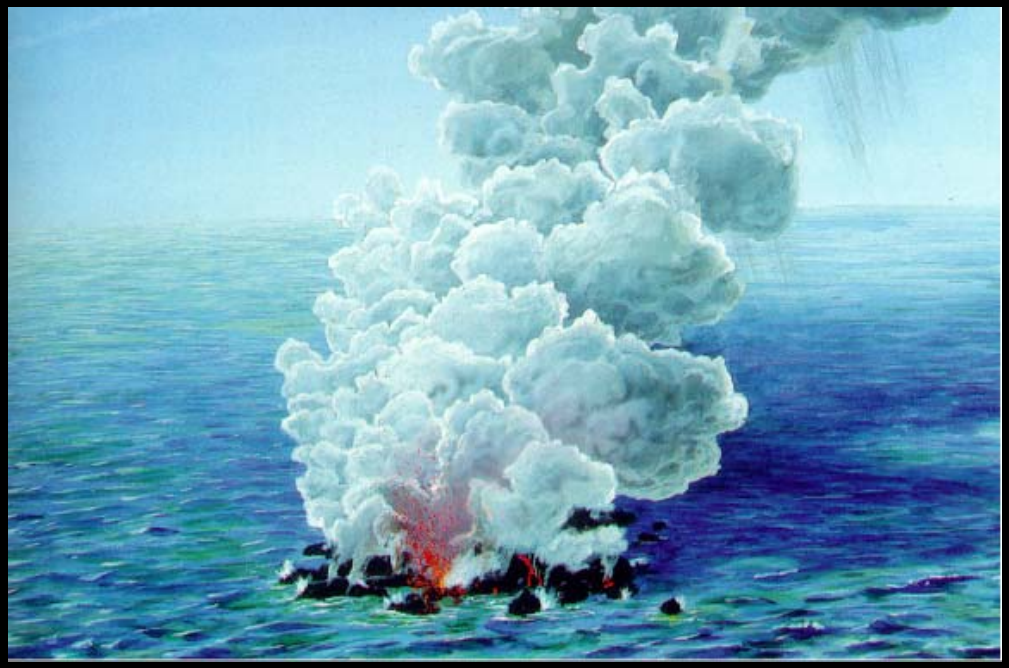
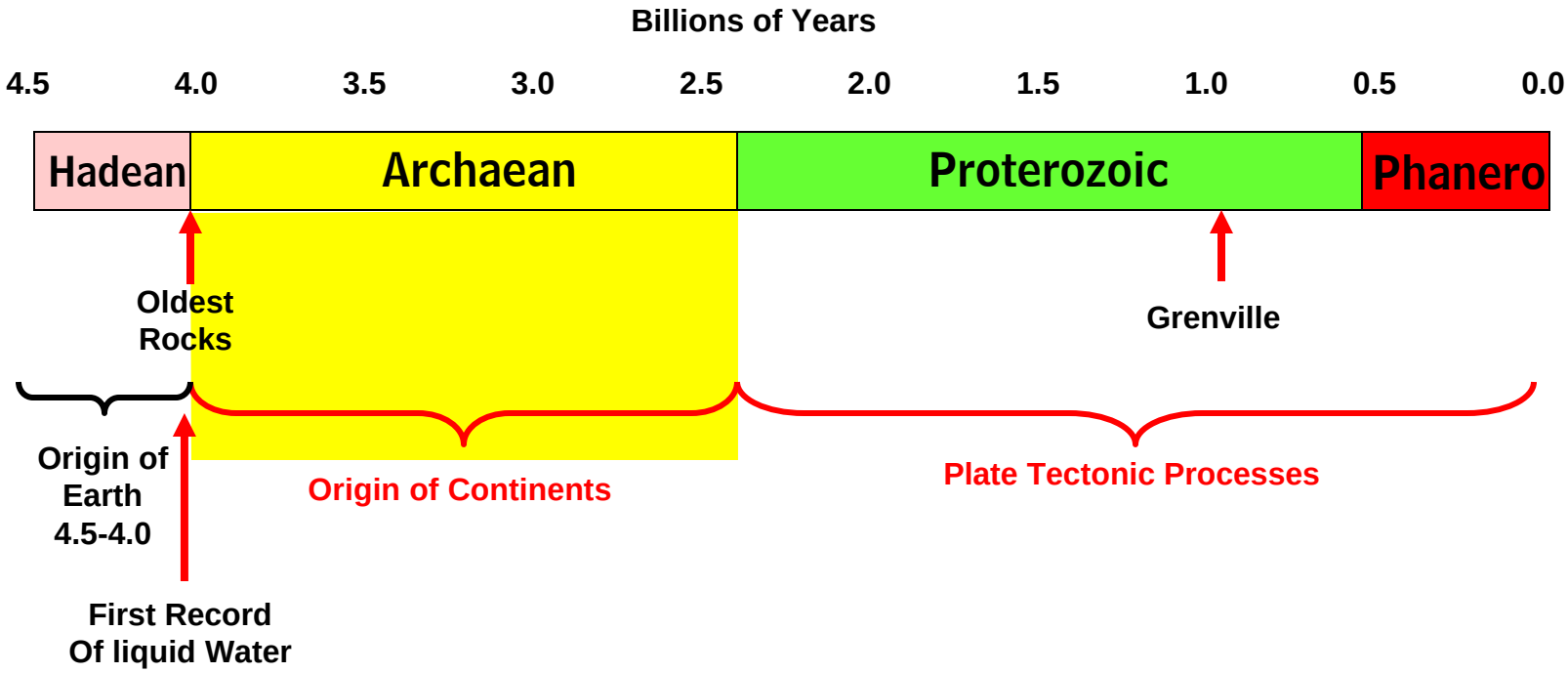
Archaean Crustal Evolution

Protocontinents to Microcontinents



~ 4.0 Ga. One of the first islands to form on the Earth. The picture shows a bright sunny day, but the atmosphere is likely to have been dark and smoggy. All land at this time was formed by volcanic activity, either from hot spots or subduction zones. Continents, even small ones, are still a distance in the future.

Just How Long is Earth History ?
And When Did the Important Things Happen ?



Archaean Crustal Evolution

Central Problems

1. **What was the composition of the original crust?**

2. **Have the continents always existed, or have they grown with time?**

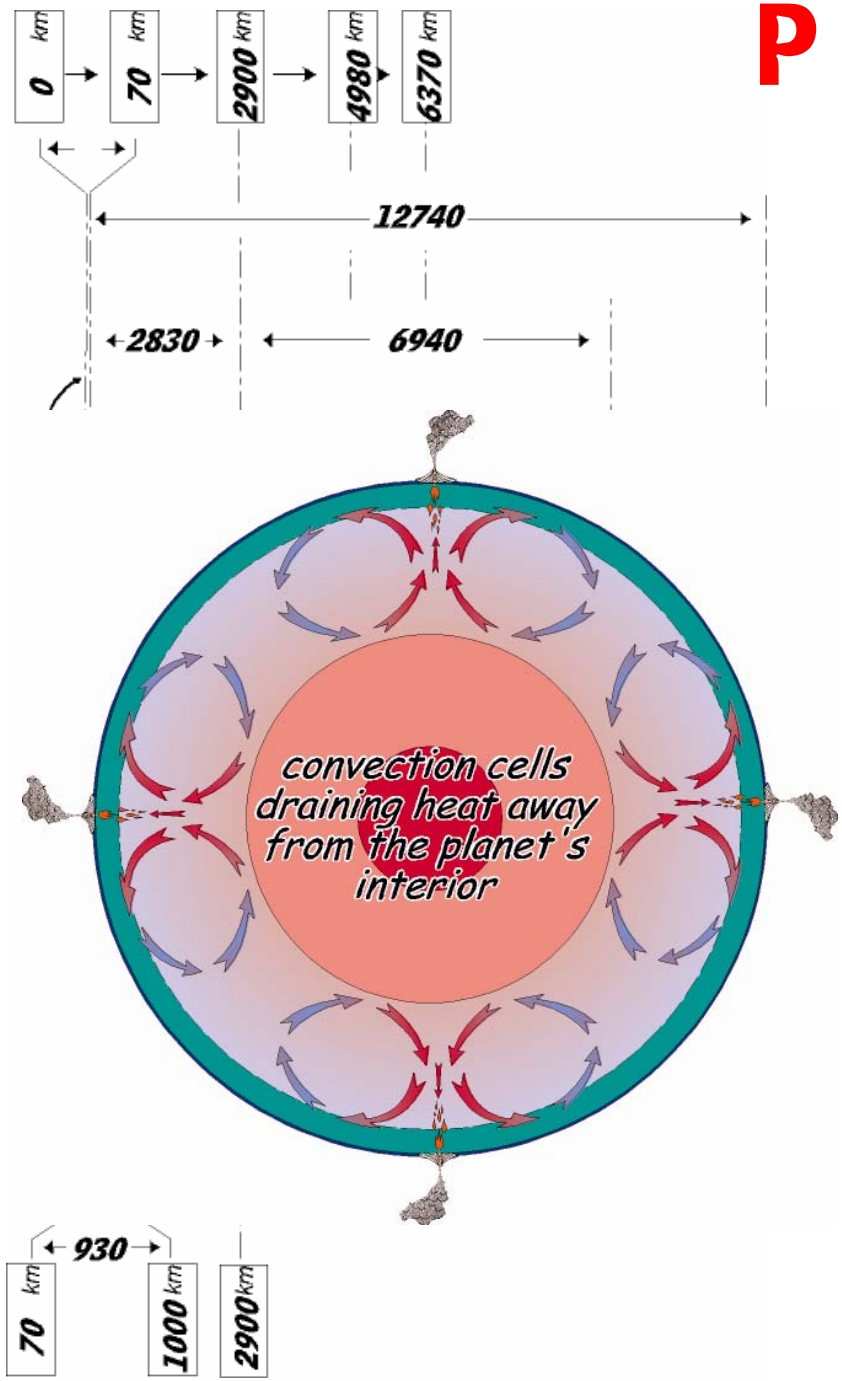
3. **Has plate tectonics always existed?**
   In essence, have the earth's processes remained basically the same (steady state), or have earth processes evolved with time?

4. **Why are there ancient rock types, and ancient kinds of land forms that are not forming today?**

A Plate Tectonic Primer

P 197

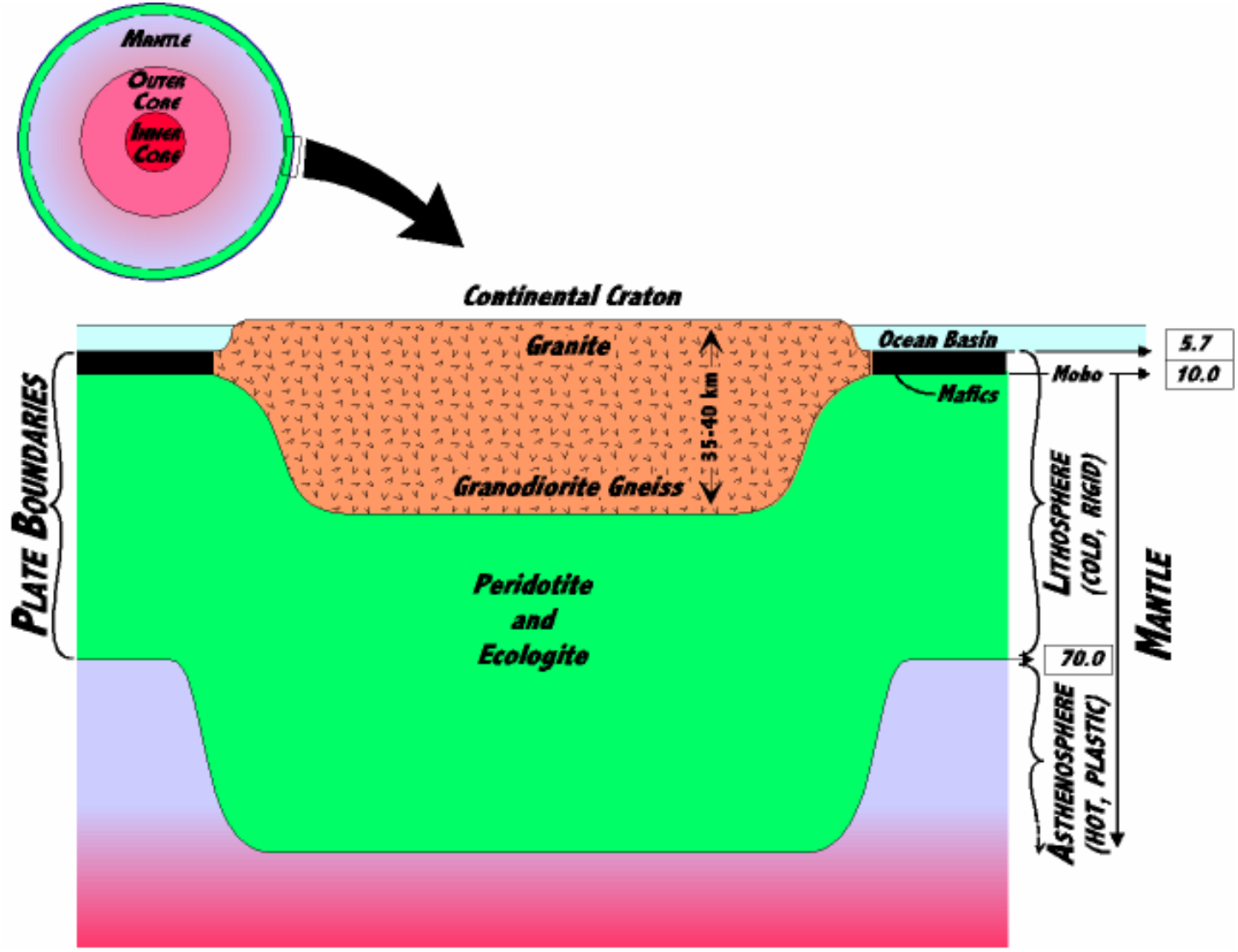
Major Divisions Of the Earth



Structure Of the Earth

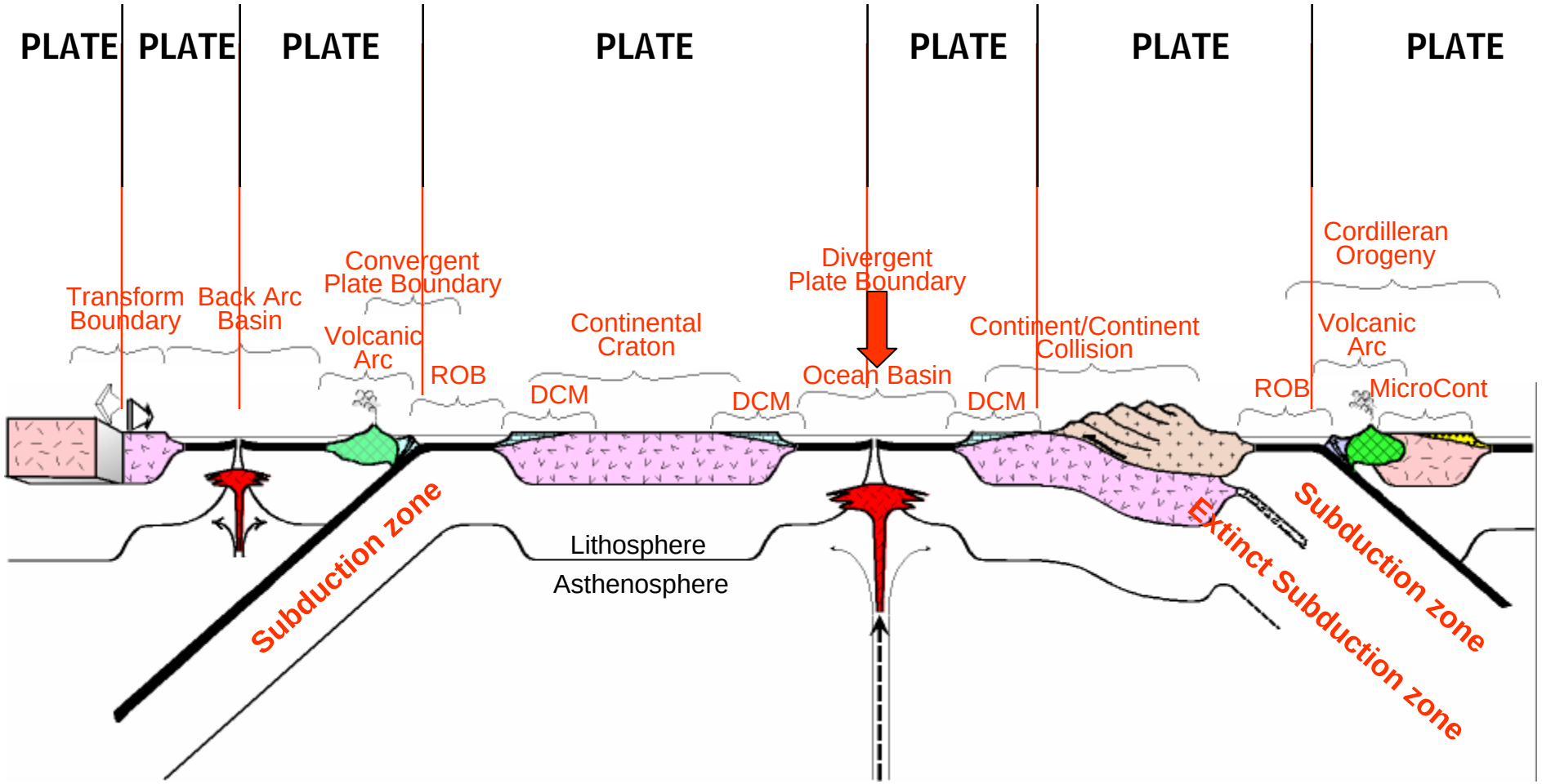
P 198

Asthenosphere and Lithosphere



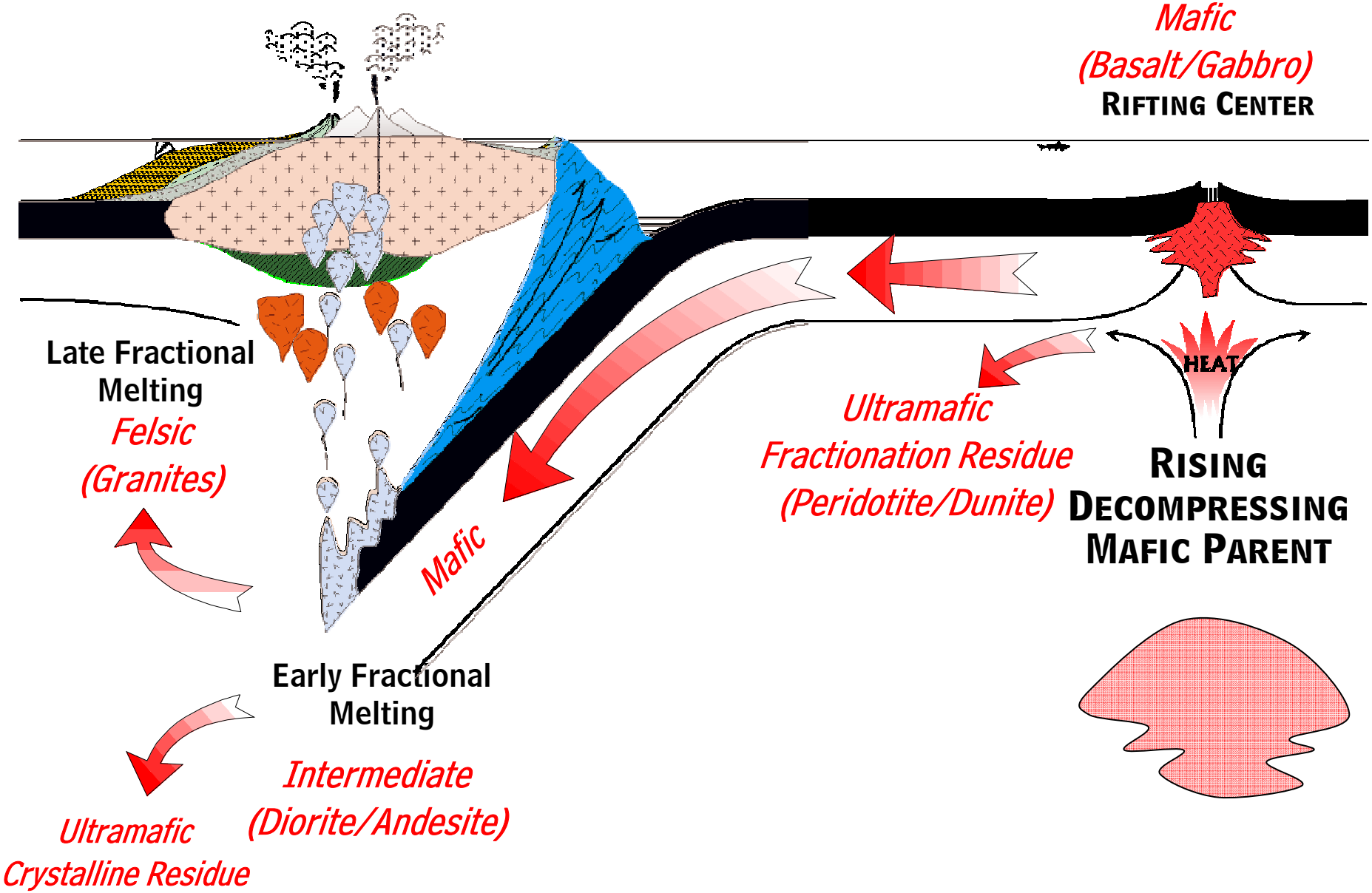
The Varieties of Plate Boundaries and Inter-Plate Relationships Defined By

