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Paleogeographic and Paleoclimatic Atlas*

C.R. Scotese¹

Search and Discovery Article #30192 (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 Reconstructions of the Circum-Arctic Region since the Late Jurassic," [Search and Discovery Article #30193 \(2011\)](#).

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Abstract

During the last six years the PALEOMAP Project has constructed a digital atlas of plate tectonic and paleogeographic reconstructions. This "PaleoAtlas" runs in ArcGIS (ESRI). The PaleoAtlas is made up of 53 paleoreconstructions in six volumes: Cenozoic, Cretaceous, Jurassic and Triassic, Late Paleozoic, Early Paleozoic, and Late Precambrian (Neoproterozoic). For each reconstructed time interval there are more than 25 feature layers that describe important tectonic, paleogeographic and paleoclimatic information, such as: modern geographic features, plate tectonic features (active plate boundaries, age of the ocean floor, and ancient plates), paleorivers and drainage basins, a 3D digital paleogeographic model (PaleoDEM), as well as estimates of highstand and lowstand shorelines, and geological information (outcrop geology, regional lithofacies, coral reefs, and ophiolites).

Work has recently begun on a companion PaleoClimate Atlas. Climate simulations were run using the Fast Ocean and Atmosphere Model (FOAM) which illustrate the Earth's evolving climate during the past 750 million years. There will be more than 50 paleoclimatic reconstructions in the completed Paleoclimate Atlas. As of June 2010, 18 simulations had been run. For each paleoclimatic reconstruction, there are ~20-feature layers describing important aspects of the Earth's ancient climate: atmospheric circulation (seasonal pressure systems and winds), seasonal temperatures, rainfall, runoff, paleorivers and drainage basins, oceanography (seasonal surface currents, salinity, areas of upwelling, areas of anoxia), and the predicted location of deltas and clastics influx to the oceans). The plate tectonic, paleogeographic and climatic information collected in the PaleoAtlas and Paleoclimate Atlas will be the principal input for the "Earth System History Archive" (ESHA). The Earth System Archive is a compilation of important paleo-environmental variables (e.g., elevation, bathymetry, temperature, rainfall, ocean currents, salinity, upwelling, etc). The goal of the ESHA is to provide earth scientists and earth historians with a concise, accurate, and informative digital description of the evolution of the Earth System during the past one billion years. Using GIS technology it is now possible to store, retrieve, and visualize this wealth of information about the Earth's distant past.

Selected References

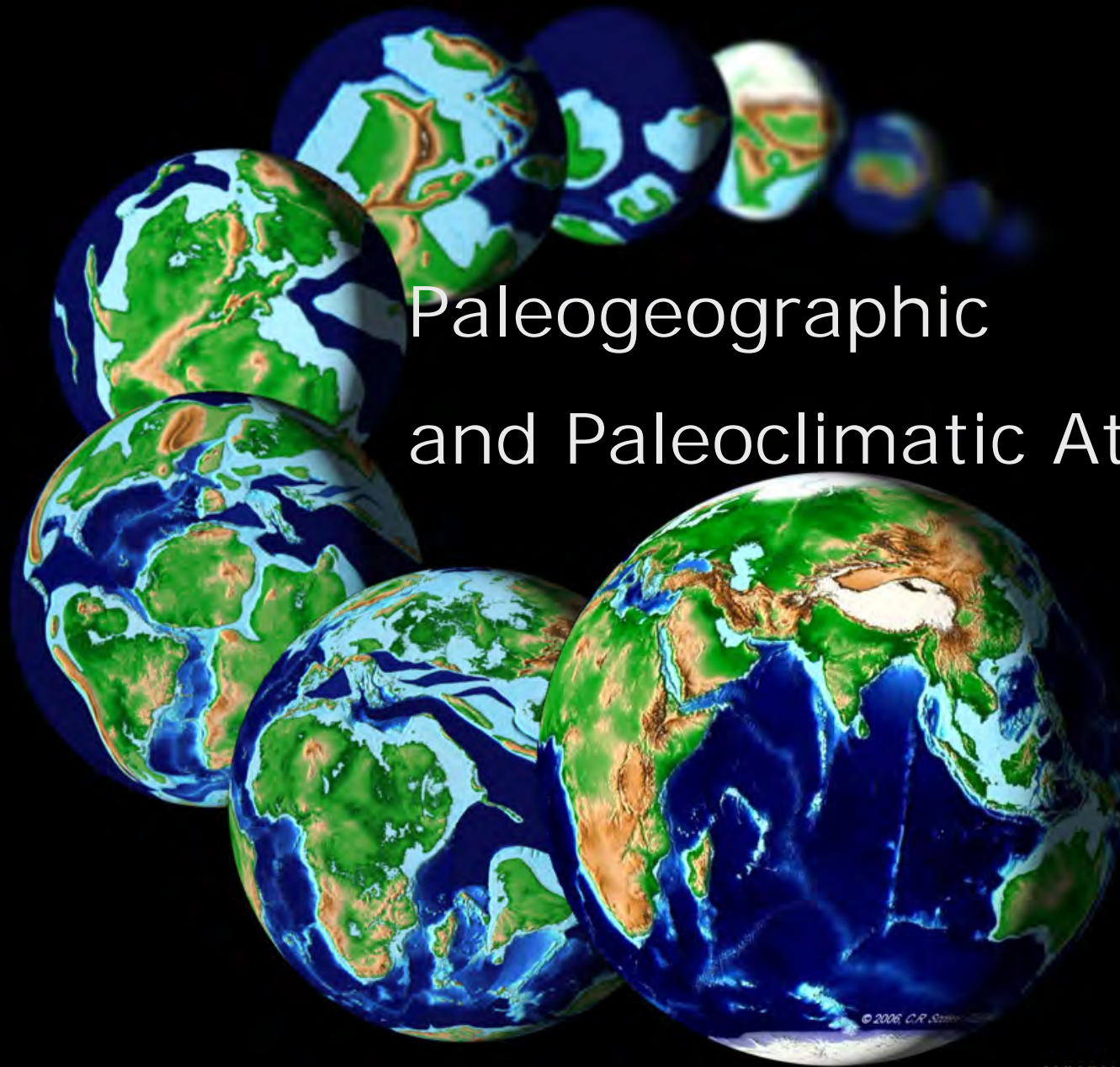
Kiessling, W., 2002, Secular variations in the Phanerozoic reef ecosystem, *in* W. Kiessling, E. Fluegel, and J. Golonka (eds.) Phanerozoic reef patterns: Special Publication SEPM, Tulsa, Oklahoma, v. 72, p. 625-690.

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.

Websites

Blakey, R., Global Paleogeography: Web accessed 19 September 2011, <http://www2.nau.edu/rcb7/65moll.jpg>

Scotese, C.R., Paleomap Project: Web accessed 19 September 2011, <http://www.scotese.com/>



Paleogeographic and Paleoclimatic Atlas

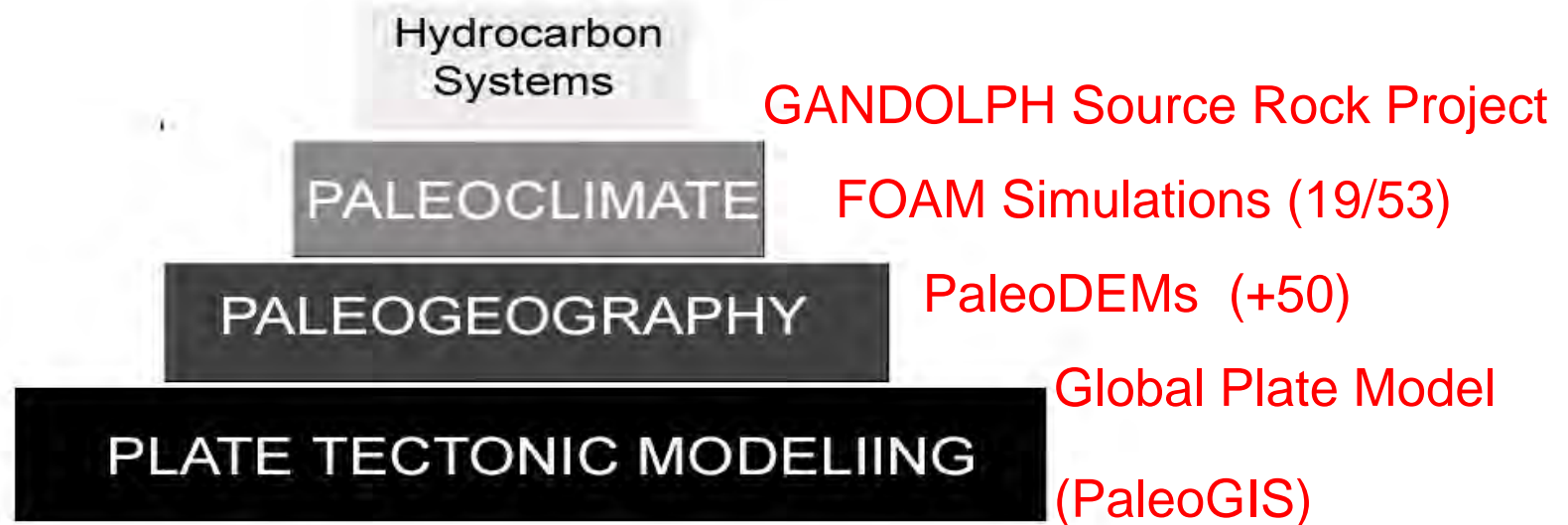
www.scotese.com

by C. R. Scotese, PALEOMAP Project

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 History of the Earth."

PALEOMAP Project Approach



What I do, What I Know

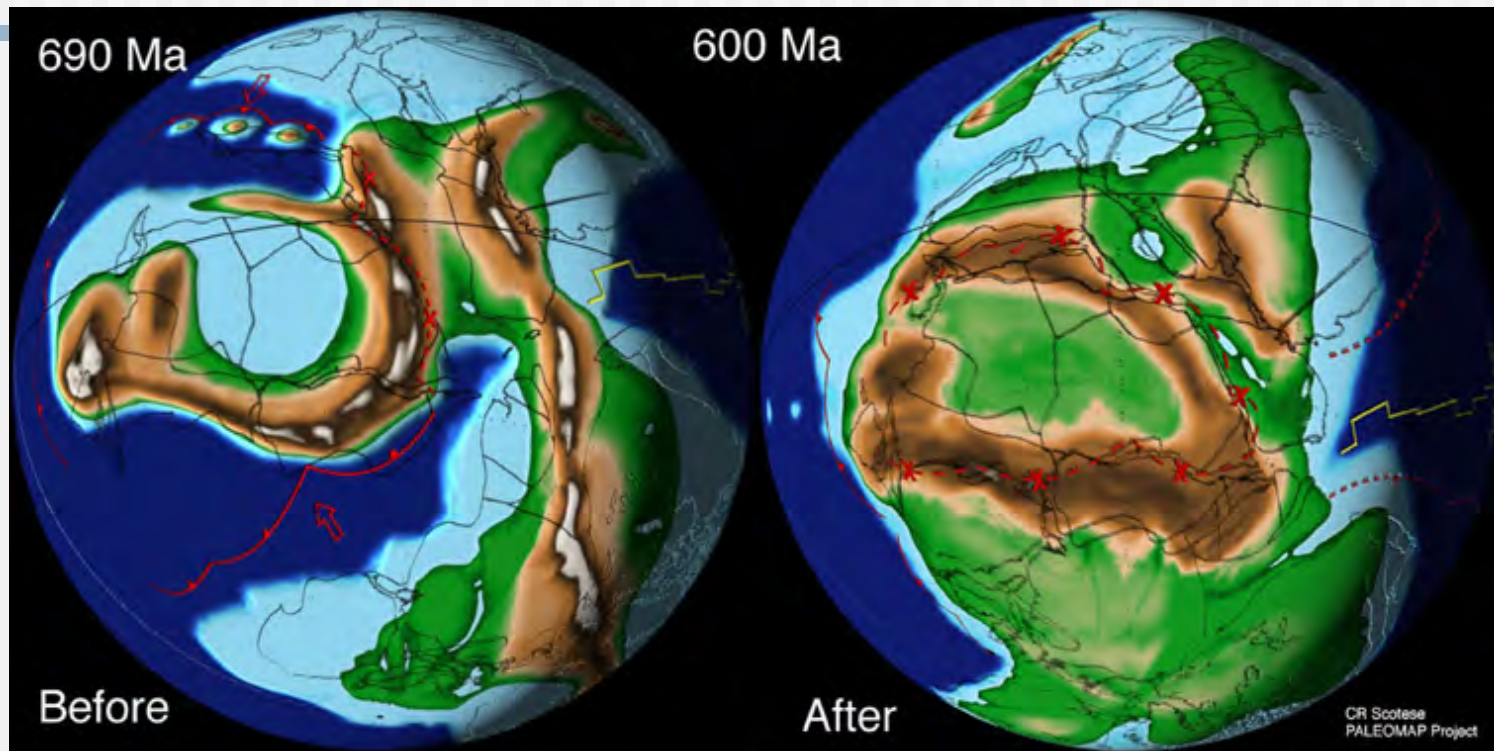
- Plate Tectonics global history, driving mechanisms
 - Global Plate Model (100Ma Future), PaleoGIS
ArcGIS reconstruction software
- Paleogeography PaleoDigital Elevation Model
 - ArcGIS PaleoAtlas (50+ Time Slices)
- Paleoclimate Modeling 19/53 simulations finished
- Hydrocarbon Systems GANDOLPH /
SourceFinder & PaleoTemperature Tool

PALEOMAP PaleoAtlas for ArcGIS

PALEOMAP PaleoAtlas Time Intervals

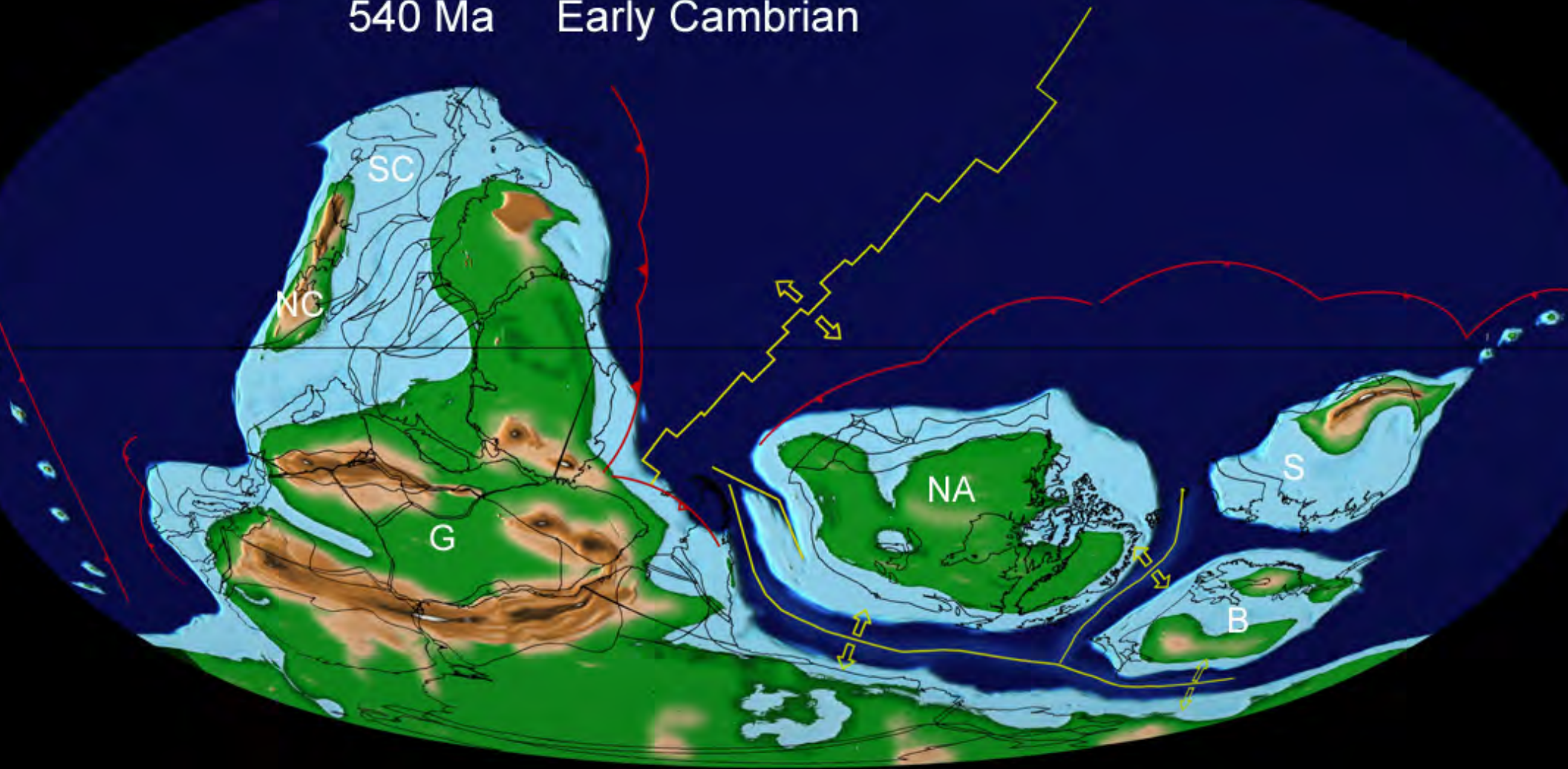
- Cenozoic 10
- Cretaceous 8
- Jurassic 6
- Triassic 4
- Late Paleozoic 12
- Early Paleozoic 10
- Neoproterozoic 3

Assembly of Gondwana



Collision of Congo craton with Rodinia
during Pan-African Orogeny

540 Ma Early Cambrian



Principal Feature Groups

- Graticule
- Modern Boundaries
(rivers, lakes, cities, basins, high & low resolution political boundaries)
- Lithology (reefs, ophiolites, Boucot, PGAP, ODP)
- Plate Tectonics (ancient plates, active plate boundaries, motion vectors, labels, isochron, age of oceans, *XOM Tectonic Map*)
- PaleoRivers & Drainage (ArcGIS Hydrology Tool)
- PaleoClimate (Climate Zones, *FOAM Results*)
- Paleogeography (Simple Pgeog, Hi-Res Pgeog, Highstand & Lowstand shorelines, PaleoDEM)
- Geology (Geological Map of the World)

Modern Features

- Coastlines
- Political Boundaries
- Cities
- Lakes & Rivers
- Sedimentary Basins

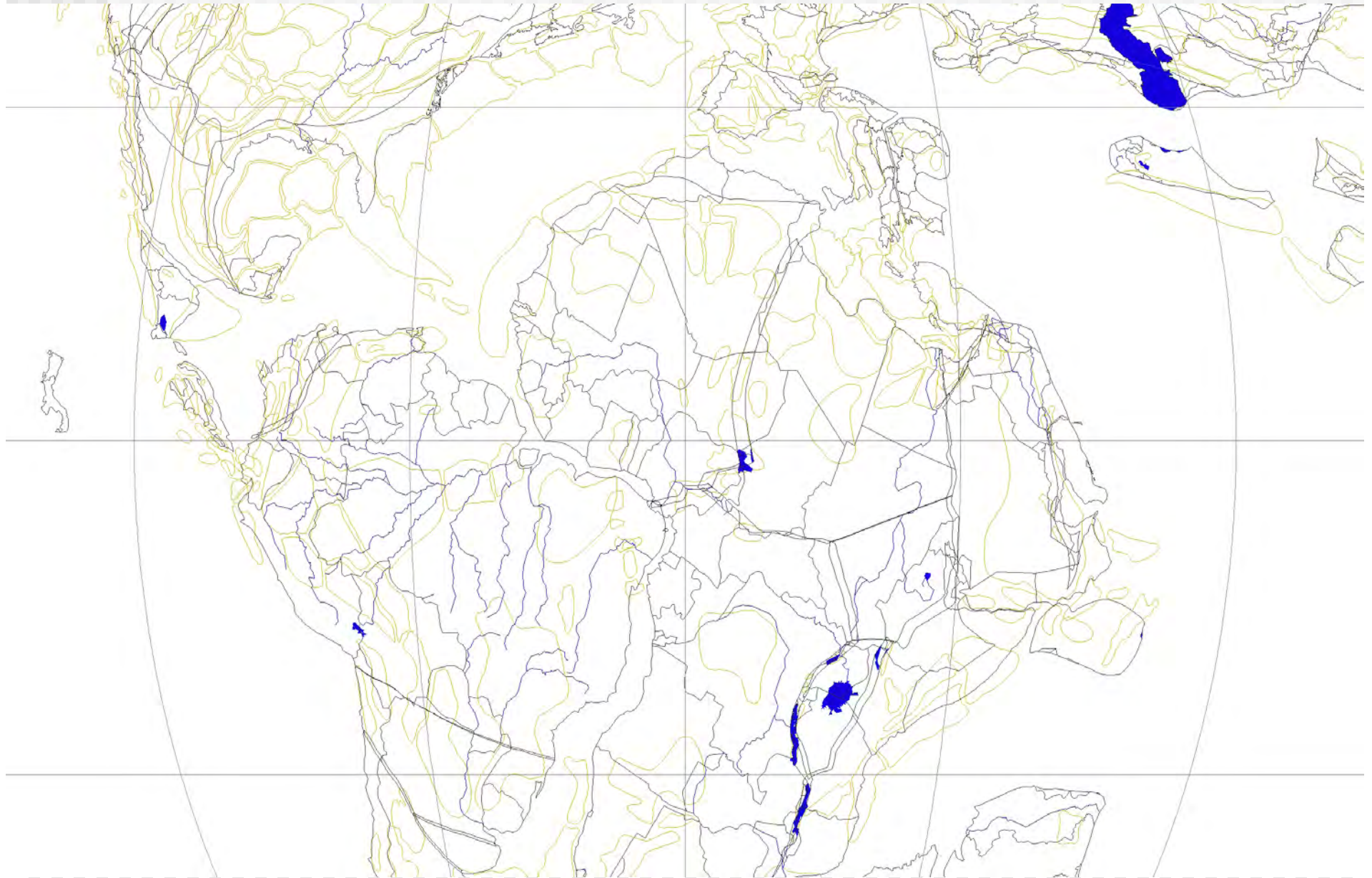
Modern Coastlines & Political Boundaries



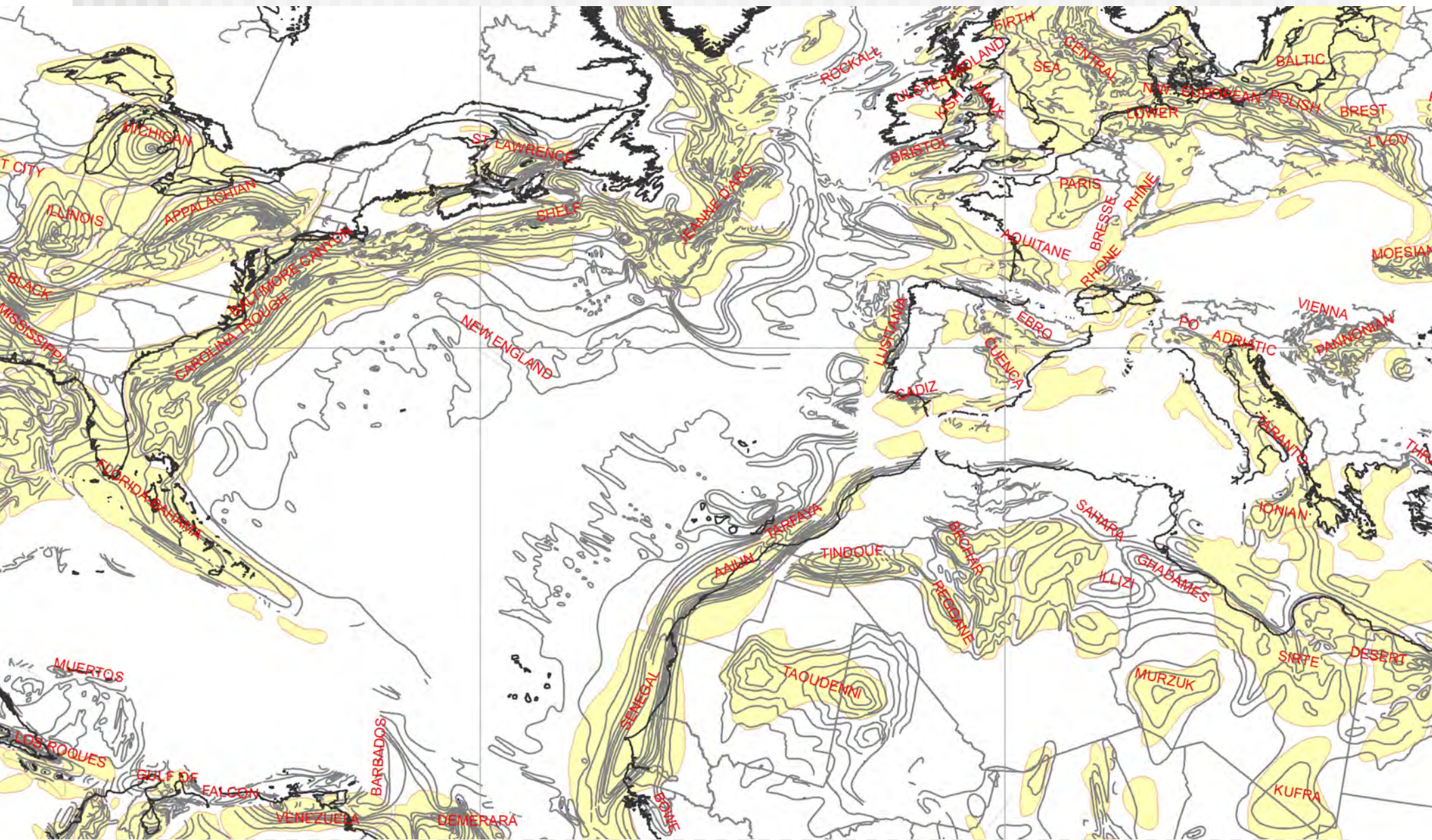
High Resolution Modern Coastlines & Political Boundaries



