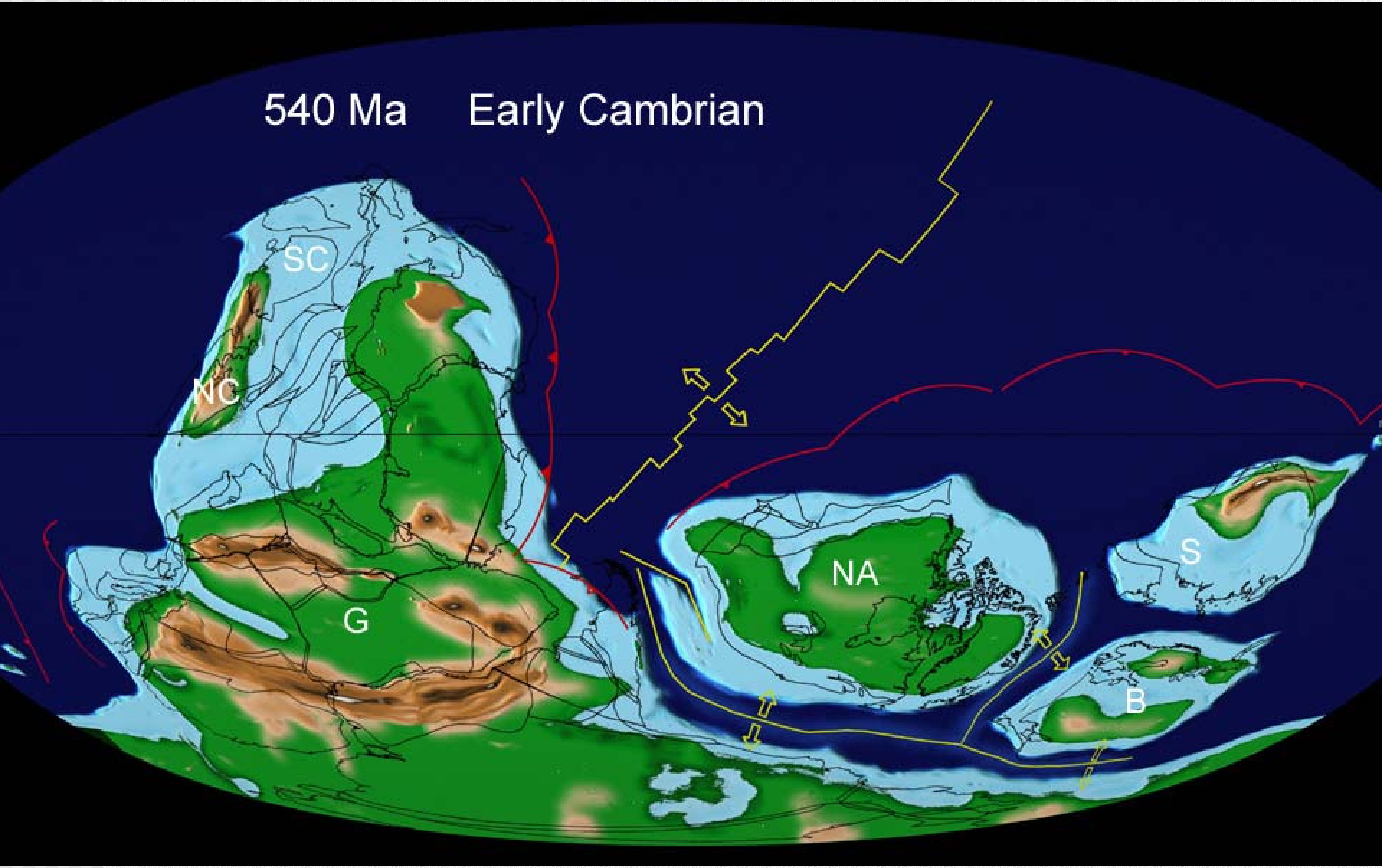

North Polar
Equatorial
South Polar
Cenomanian/Turonian
Kimmeridgian/Tithonian
Sakmarian/Artinskian
Frasnian/Famennian


690 Ma
600 Ma
Before
After
CR Scotese
PALEOMAP Project



540 Ma Early Cambrian
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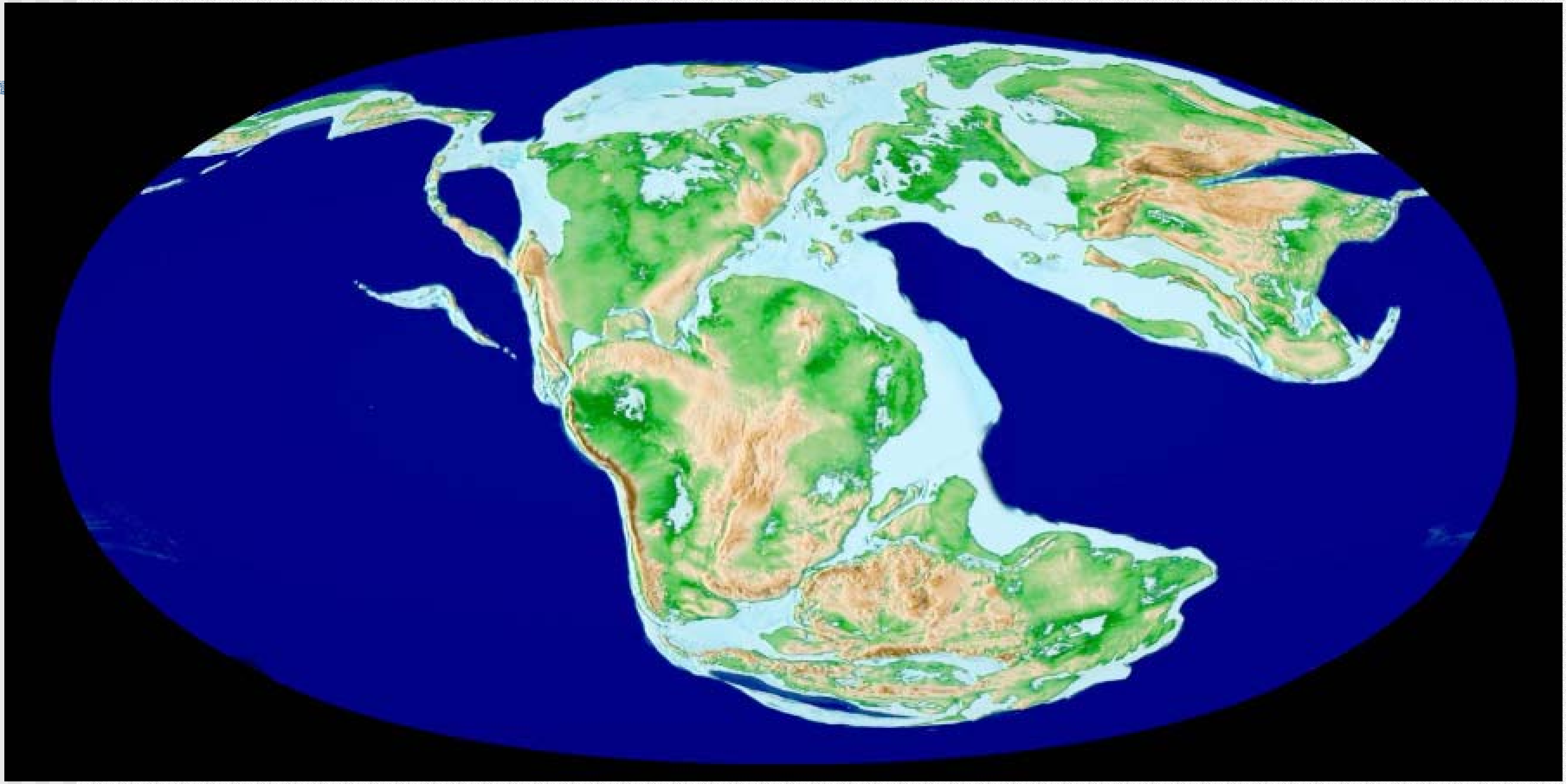