Plate Tectonic Theory



Archaean Proto and Micro Continents

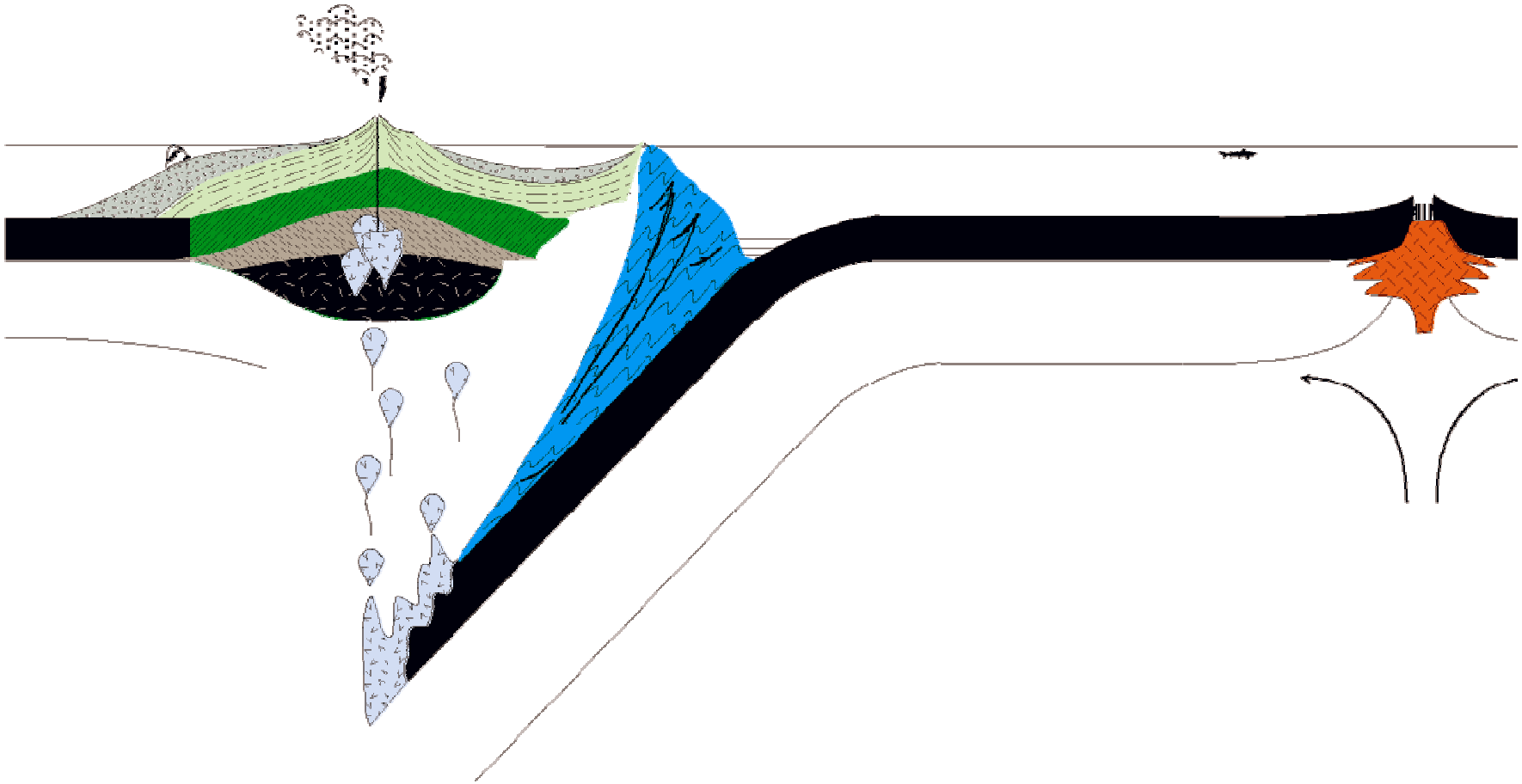
By igneous fractionation processes we already understand.



The result was the formation of . . .

P 210

. . . volcanic island arcs

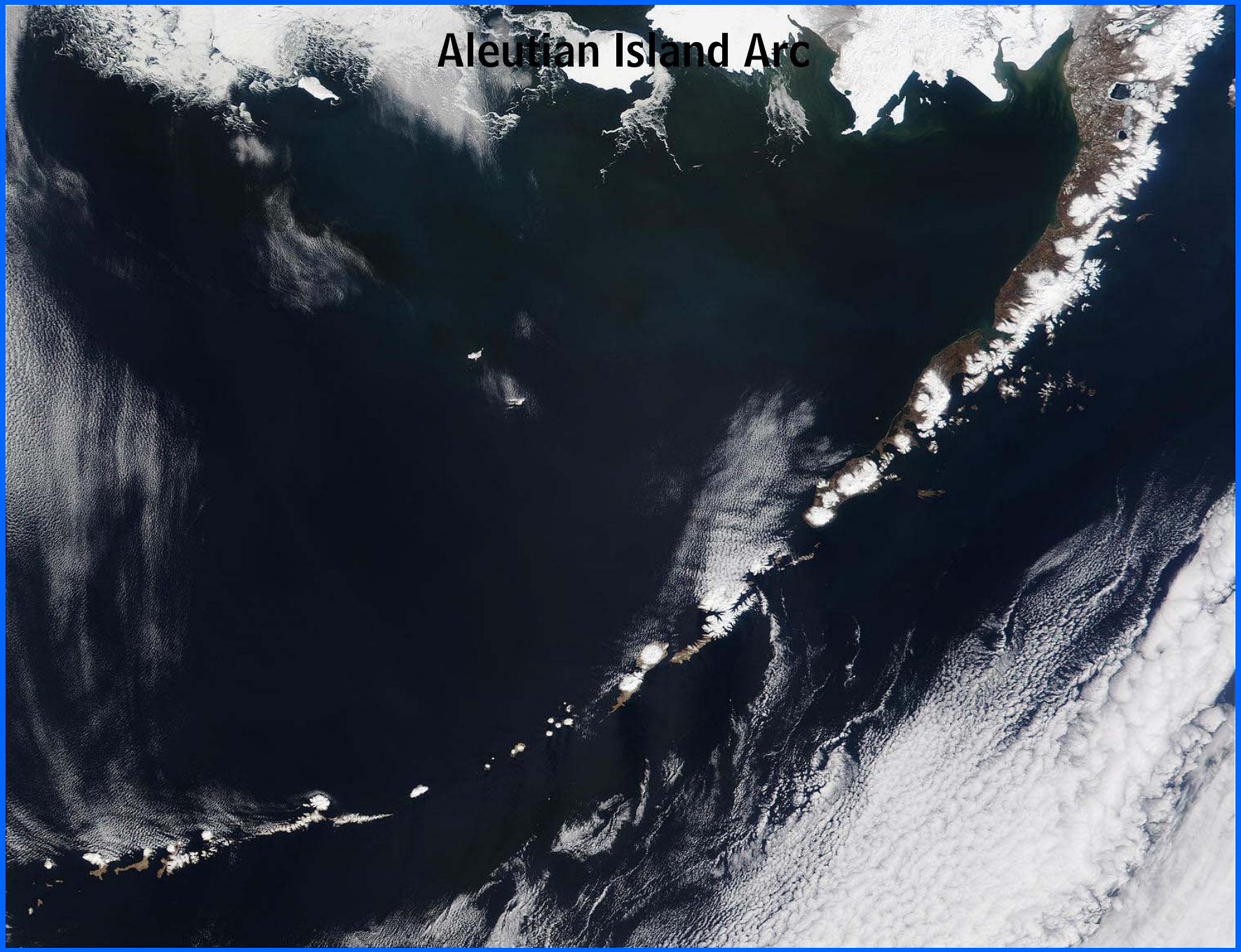


Aleutian Islands

Java Island Arc

Japan Island Arc

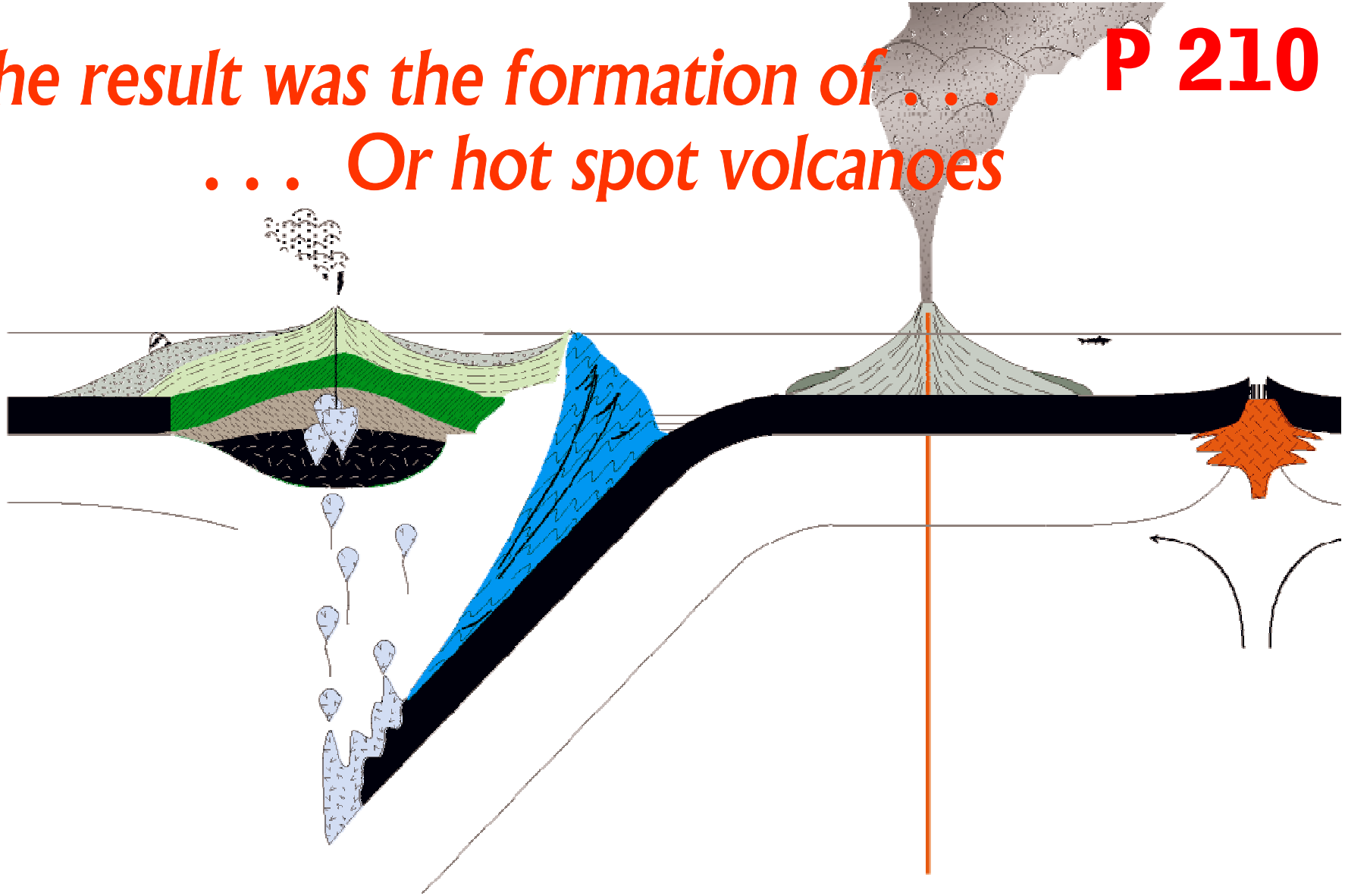
Aleutian Island Arc



The result was the formation of . . .

P 210

. . . Or hot spot volcanoes

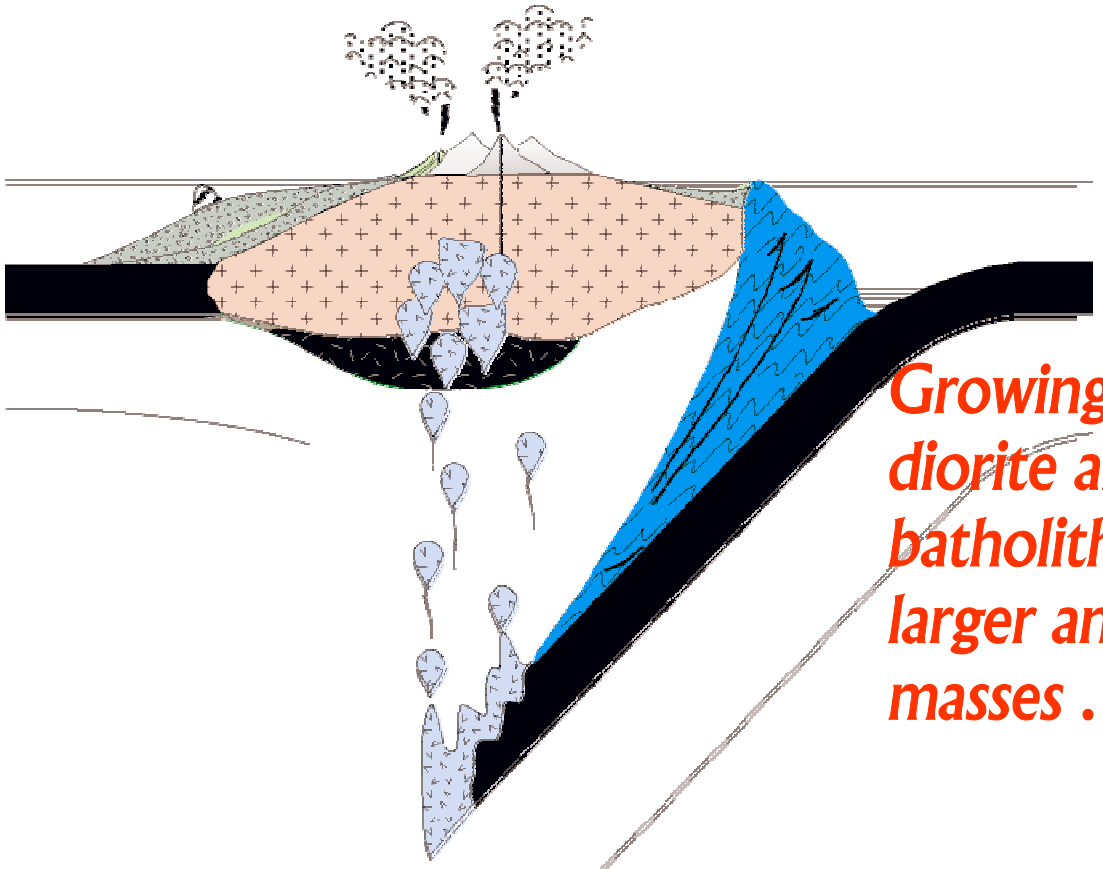


Hawaii

Or, this . . .

http://austral.chez.tiscali.fr/v3/accueil.php?nav=galleries&page=gallery2

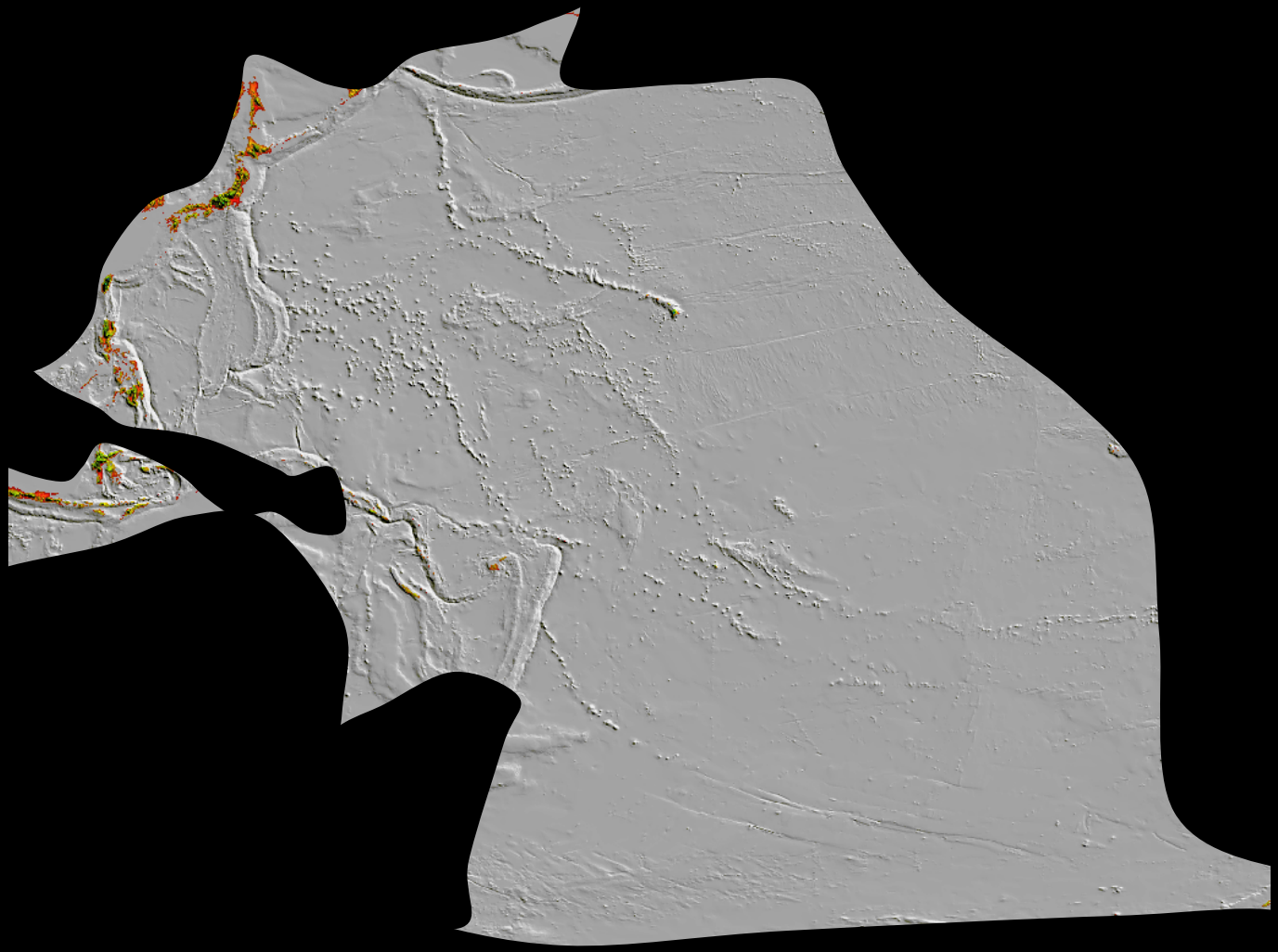
That evolved into microcontinents . . . **P 210**



Growing as more and more diorite and plagiogranite batholiths emplaced to form larger and larger continental masses . . .

. . . which because they are light weight rocks compared to the ocean floor basalts and gabbros float higher in the lithosphere emerging above sea level.

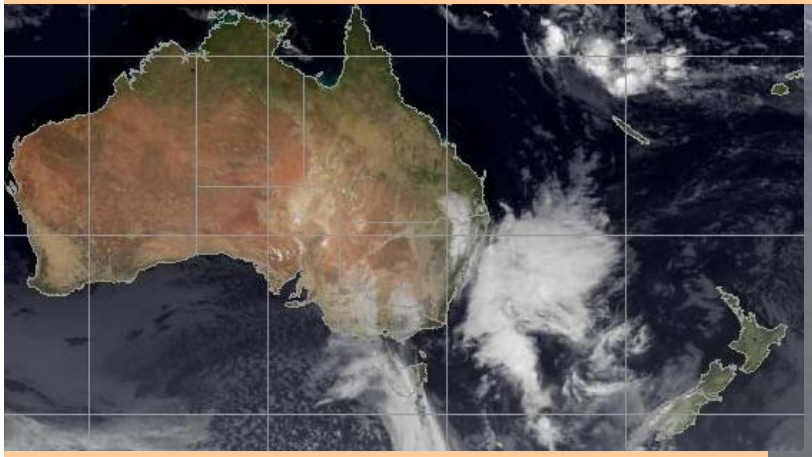
At this early Earth had no continental land areas, perhaps not even large islands.