Rivers, Lakes & Sedimentary Basins



Sedimentary Basins from XOM Tectonic Map



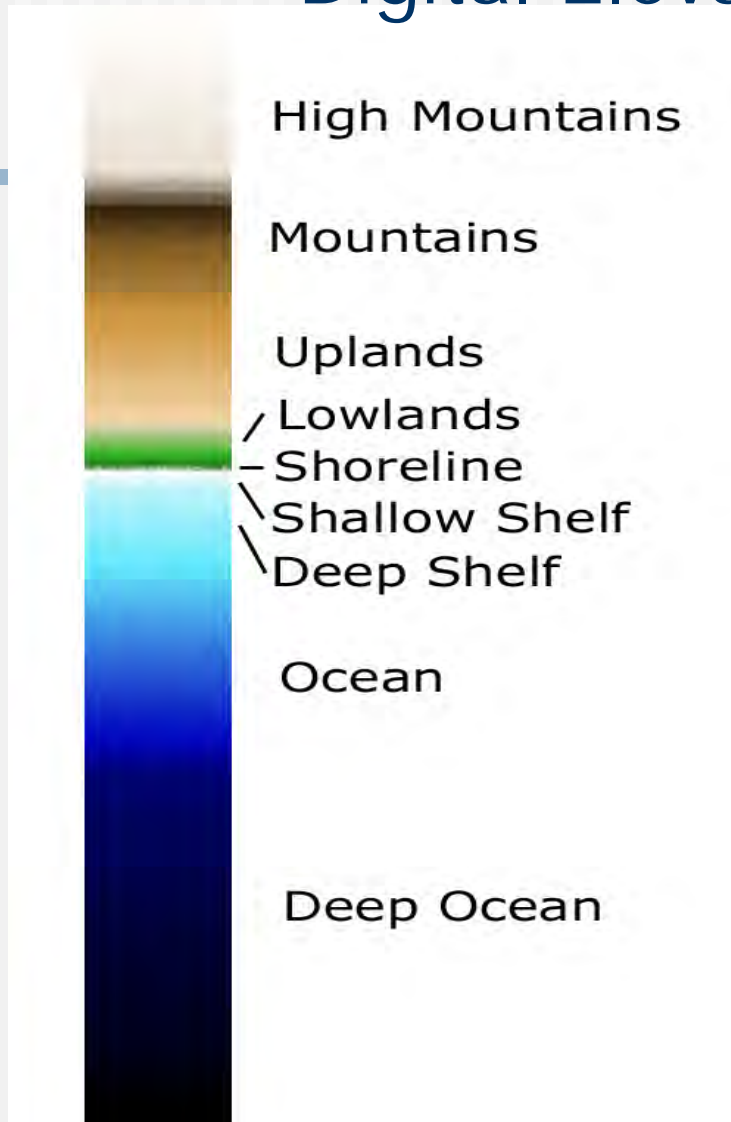
Paleogeography

- High Resolution
- Simplified
- High & Low Shorelines

PALEOGEOGRAPHIC RECONSTRUCTIONS

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

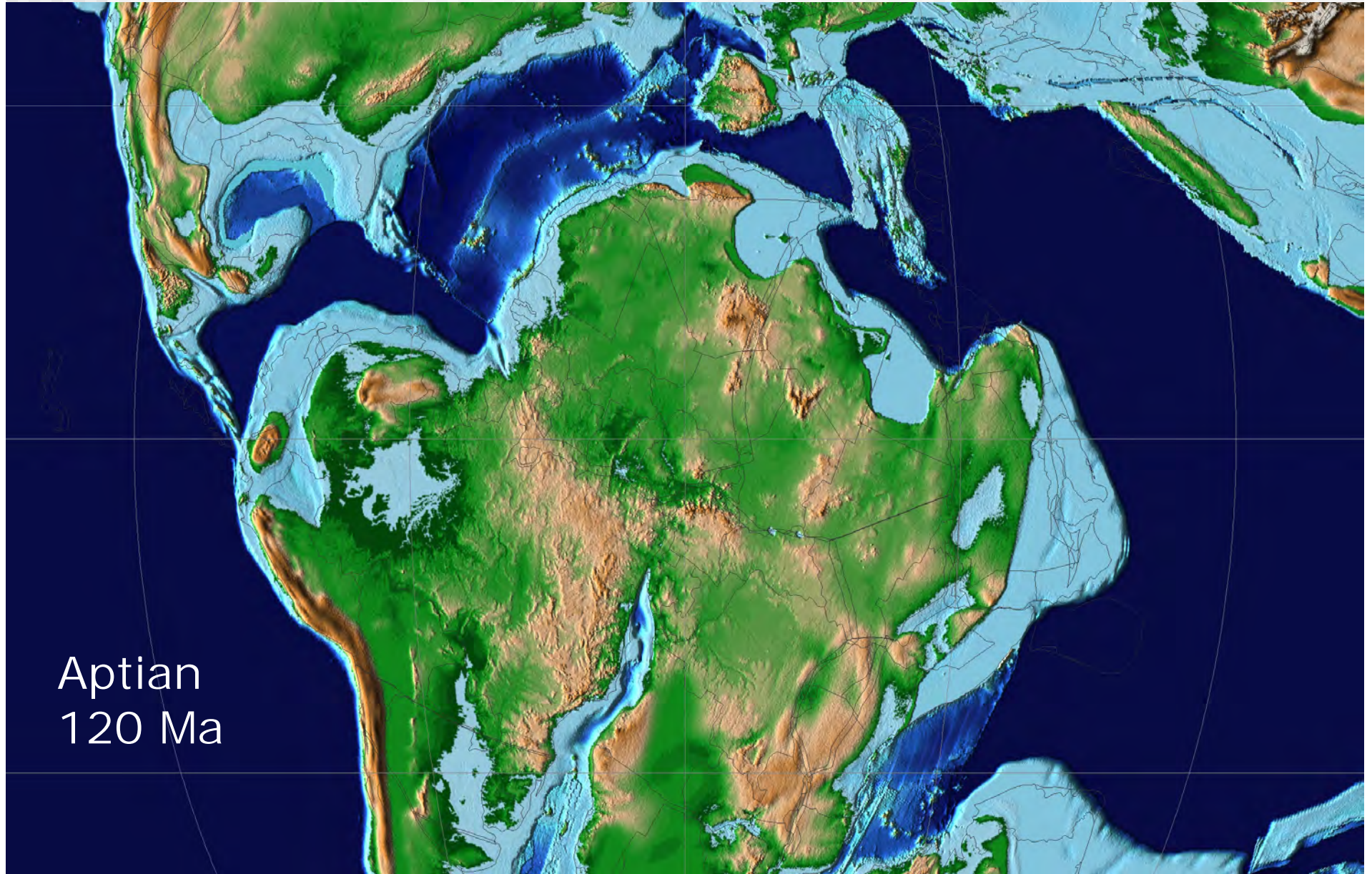
Digital Elevation Model



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

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

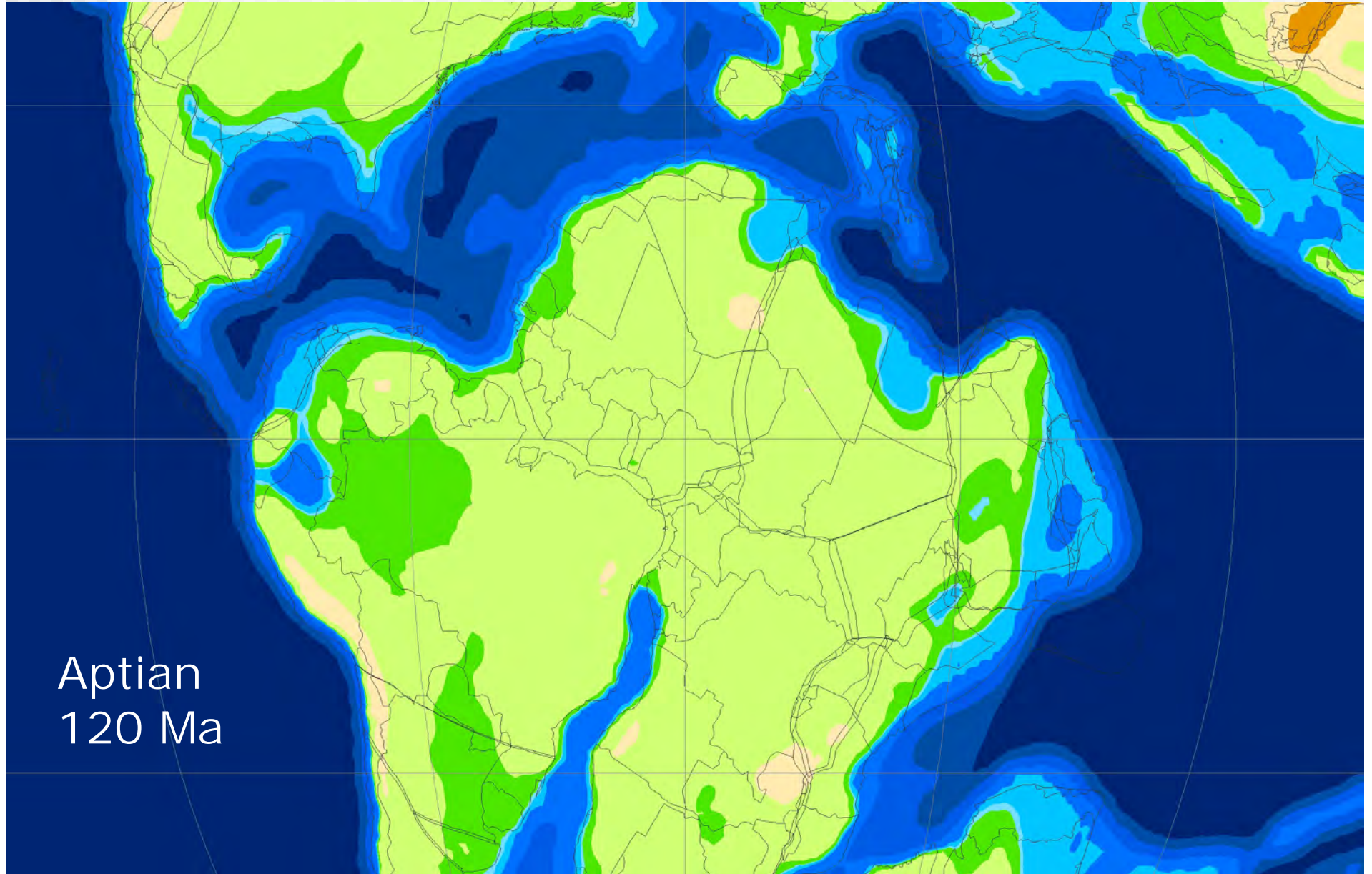
High Resolution Paleogeography



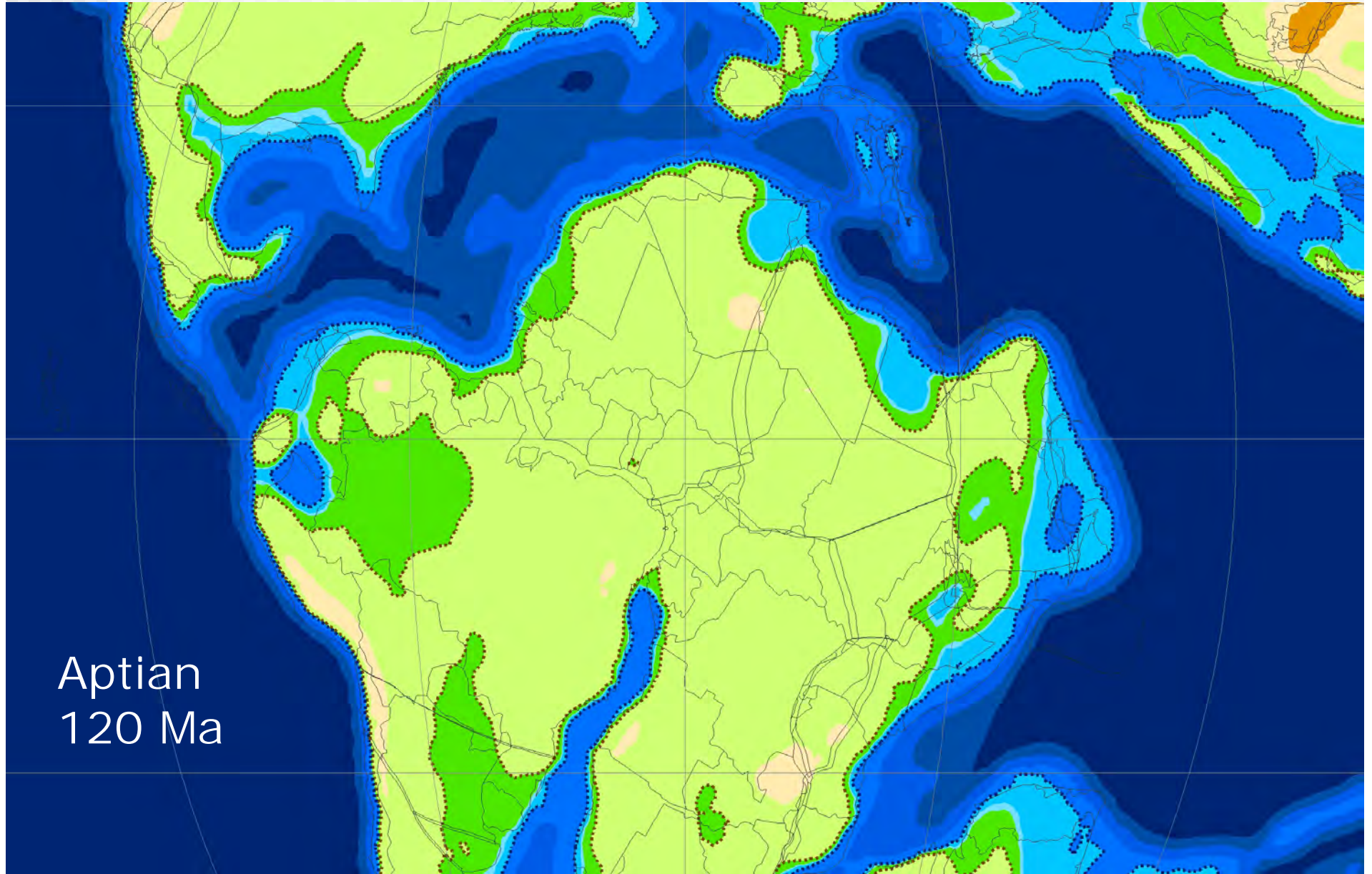
High Resolution Paleogeography (close-up)



Simplified Paleogeography



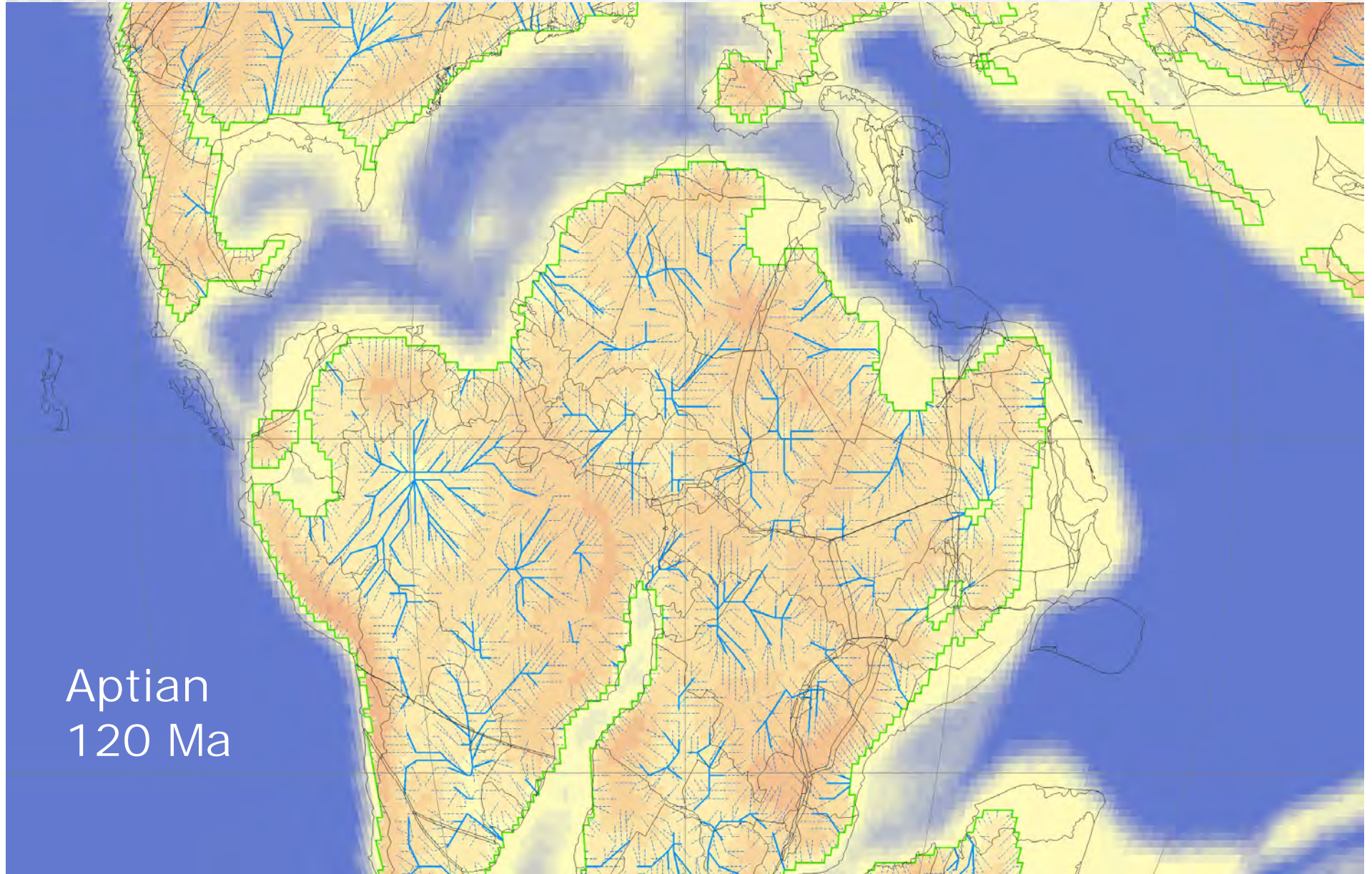
Simplified Paleogeography with Highstand and Lowstand coastlines