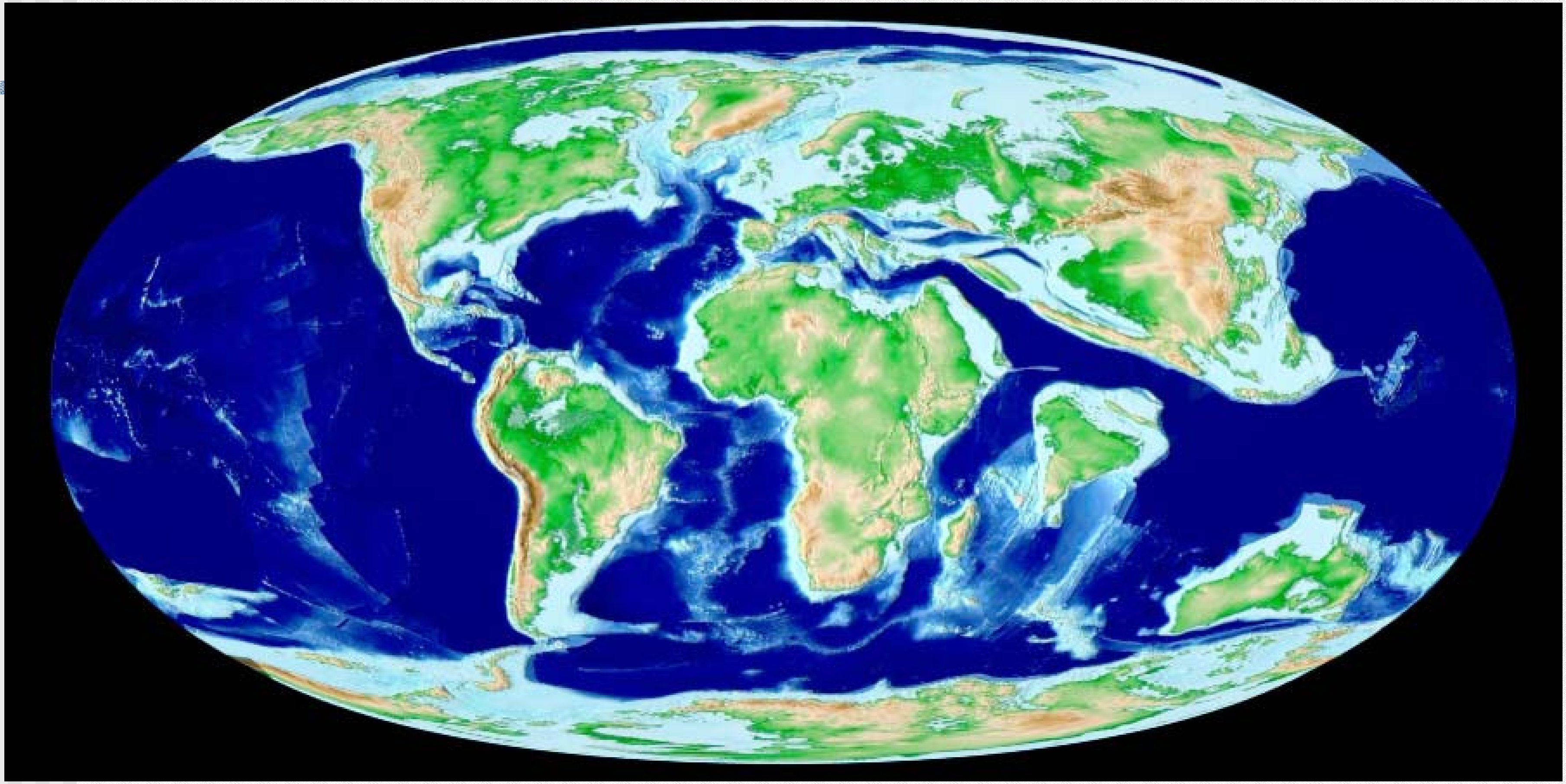
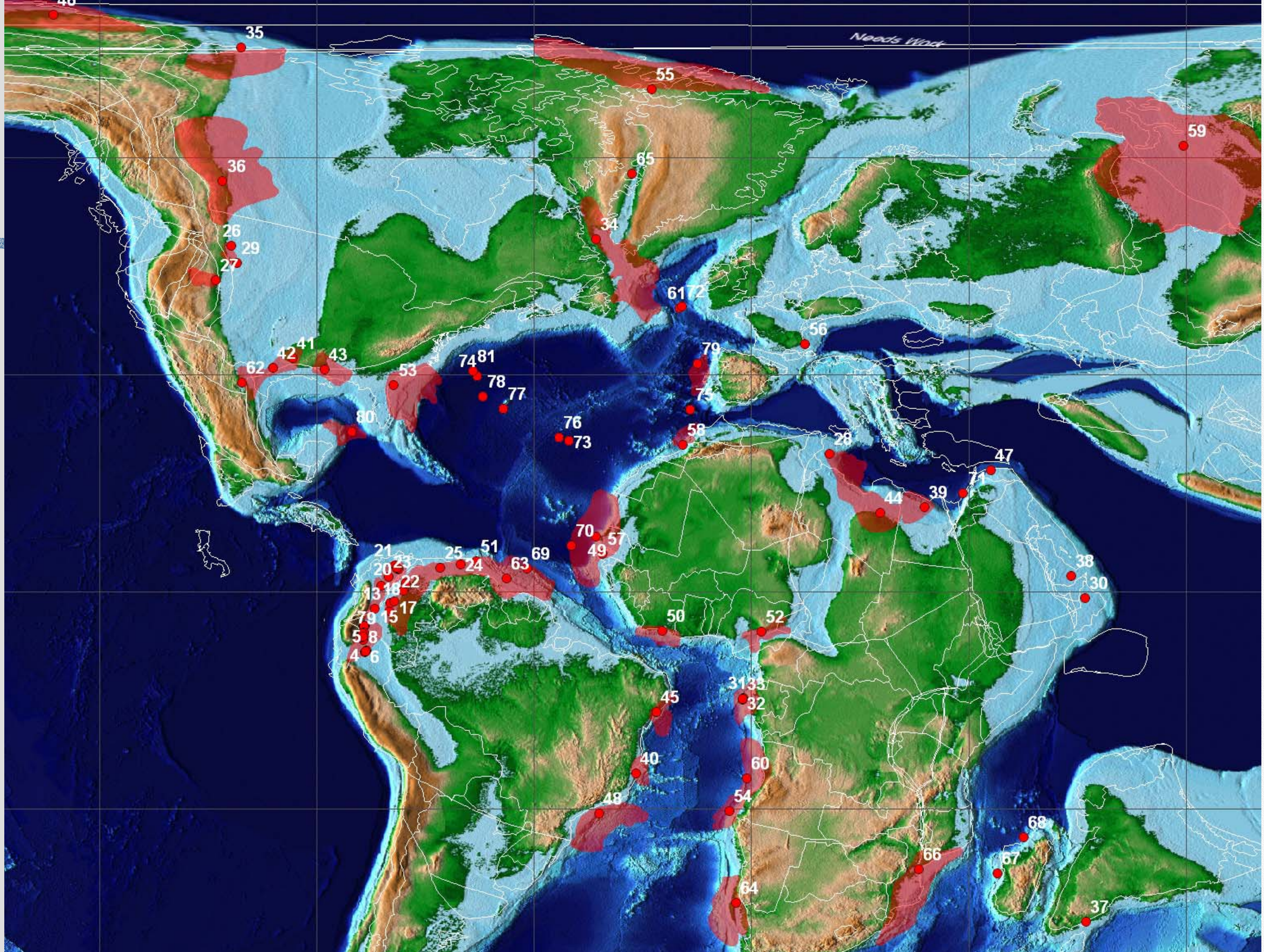




PALEOCLIMATE MODELING



Needs Work
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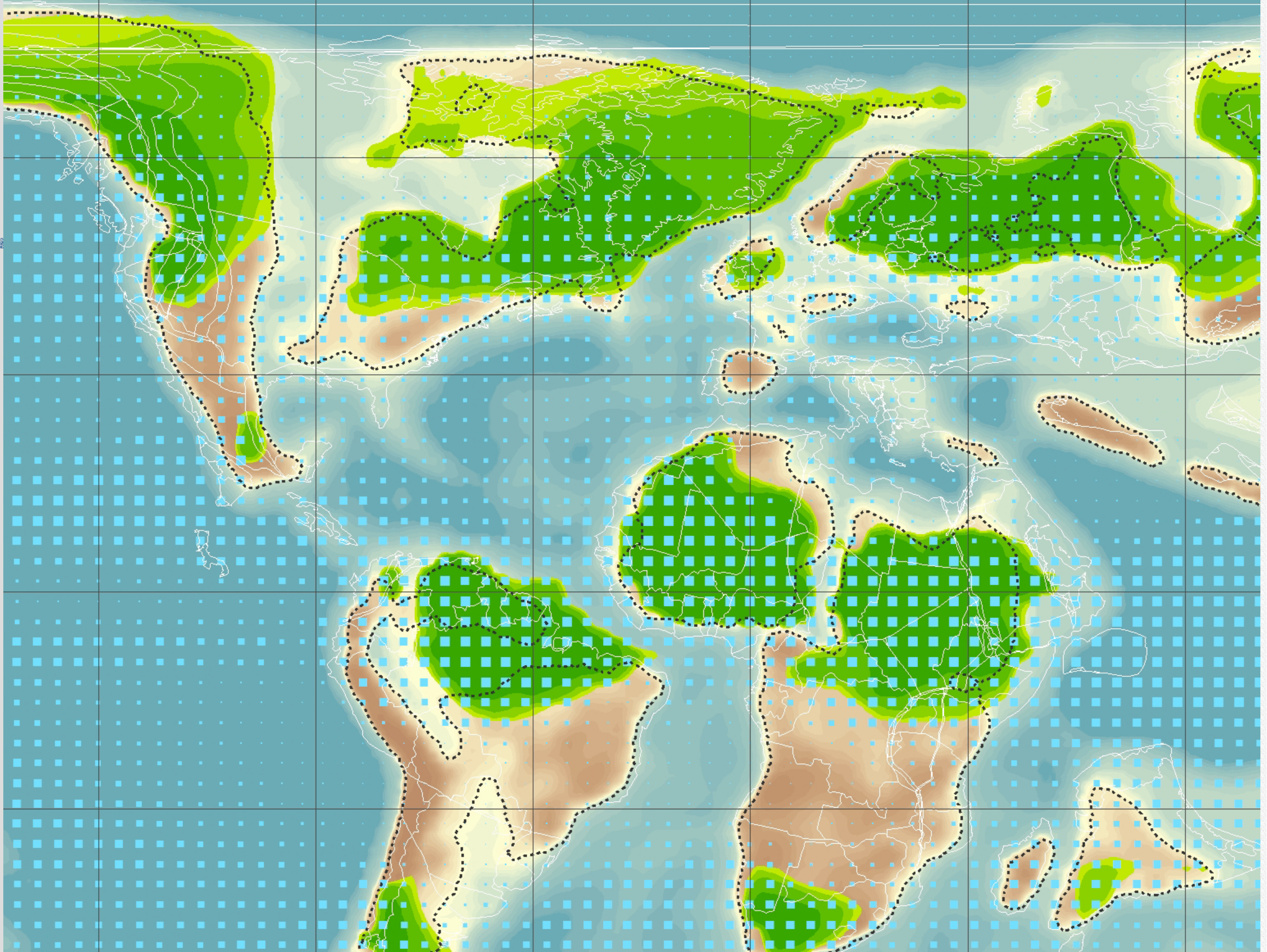

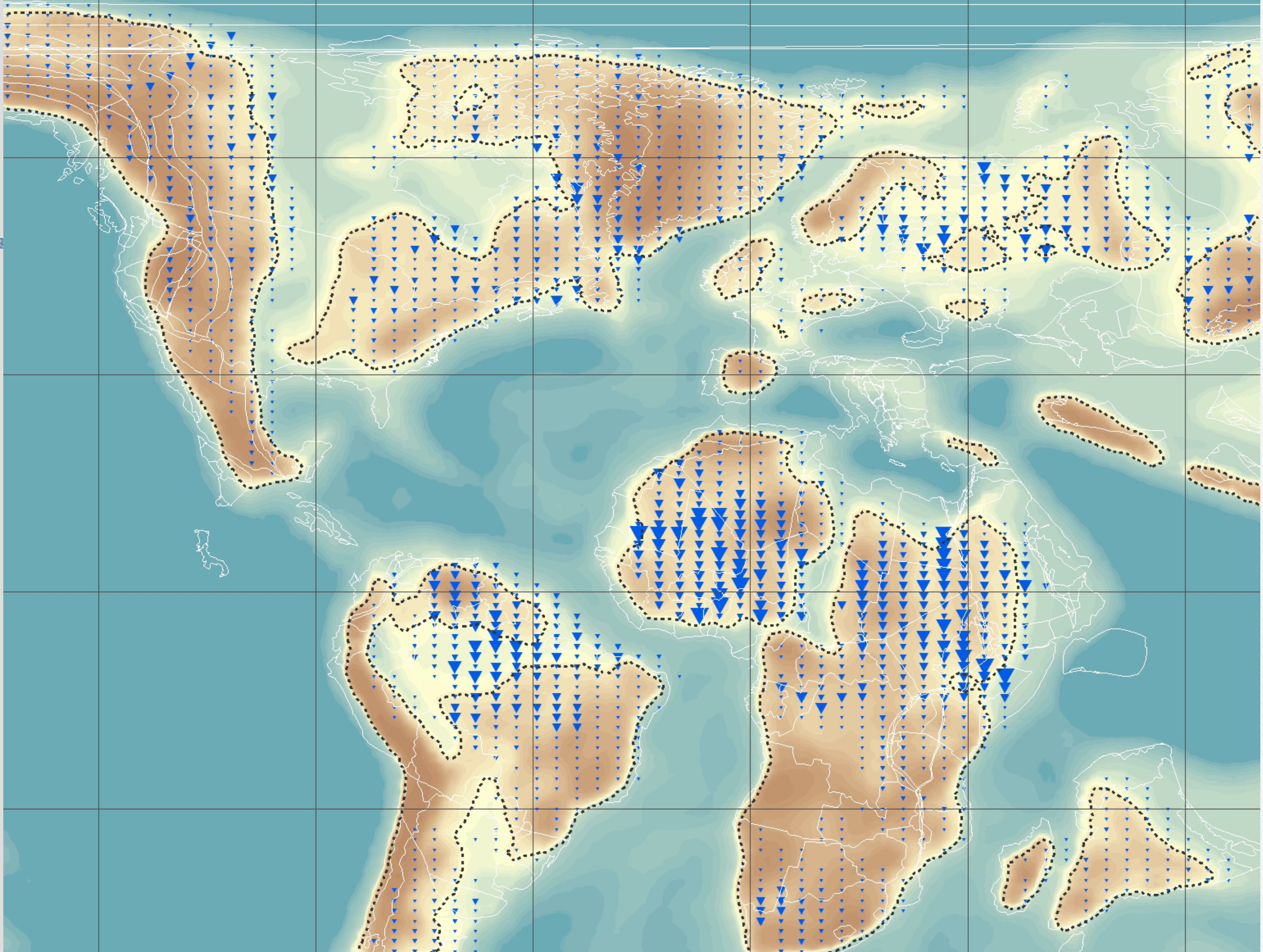