Java


Pulau Siuntjal
Pulau Sebesi
Pulau Tunda
Pulau Pandjang
Pulau Krakatau
(Jakarta)
Djakarta
Pulau Panaitan
Pulau Tjinjil
Bandung
Semarang
Jawa (Java)
Nusa Kambangan
Yogyakarta
Surabaja
surabaya
Gili Radja
Pulau Sempu
Pulau Barung
© 2006 Europa Technologies
Image © 2006 TerraMetrics
©2006 Google™
The Settlement
Pointer 6°59'45.54" S 109°41'08.97" E elev 481 ft
Streaming 100%
Eye alt 573.72 mi

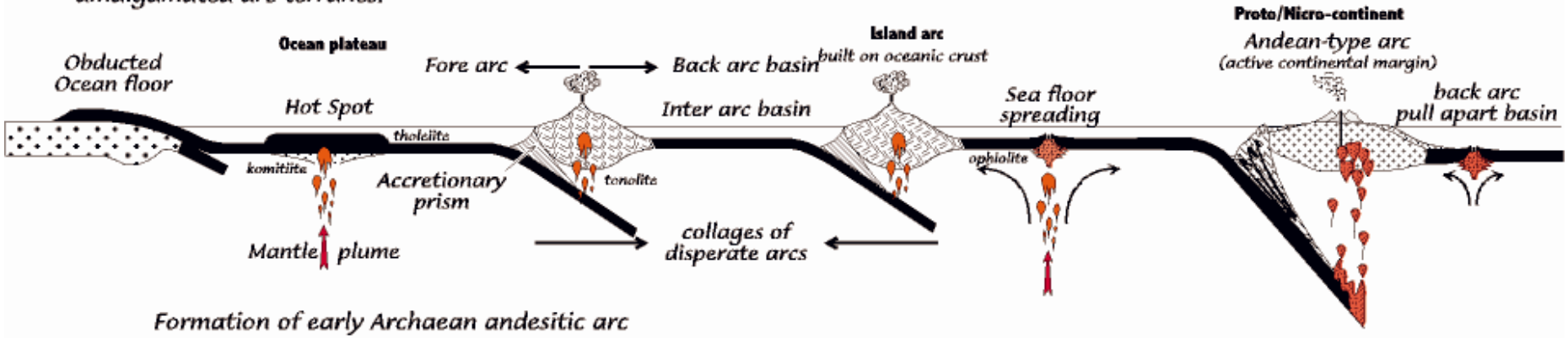
New Zealand



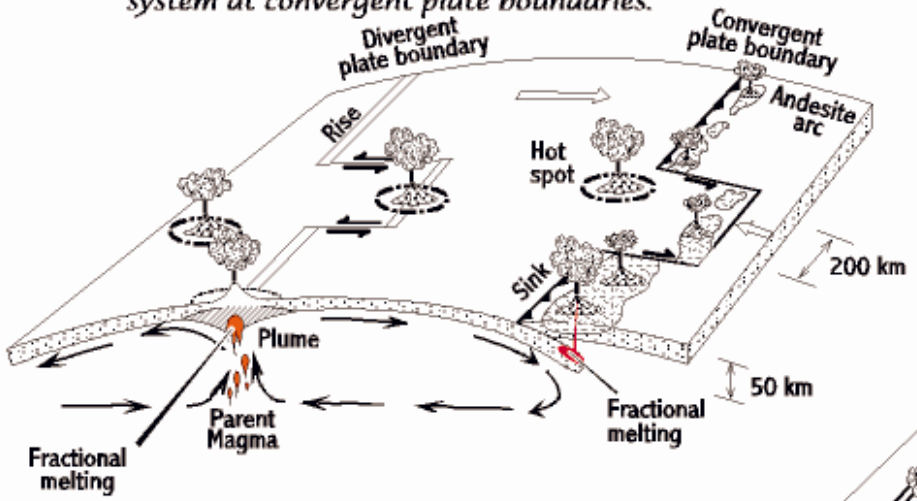
Madagascar

Plate Tectonic Analogues for Archaean Greenstone Belts

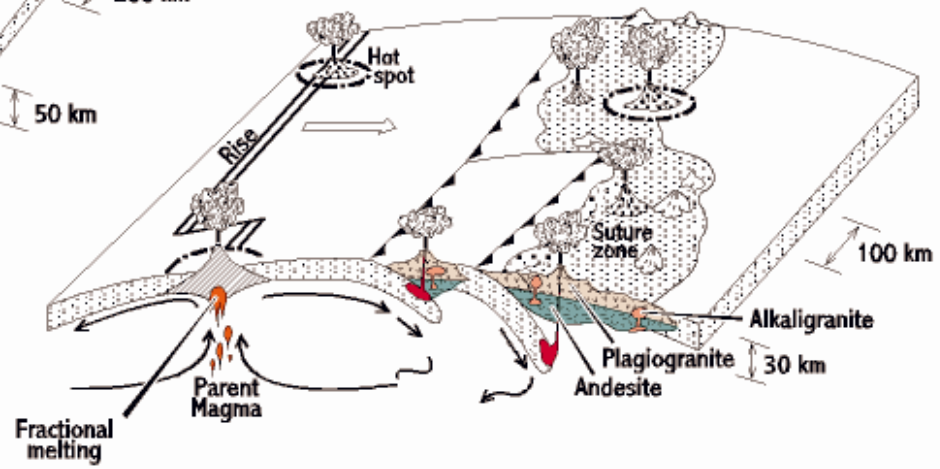
In contrast to a decade ago, there is now general agreement internationally that most greenstone belts formed as a result of sea-floor spreading followed by subduction-accretion processes associated with island arcs. Possible modern analogues include obducted slabs of ocean floor, island arcs built on oceanic crust, segments of arcs, ranging from fore-arcs to closed back-arc basins, intra-arc basins, collages of disparate arcs, arcs thrust onto continental crust, volcanic arcs and pull-apart basins developed on an active continental margin, and accretionary prisms that overstep and seal amalgamated arc terranes.



Formation of early Archaean andesitic arc system at convergent plate boundaries.



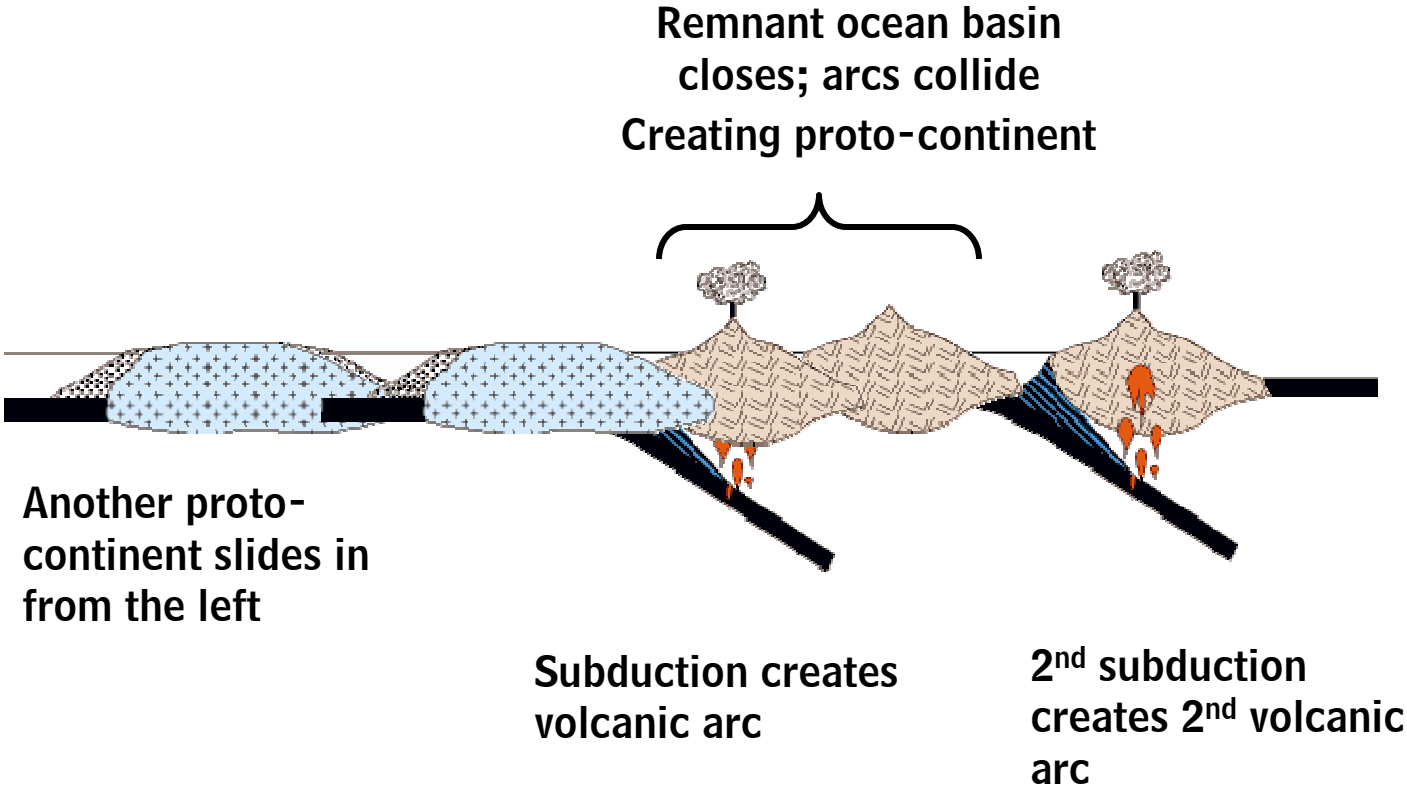
Growth of late Archaean sialic crust by tonalite-trondhjemite plutonism and arc-arc collisions. High K granitic plutons are produced by partial melting of andesititc rocks in the lower crust.



P 211

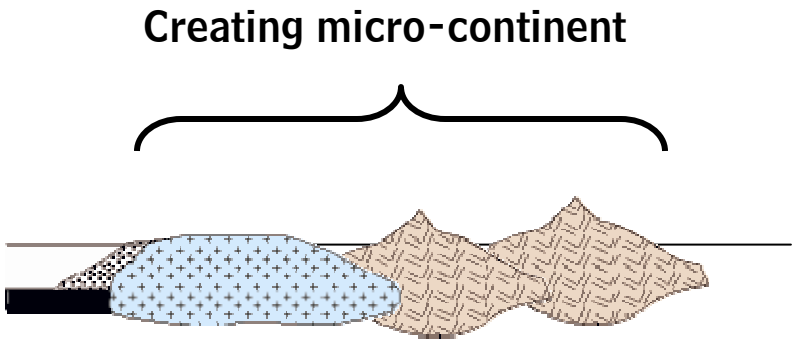
But these processes where going on all over the planet in dozens of places.

Leading to remnant ocean basins and collisions among the newly forming islands

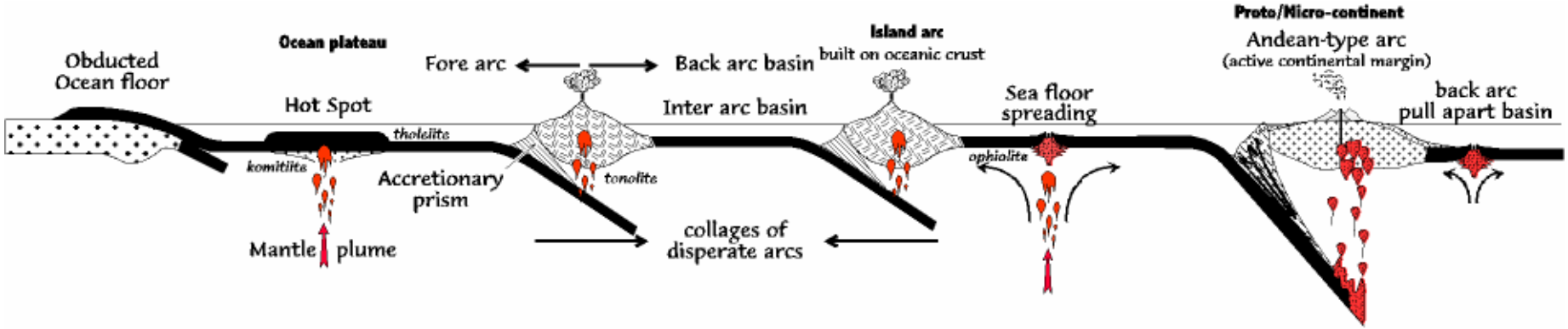


P 211

But these processes where going on all over the planet in dozens of places.

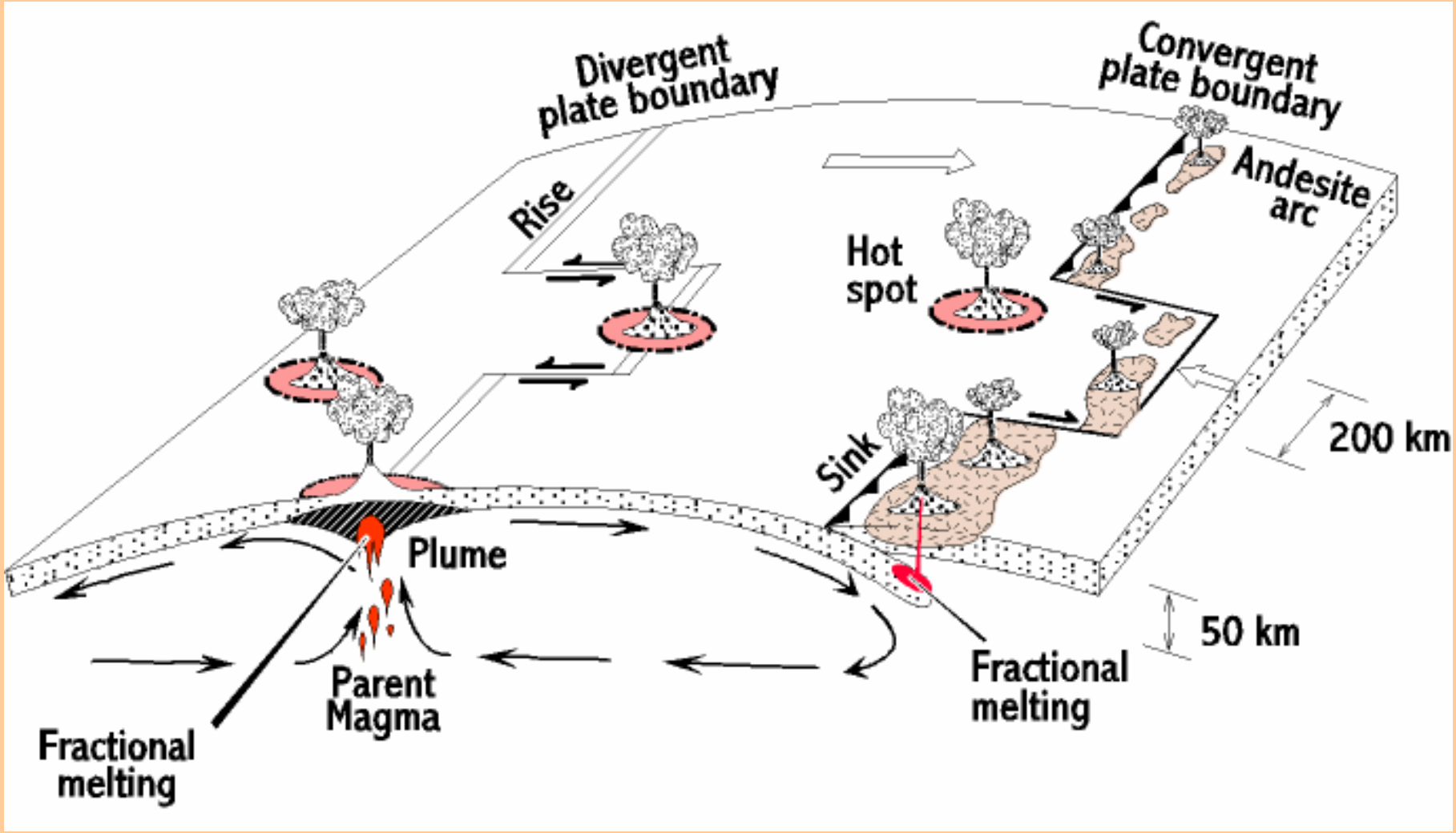


The process continues in multiple combinations and permutations all over the globe



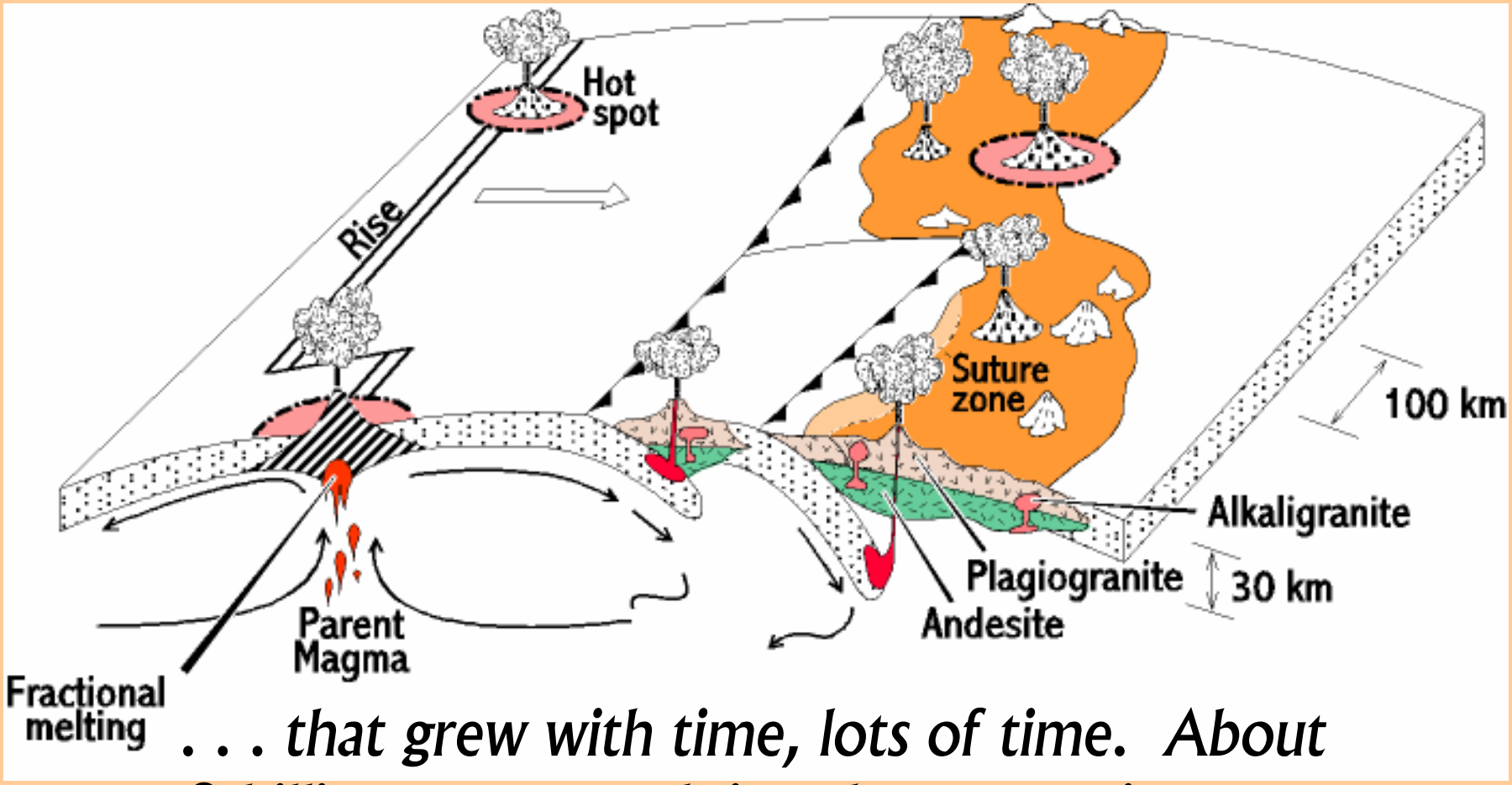
P 211

Leading to the growth of continents



P 211

Leading to the growth of continents



. . . that grew with time, lots of time. About 2 billion years worth into larger continents.