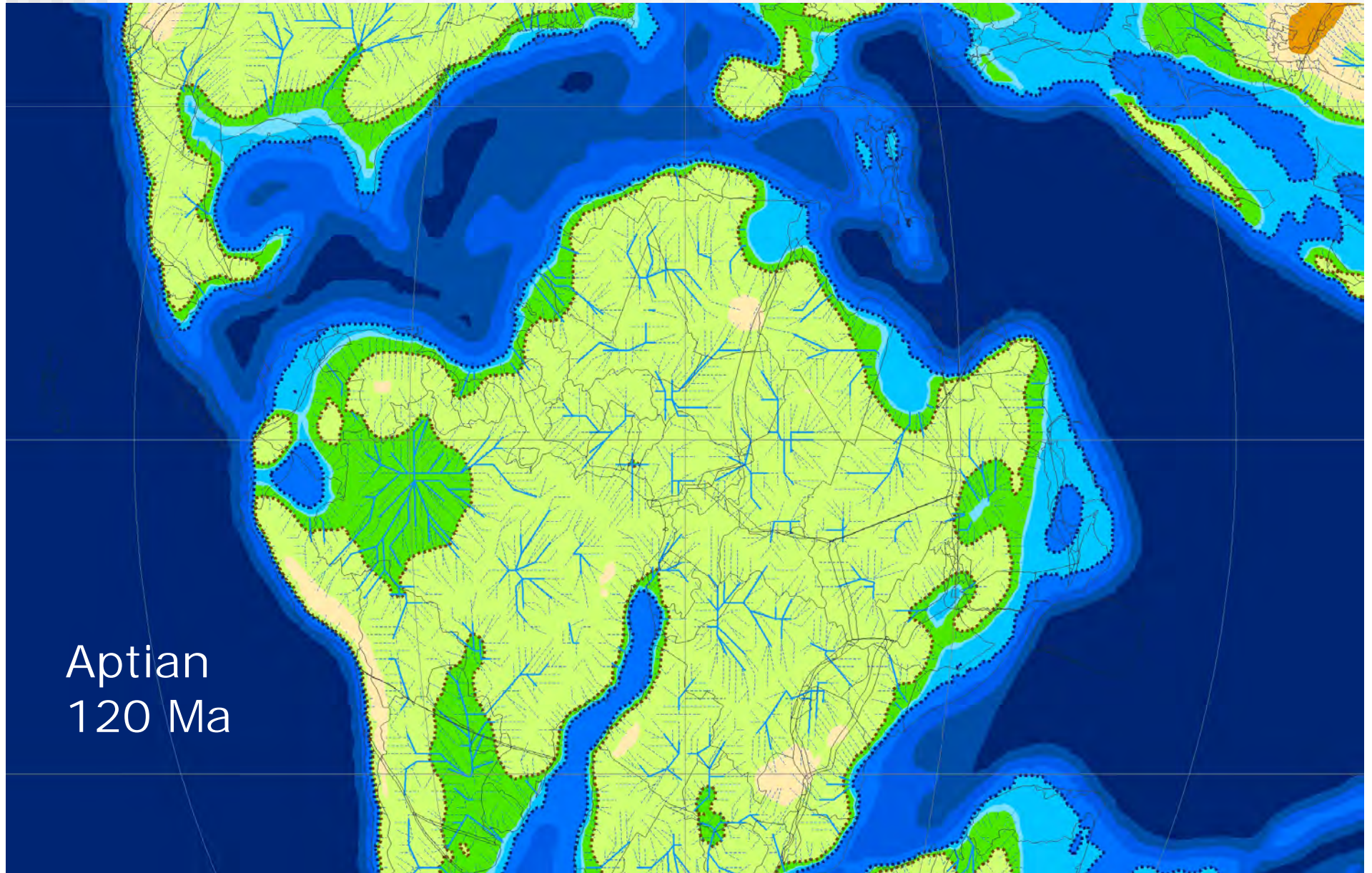
PaleoRivers & Drainage

- Drainage Basins
- PaleoRivers

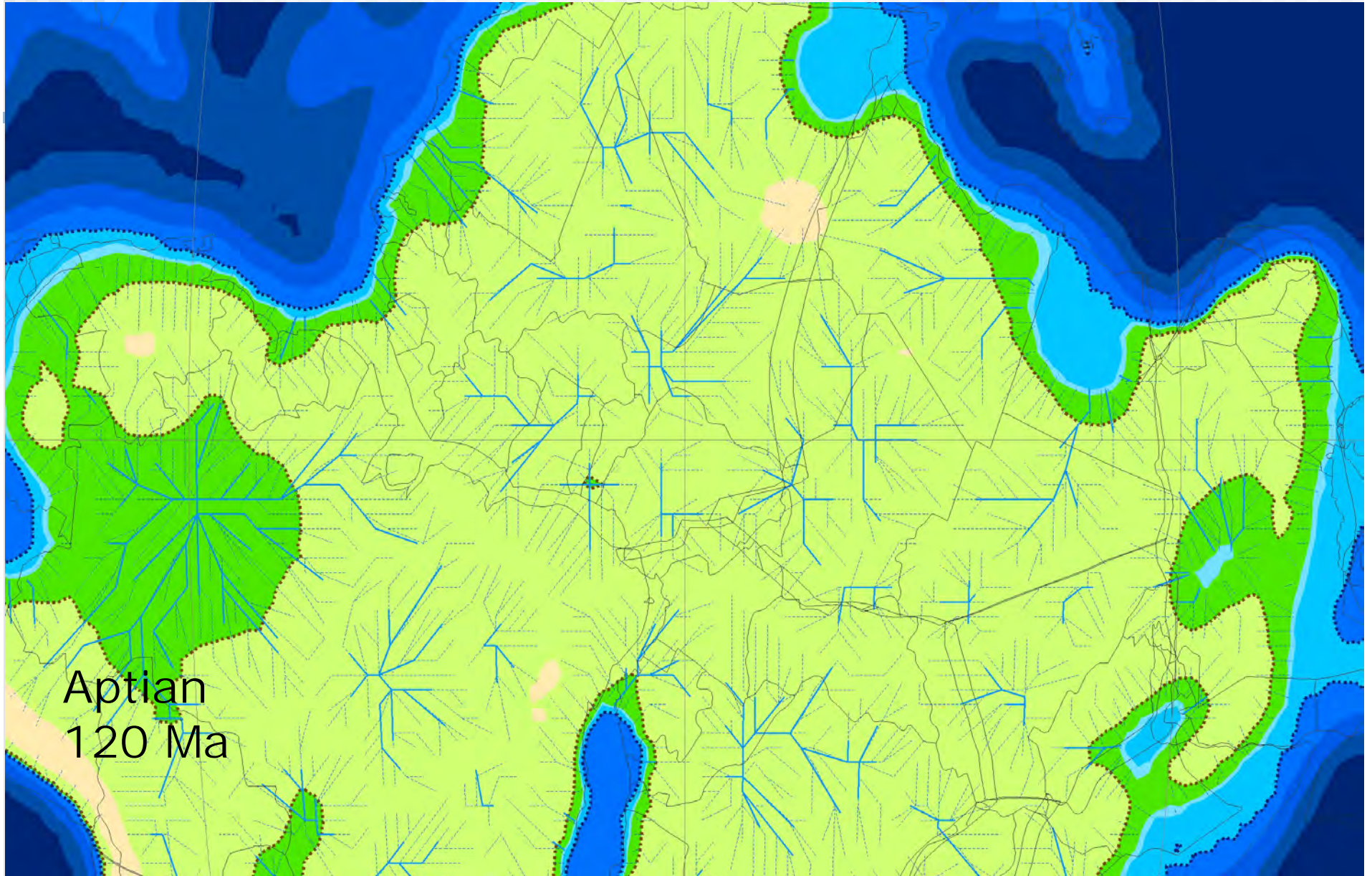
Paleo-Rivers and Drainage Pattern



Paleo-Rivers & Drainage on Simple Paleogeography



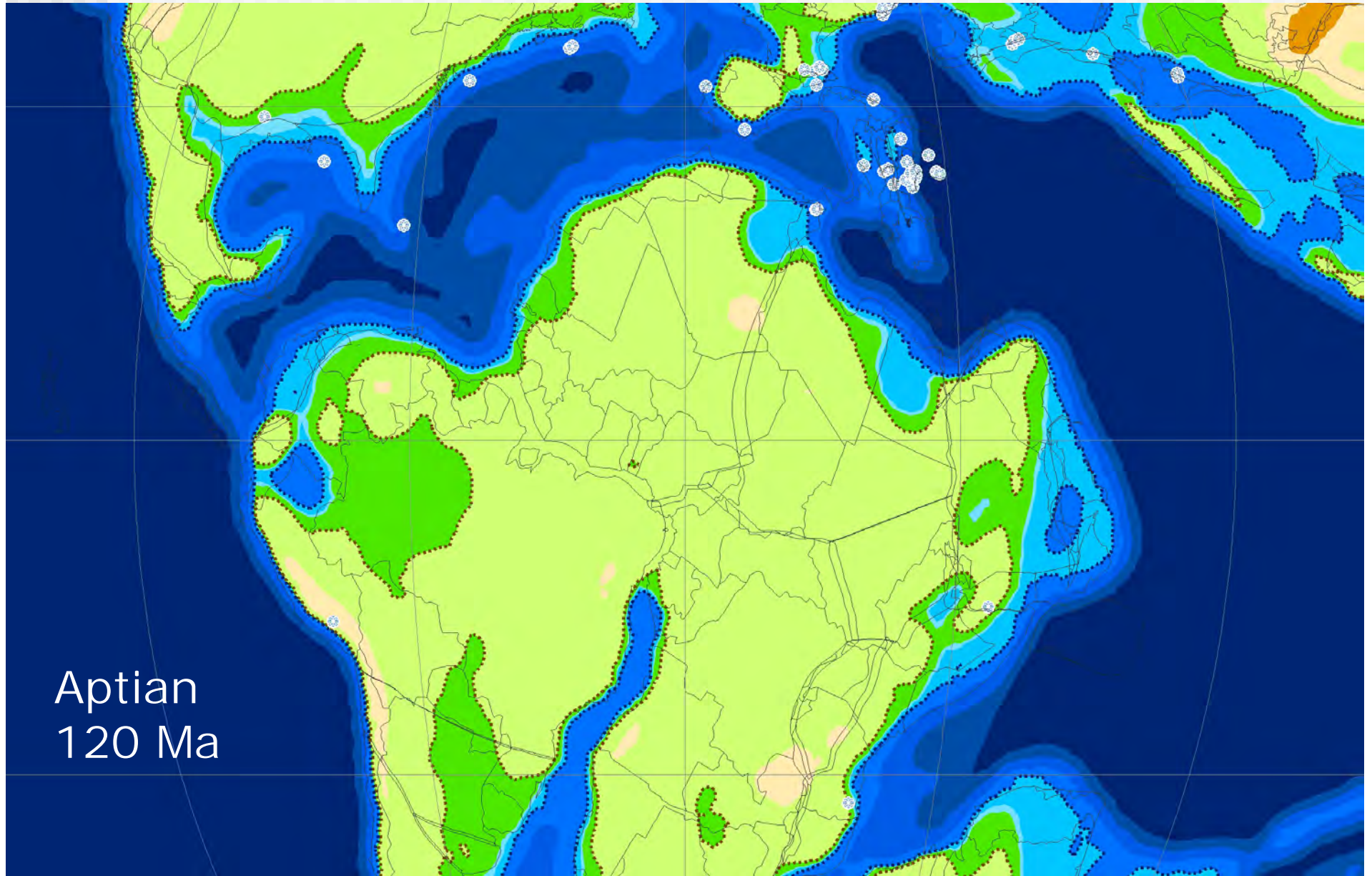
Paleo-Rivers & Drainage on Simple Paleogeography (close-up)



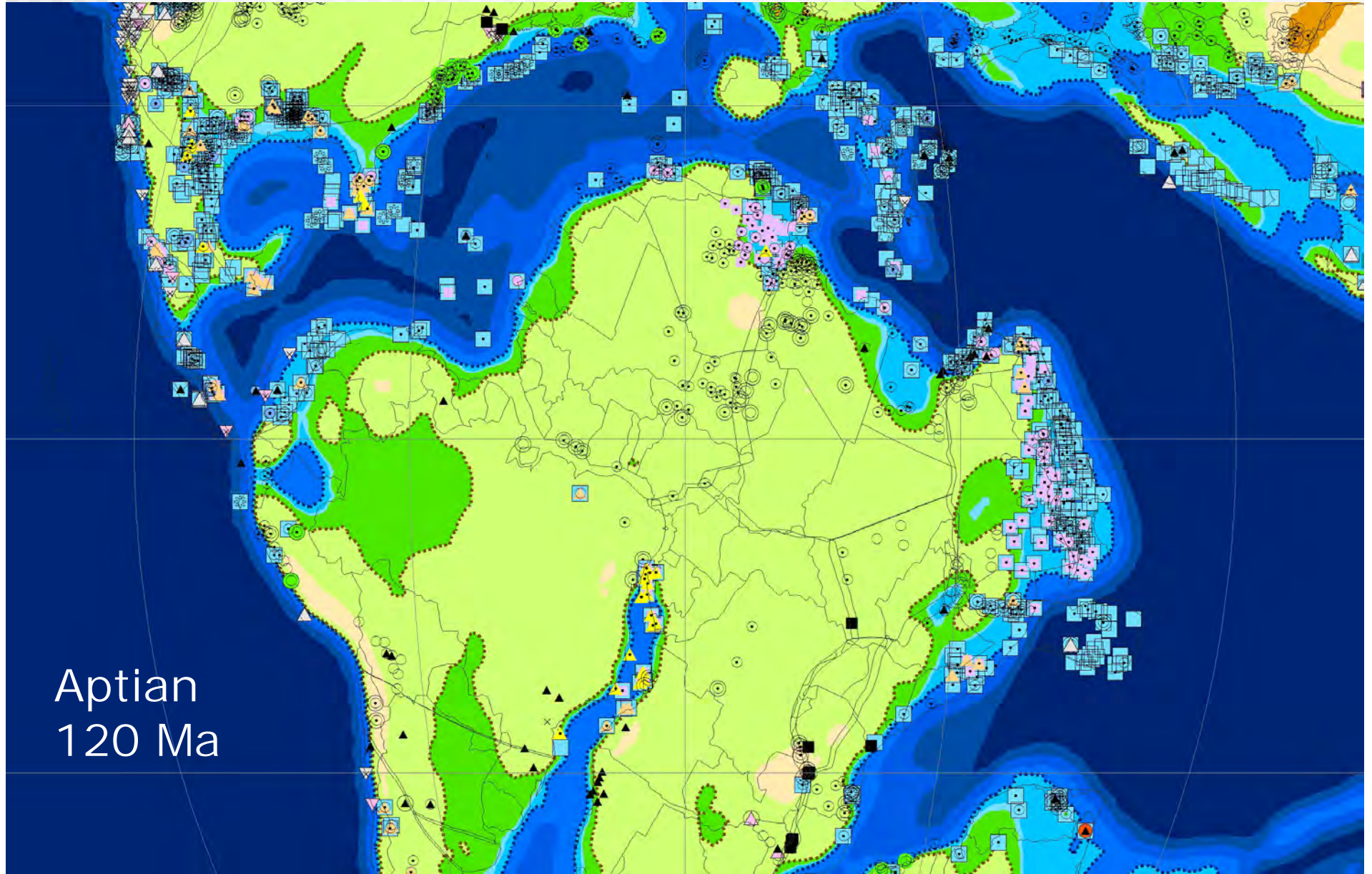
Lithology

- Reefs
- Ophiolites
- Lithology
- Depositional Environment
- Climatic Lithofacies

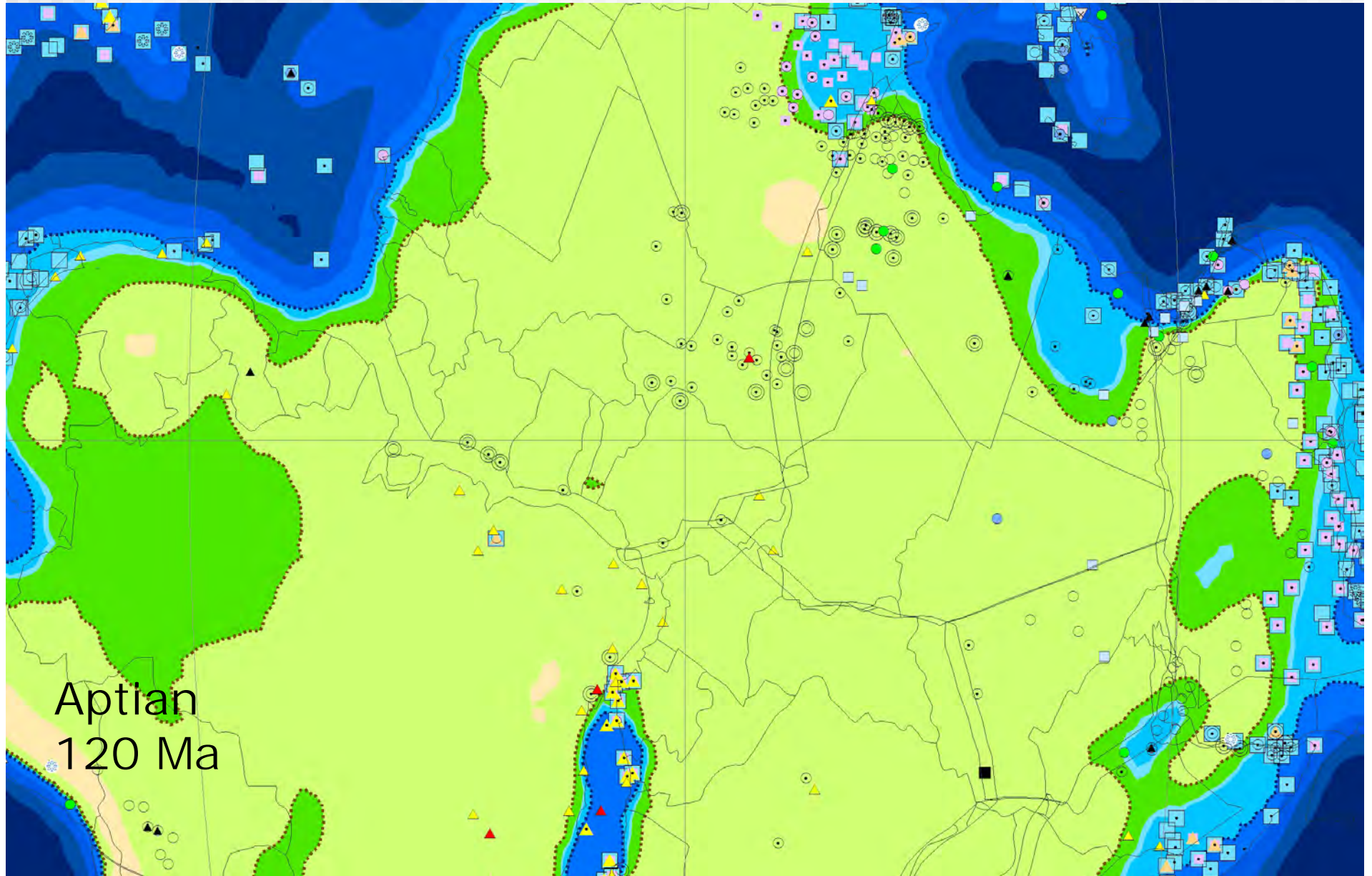
Reefs (Kiessling, 2002)



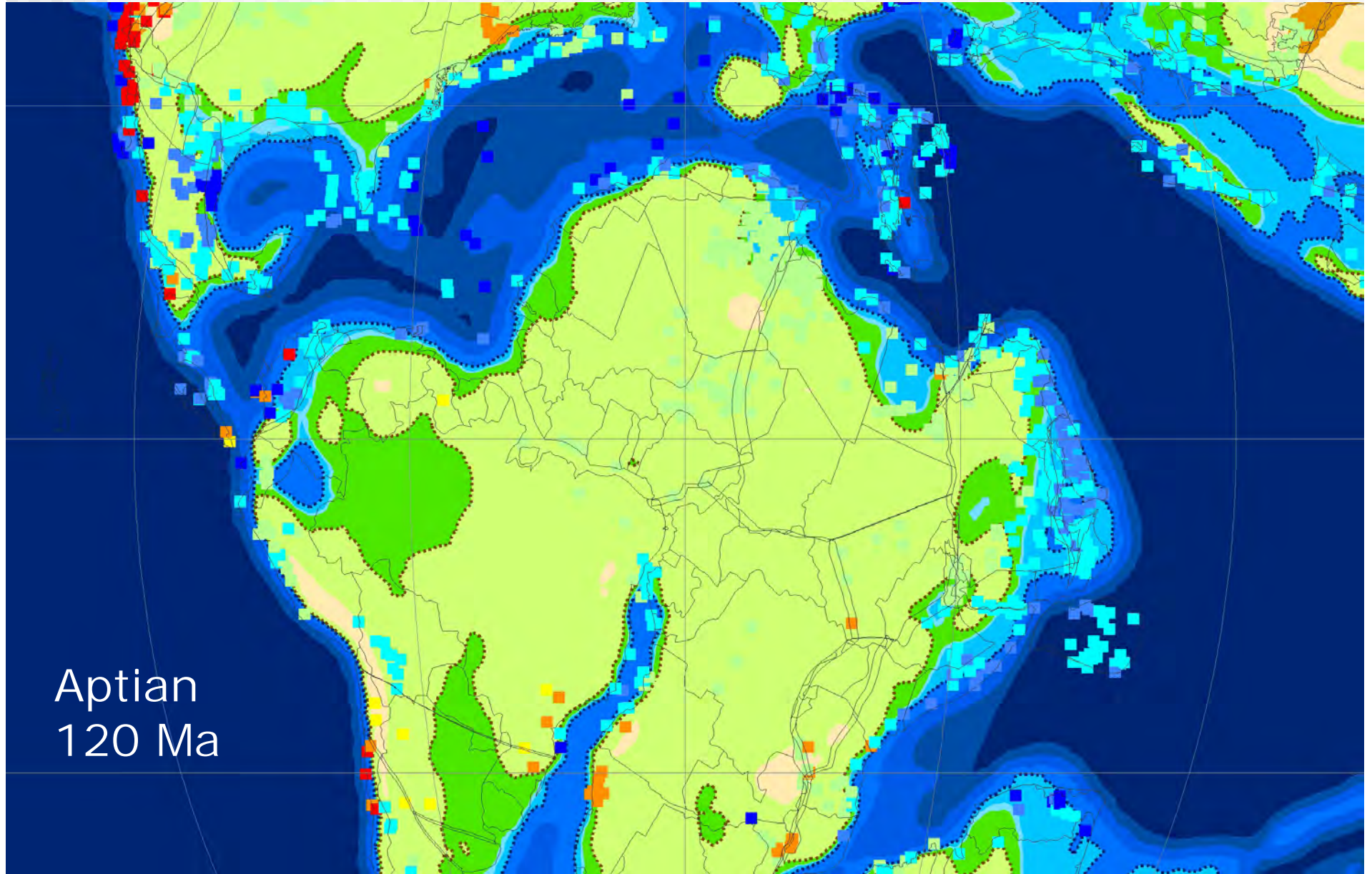
Lithofacies (U. Chicago, Ziegler et al., 2003)



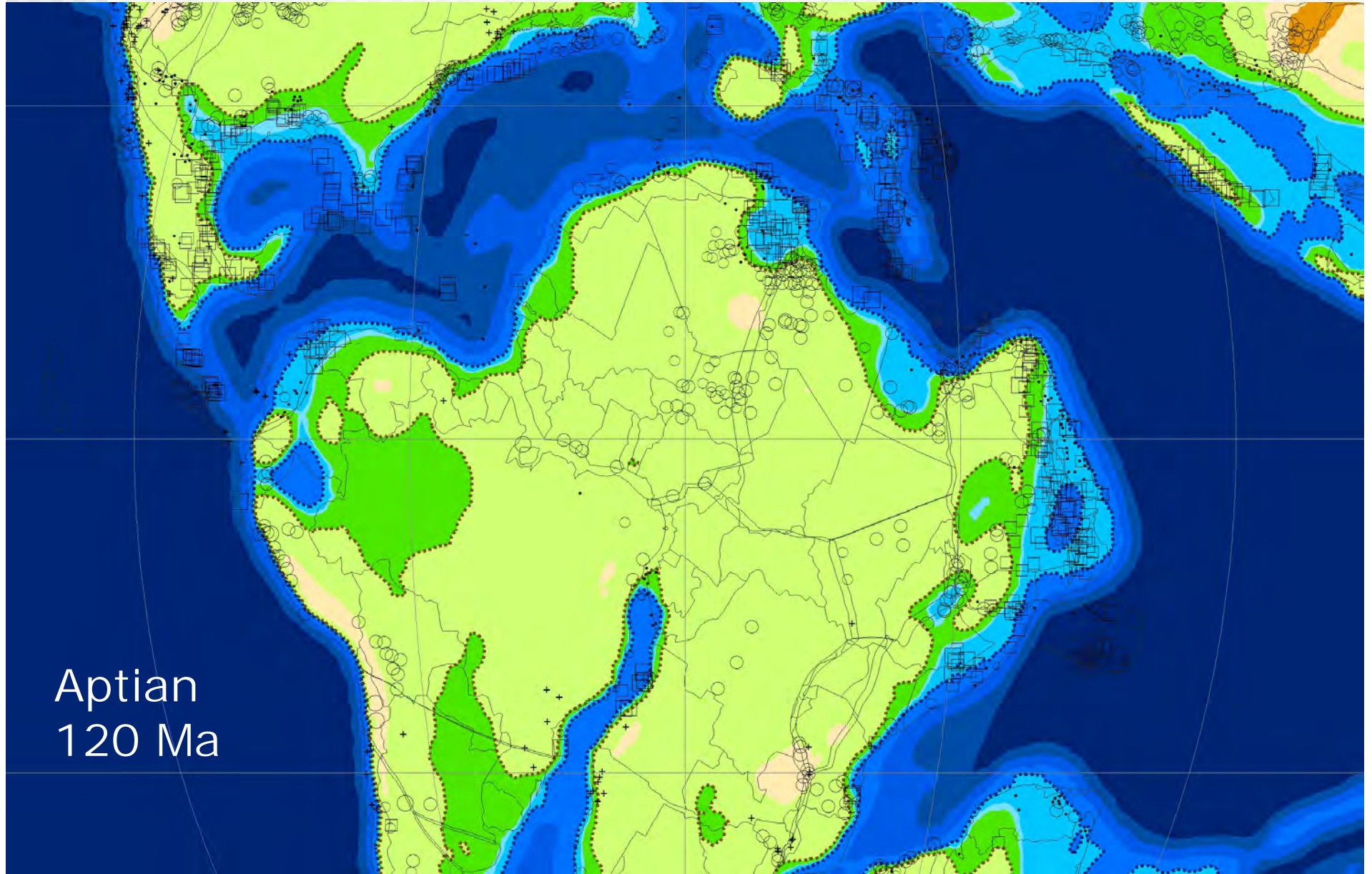
Lithofacies (close-up)