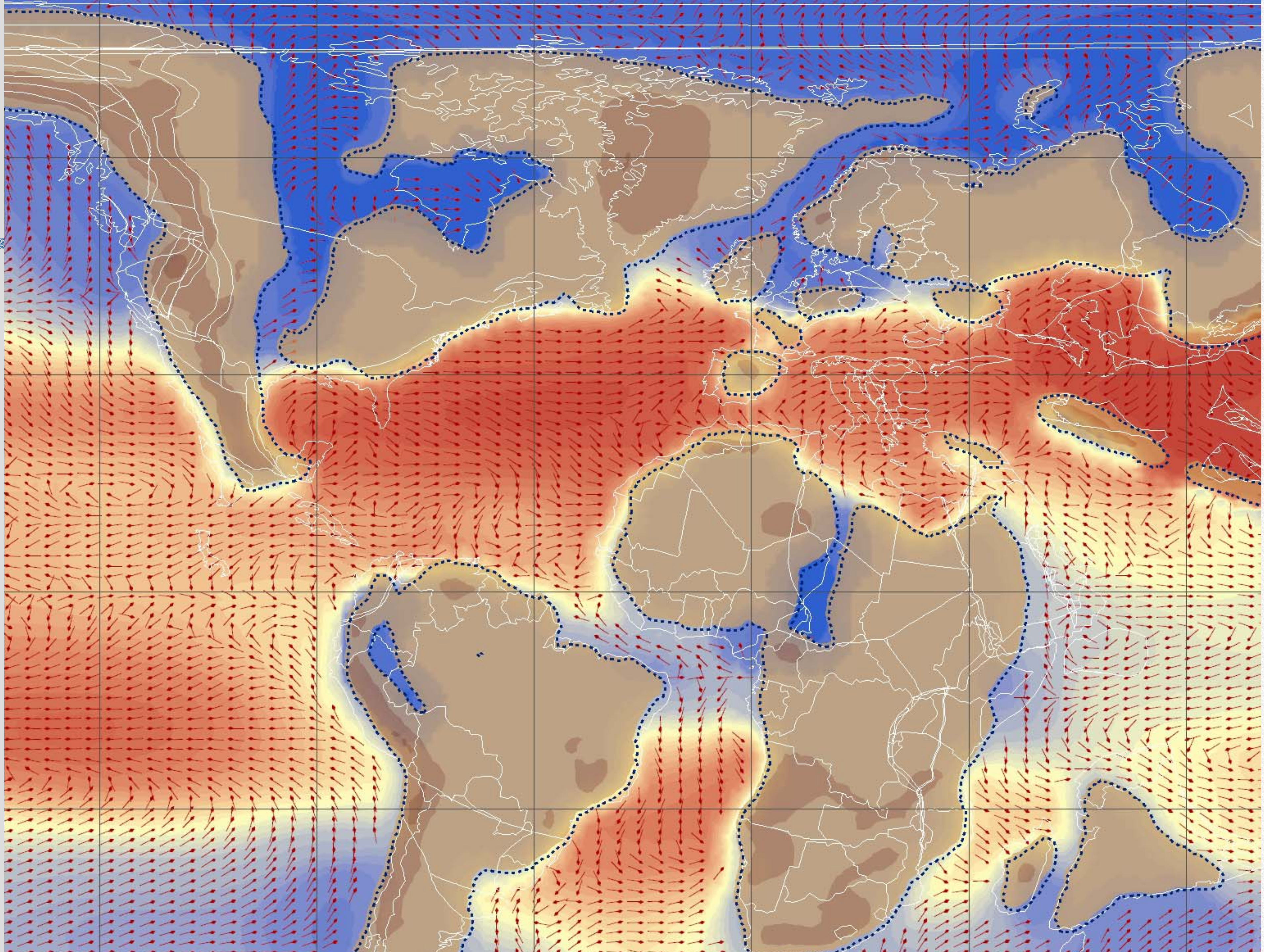

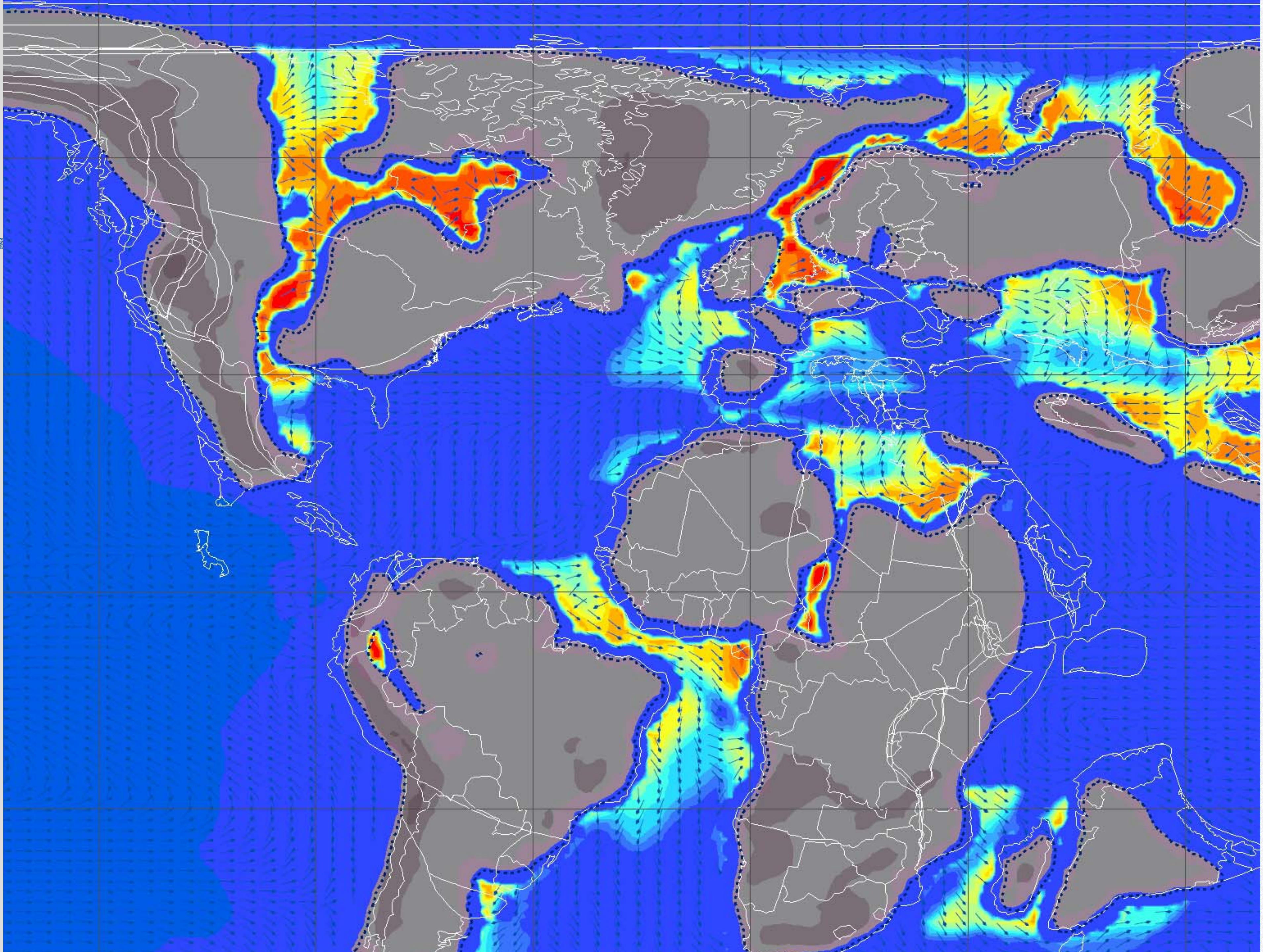

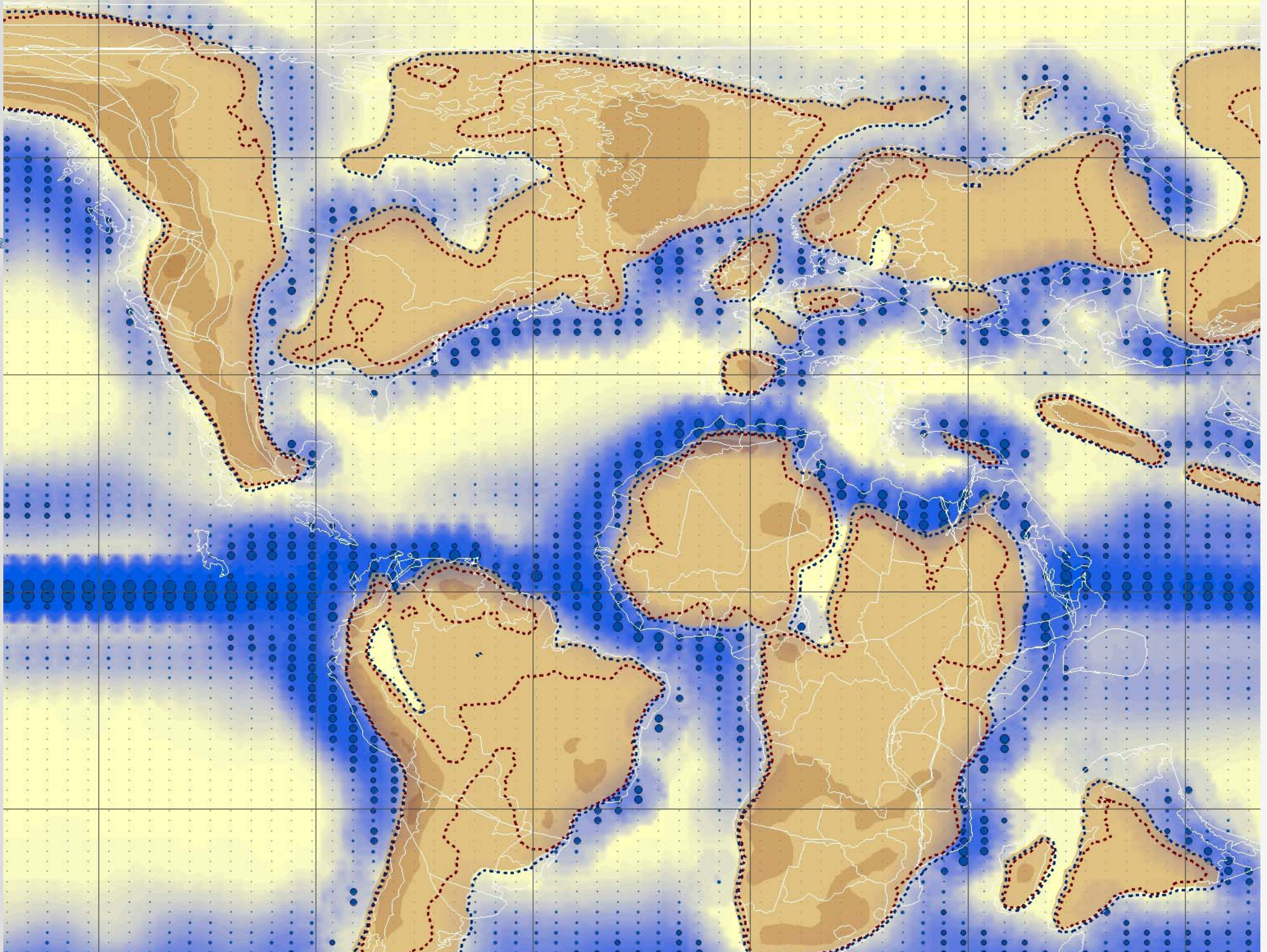

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Phanerozoic	Cenozoic	Quaternary	Holocene		0.01
			Pleistocene	Late	0.8
				Early	1.8
		Tertiary – Neogene	Pliocene	Late	3.6