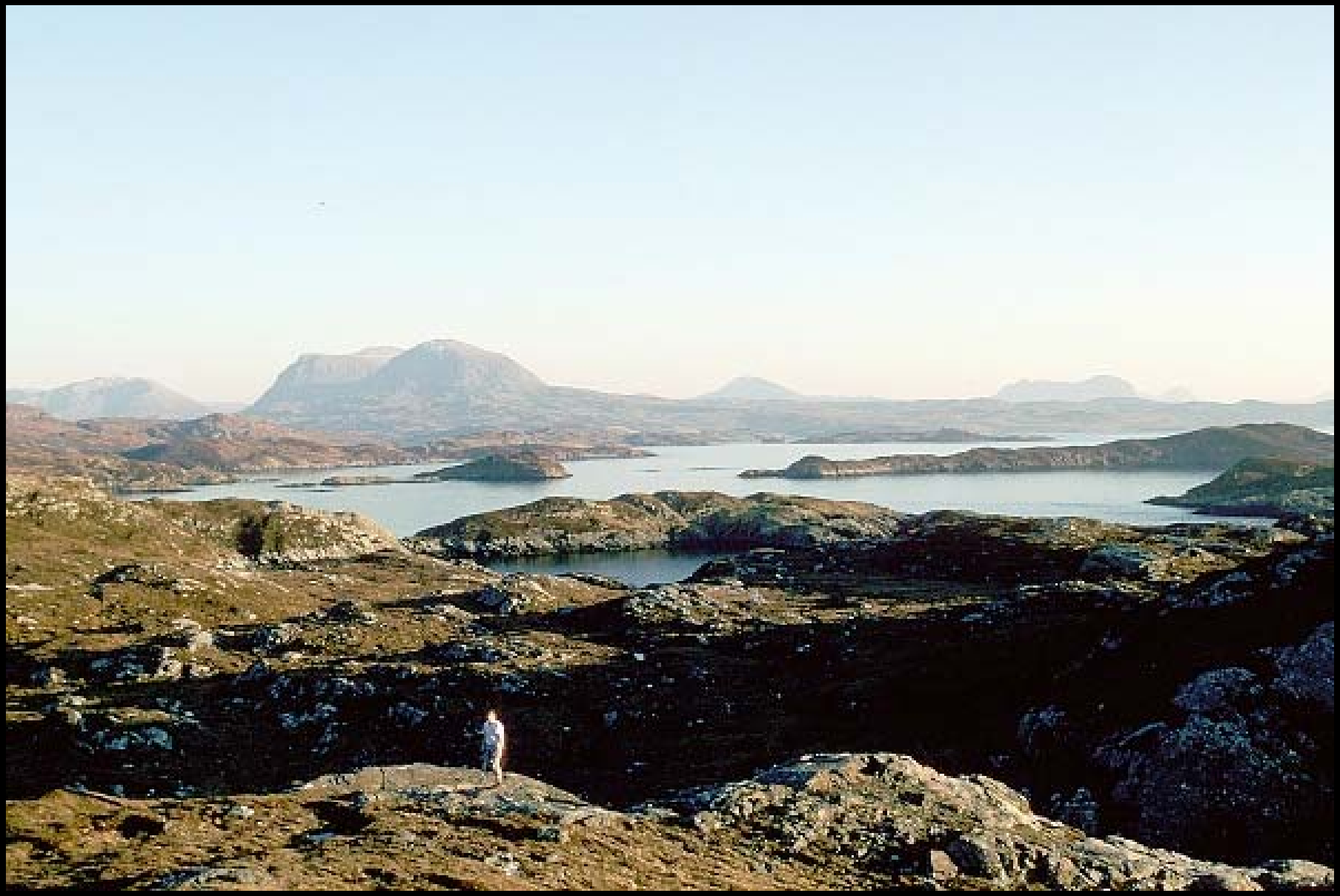
Today rocks from this period of time are preserved in a number of places, like Western Greenland.

http://www.geosciences.unl.edu/~faebly/photos/greenland/photo001.html

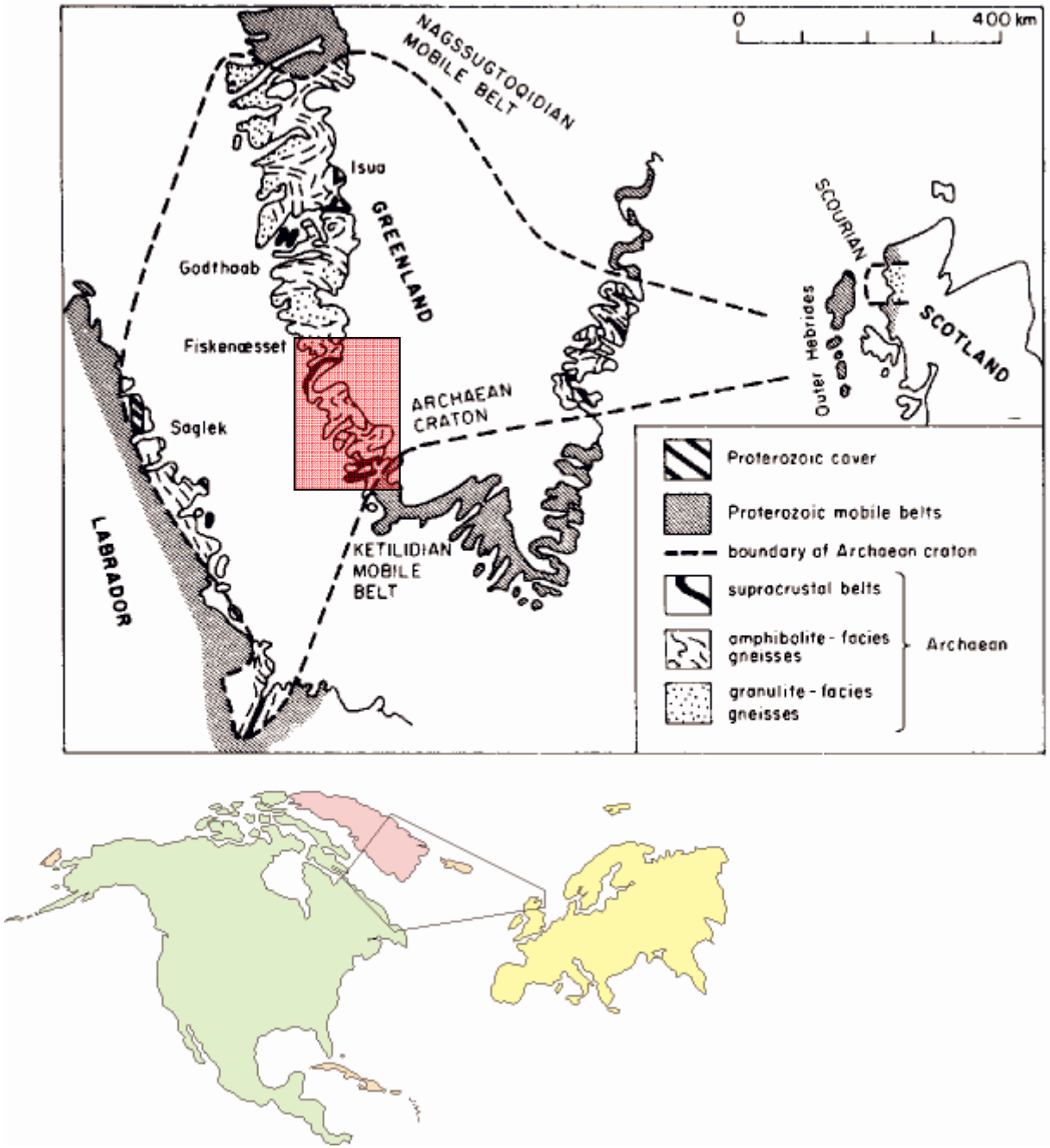
Today rocks from this period of time are preserved in a number of places, like Western Greenland.

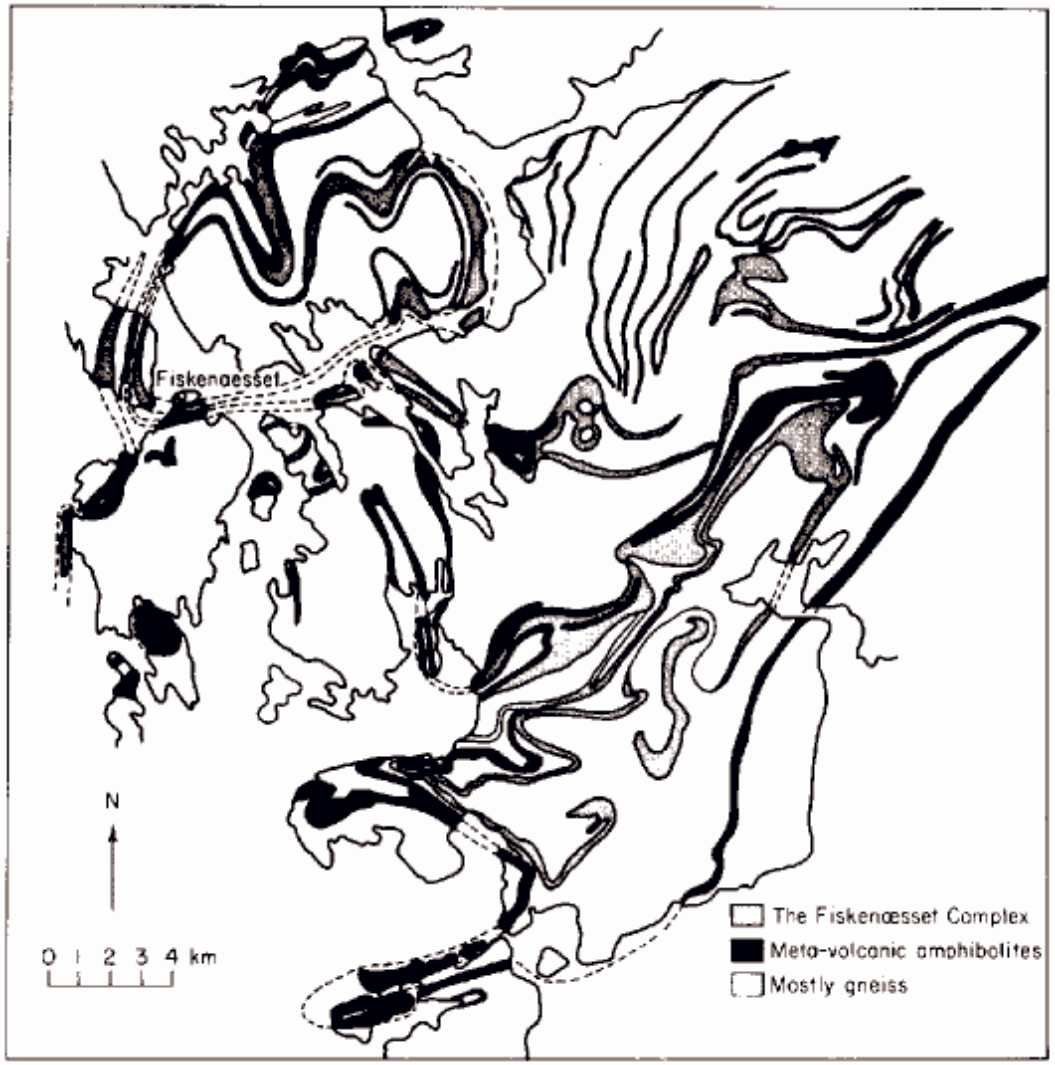
http://www.geosciences.unl.edu/~faebly/photos/greenland/photo001.html

And, Scourie Scotland



http://www.earth.ox.ac.uk/~oesis/nws/loc-scourie.html


0
400 km
NAGSSUGTOQIDIAN MOBILE BELT
Isua
GREENLAND
Godthaab
Fiskenæsset
ARCHAEAN CRATON
Saglek
LABRADOR
KETILIDIAN MOBILE BELT
SCOURIAN
Outer Hebrides
SCOTLAND
Proterozoic cover
Proterozoic mobile belts
boundary of Archaean craton
supracrustal belts
amphibolite - facies gneisses
granulite - facies gneisses
Archaean



And the rocks are folded, stretched, twisted, mangled, and metamorphosed, . . . more than once, and are in general FUBAR.

F#□*&#@ Up Beyond All Recognition

- Fiskanaesset Complex = Anorthosite
- Meta-volcanic Amphibolites = rest of the layered igneous complex

} **Oceanic lithospheric rocks**

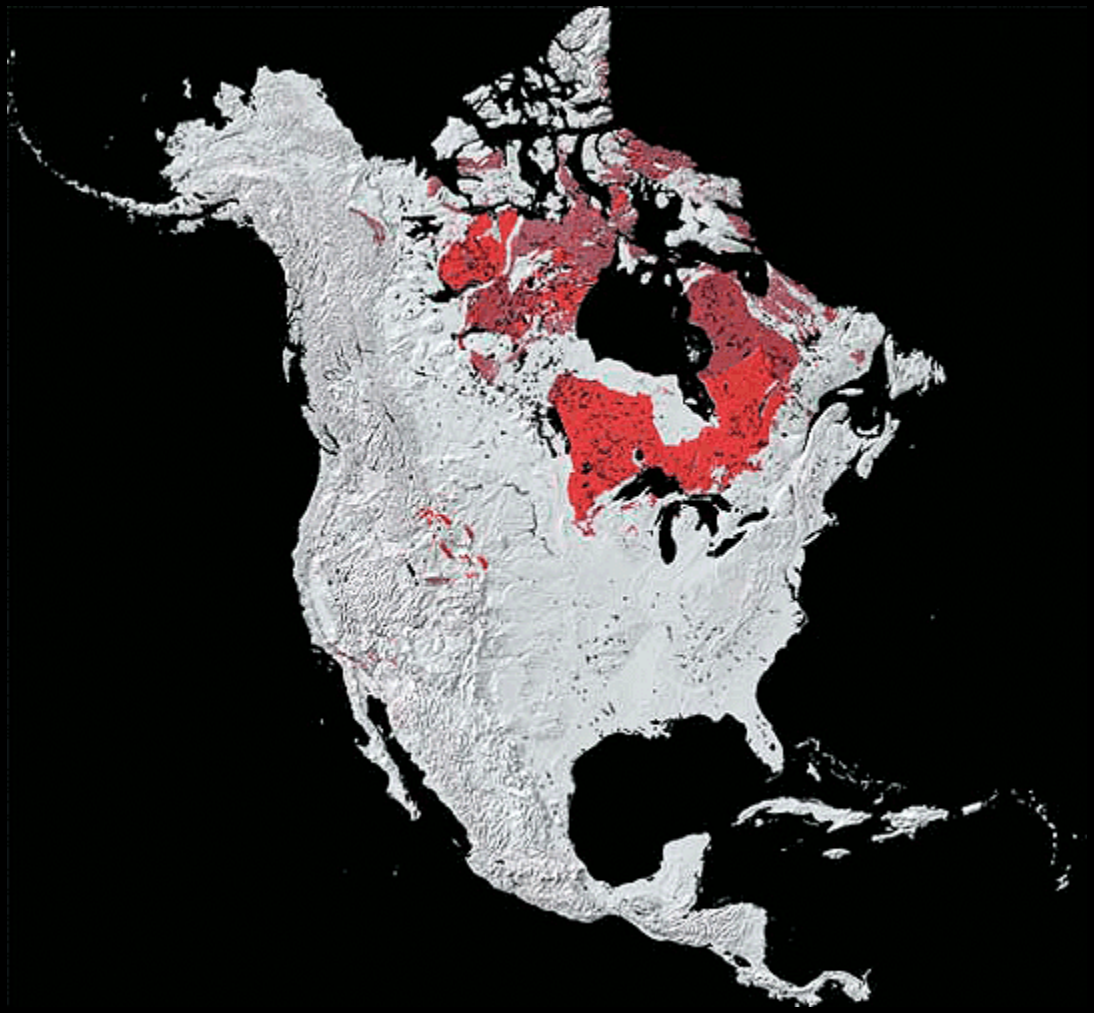
- "Mostly gneiss" = Granulite-gneiss belts

} **Proto-continent rocks**

Stretched, twisted, folded, and refolded like taffy . . .

"The complexes range up to about 1 km in thickness but often, due to tectonic disruption and thinning, they are only tens of metres to 100 m or so thick, and where extensively migmatized (invasion by late gneisses) they may be represented by only a few meter-sized pods" (Windley, Brian 1984, The Ev

Ali, Frank and Max at mirror maze in Frankenmuth, MI

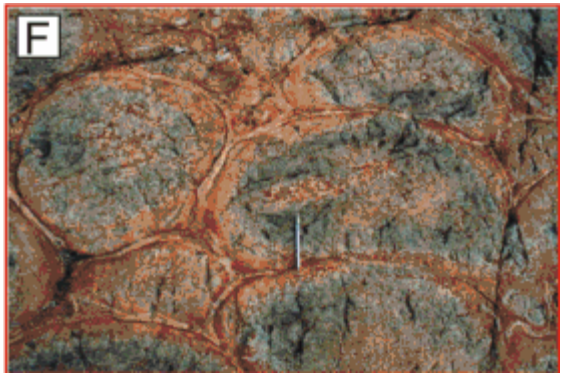


http://mineral-rock.blogspot.com/2005/12/yellowknife.html

http://mineral-rock.blogspot.com/2005/12/yellowknife.html

Dating from the Hadean at least 4.03-4.055 Ga, is Earth's oldest known crustal rock outcrop. The complex comprises mostly Gray gneiss (granodioritic gneiss), White gneiss (tonalitic to granitic gneiss), foliated granite (3.6 Ga)