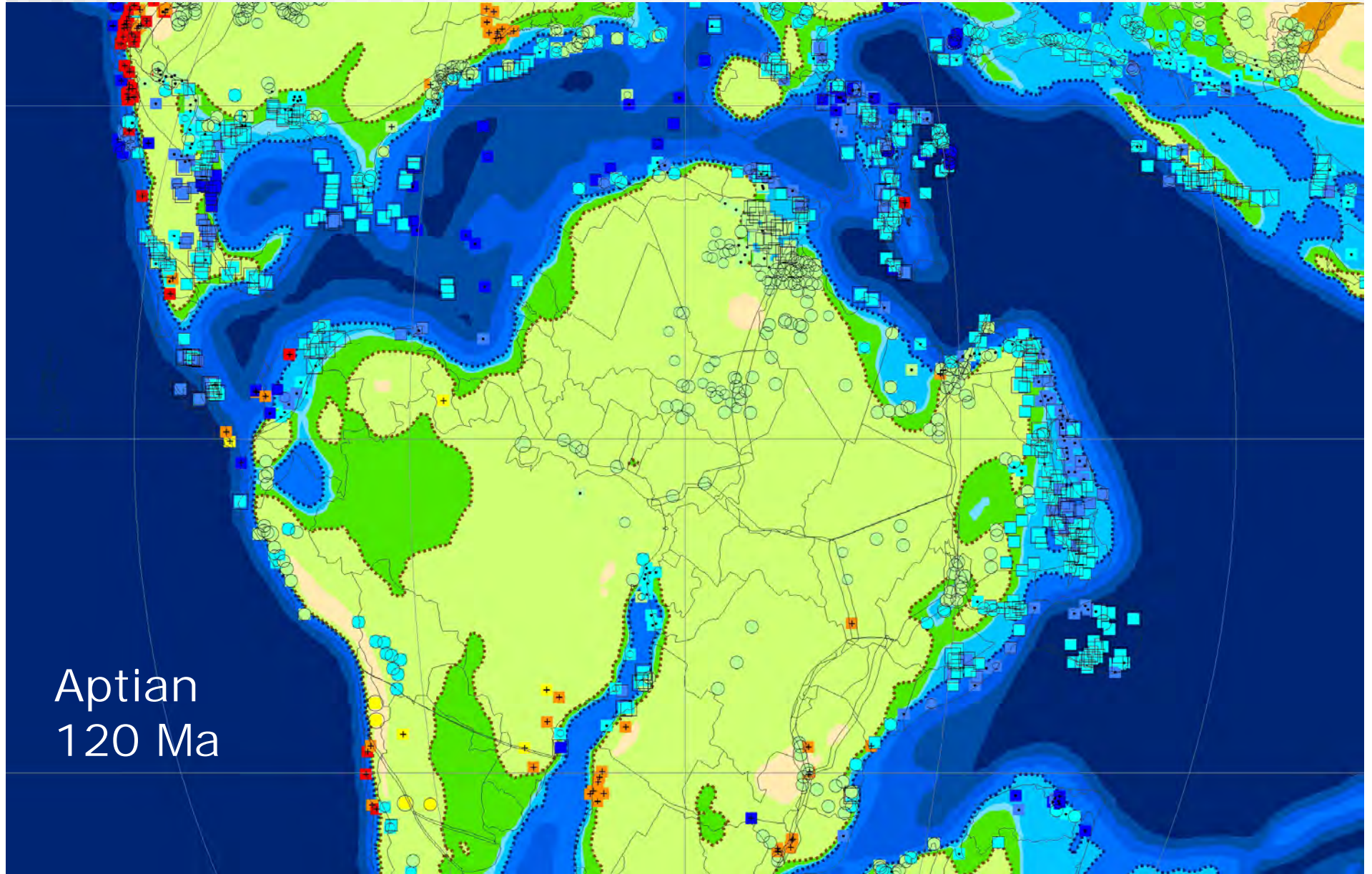
Environments of Deposition (Ziegler et al., 2003)



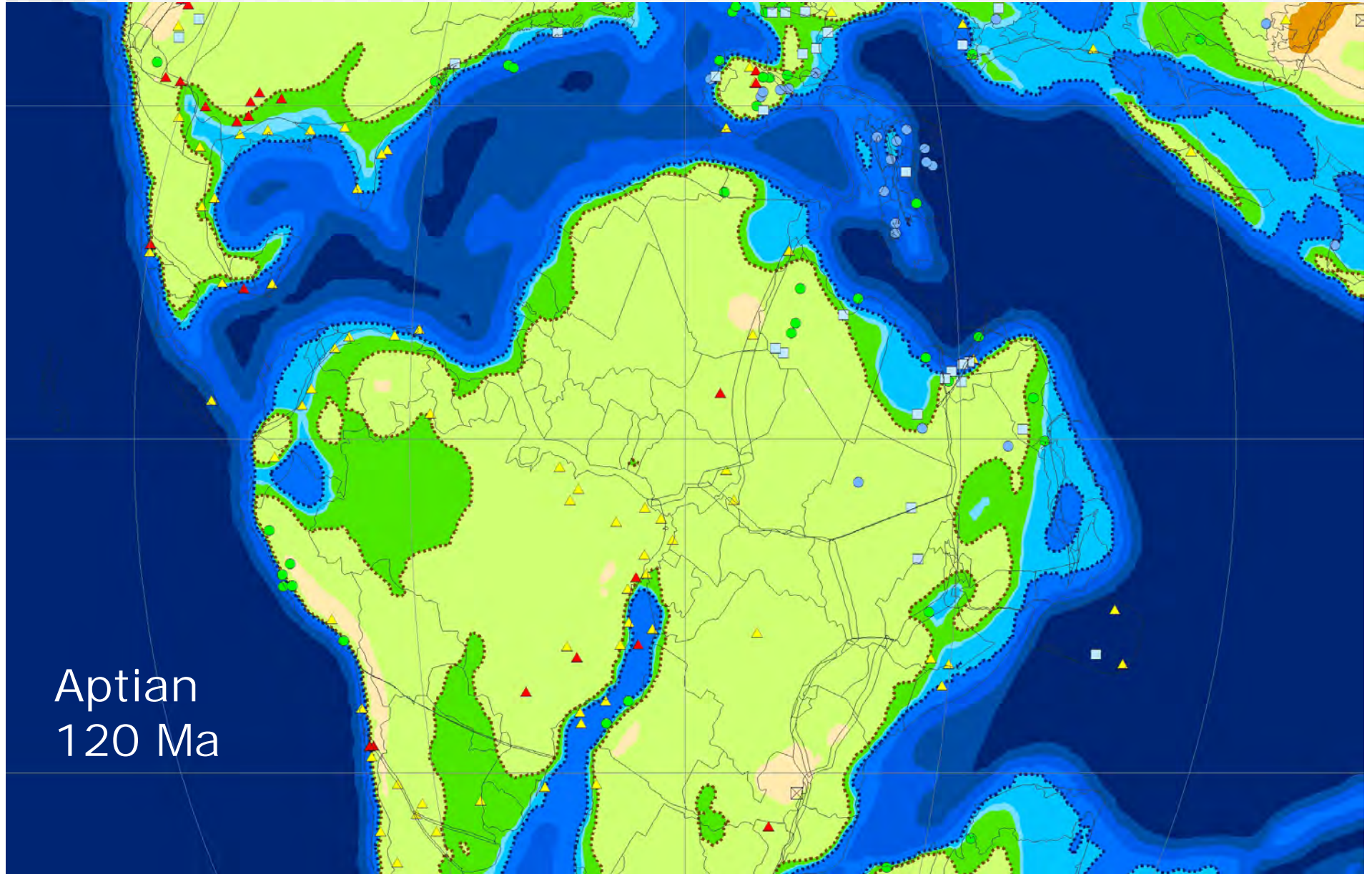
Clastic/Carbonate Ratio (Ziegler et al., 2003)



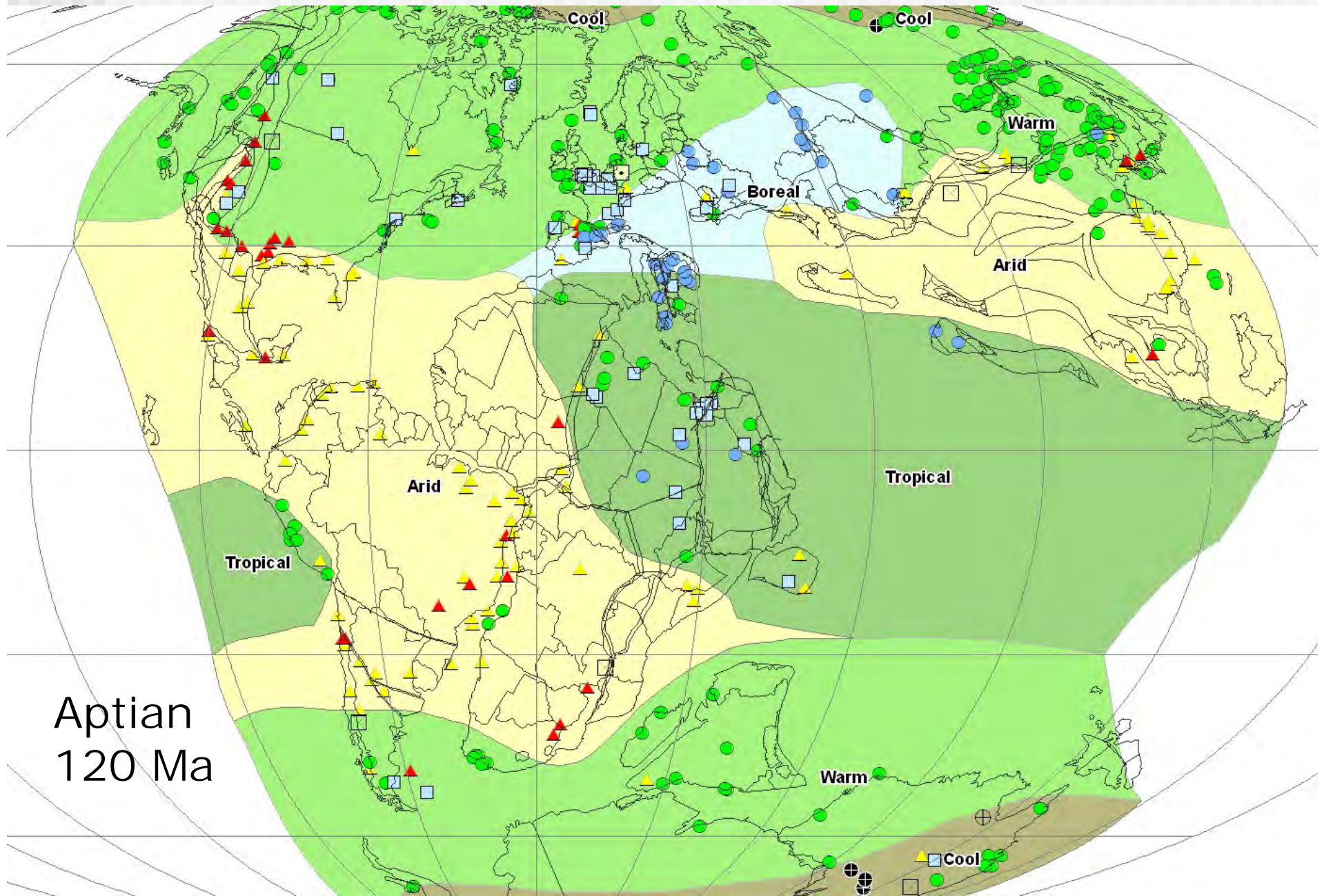
Combined Environments & Clastic/Carbonate Ratio



Lithologic Indicators of Climate (Boucot et al., in press)



Climatic Zones derived from Lithologies



Climatic Zones derived from Lithologies (close-up)

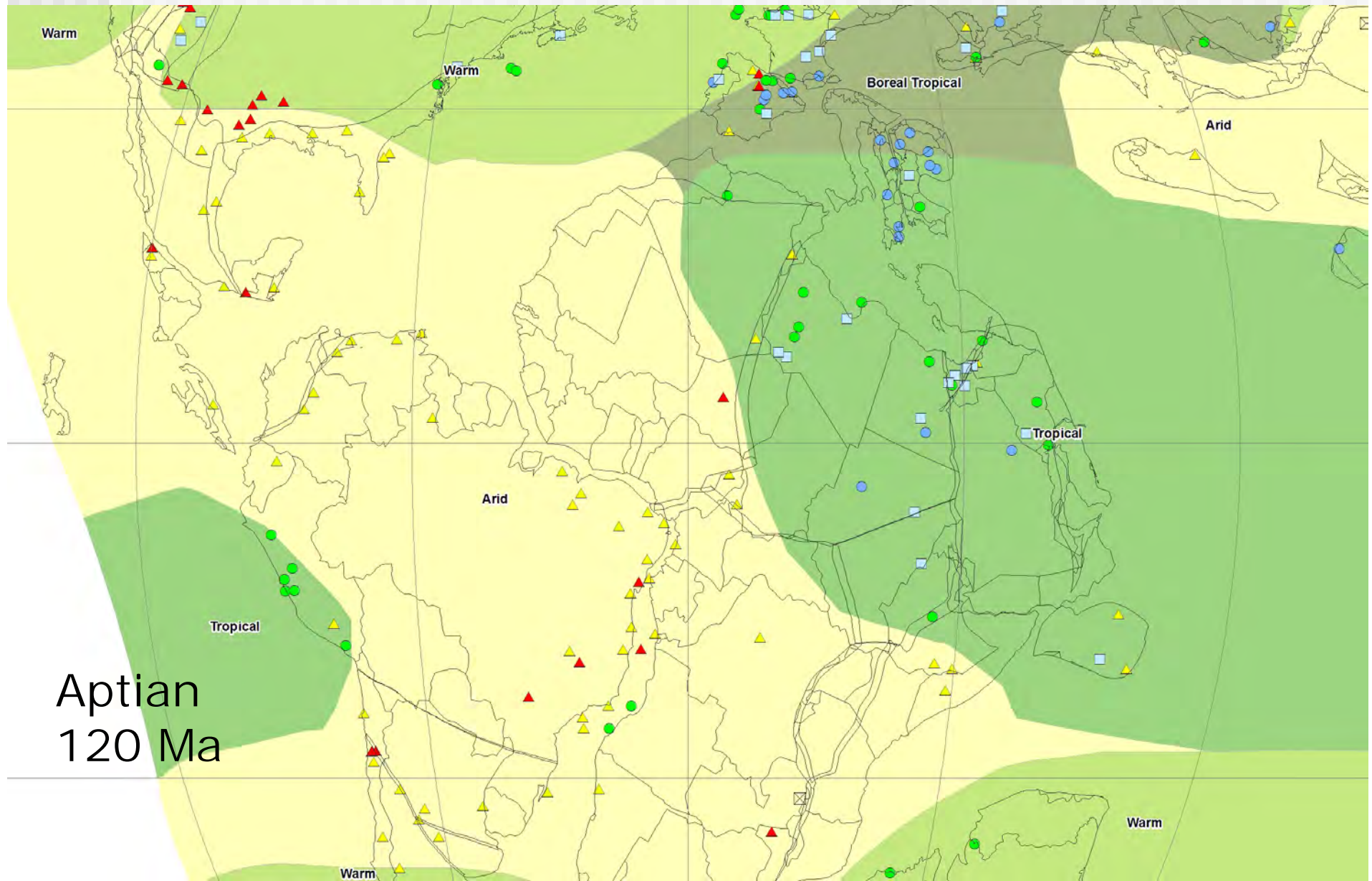


Plate Tectonics

- Ophiolites
- Age of Ocean
- Isochrons
- Active Plate Boundaries
- Ancient Plates

Plate Tectonic Reconstruction

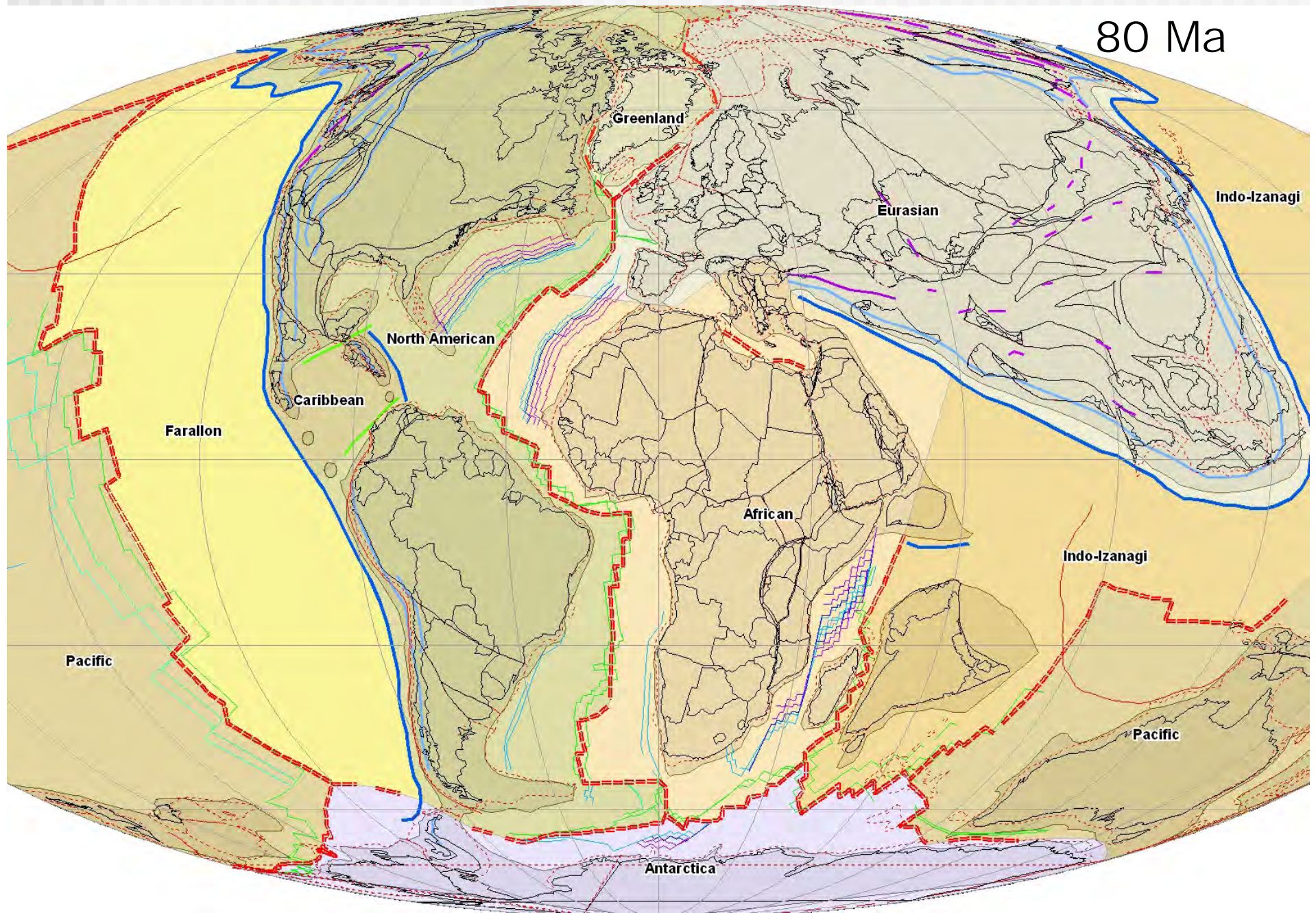
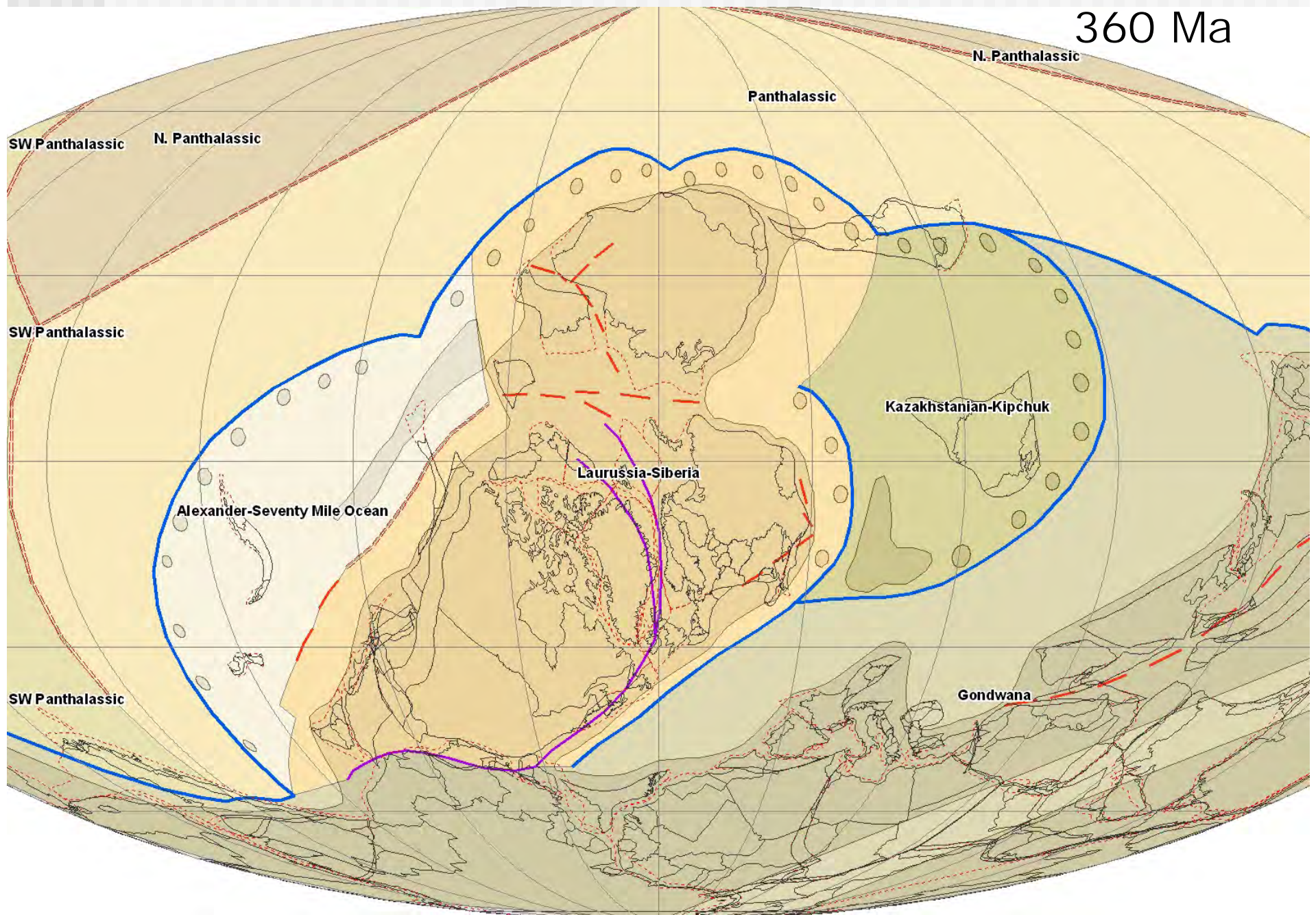
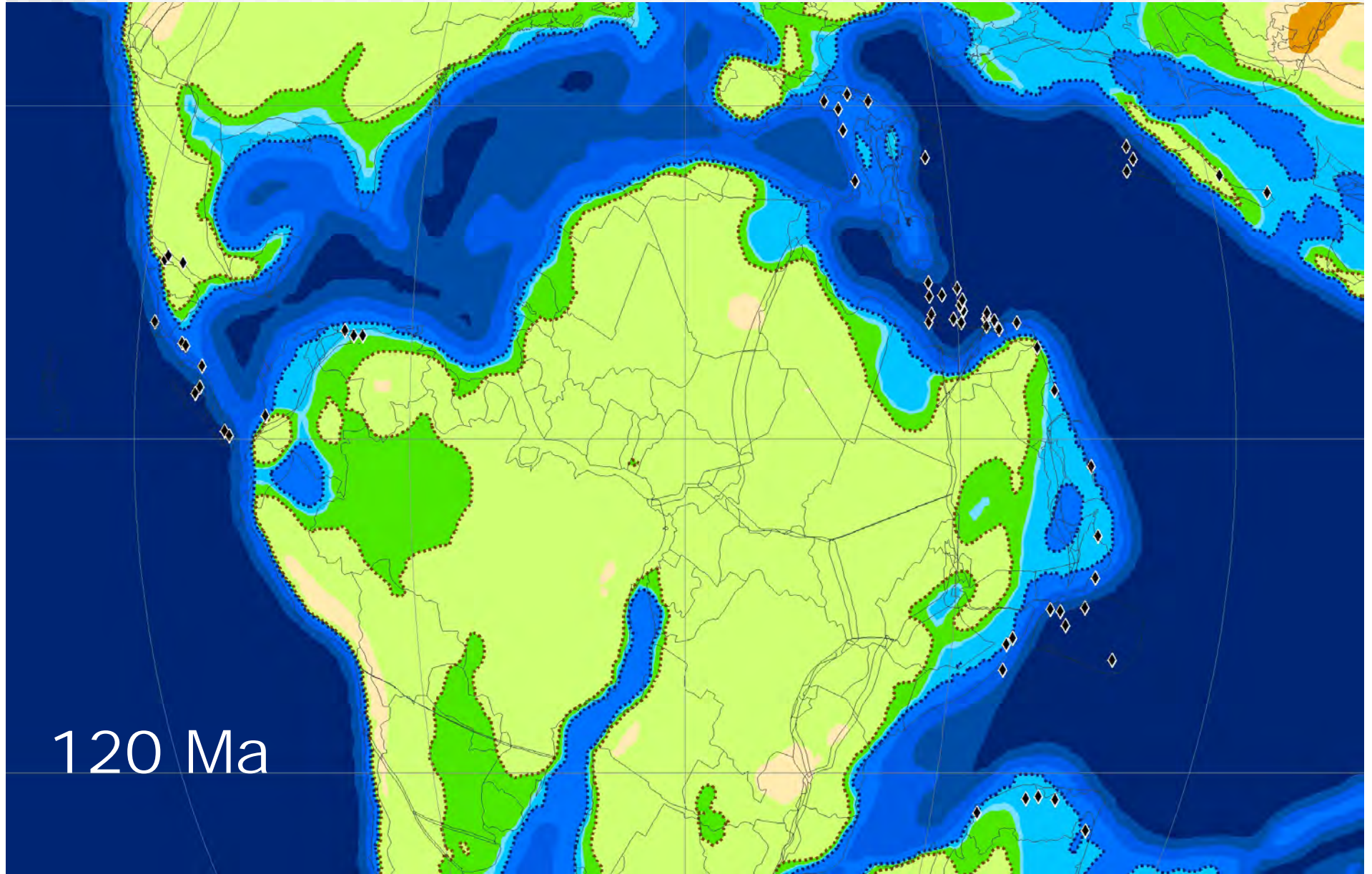