				Early	5.3
			Miocene	Late	11.6
				Middle	16.0
				Early	23.0
			Oligocene	Late	28.4
				Early	33.9
		Tertiary – Paleogene	Eocene	Late	37.2
				Middle	48.6
				Early	55.8
			Paleocene	Late	61.7
				Early	65.5
	Mesozoic	Cretaceous	Late		100
			Early		146
		Jurassic	Late		161
			Middle		176
			Early		200
		Triassic	Late		228
			Middle		245
			Early		251
	Paleozoic	Permian	Late		271
			Early		299
		Carboniferous	Pennsylvanian		318
			Mississippian		359
		Devonian	Late		385
			Middle		398
			Early		416
		Silurian	Late		428
			Early		444
		Ordovician	Late		461
			Middle		472
			Early		488
		Cambrian	Late		501
			Middle		513
			Early		542
Precambrian	Proterozoic	Late			1000
		Middle			1600
		Early			2500
	Archean	Late			3000
		Middle			3400
		Early			

INTERVAL: ← YEAR

INTERVAL	GANDOLPH TIME SLICES
2	15 - Miocene
4	30 - Oligocene
3	45 - Middle Eocene (Thanetian)
4	70 - Tertiary/Cretaceous Boundary
1	90 - Late Cretaceous (Turonian-Cenomanian)
2	120 - Early Cretaceous (Albian-Aptian)
2	140 - Early Cretaceous (Barremian-Berriasian)
1	160 - Late Jurassic (Tithonian-Oxfordian)
3	180 - Early Jurassic (Callovian-Hettangian)
2	210 - Late Triassic (Rhaetian-Anisian)
4	250 - Permo-Triassic Boundary
1	280 - Permo-Carboniferous
3	340 - Mississippian
1	360 - Late Devonian (Frasnian-Famennian)
4	400 - Siluro-Devonian (Givetian-Wenlock)
2	440 - Late Ordovician - Early Silurian
4	480 - Late Cambrian - Ordovician
3	600 - Late Neoproterozoic (Ediacaran)

Age of FOAM Simulation

PALEOMAP Project Approach