http://mineral-rock.blogspot.com/2005/12/yellowknife.html


F

Archaean Growth of the North American Continent

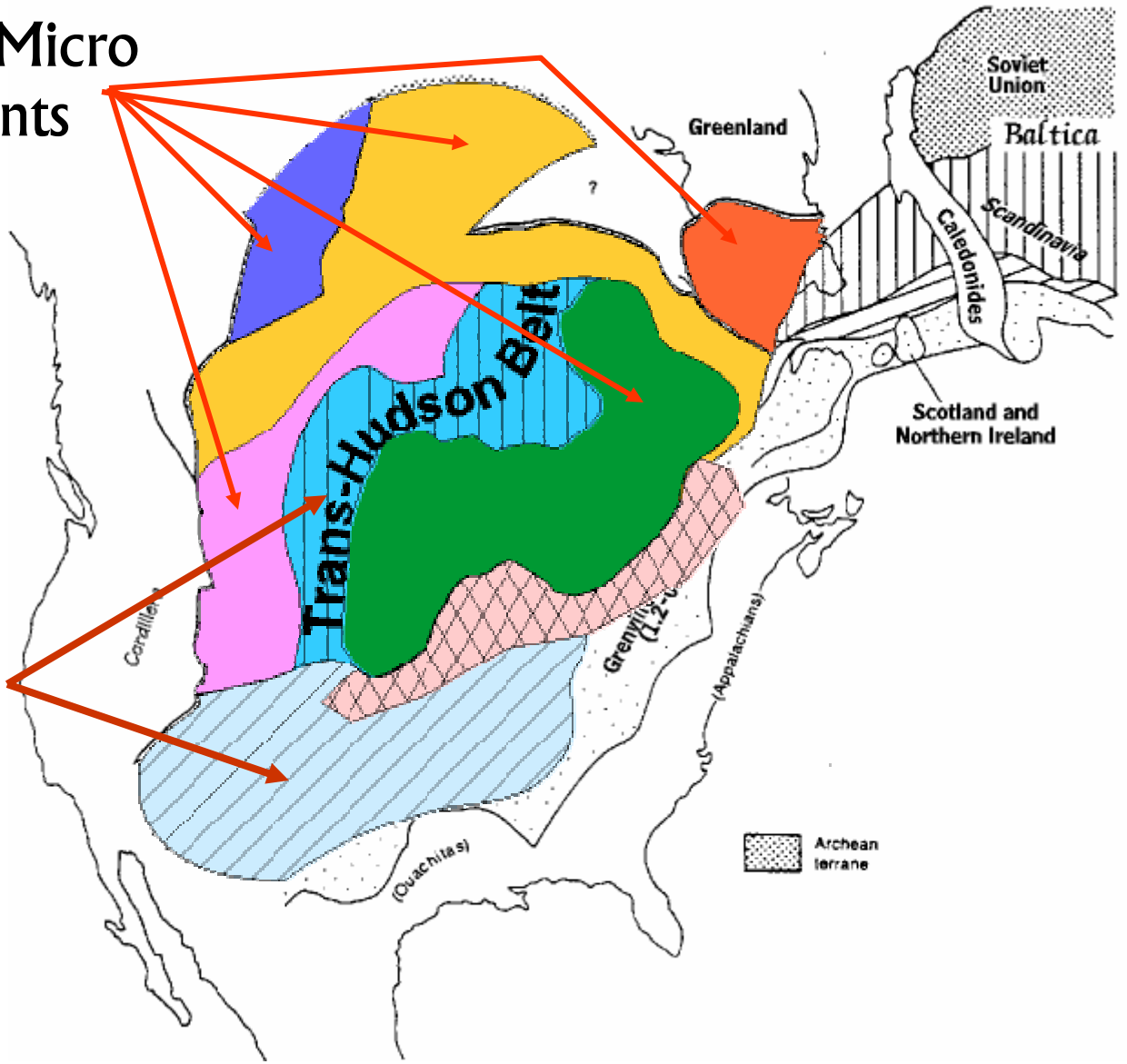
First Phase: Building the Core

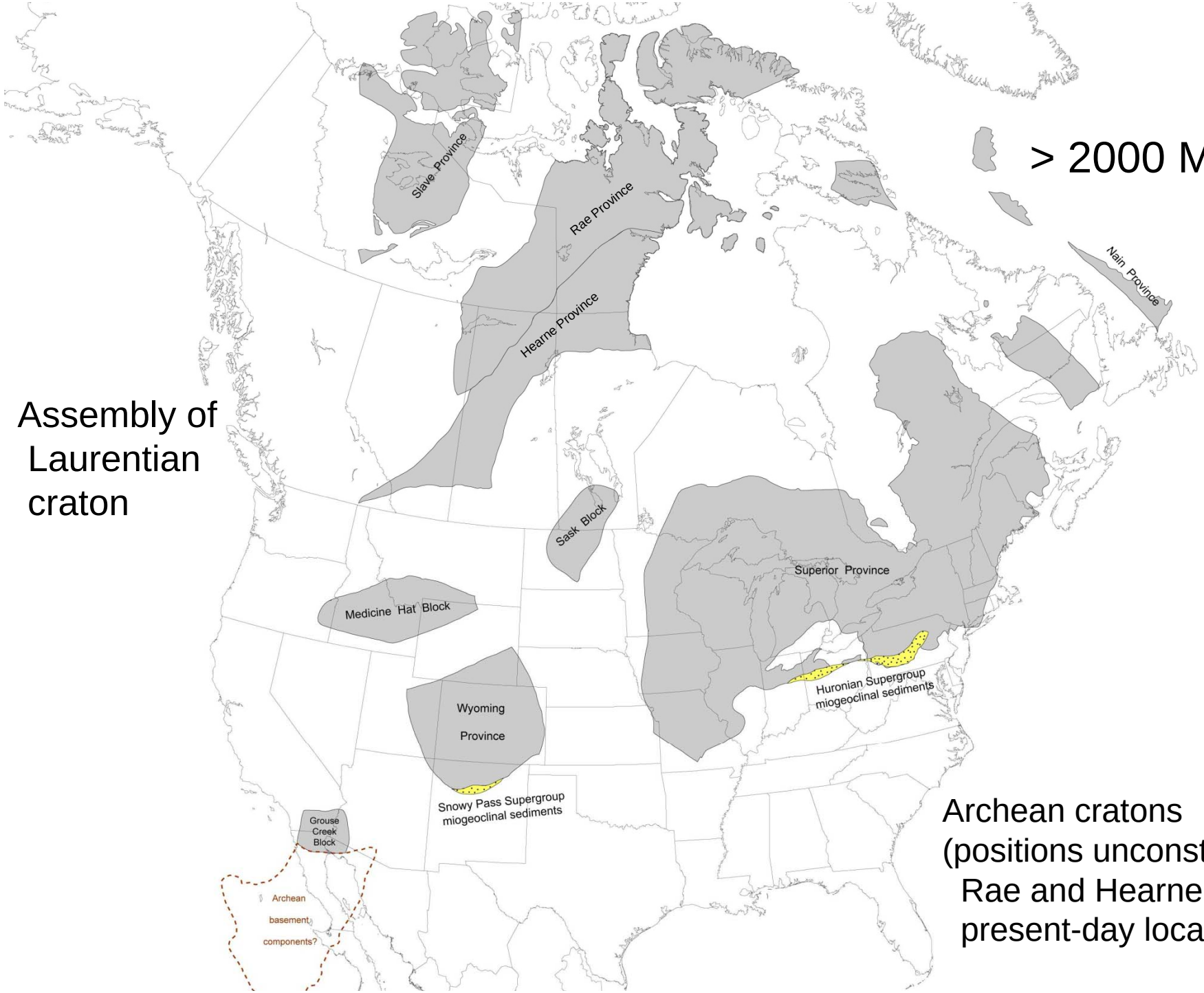
United Plates of North America

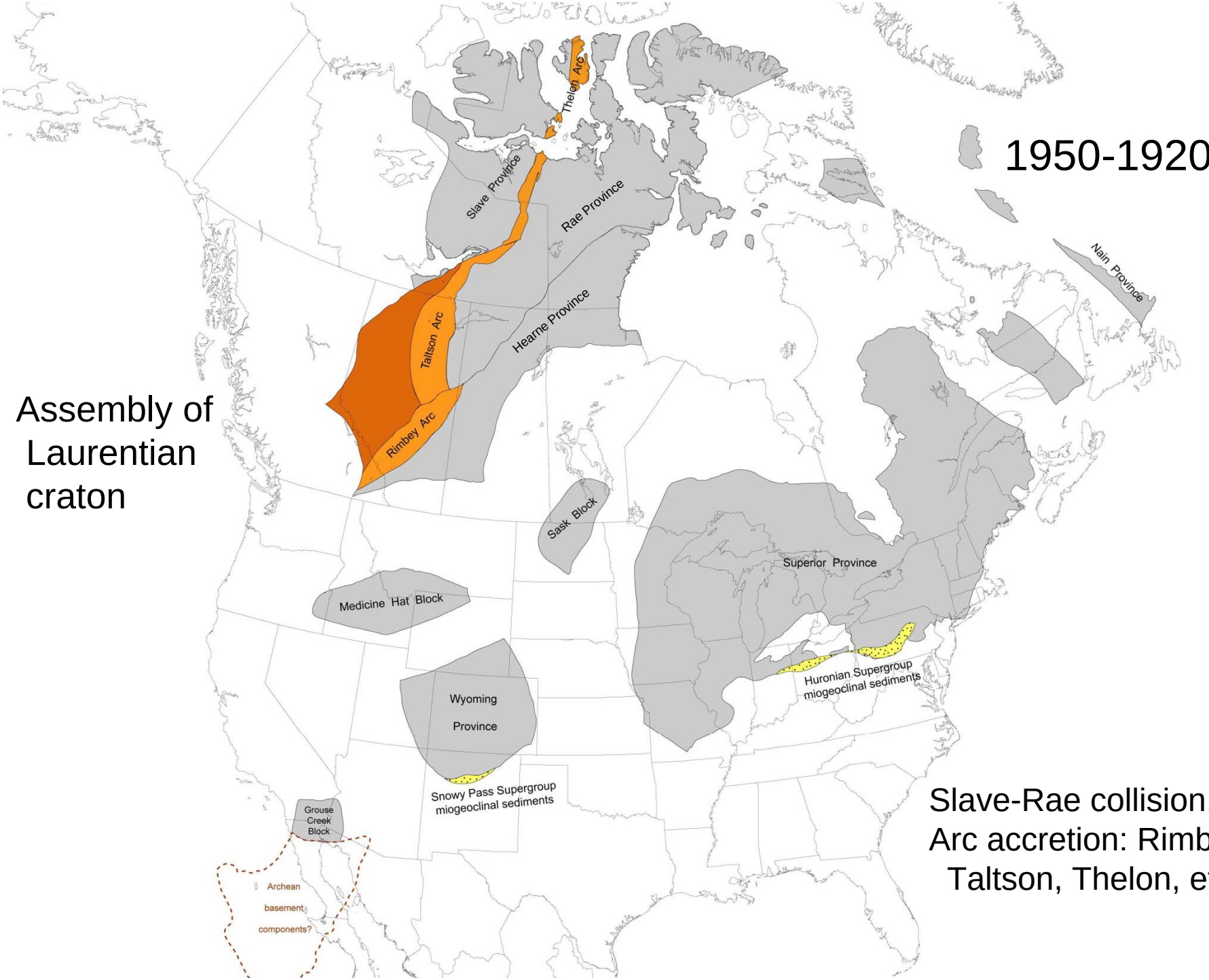
P 212

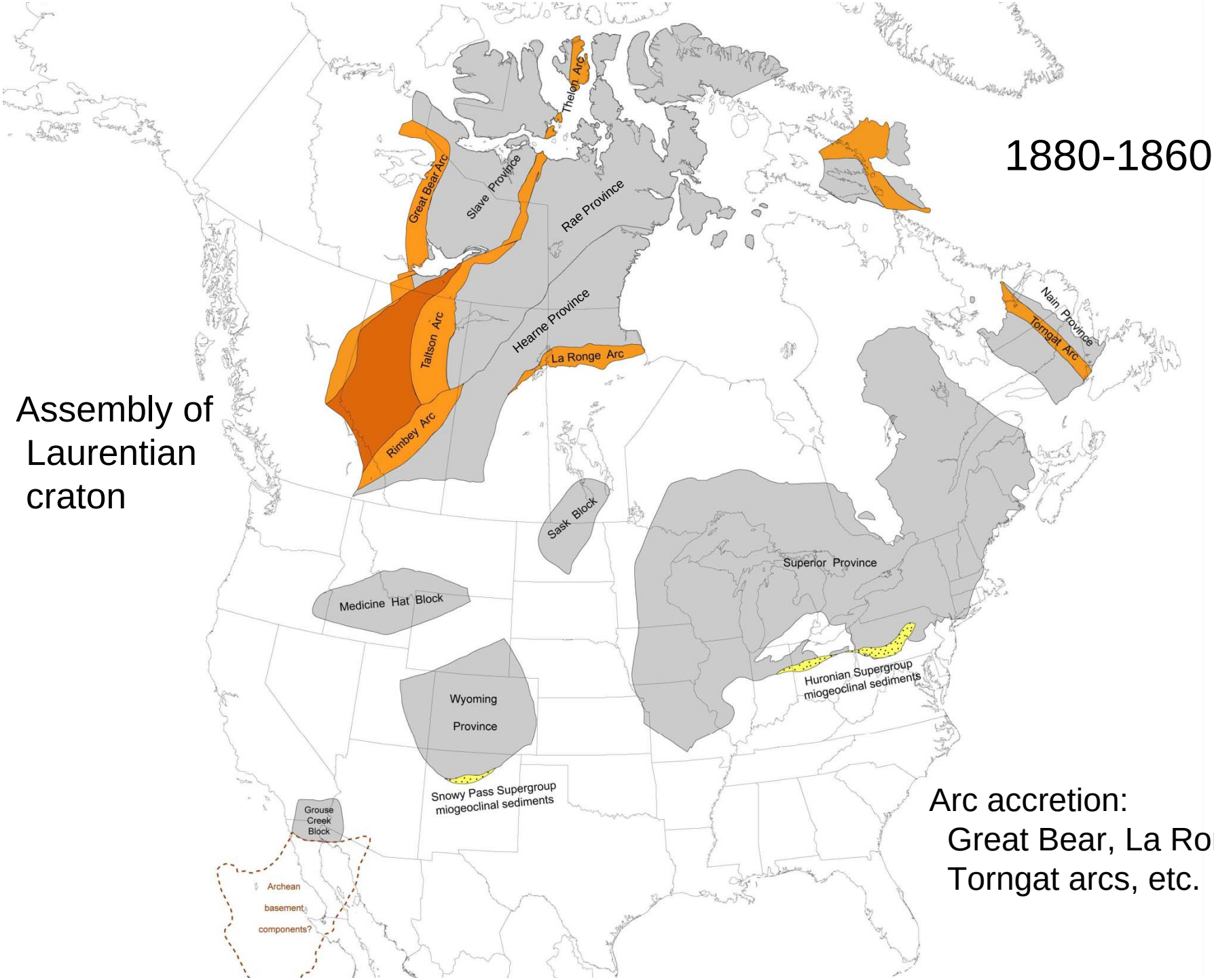
Archaean Micro Continents

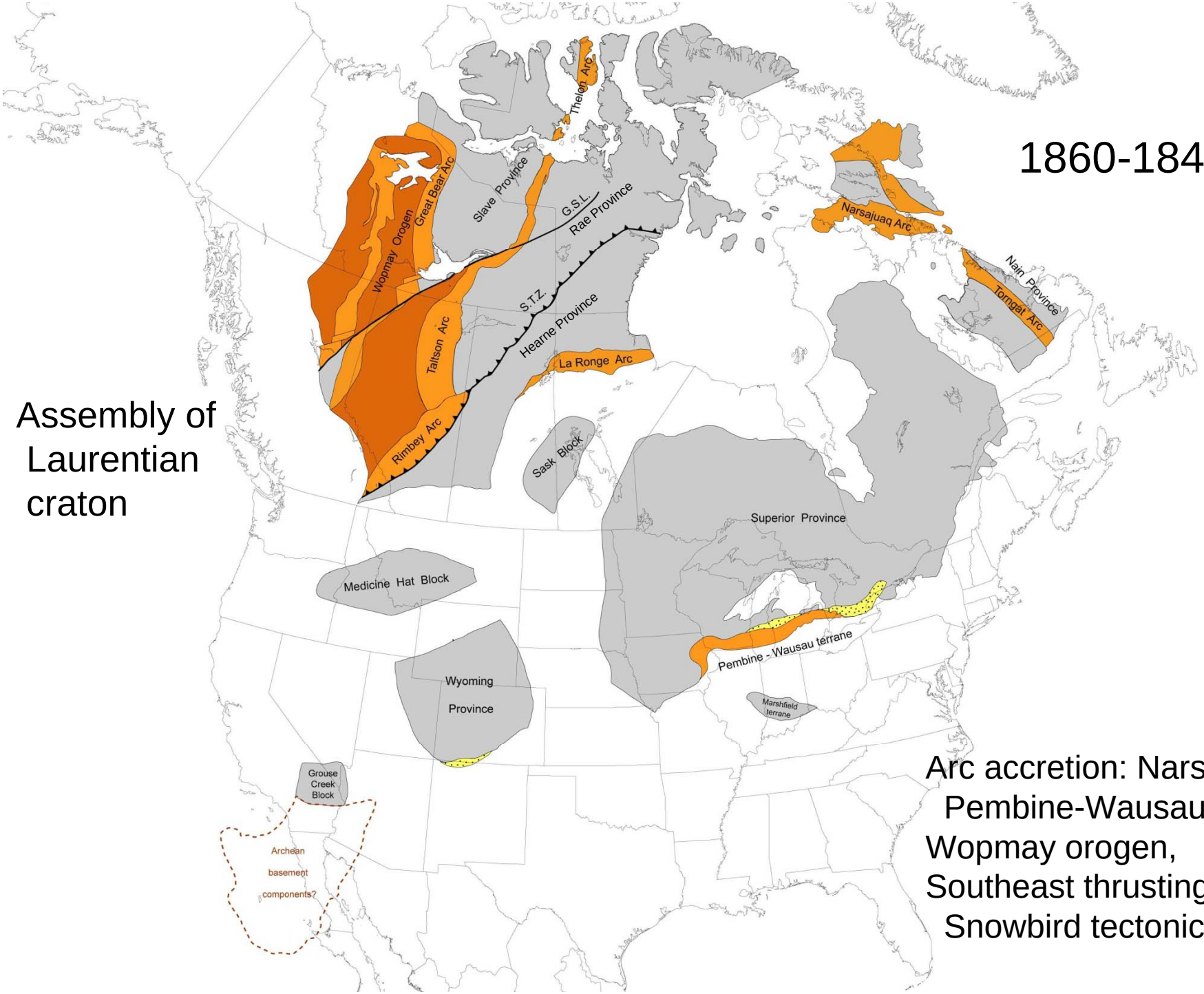
Proterozoic Later Additions




> 2000 Ma
Assembly of Laurentian craton
Slave Province
Rae Province
Hearne Province
Nain Province
Sask Block
Superior Province
Medicine Hat Block
Huronian Supergroup miogeoclinal sediments
Wyoming Province
Snowy Pass Supergroup miogeoclinal sediments
Grouse Creek Block
Archean basement components?
Archean cratons (positions unconstrained; Rae and Hearne in present-day locations)

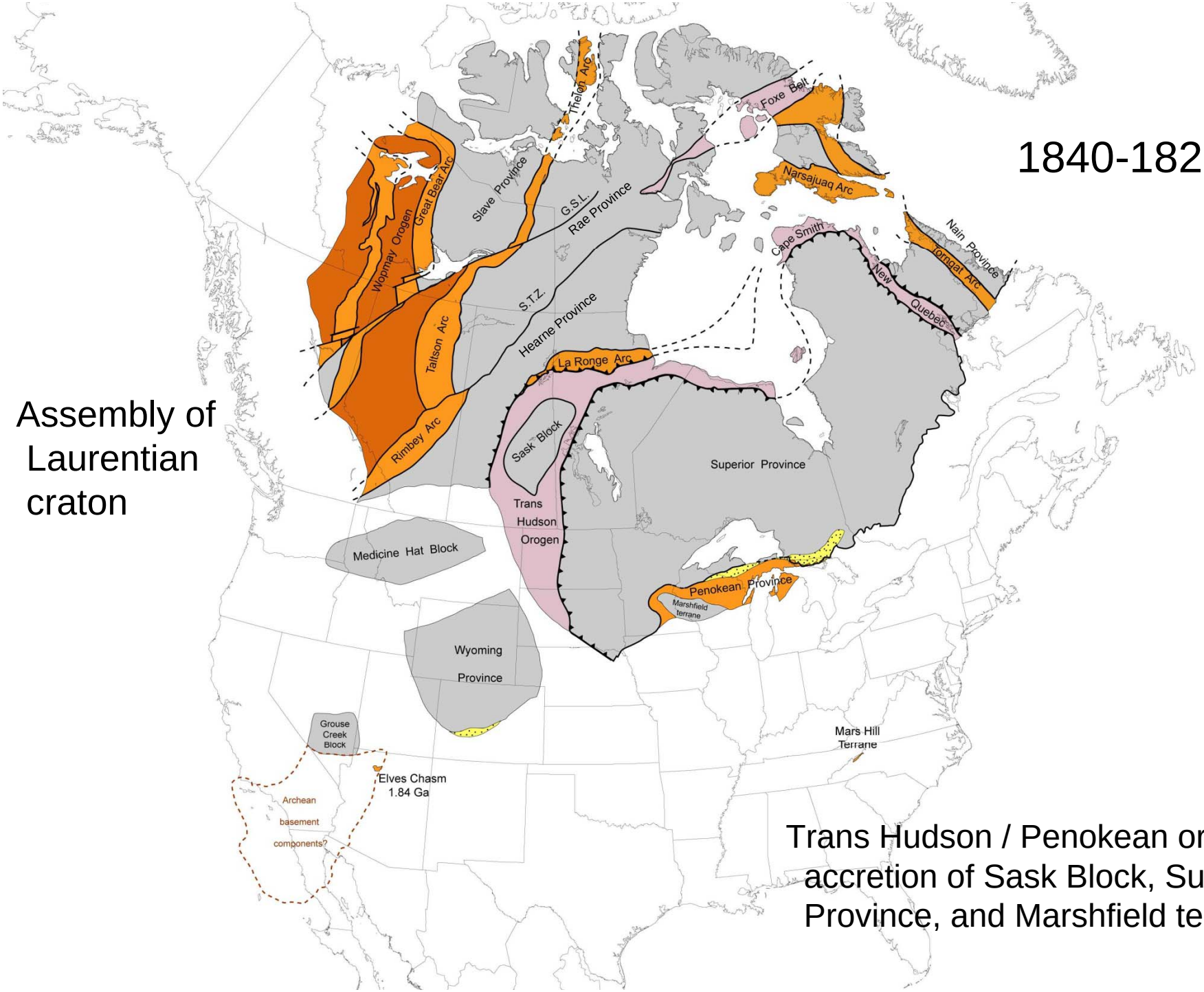

1950-1920 Ma
Assembly of Laurentian craton
Thelon Arc
Slave Province
Rae Province
Hearne Province
Tallson Arc
Rimbey Arc
Nain Province
Sask Block
Superior Province
Medicine Hat Block
Huronian Supergroup miogeoclinal sediments
Wyoming Province
Snowy Pass Supergroup miogeoclinal sediments
Grouse Creek Block
Archean basement components?
Slave-Rae collision,
Arc accretion: Rimbey,
Taltson, Thelon, etc.


1880-1860 Ma
Assembly of Laurentian craton
Thelon Arc
Great Bear Arc
Slave Province
Rae Province
Tallson Arc
Hearne Province
La Ronge Arc
Rimbey Arc
Nain Province
Torngat Arc
Sask Block
Superior Province
Medicine Hat Block
Huronian Supergroup miogeoclinal sediments
Wyoming Province
Snowy Pass Supergroup miogeoclinal sediments
Grouse Creek Block
Archean basement components?
Arc accretion:
Great Bear, La Ronge, Torngat arcs, etc.