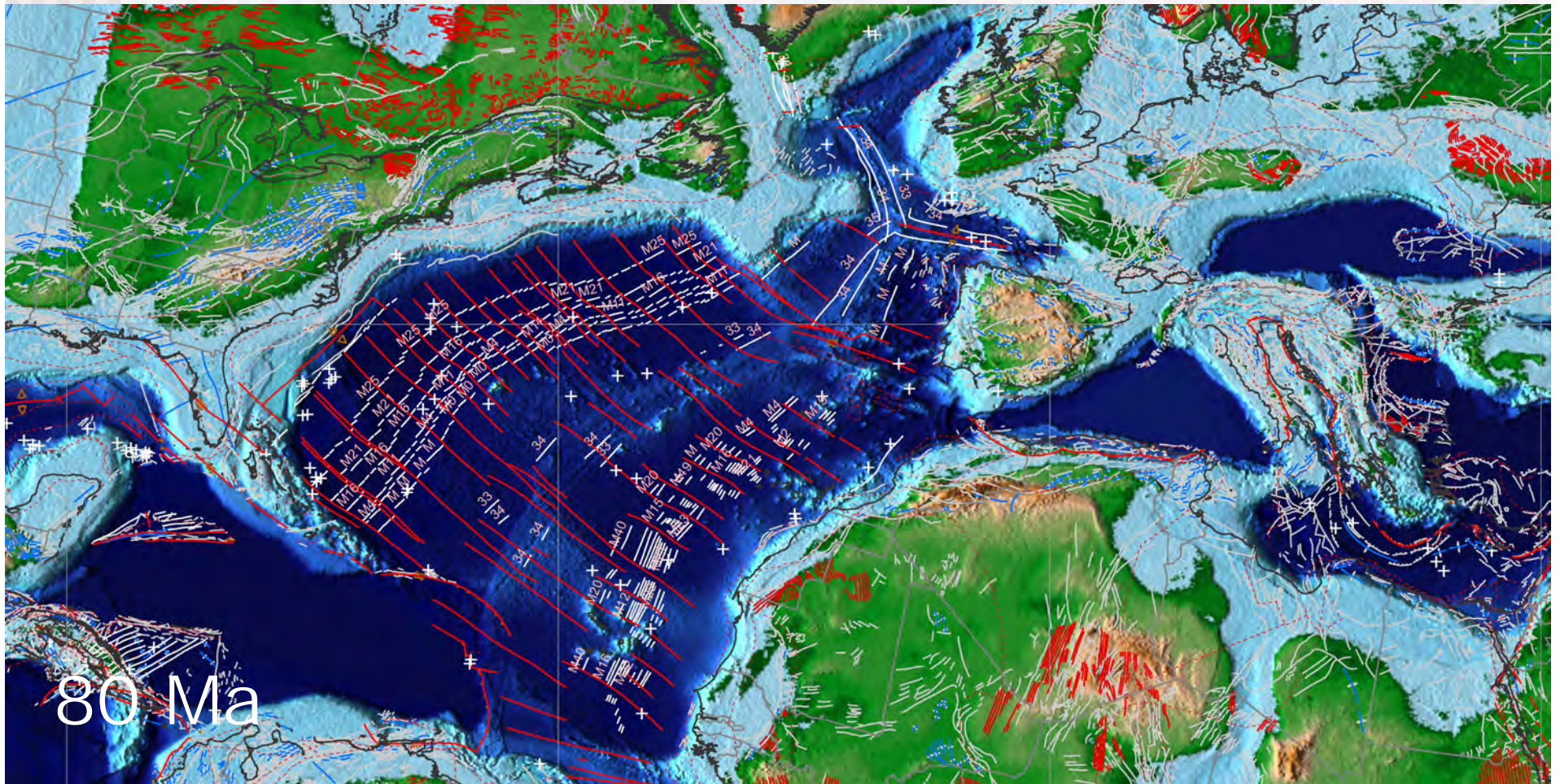
Plate Tectonic Reconstruction



Ophiolites



XOM Tectonic Map on Late Cretaceous Paleogeographic Reconstruction



XOM Tectonic Map on Late Cretaceous Paleogeographic Reconstruction (close-up)

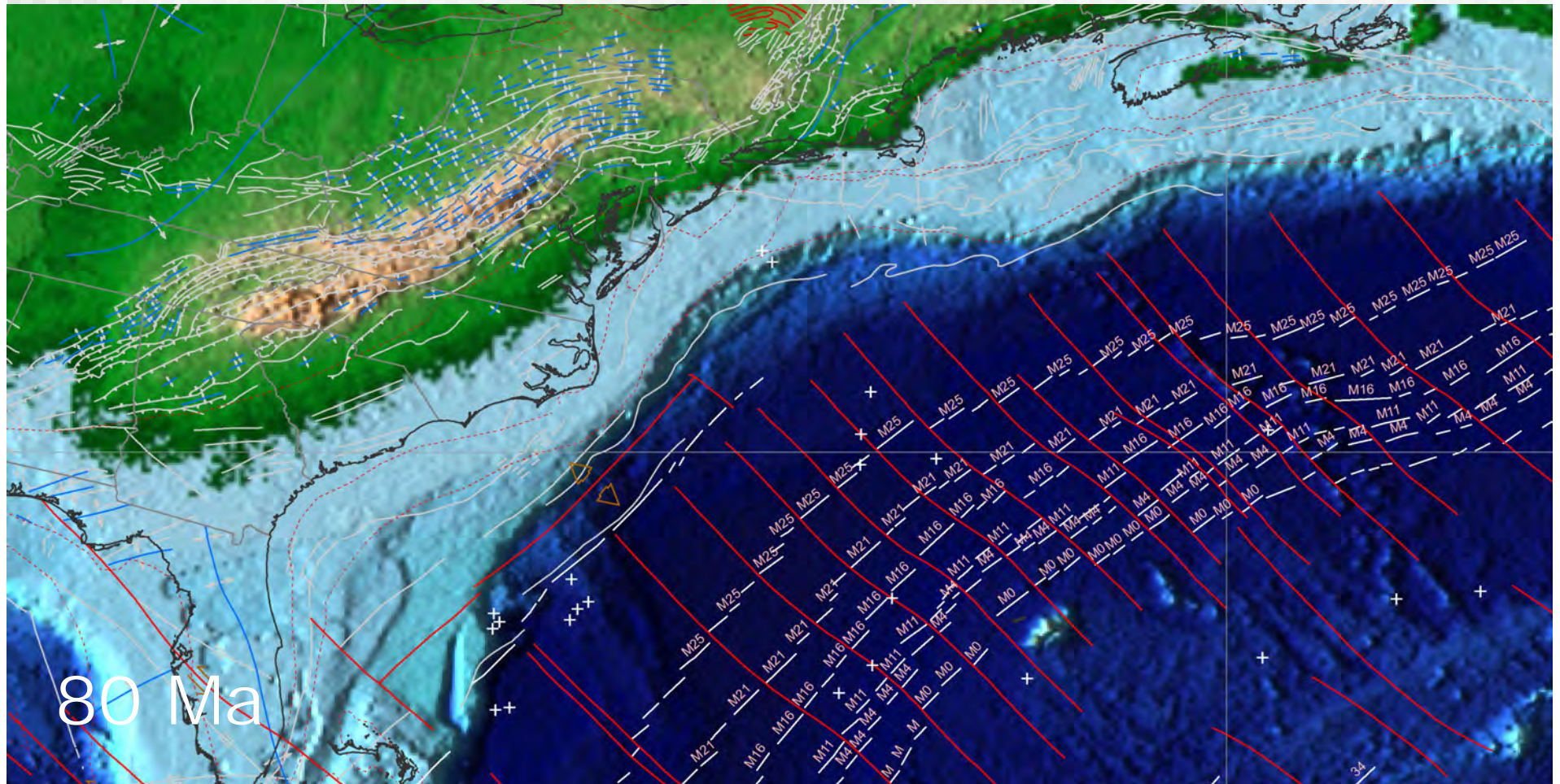


Plate Tectonic Reconstruction: XOM Tectonic Map Overlay

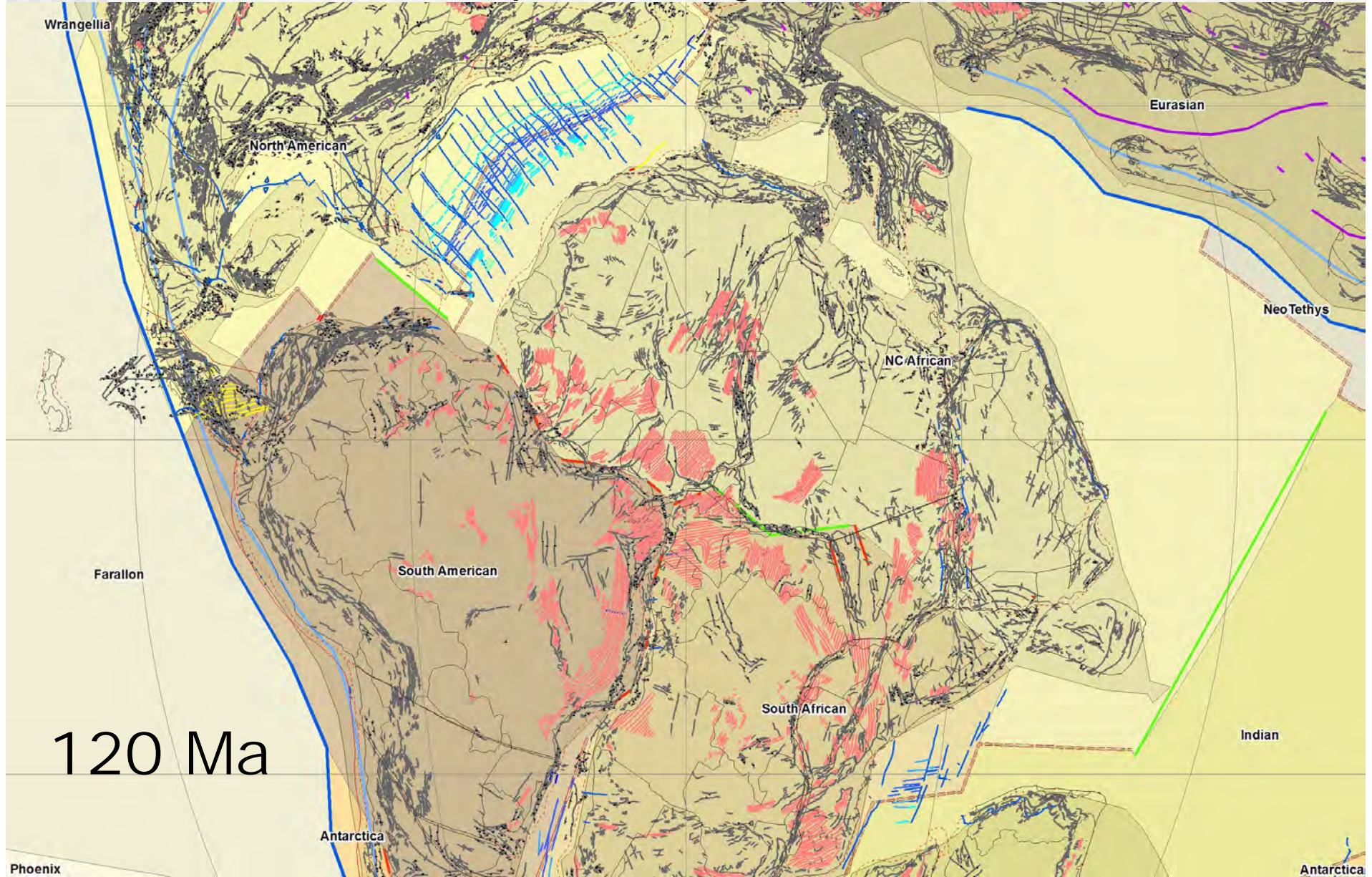


Plate Tectonic Reconstruction: XOM Tectonic Map Overlay (close-up)

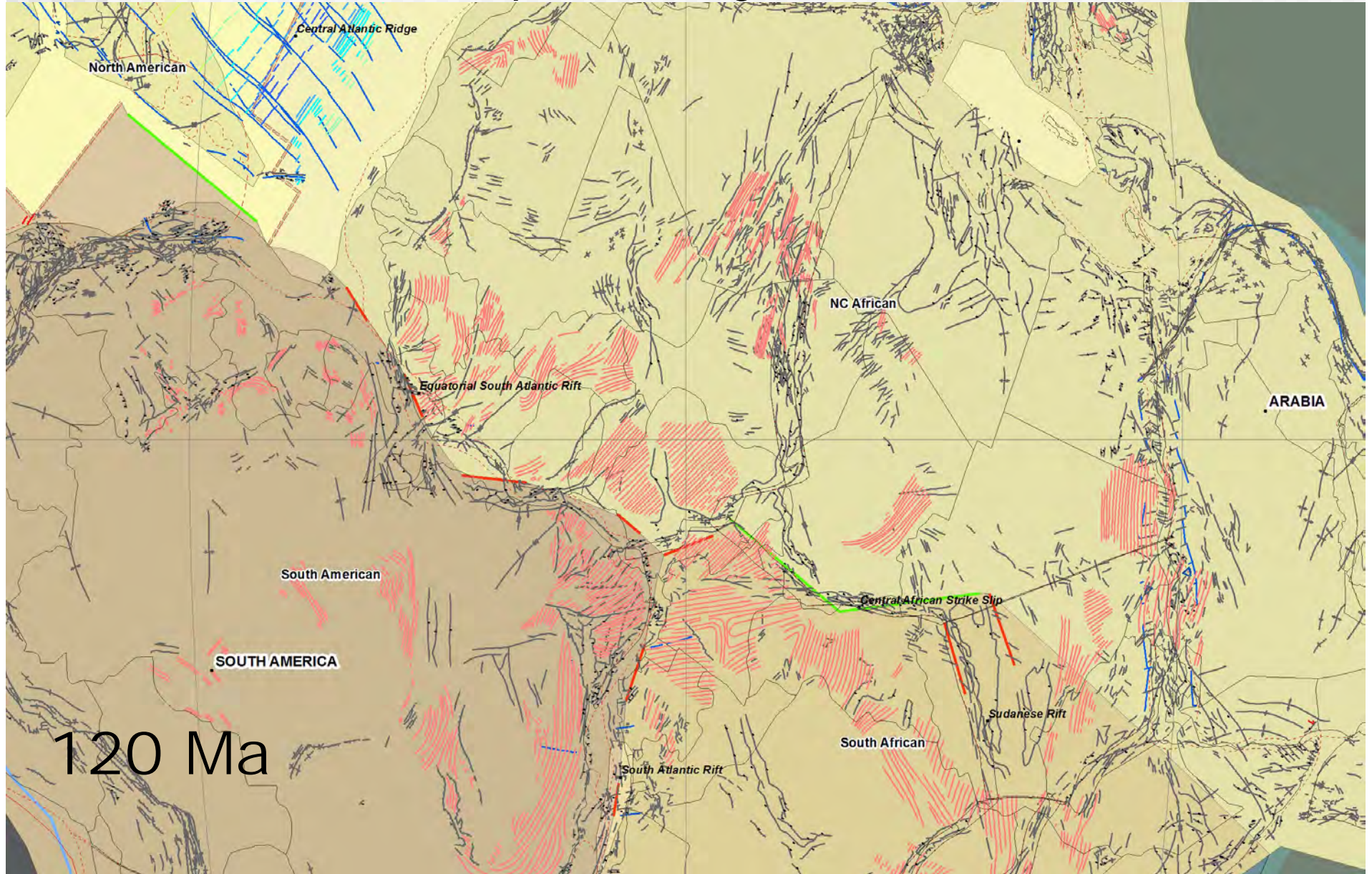


Plate Tectonic Reconstruction: Ancient Plates

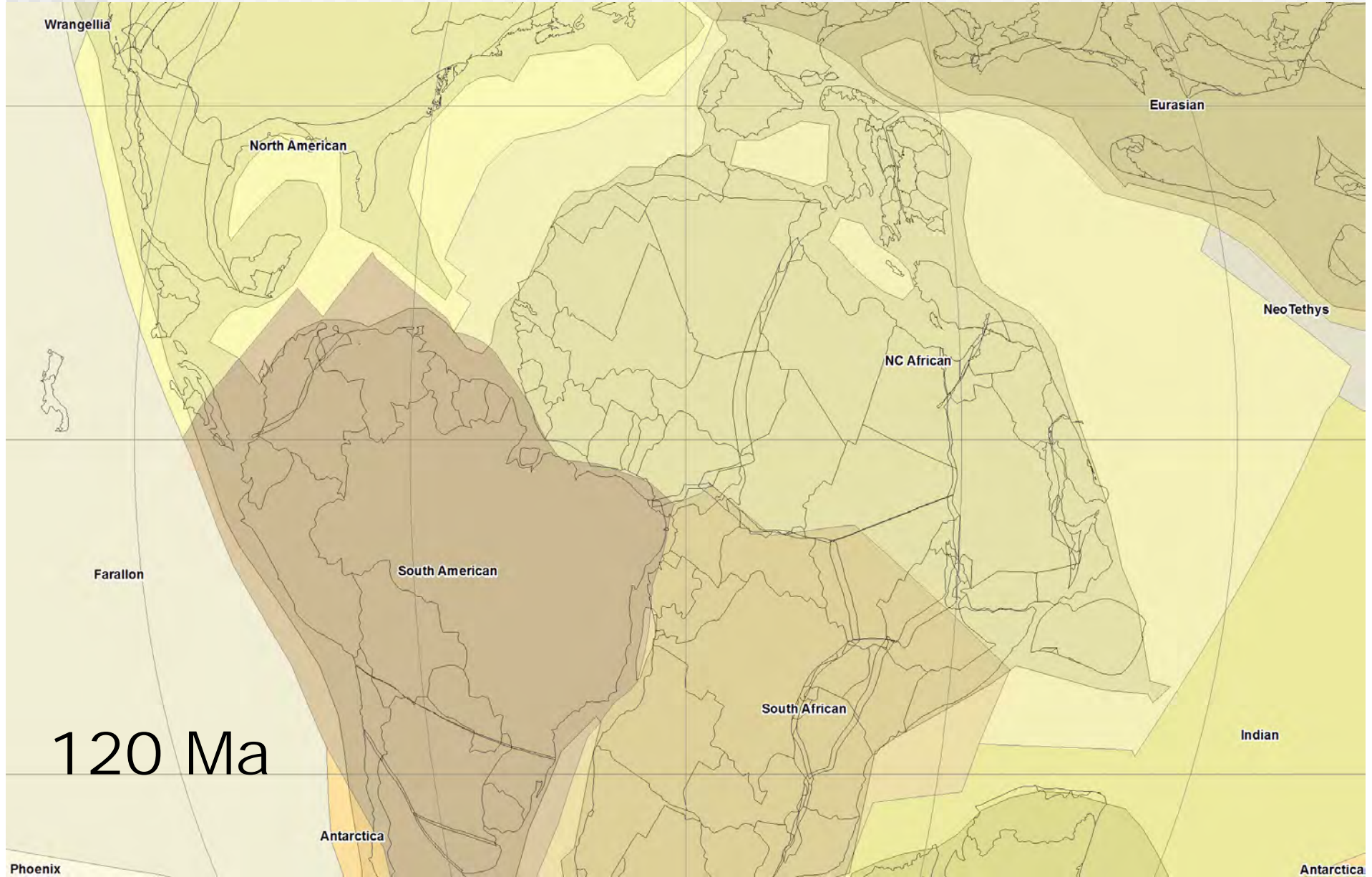


Plate Tectonic Reconstruction: Ancient Plates & Oceanic Isochrons

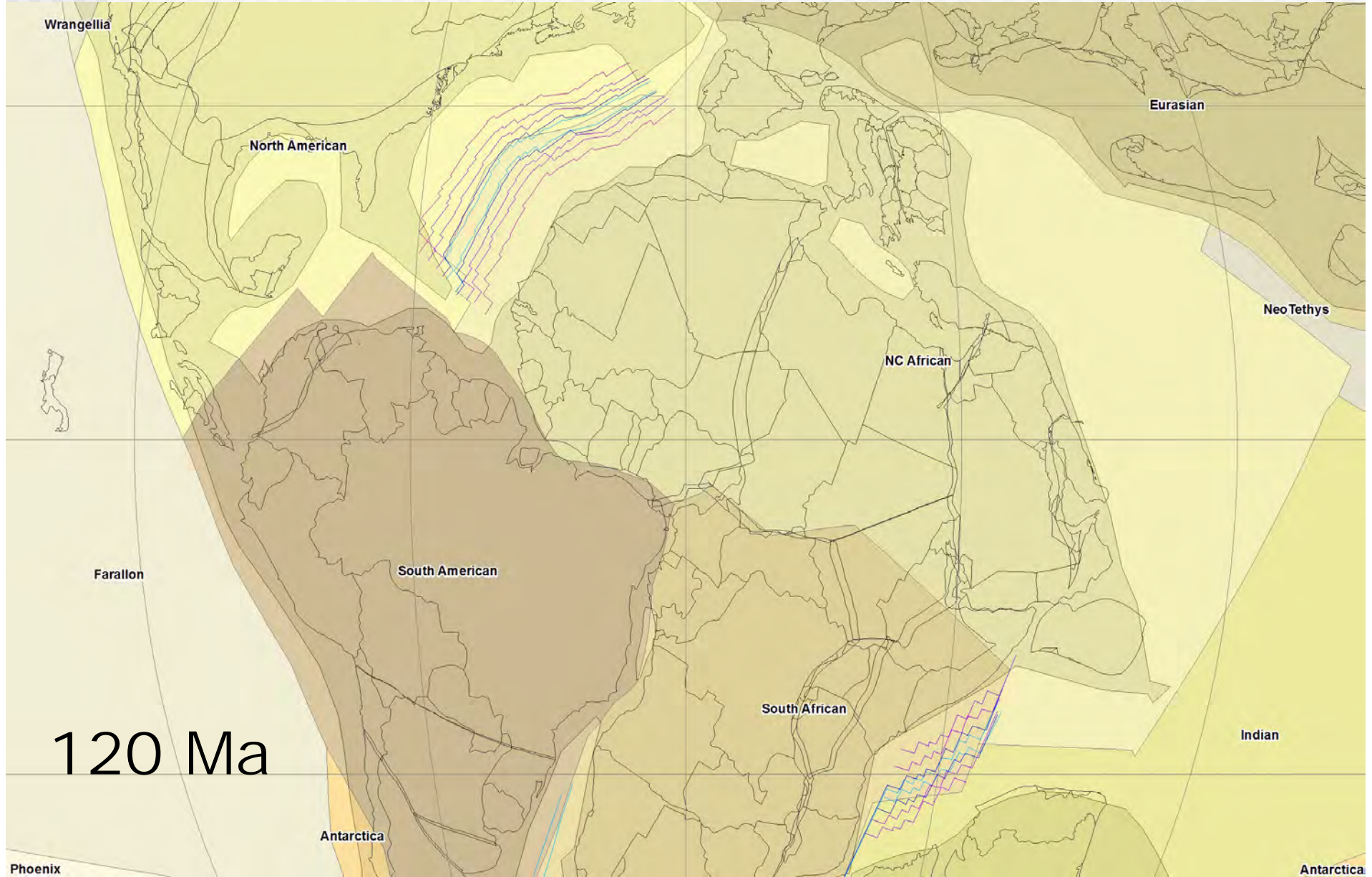


Plate Tectonic Reconstruction: Ancient Plates & Active Plate Boundaries

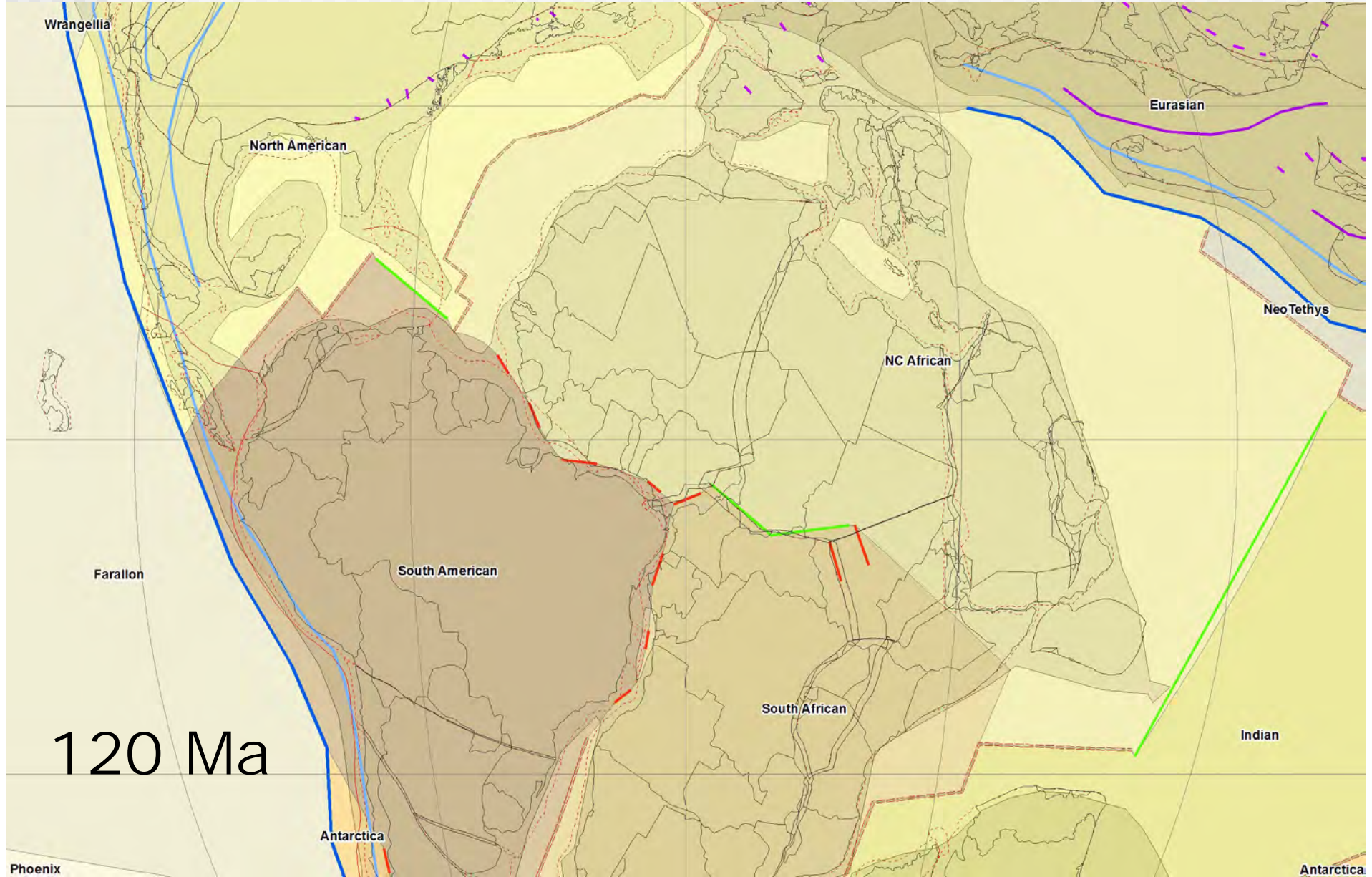
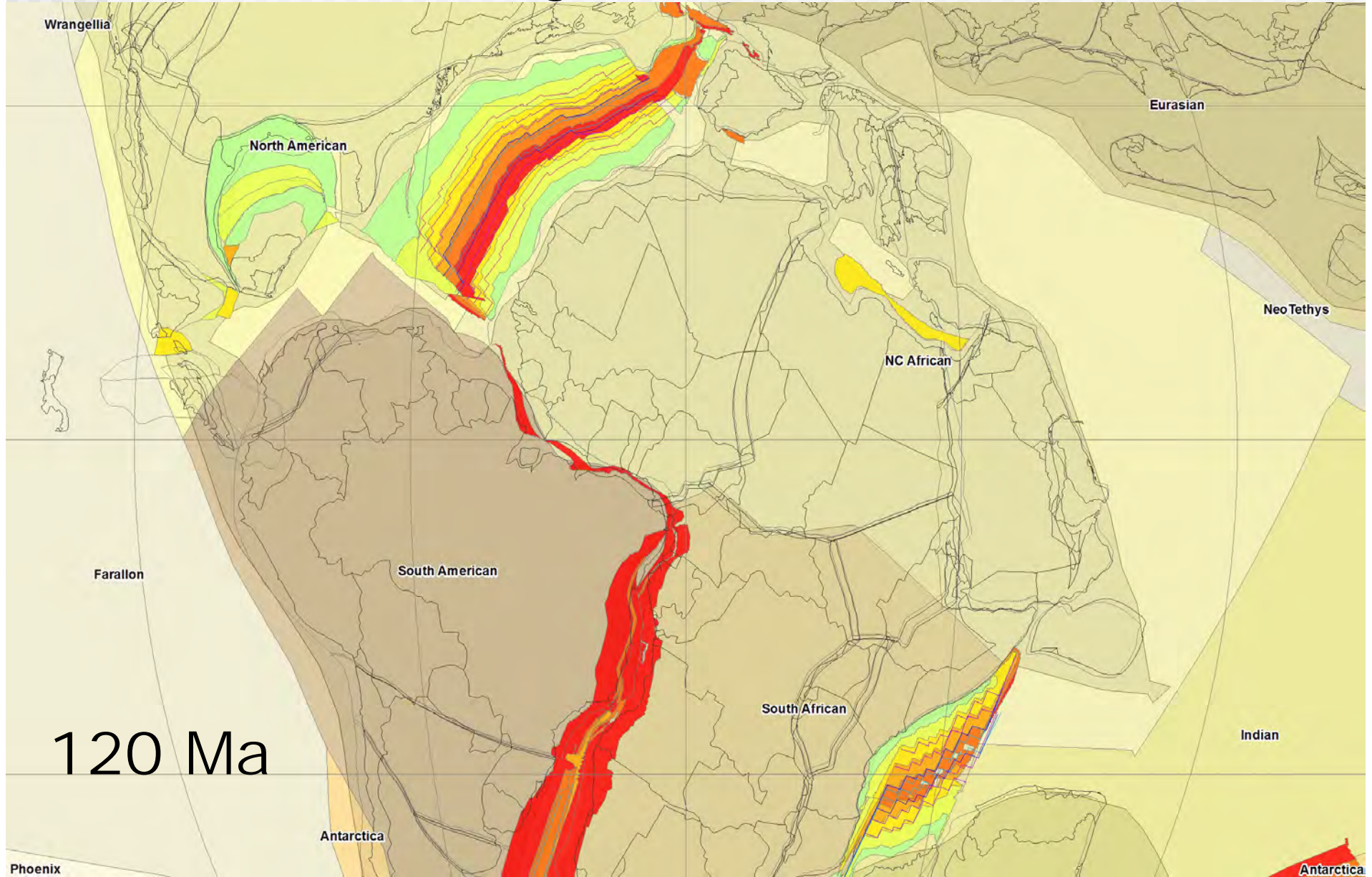
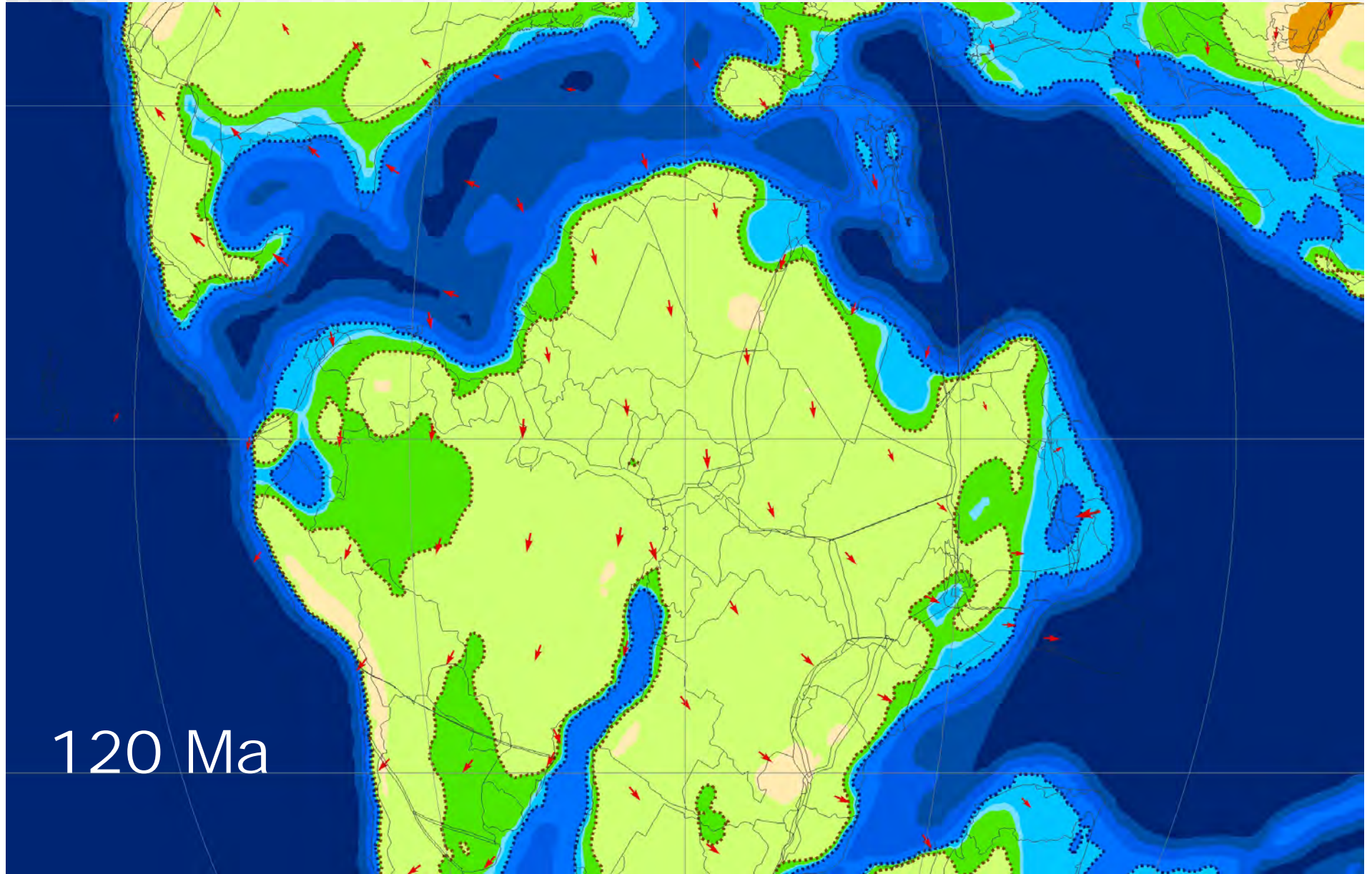


Plate Tectonic Reconstruction: Ancient Plates & Age of Ocean Floor



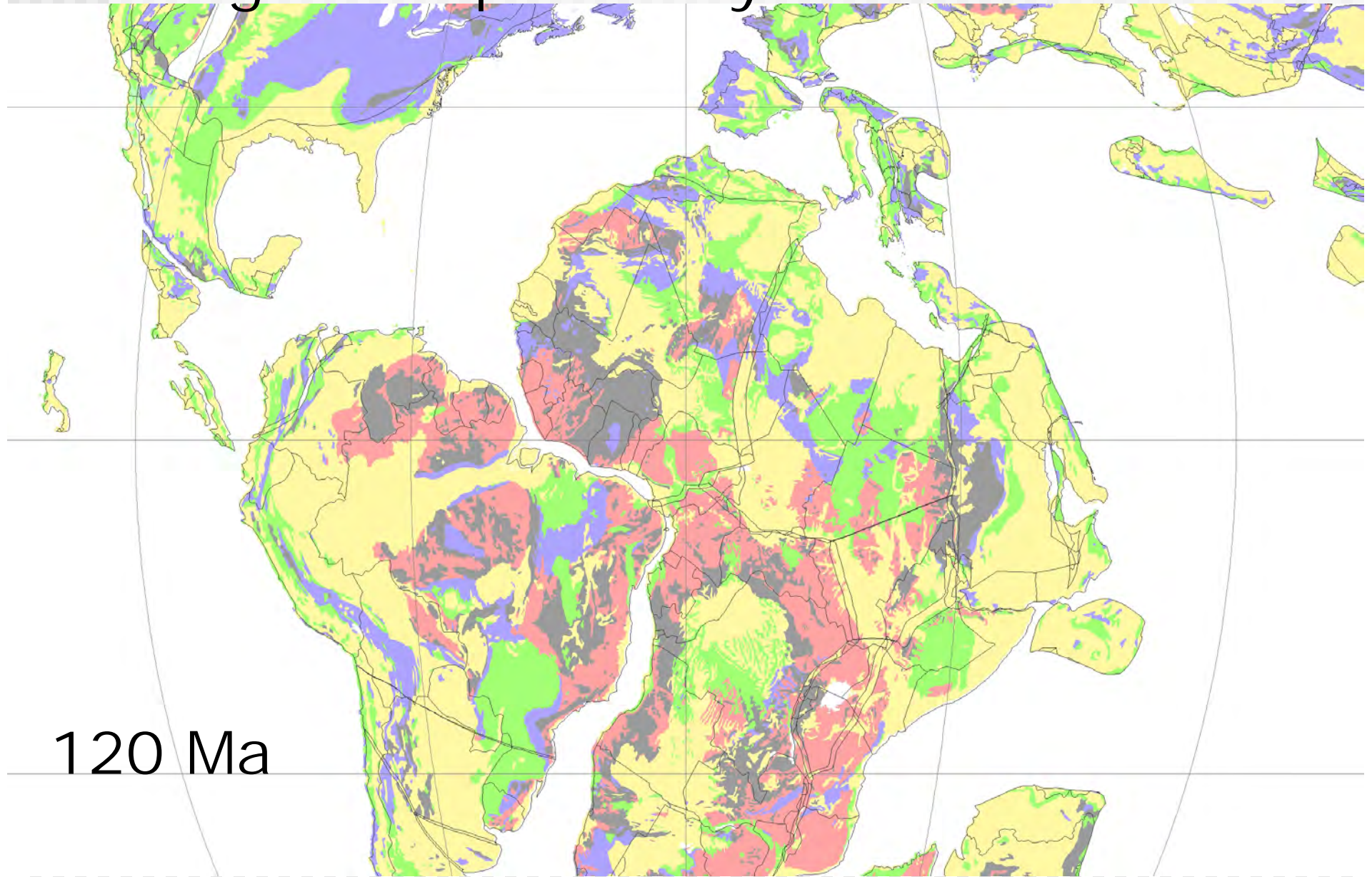
Simple Paleogeography: Instantaneous Plate Motion Vectors



Geology

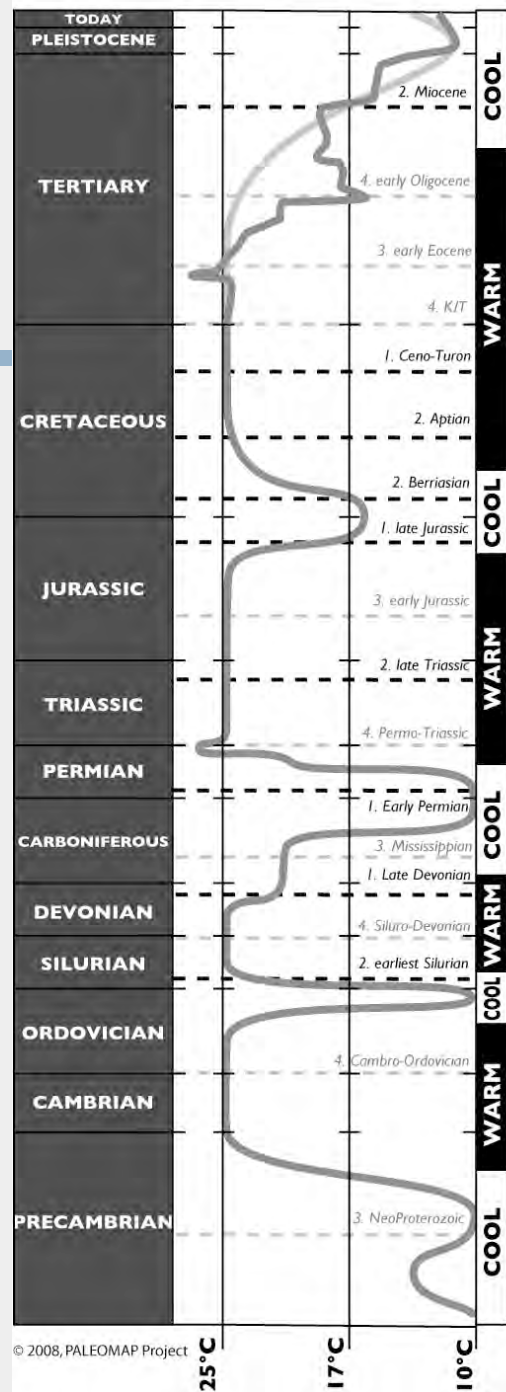
Global Geological Map

Paleoreconstruction with Global Geological Map Overlay



Paleoclimate

- Temperature
- Winds & Pressure
- Rainfall & Runoff
- Rivers & Deltas
- Salinity
- Ocean Currents
- Upwelling



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Phanerozoic Global Climate Change

This curve describes the changing mean Annual Temperature (MAT) during the past 600 million years.

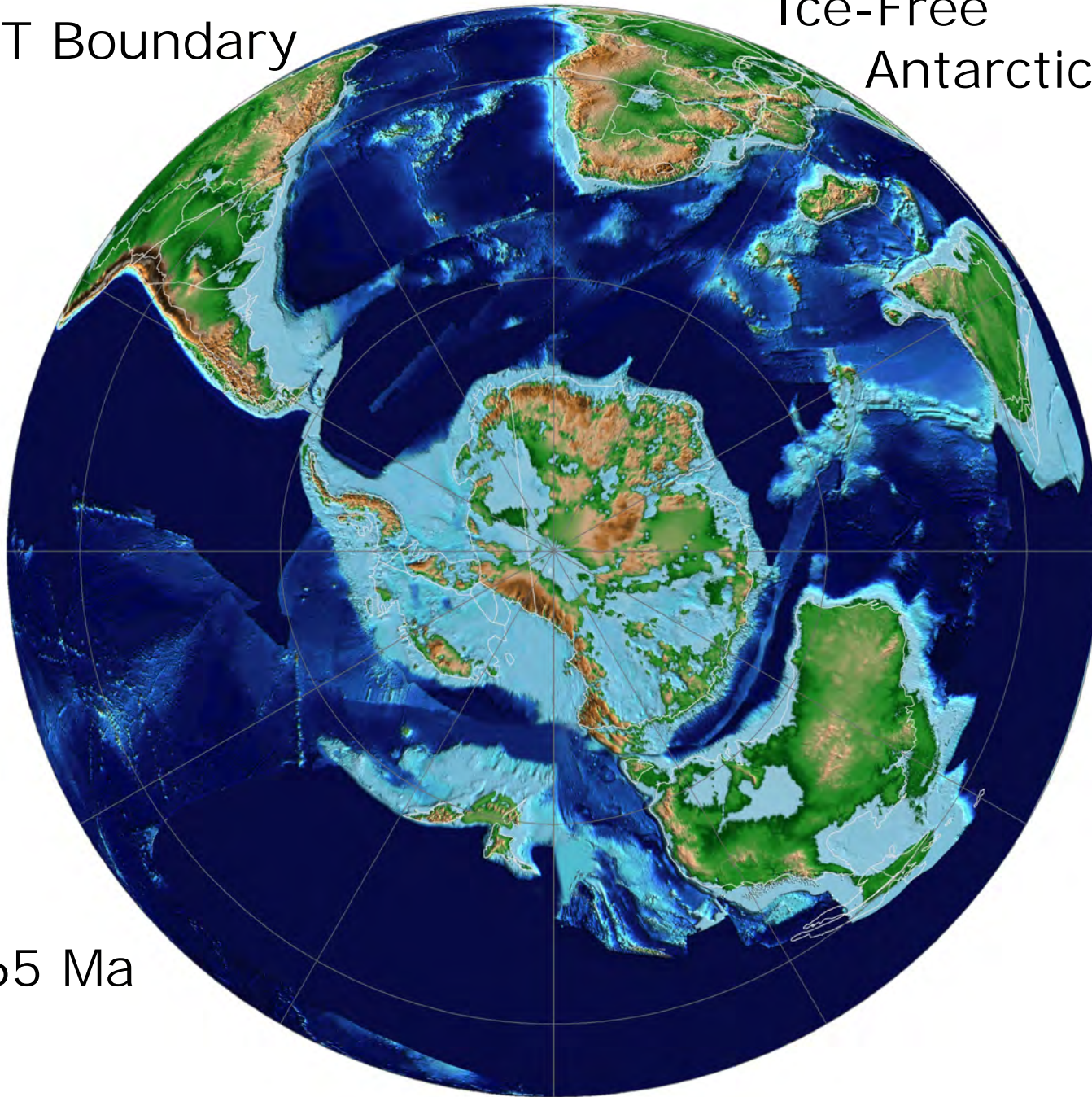
The Earth's climate has alternated between ice house and hot house states.

The dashed lines are 18 time Intervals for which paleoclimate simulations have been run.