1860-1840 Ma
Assembly of Laurentian craton
Thelon Arc
Slave Province
Great Bear Arc
Wopmay Orogen
G.S.L.
Rae Province
S.T.Z.
Hearne Province
Tallson Arc
Rimbey Arc
La Ronge Arc
Sask Block
Narsajuaq Arc
Nain Province
Torngat Arc
Superior Province
Medicine Hat Block
Pembine - Wausau terrane
Wyoming Province
Marshfield terrane
Grouse Creek Block
Archean basement components?
Arc accretion: Narsajuaq, Pembine-Wausau, etc.
Wopmay orogen, Southeast thrusting along Snowbird tectonic zone

1840-1820 Ma

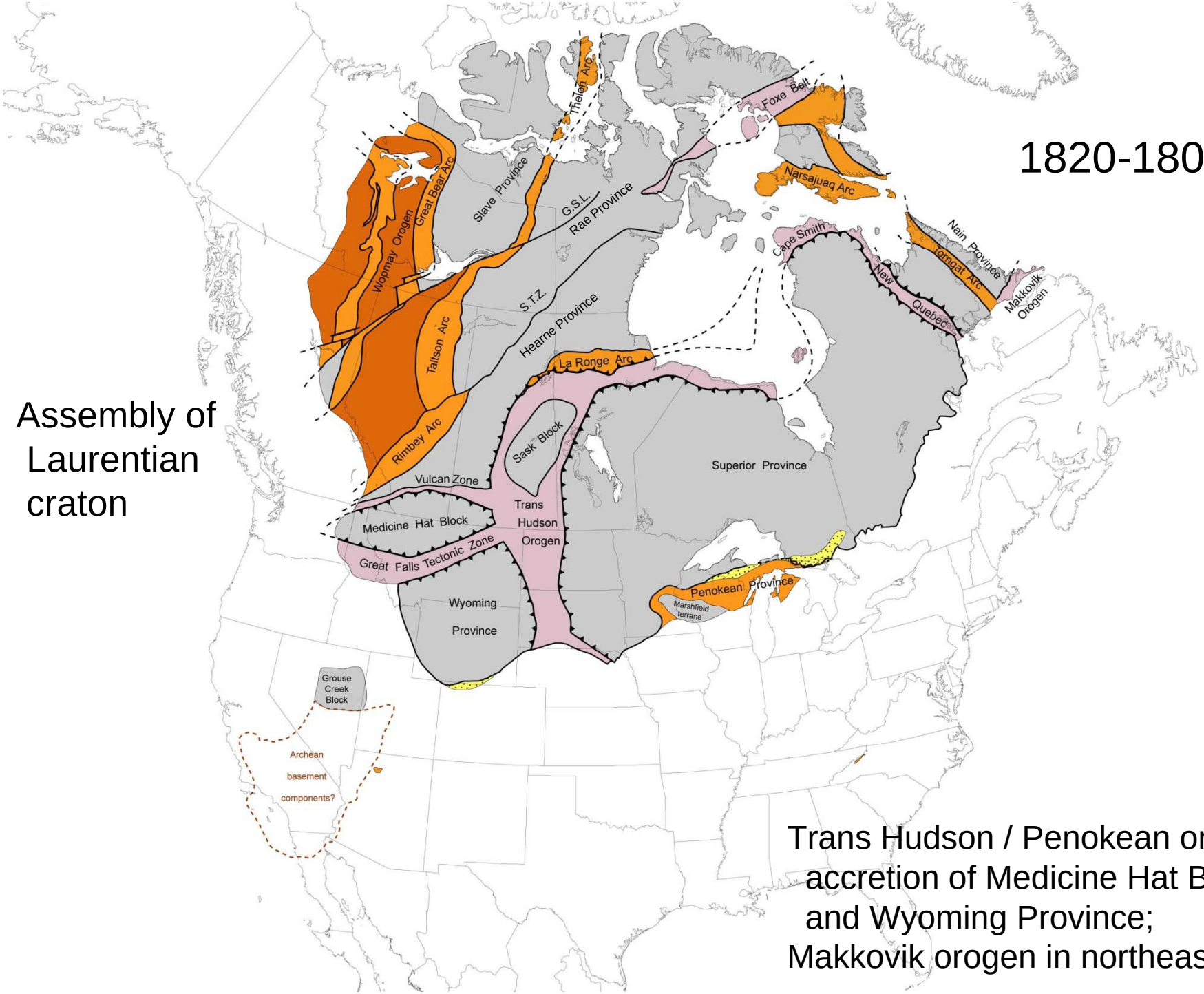
Assembly of Laurentian craton



Trans Hudson / Penokean orogens: accretion of Sask Block, Superior Province, and Marshfield terrane

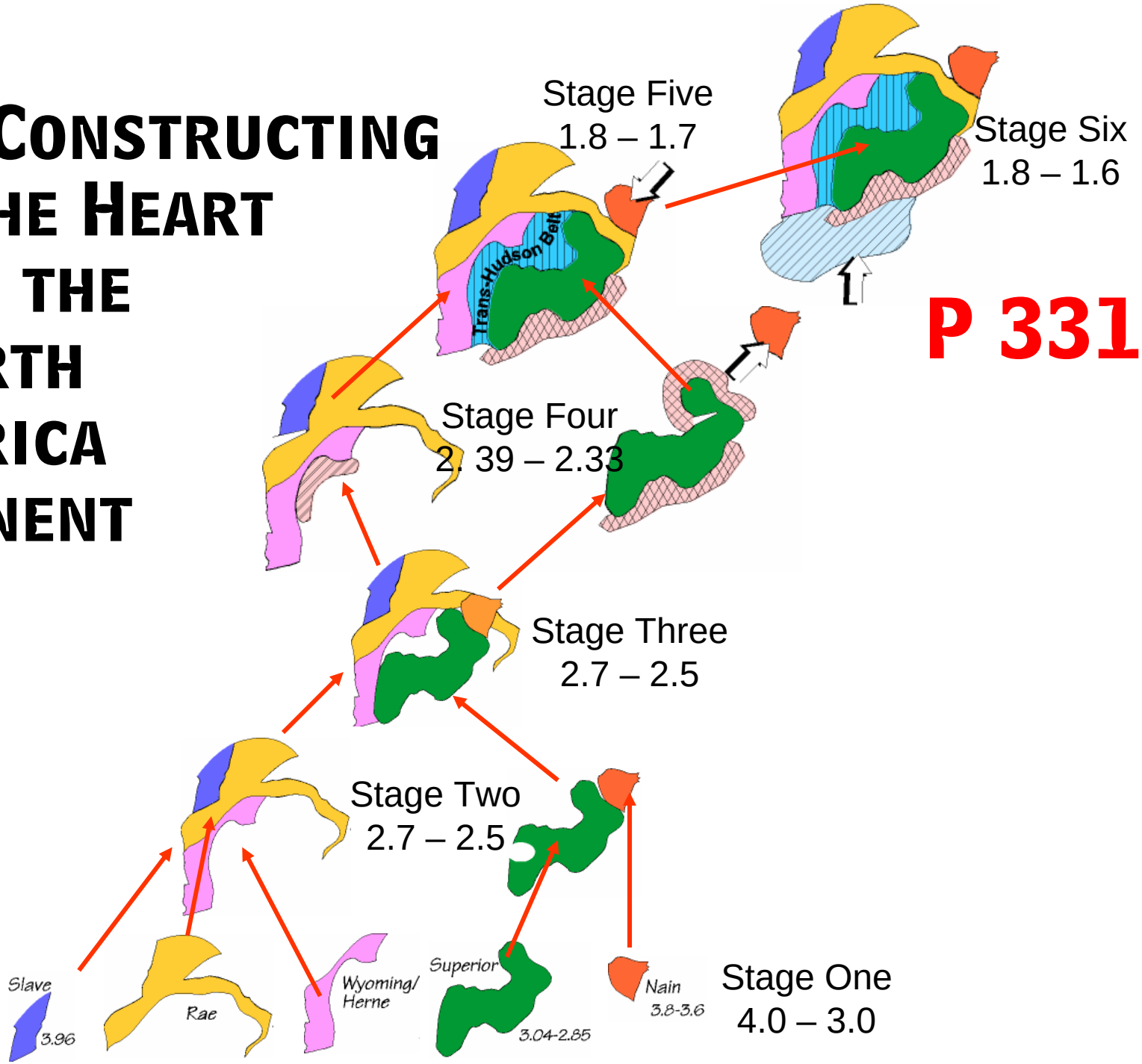
1820-1800 Ma

Assembly of Laurentian craton



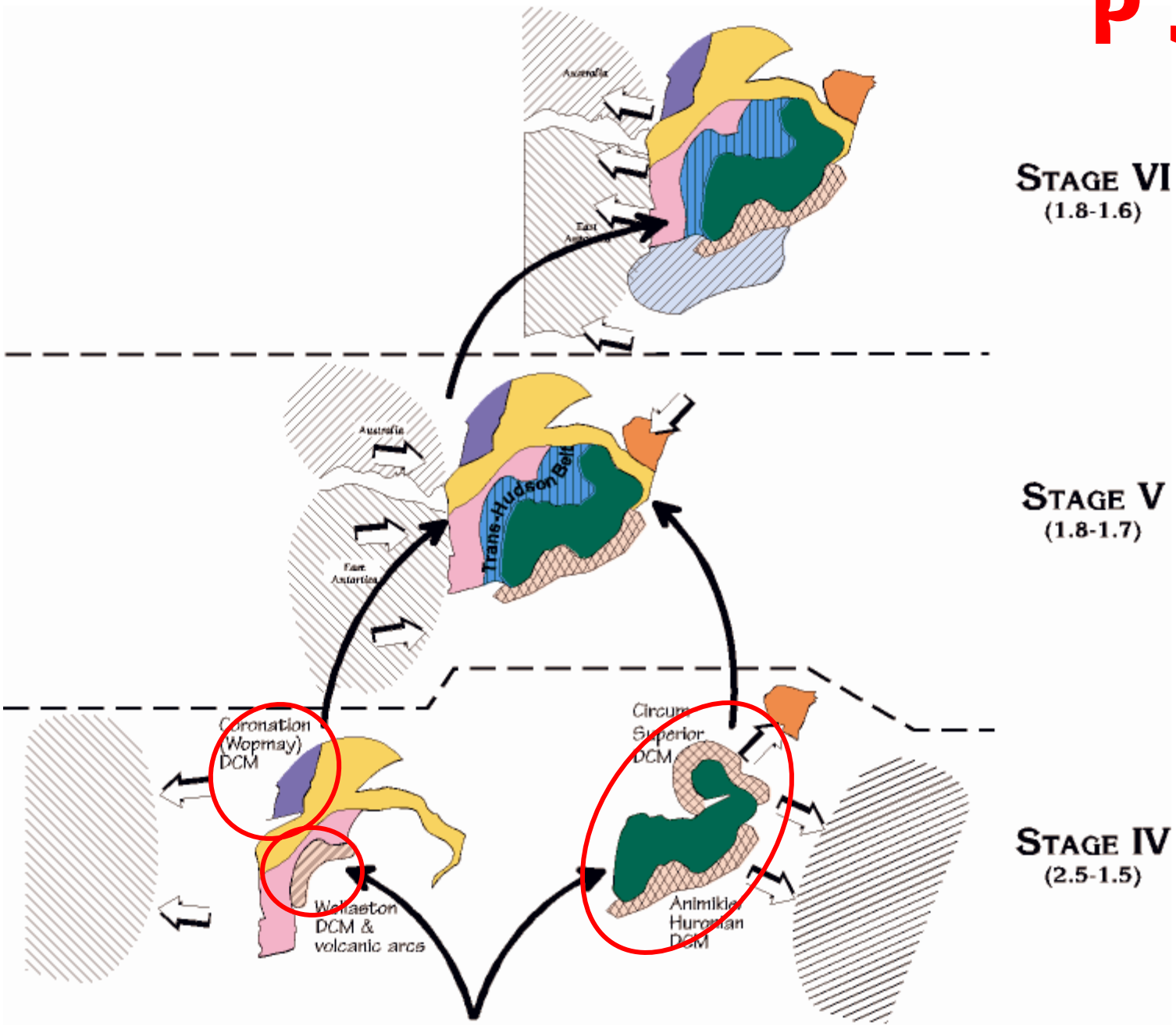
Trans Hudson / Penokean orogens: accretion of Medicine Hat Block, and Wyoming Province; Makkovik orogen in northeast

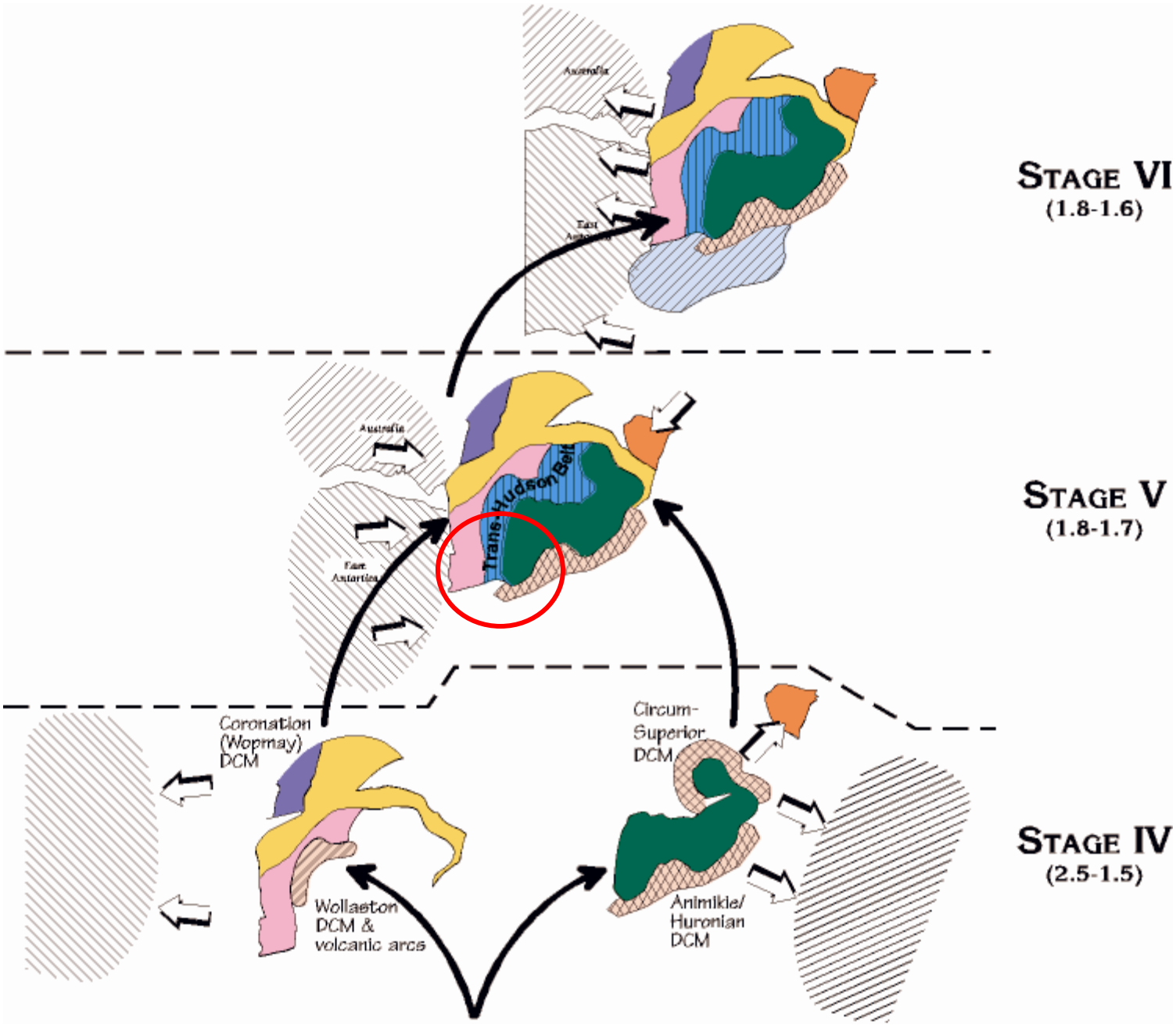
Constructing The Heart Of the North America Continent

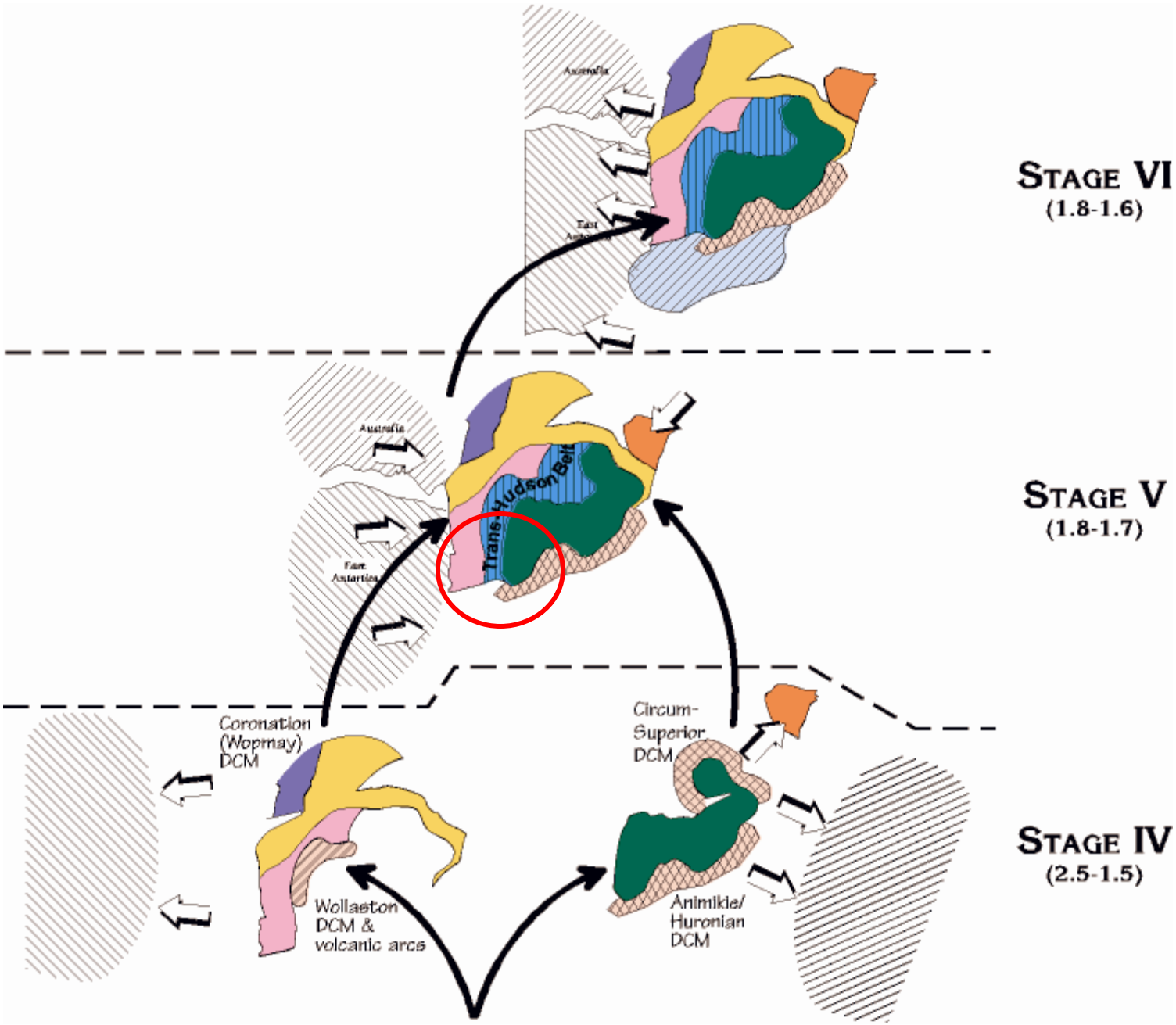


P 331

P 331


Australia
East Antarctica
Trans-Hudson Belt
Coronation (Wopmay) DCM
Circum Superior DCM
Wollaston DCM & volcanic arcs
Animikie Huronian DCM
STAGE VI
(1.8-1.6)
STAGE V
(1.8-1.7)
STAGE IV
(2.5-1.5)


Australia
East Antarctica
Trans-Hudson Belt
Australia
East Antarctica
Coronation (Wopmay) DCM
Wollaston DCM & volcanic arcs
Circum-Superior DCM
Animikie/ Huronian DCM
STAGE VI
(1.8-1.6)
STAGE V
(1.8-1.7)
STAGE IV
(2.5-1.5)