KT Boundary

Ice-Free
Antarctica

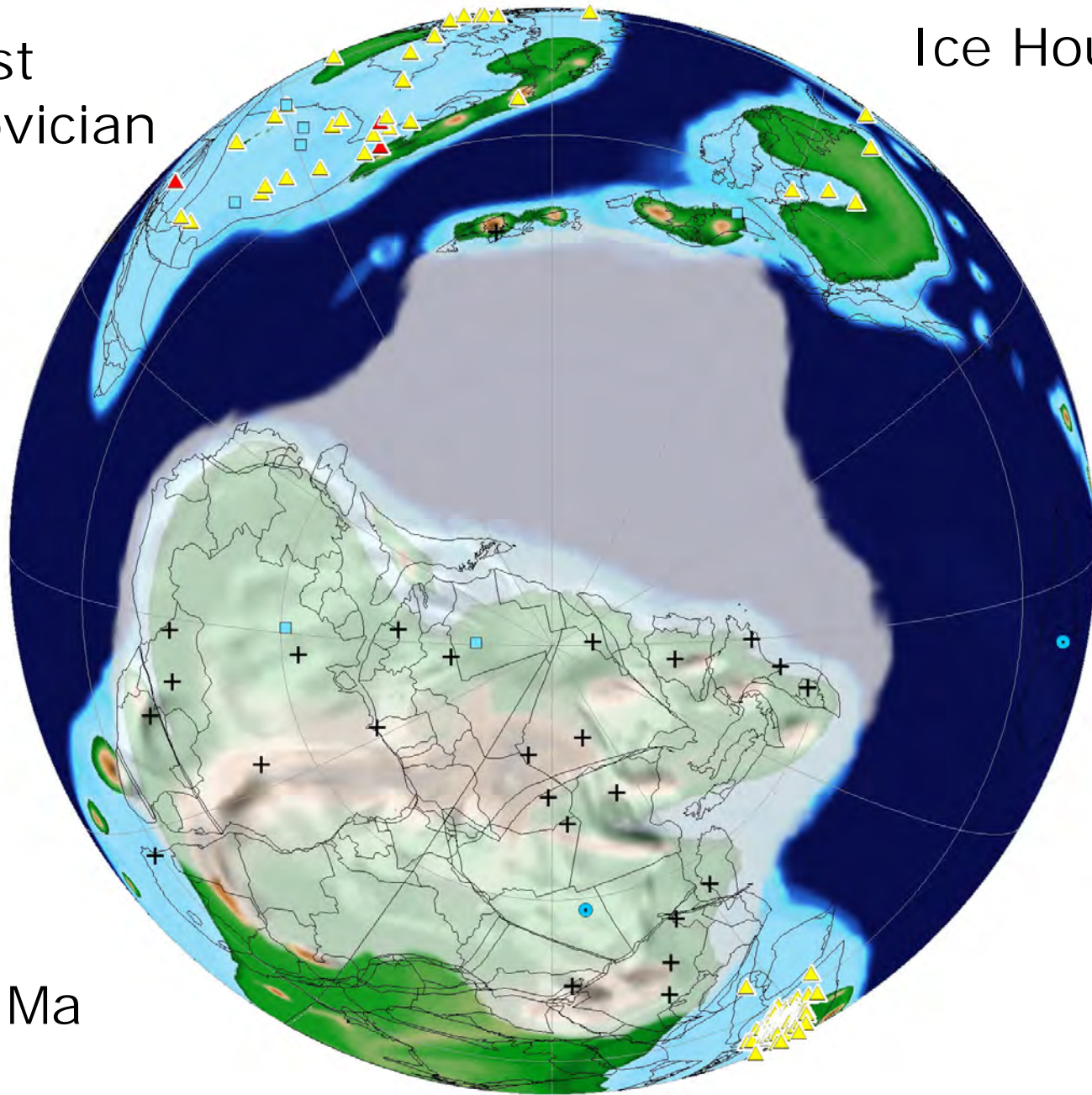
65 Ma



Latest
Ordovician

Ice House

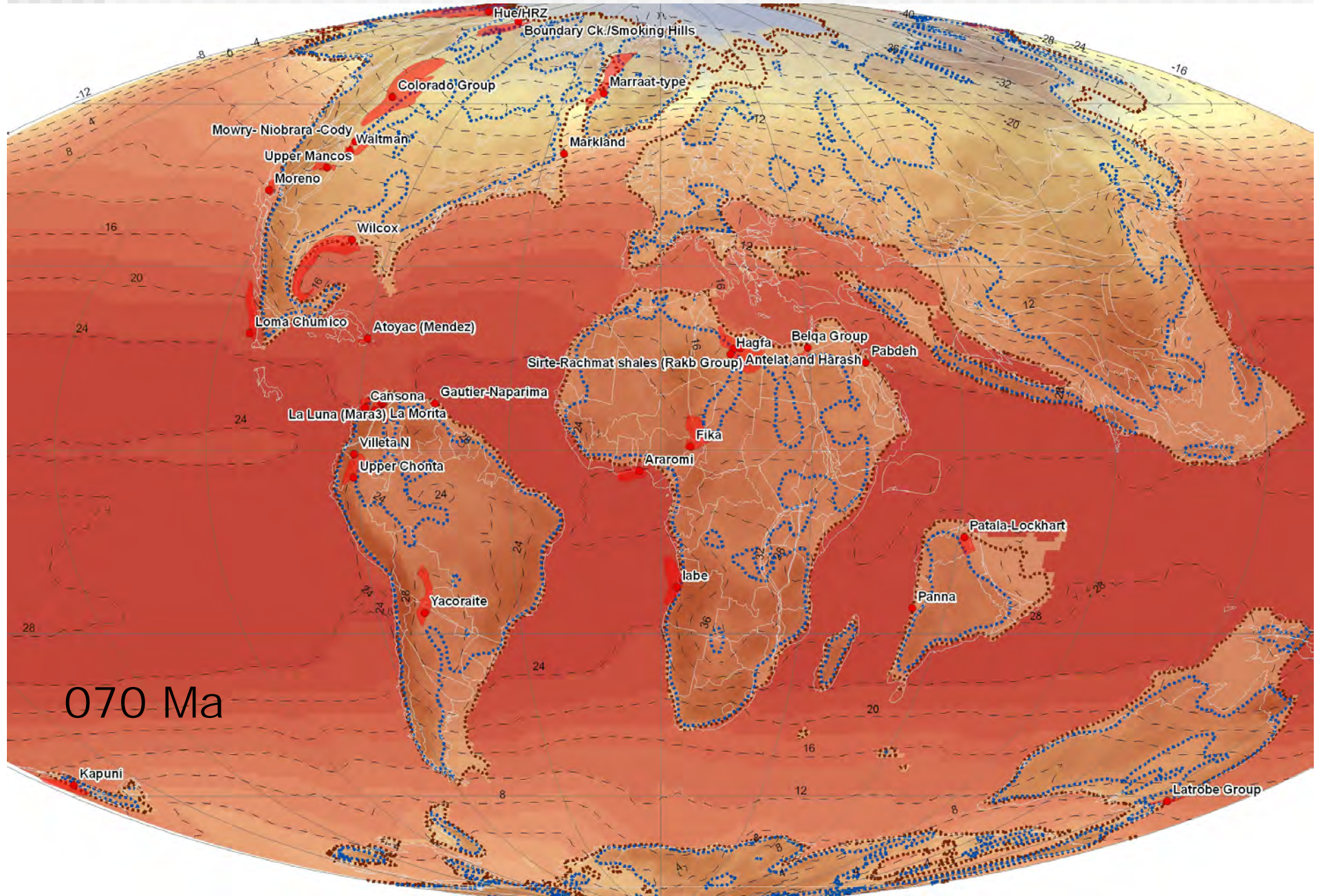
445 Ma



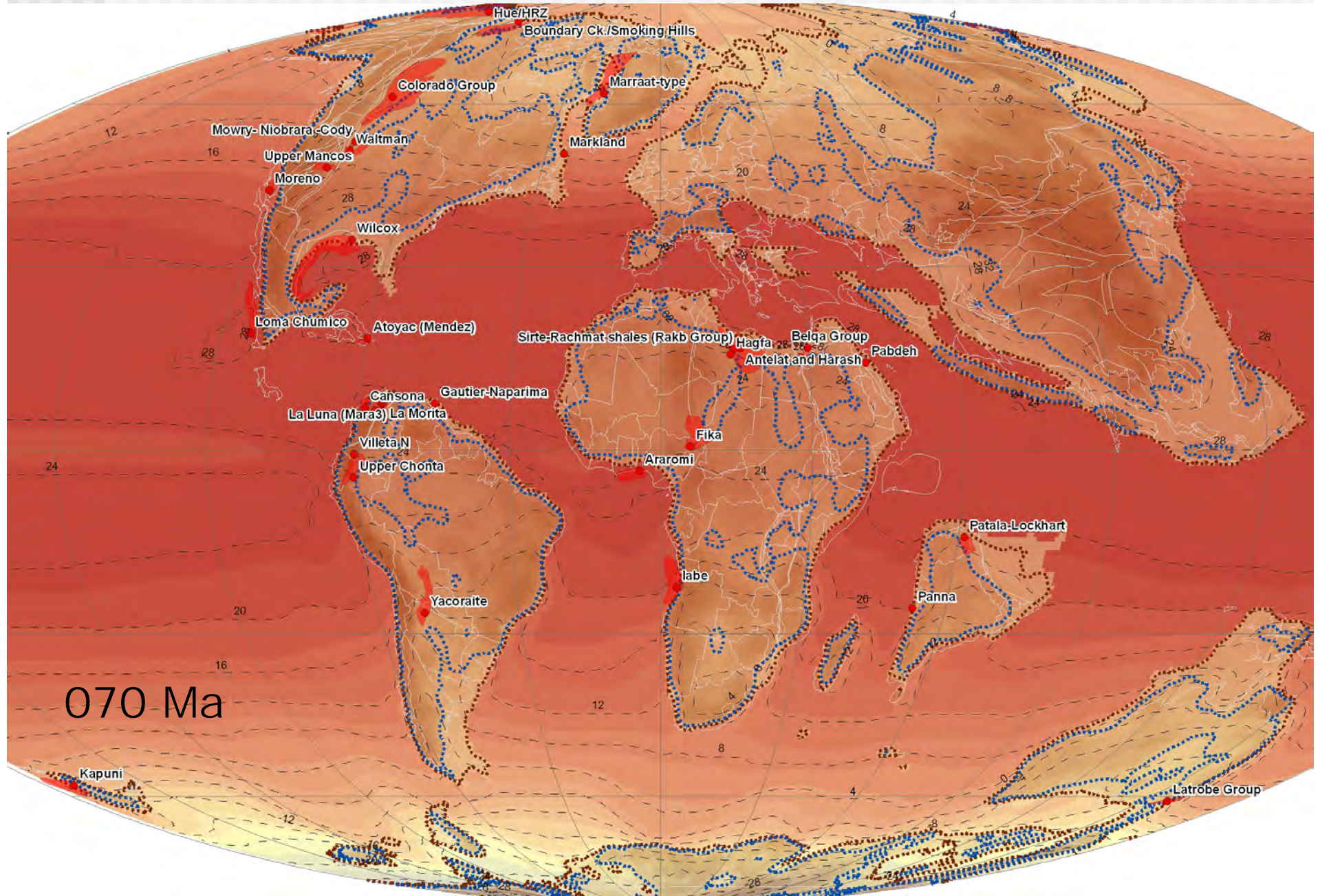
Time Intervals with Paleoclimate Simulations

EON	ERA	PERIOD	EPOCH	Ma	INTERVAL	GANDOLPH TIME SLICES
Phanerozoic	Cenozoic	Quaternary	Holocene	0.01	YEAR ↓	
			Pleistocene	0.8		
		Tertiary	Pliocene	1.8		
				3.6		
			Miocene	5.3		
				11.6		
			Oligocene	16.0		15 - Miocene
				23.0		
			Eocene	28.4		30 - Oligocene
				33.9		
		Paleogene	Eocene	37.2		45 - Middle Eocene (Thanetian)
				48.6		
			Paleocene	55.8		
				61.7		70 - Tertiary/Cretaceous Boundary
	Mesozoic	Cretaceous	Late	65.5	1 2 2 1	90 - Late Cretaceous (Turonian-Cenomanian)
			Early	100		120 - Early Cretaceous (Albian-Aptian)
		Jurassic	Late	146		140 - Early Cretaceous (Barremian-Berriasian)
			Middle	161		160 - Late Jurassic (Tithonian-Oxfordian)
		Triassic	Early	176		180 - Early Jurassic (Callovian-Hettangian)
			Late	200		
			Middle	228		210 - Late Triassic (Rhaetian-Anisian)
			Early	245		
	Paleozoic	Permian	Late	251		250 - Permo-Triassic Boundary
			Early	271		
		Carboniferous	Pennsylvanian	299		280 - Permo-Carboniferous
			Mississippian	318		
			Late	359		340 - Mississippian
		Devonian	Middle	385		360 - Late Devonian (Frasnian-Famennian)
			Early	398		
			Late	416		400 - Siluro-Devonian (Givetian-Wenlock)
		Silurian	Early	428		
			Late	444		440 - Late Ordovician - Early Silurian
		Ordovician	Middle	461		
			Early	472		
			Late	488		480 - Late Cambrian - Ordovician
		Cambrian	Middle	501		
			Early	513		
			Late	542		600 - Late Neoproterozoic (Ediacaran)
Precambrian	Proterozoic	Late		1000	3	
		Middle		1600		
		Early		2500		
	Archean	Late		3000		
		Middle		3400		
		Early				Age of FOAM Simulation

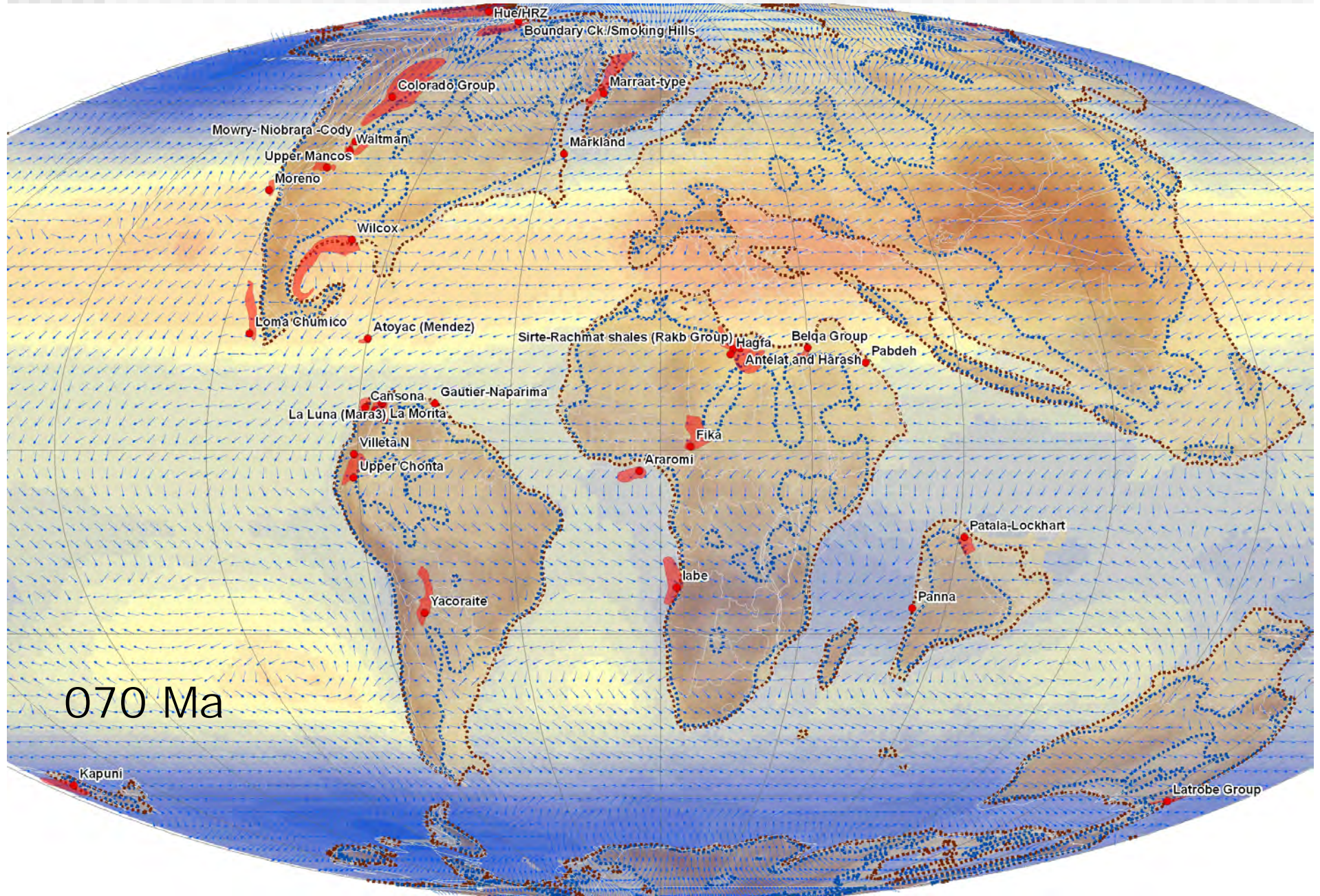
Winter Mean Annual Temperature with Isotherms



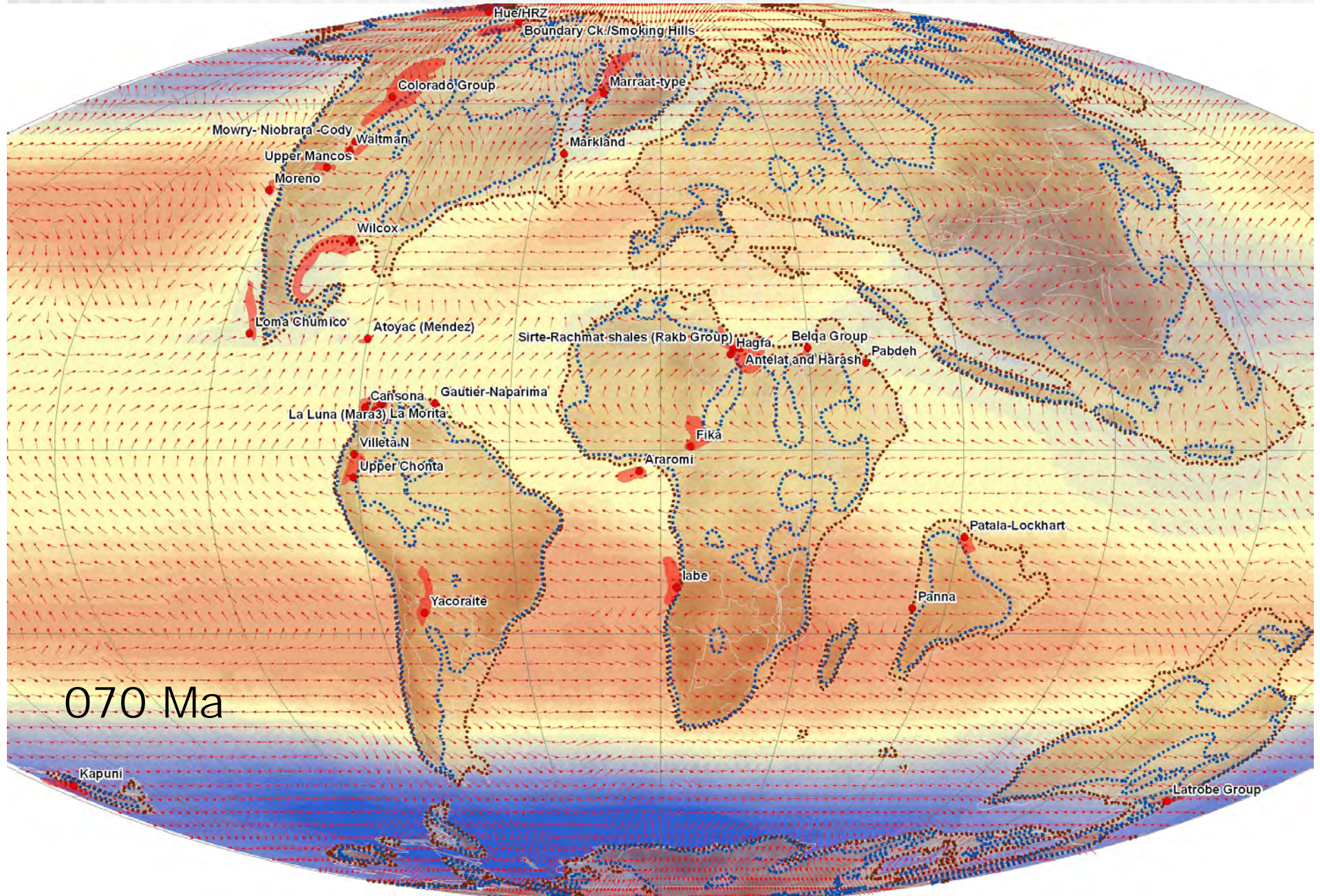
Summer Mean Annual Temperature with Isotherms



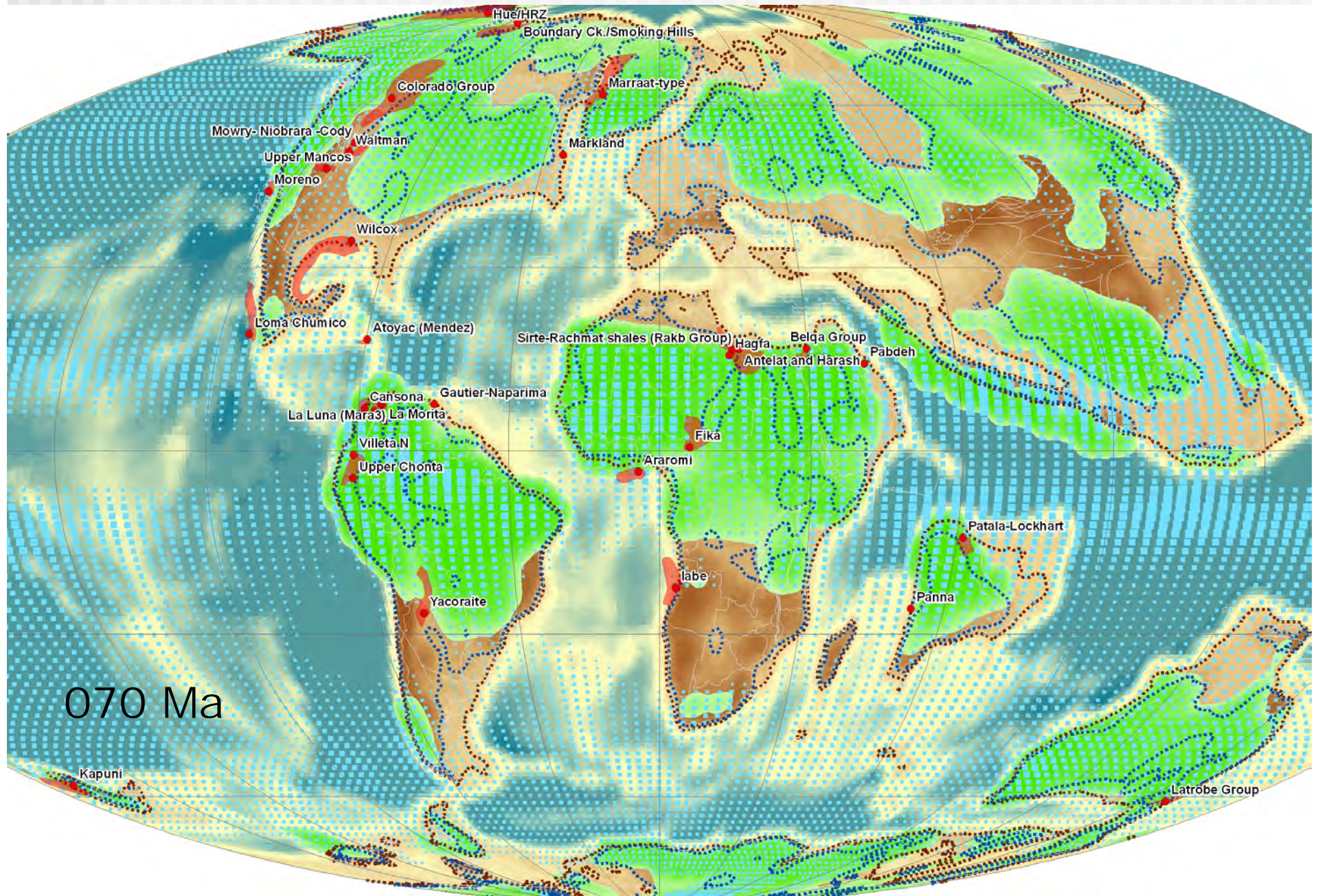
Winter Atmospheric Pressure with Surface Winds



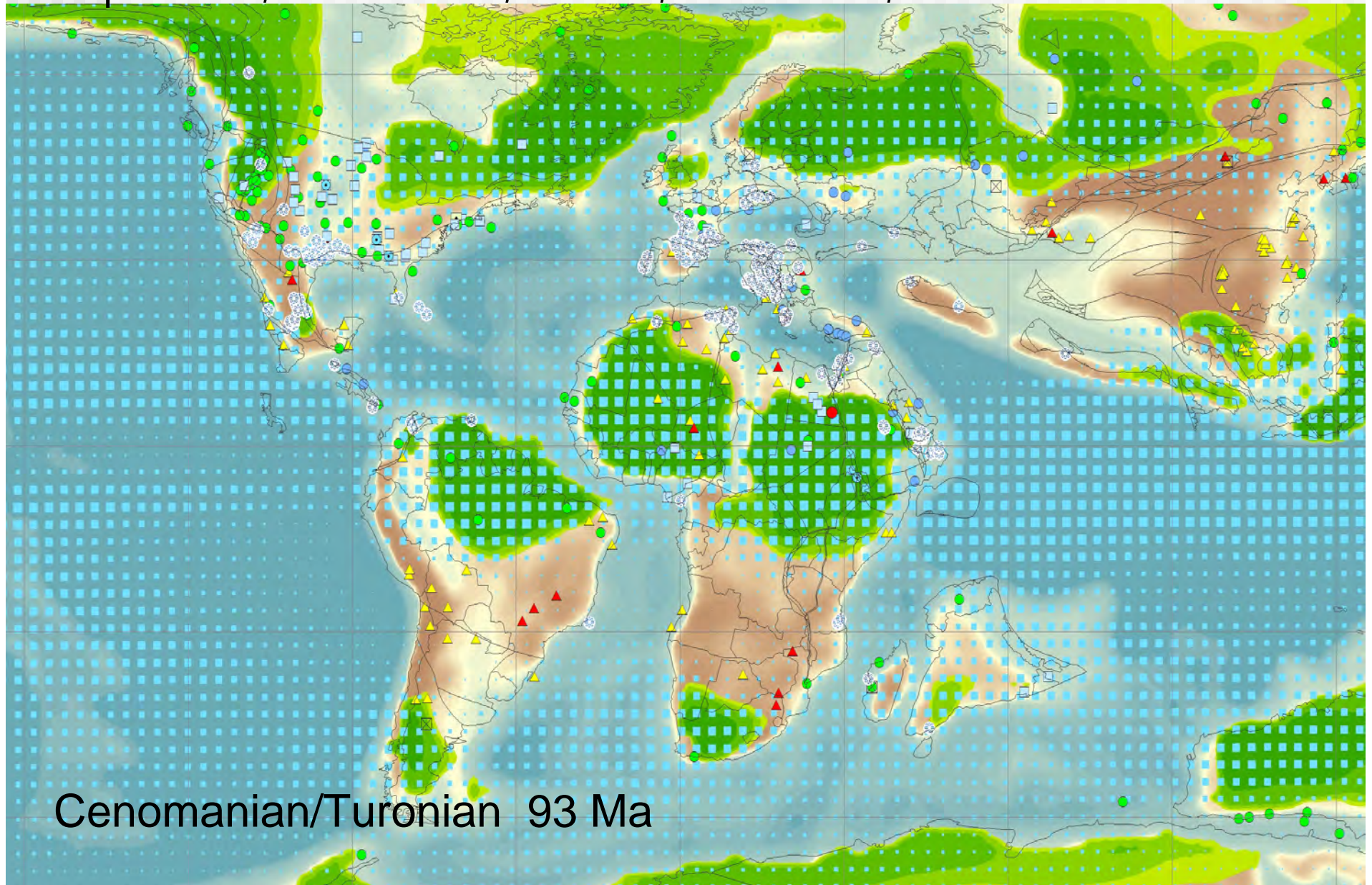
Summer Atmospheric Pressure with Surface Winds