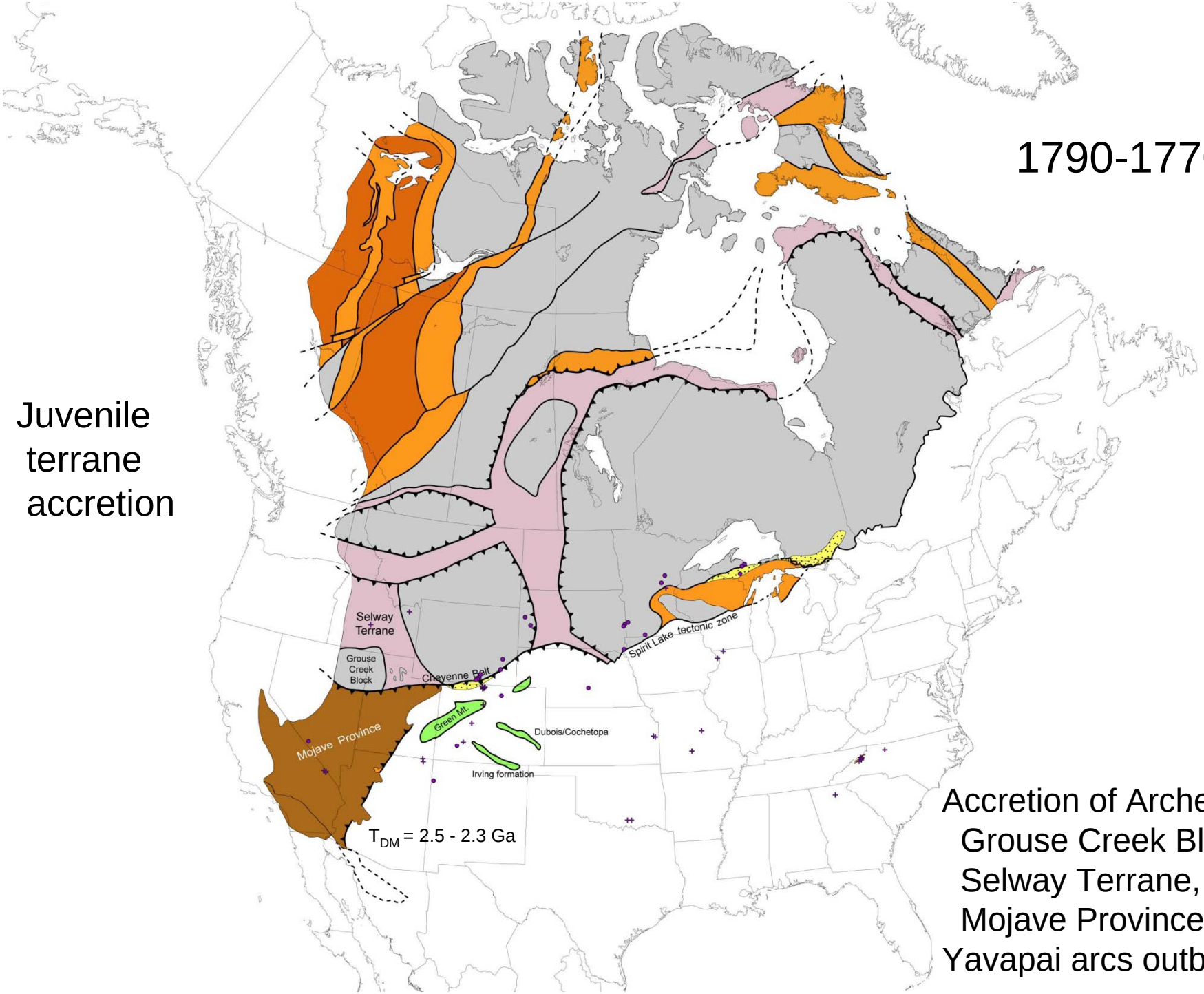

Australia
East Antarctica
Trans-Hudson Belt
Australia
East Antarctica
Coronation (Wopmay) DCM
Wollaston DCM & volcanic arcs
Circum-Superior DCM
Animikie/ Huronian DCM
STAGE VI
(1.8-1.6)
STAGE V
(1.8-1.7)
STAGE IV
(2.5-1.5)

Proterozoic Growth of the North American Continent

Second Phase: Adding the Central United States

1790-1770 Ma

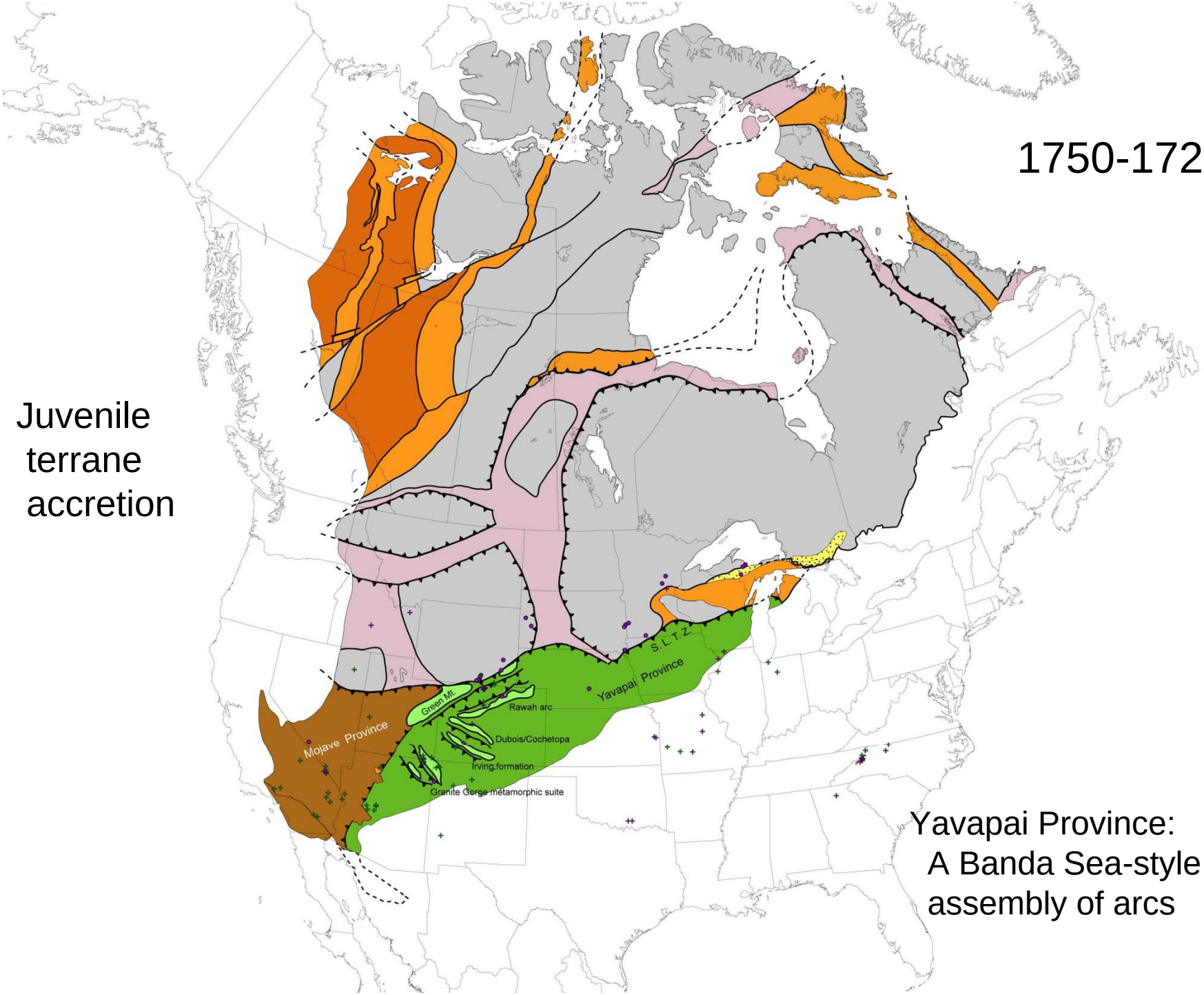
Juvenile terrane accretion



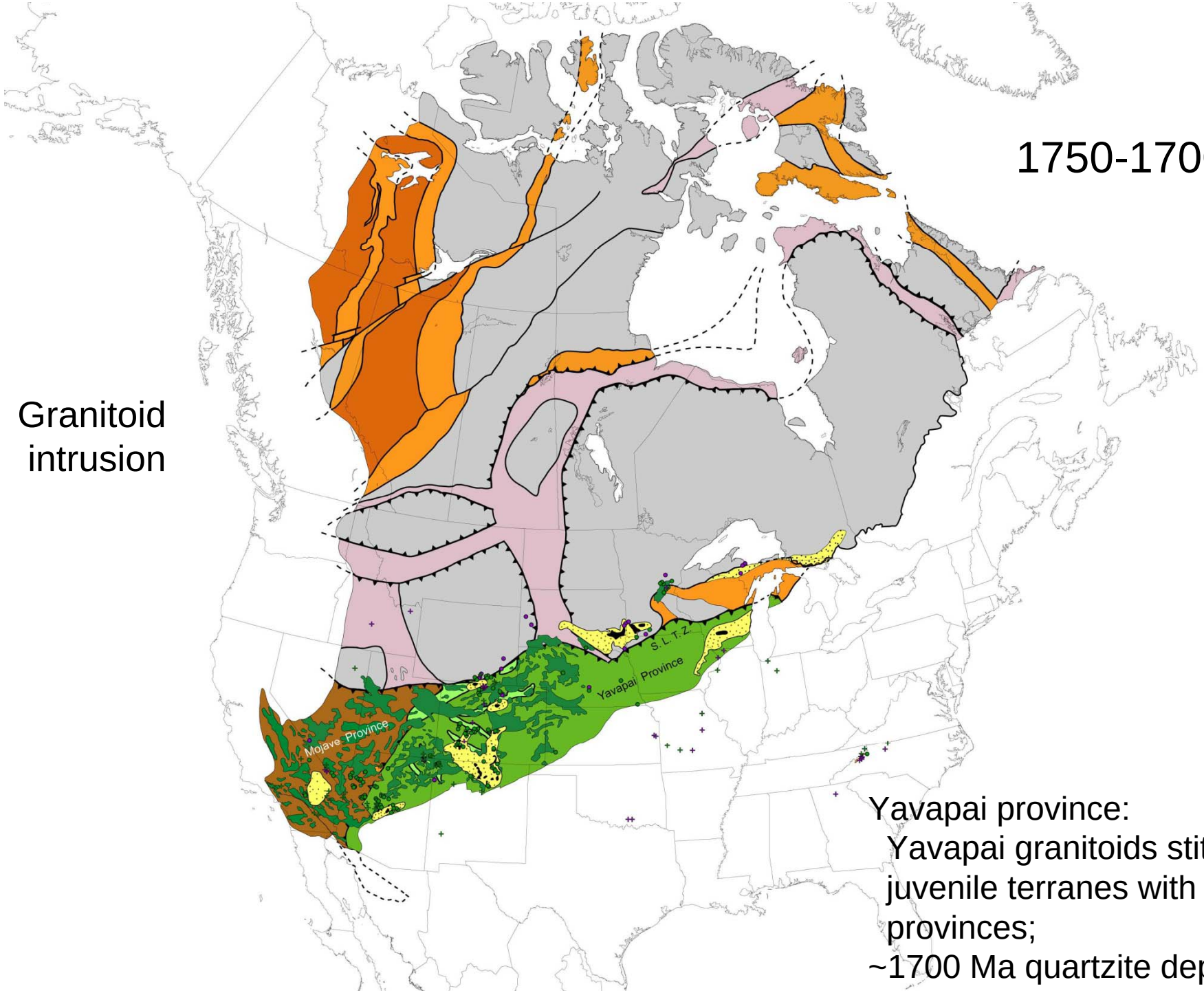
Accretion of Archean Grouse Creek Block, Selway Terrane, and Mojave Province; Yavapai arcs outboard

1750-1720 Ma

Juvenile terrane accretion



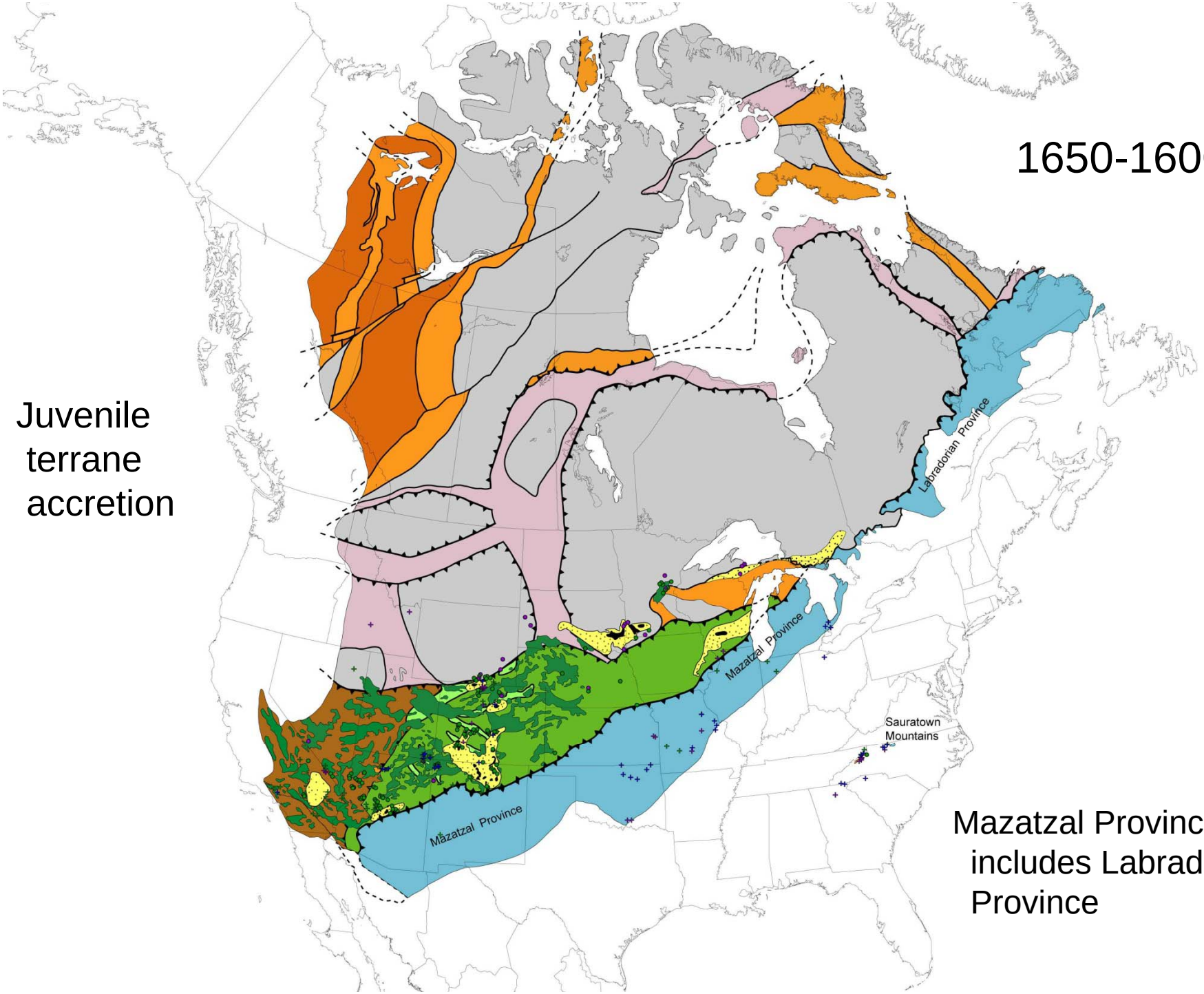
Yavapai Province:
A Banda Sea-style assembly of arcs



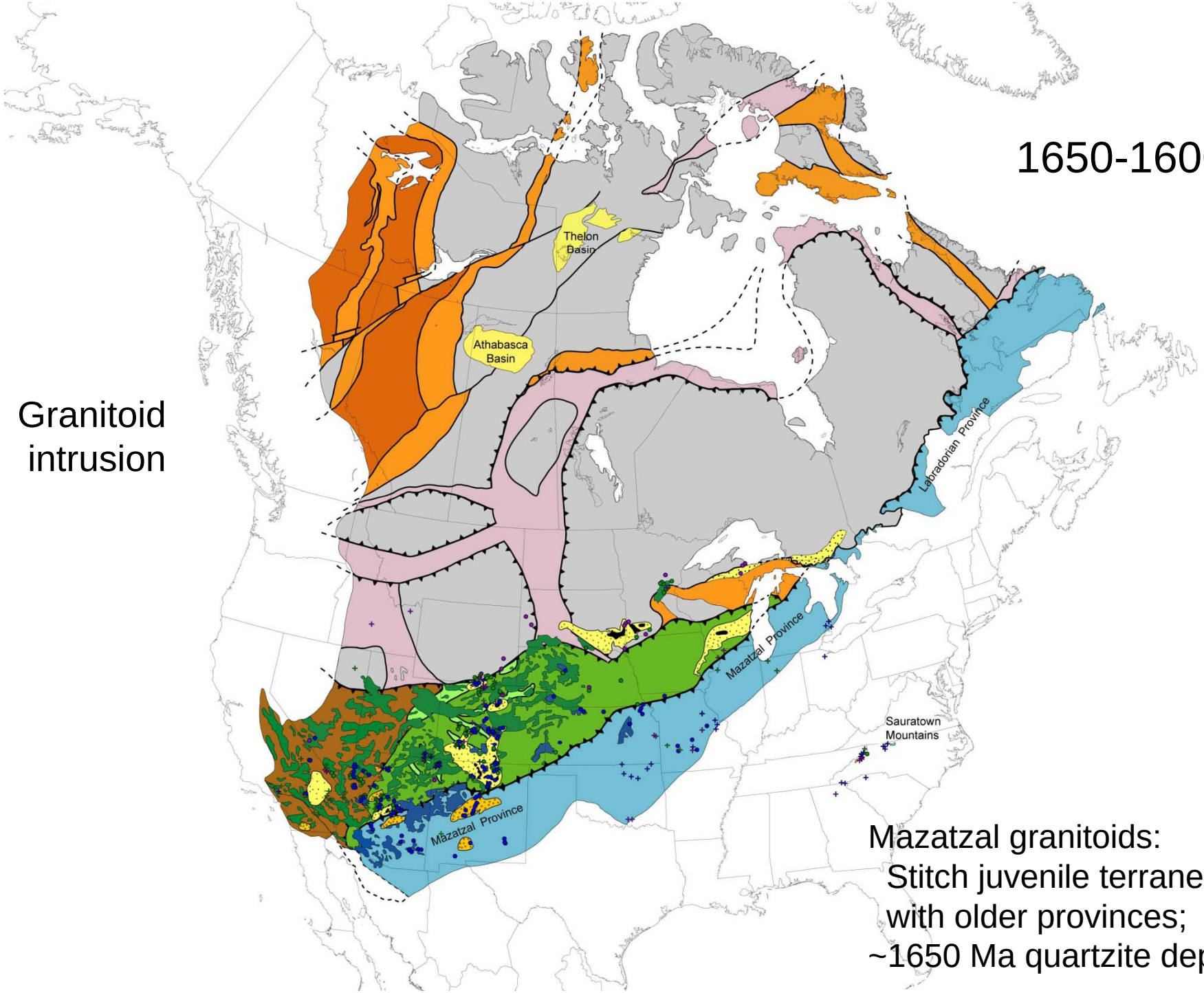
Yavapai province:
Yavapai granitoids stitch juvenile terranes with older provinces;
~1700 Ma quartzite deposition

1650-1600 Ma

Juvenile terrane accretion

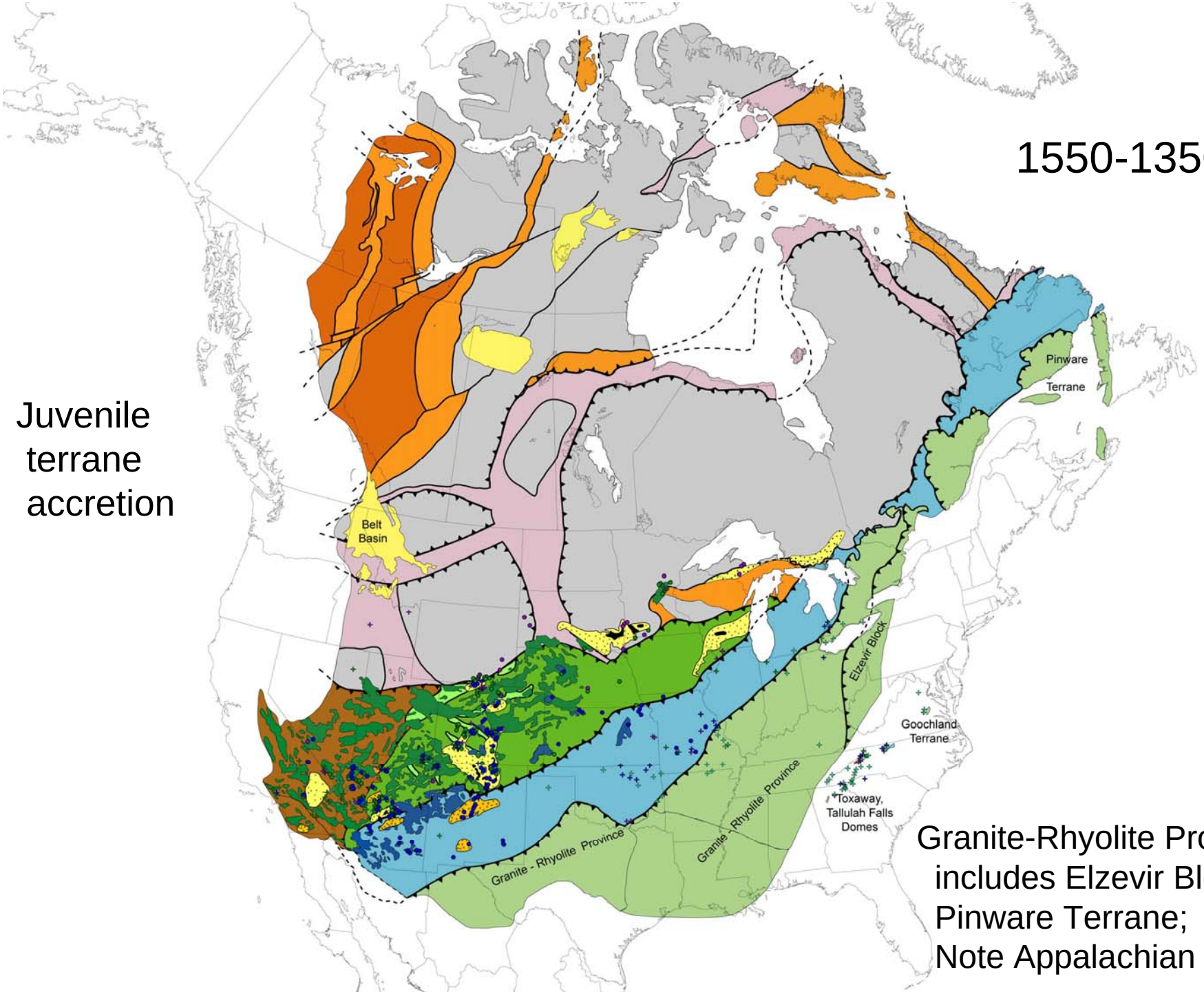


Mazatzal Province: includes Labradorian Province


1650-1600 Ma
Granitoid intrusion
Thelon Basin
Athabasca Basin
Labradorian Province
Mazatzal Province
Sauratown Mountains
Mazatzal Province
Mazatzal granitoids:
Stitch juvenile terranes
with older provinces;
~1650 Ma quartzite deposition