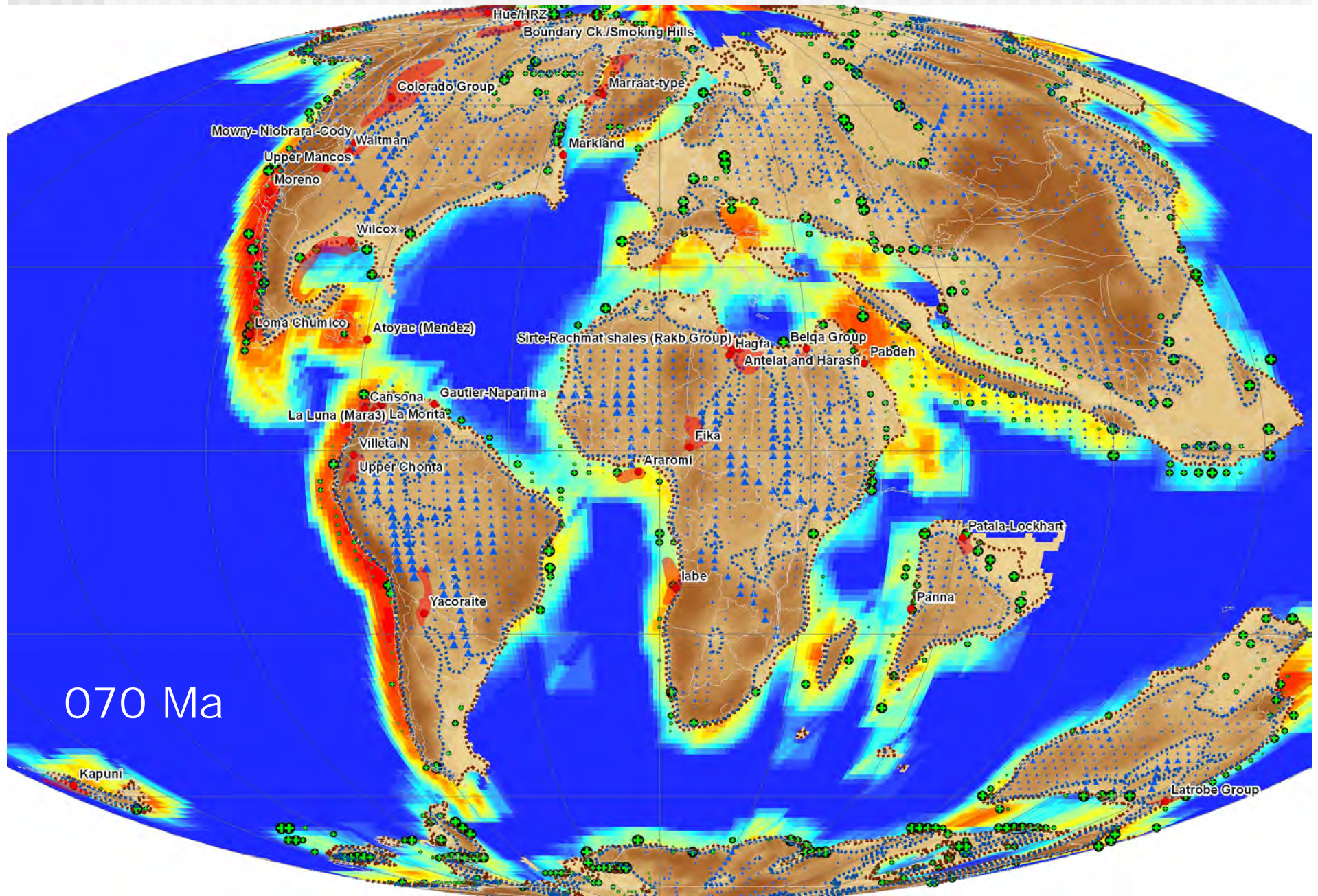
Mean Monthly Rainfall and Runoff



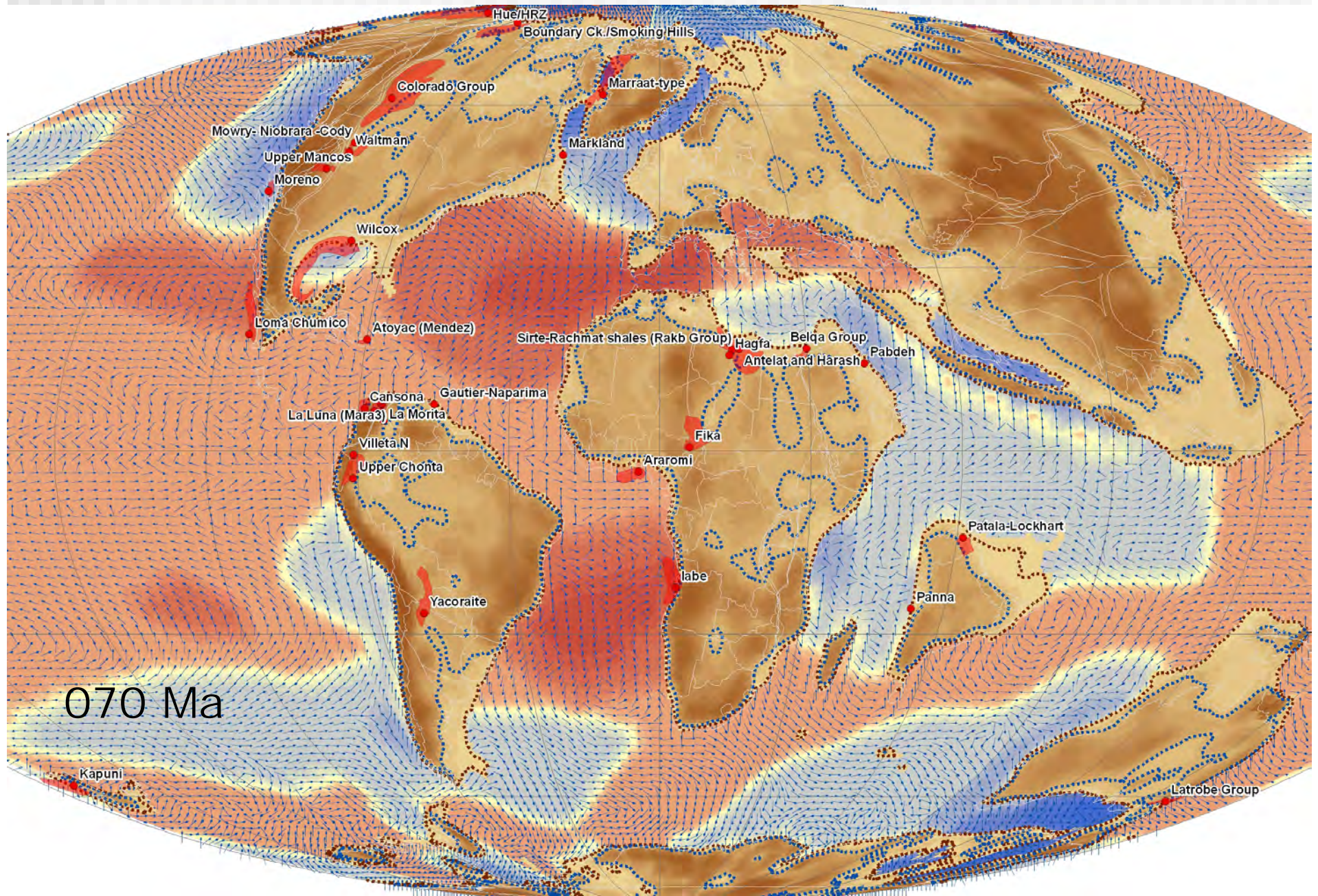
Test of Paleoclimatic Simulation of Rainfall & Runoff with Evaporites, Calcertes, Coals, Bauxites, Kaolinites & Reefs



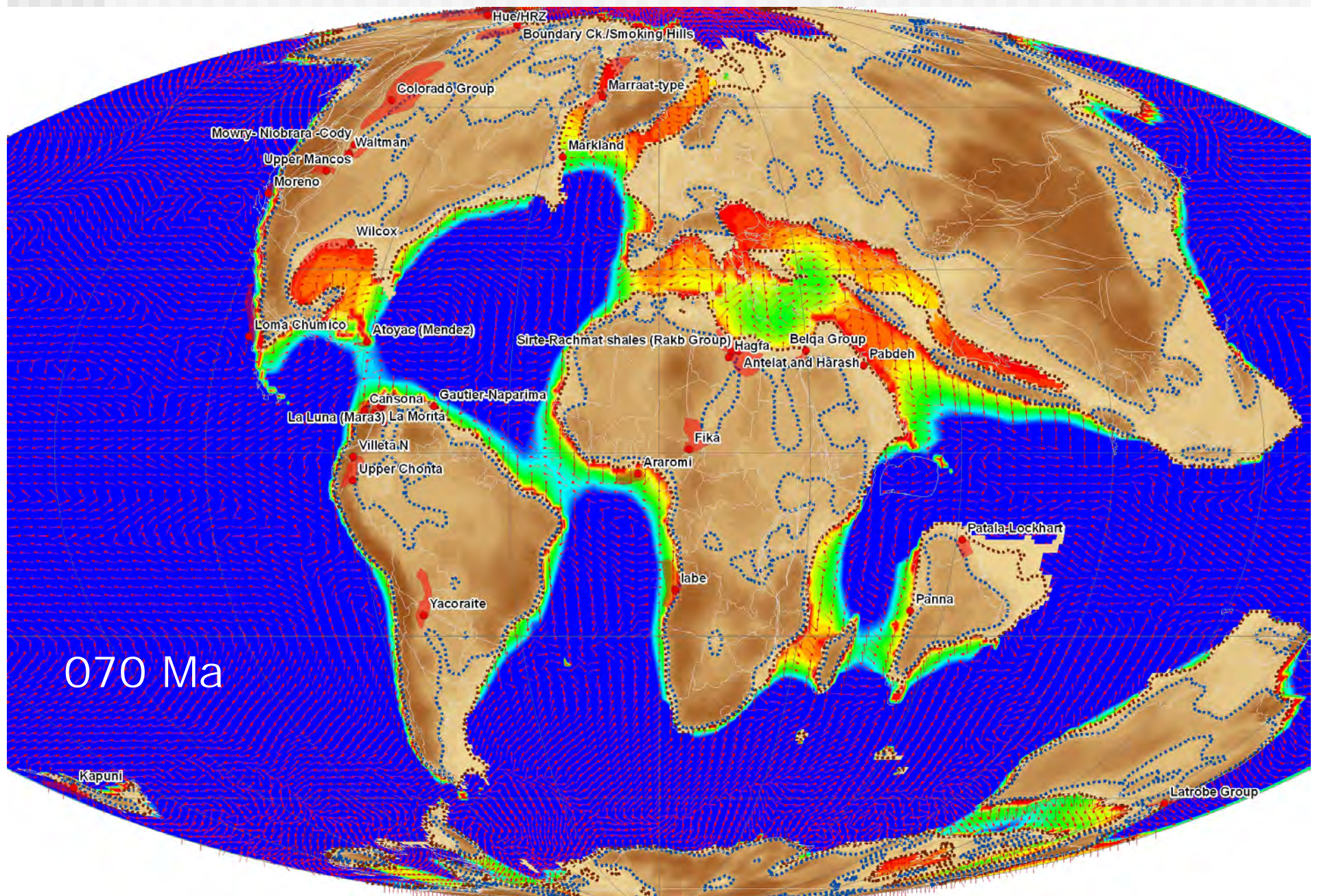
River Volume, Deltas & Clastic Input to Ocean



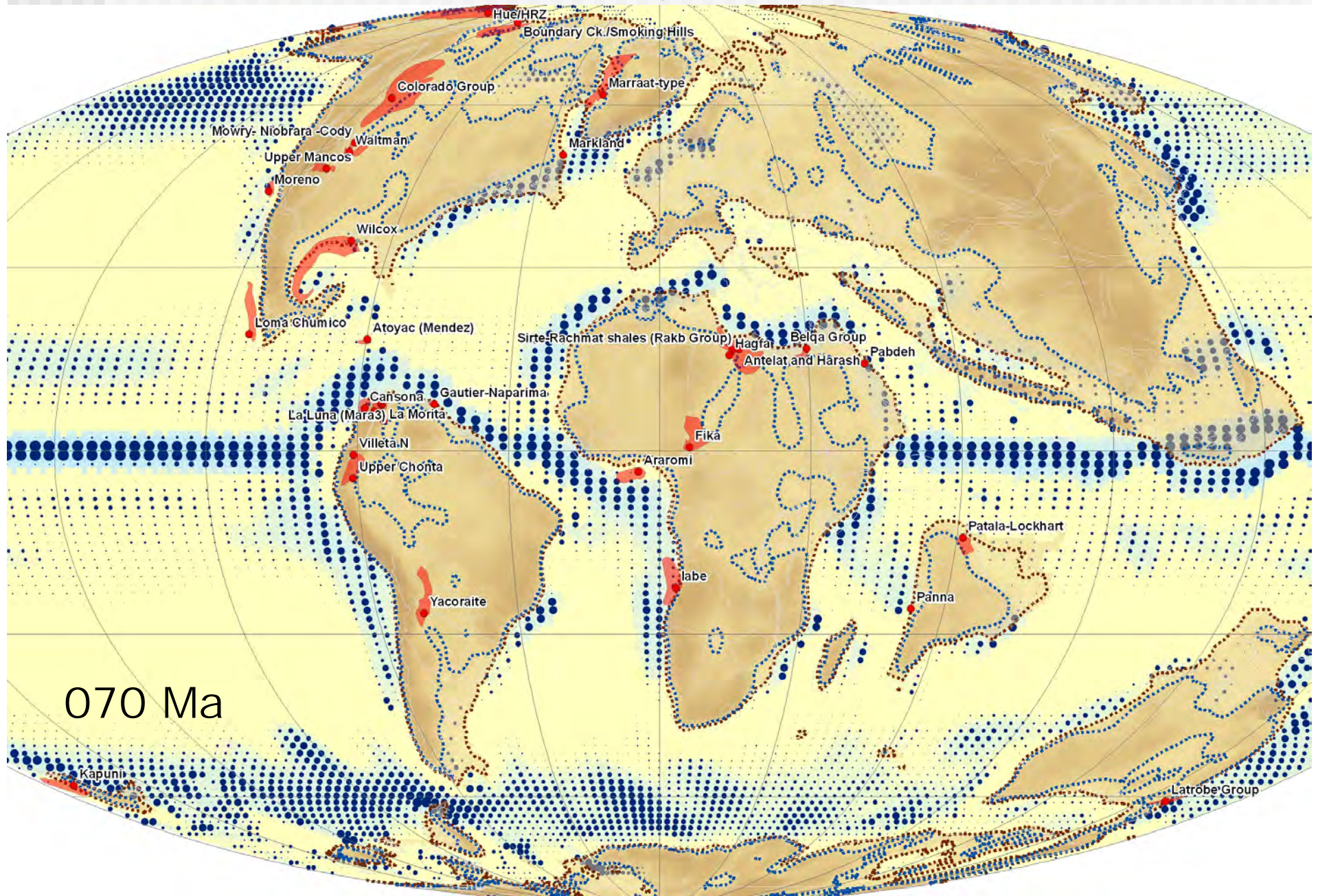
Salinity & Winter Surface Currents



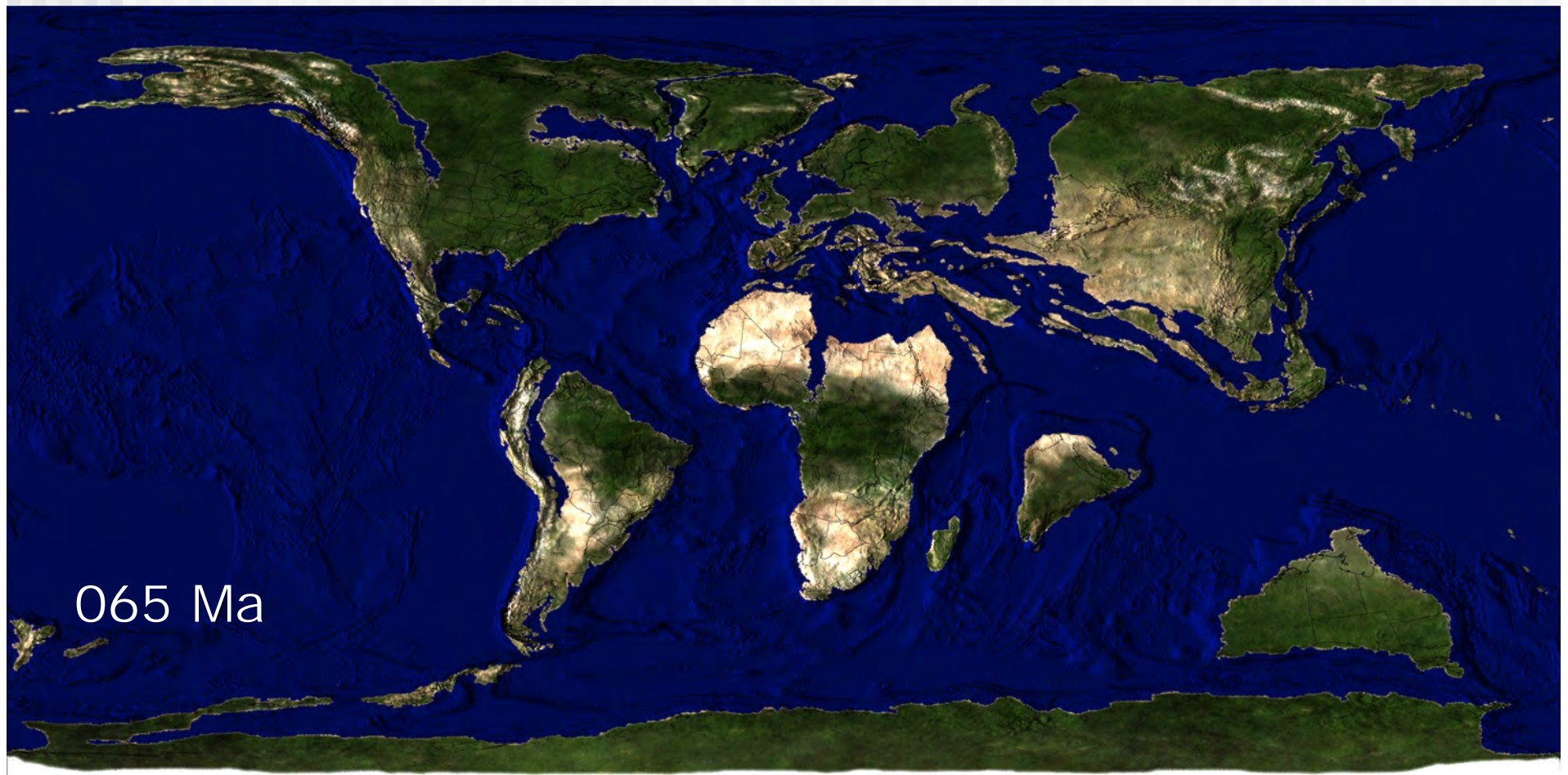
Basin Restriction (Anoxia) & Summer Surface Currents



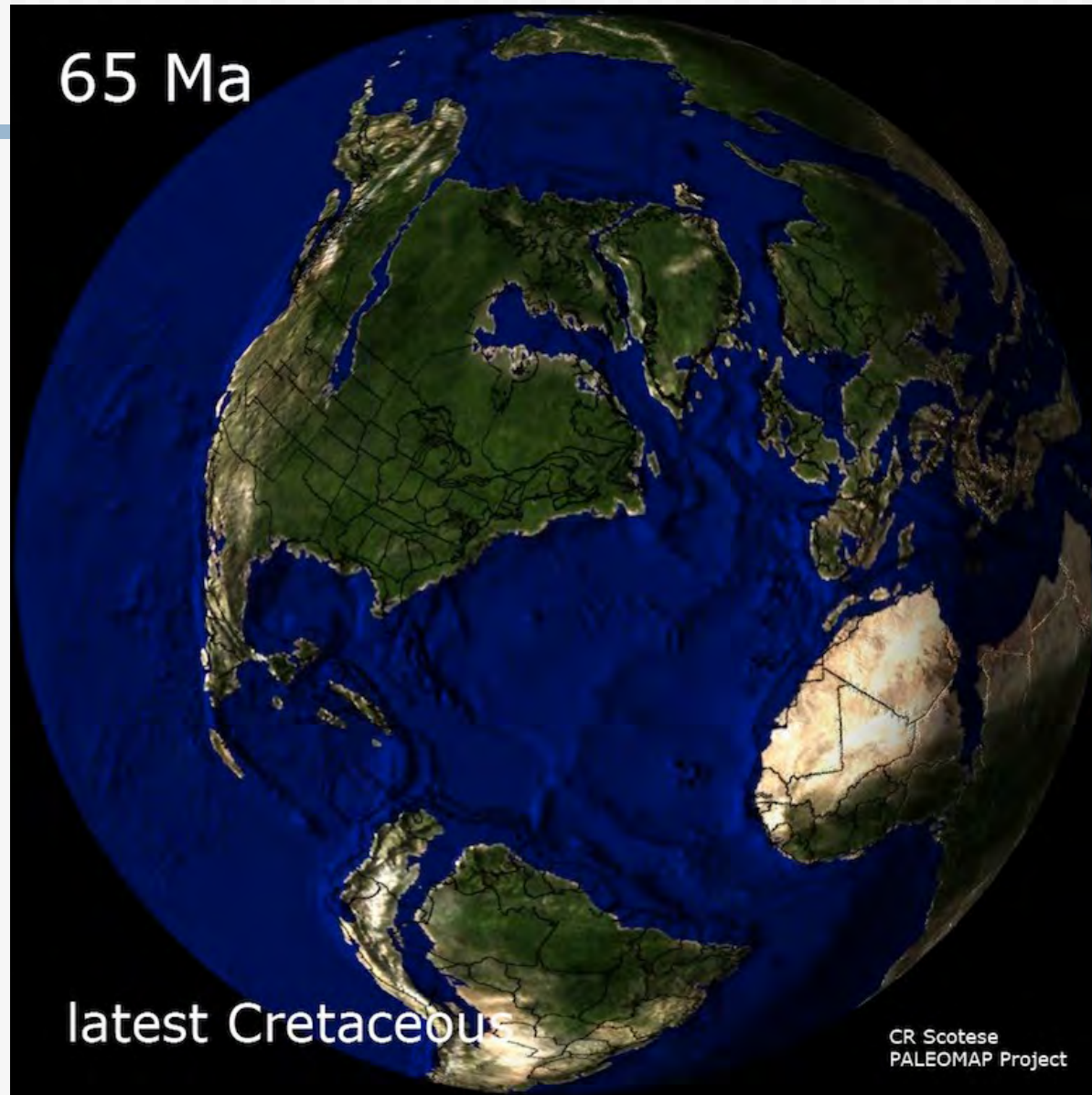
Upwelling Zones



Climatic Zones (after R. Blakey) plotted on PALEOMAP Paleogeographic Shaded Relief Map



Climatic Zones plotted on PALEOMAP Paleogeographic
Shaded Relief Map with Coastlines & Political Boundaries



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- BHP 2003
- ChevronTexaco 2003*
- (KerrMcGee 2003)
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- (Devon 2006)
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