1550-1350 Ma

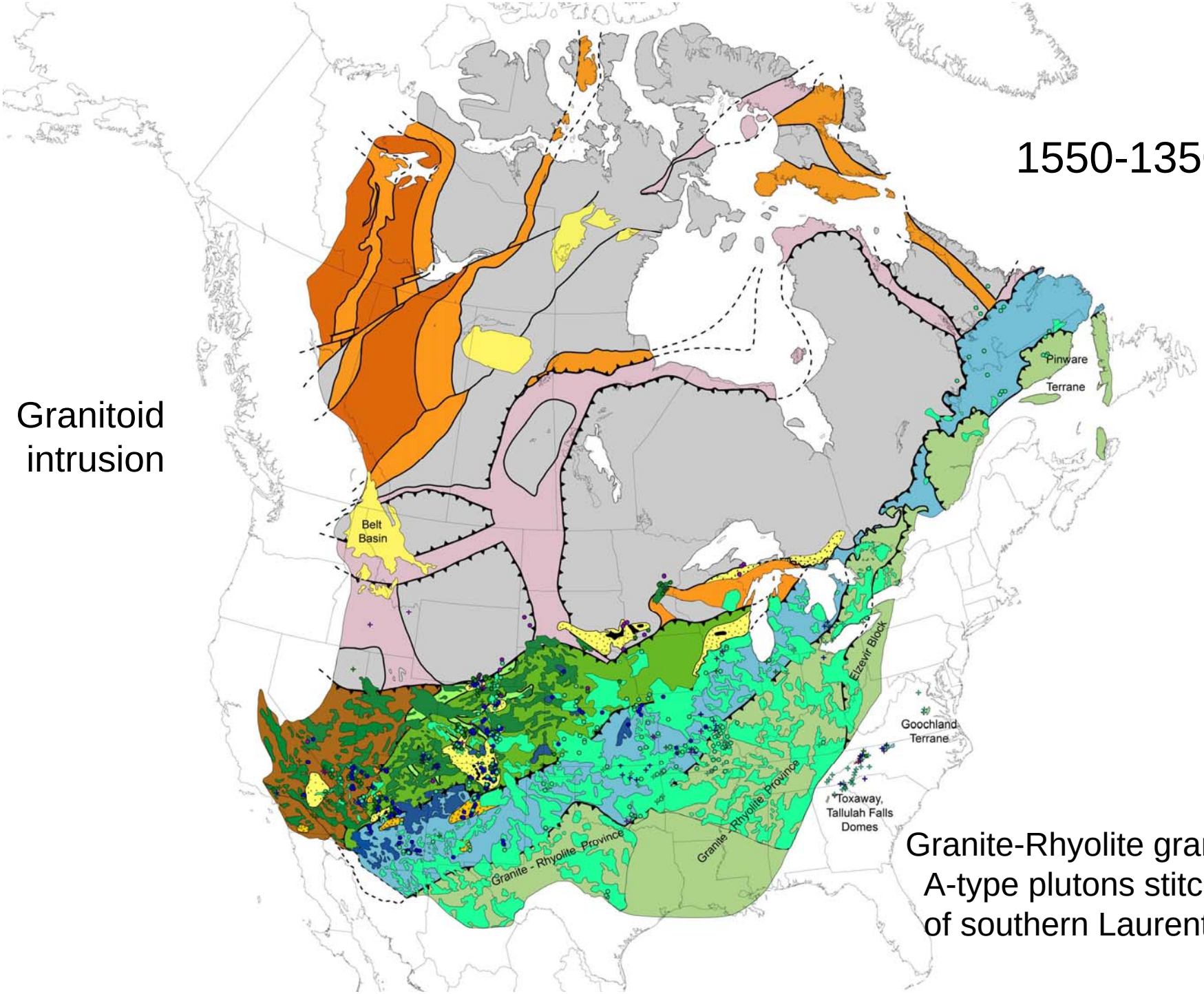
Juvenile terrane accretion



Granite-Rhyolite Province: includes Elzevir Block & Pinware Terrane; Note Appalachian outliers

1550-1350 Ma

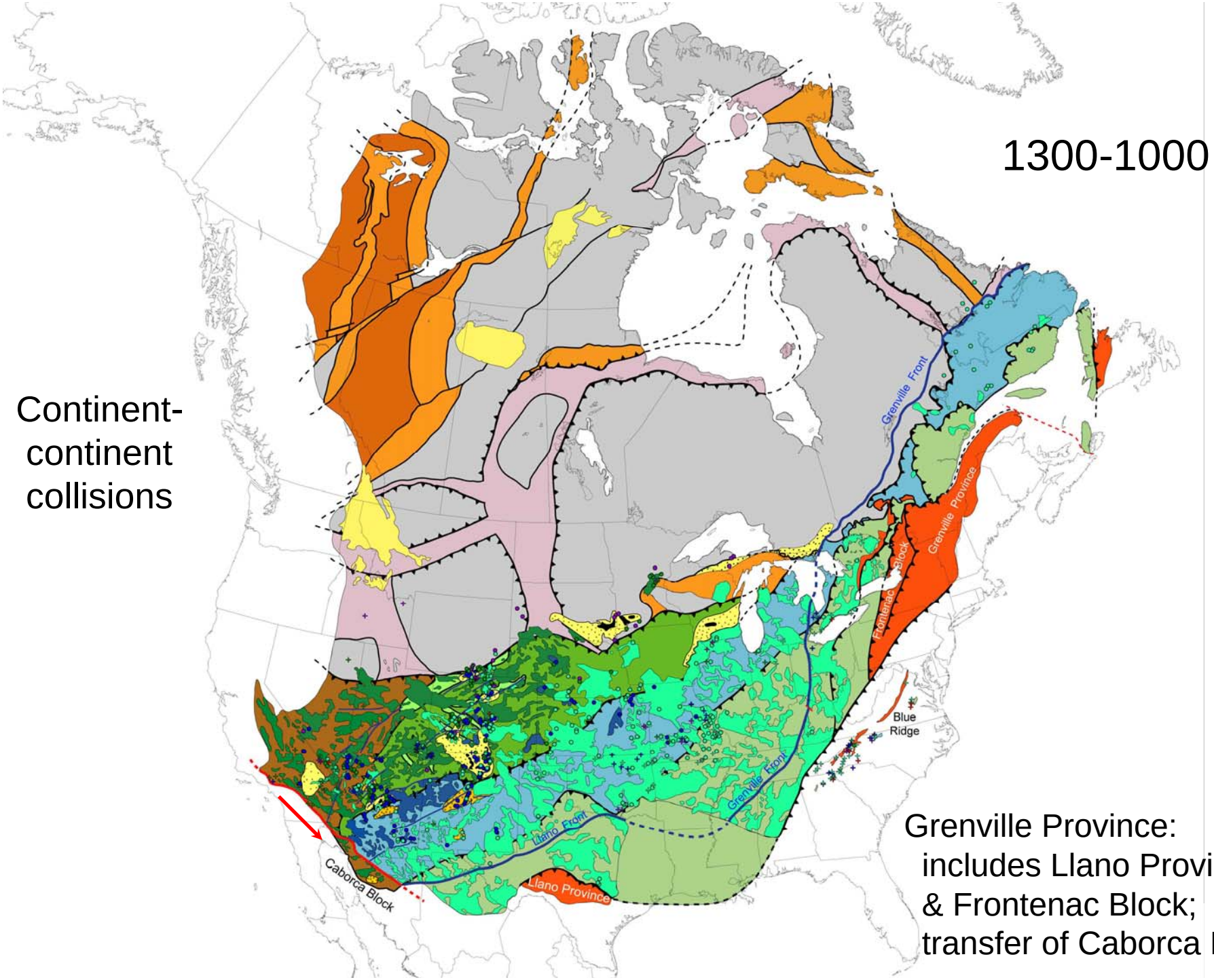
Granitoid intrusion



Granite-Rhyolite granitoids:
A-type plutons stitch much of southern Laurentia

1300-1000 Ma

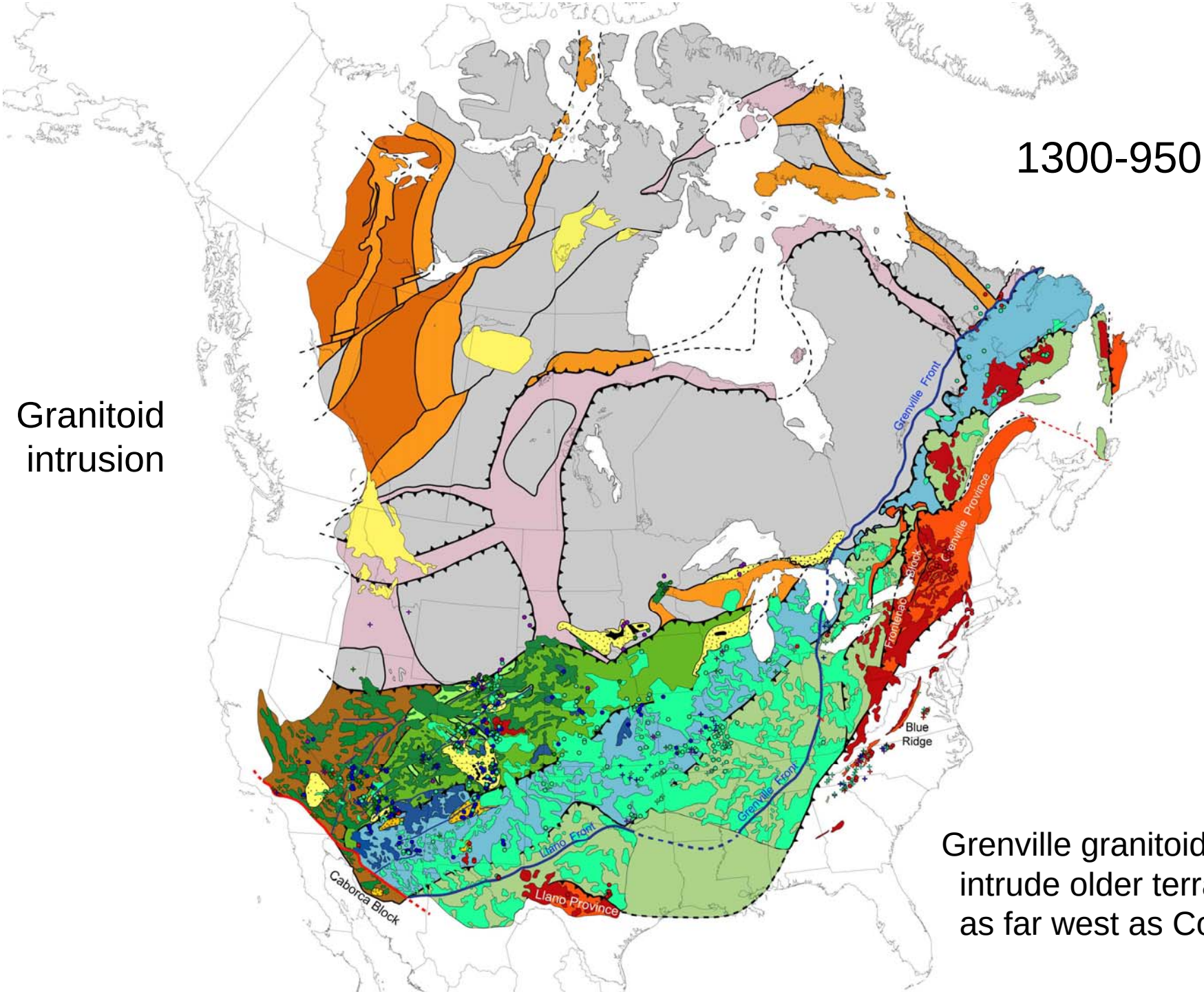
Continent-continent collisions



Grenville Province:
includes Llano Province
& Frontenac Block;
transfer of Caborca Block

1300-950 Ma

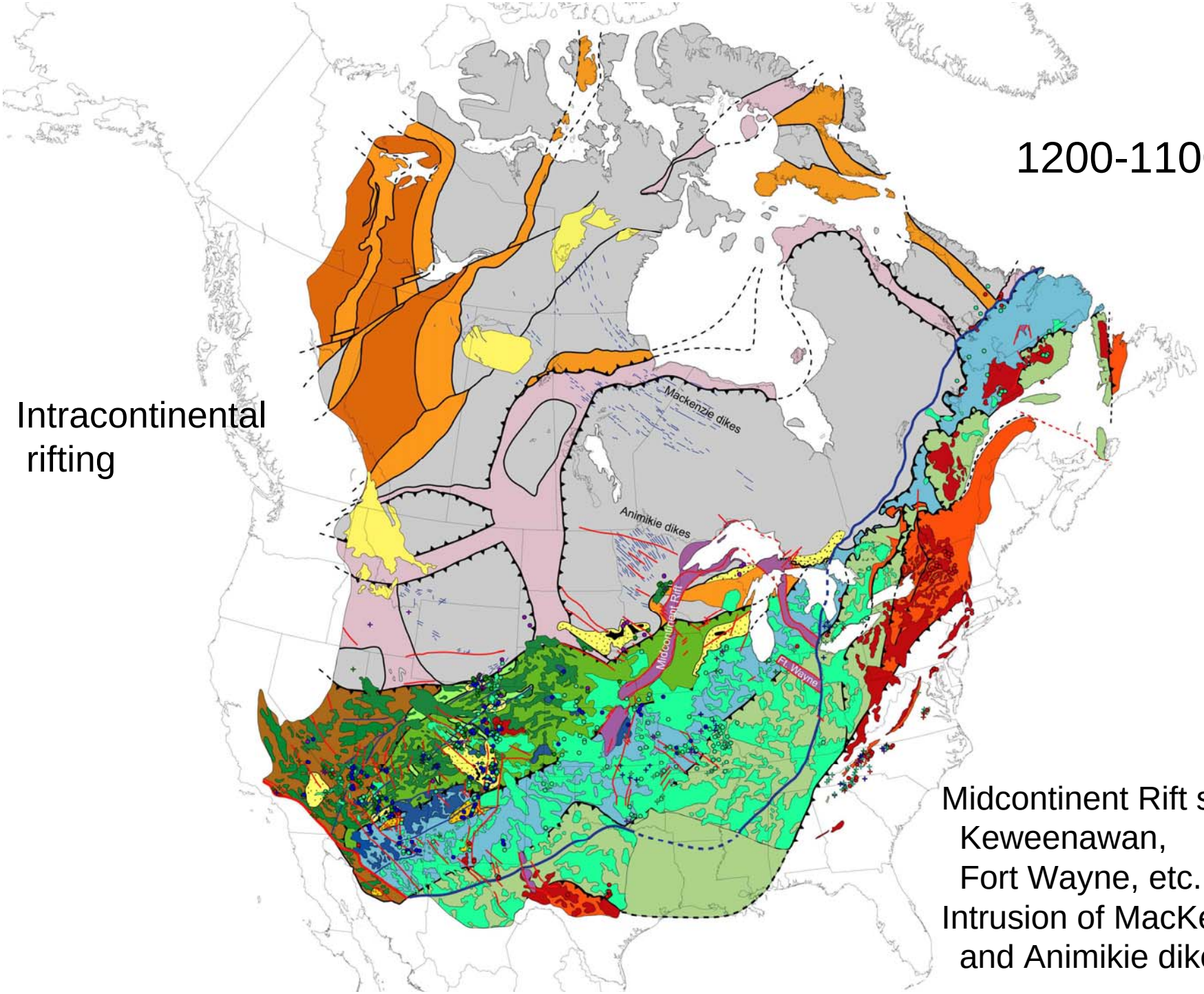
Granitoid intrusion



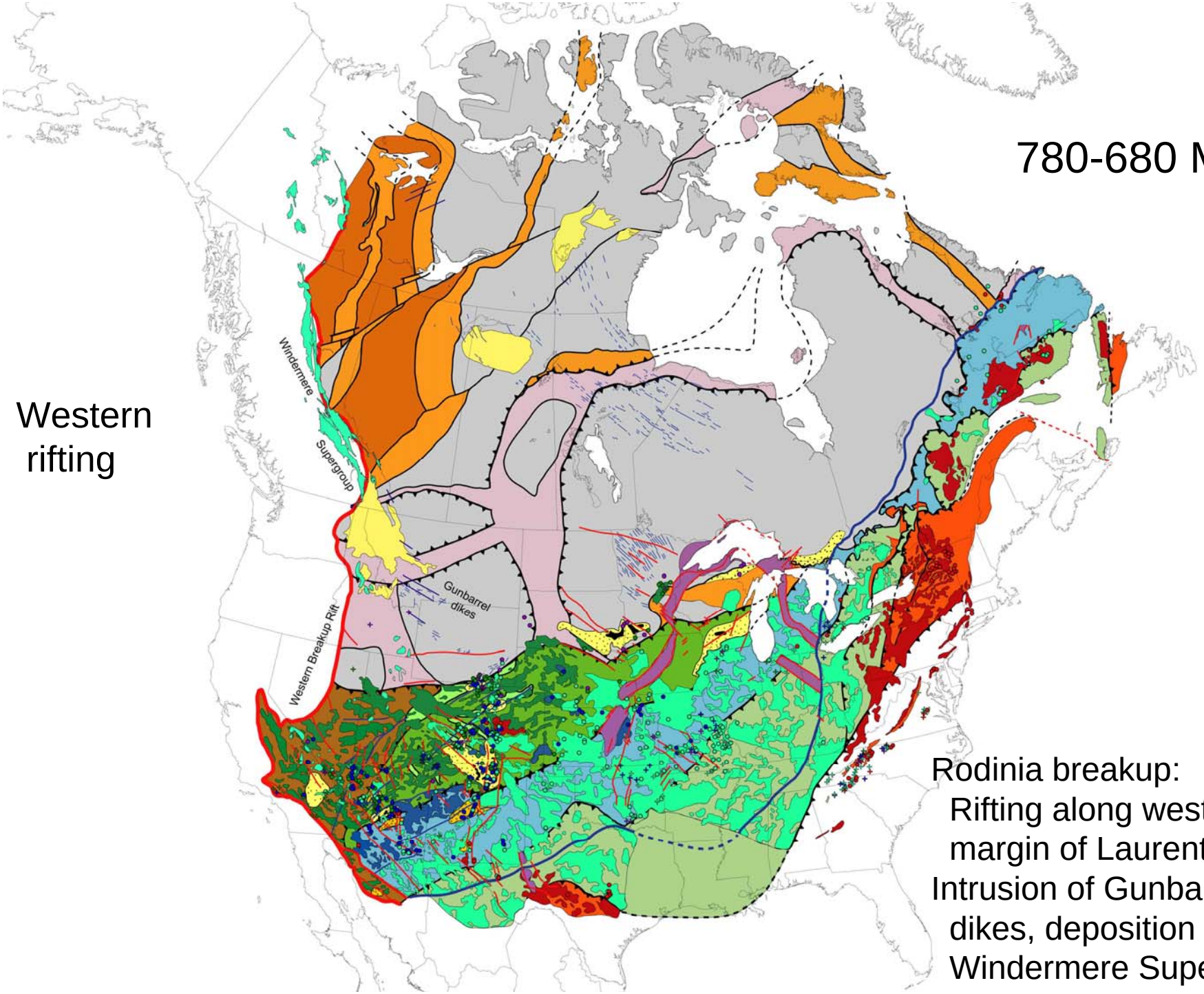
Grenville granitoids:
intrude older terranes
as far west as Colorado

1200-1100 Ma

Intracontinental rifting

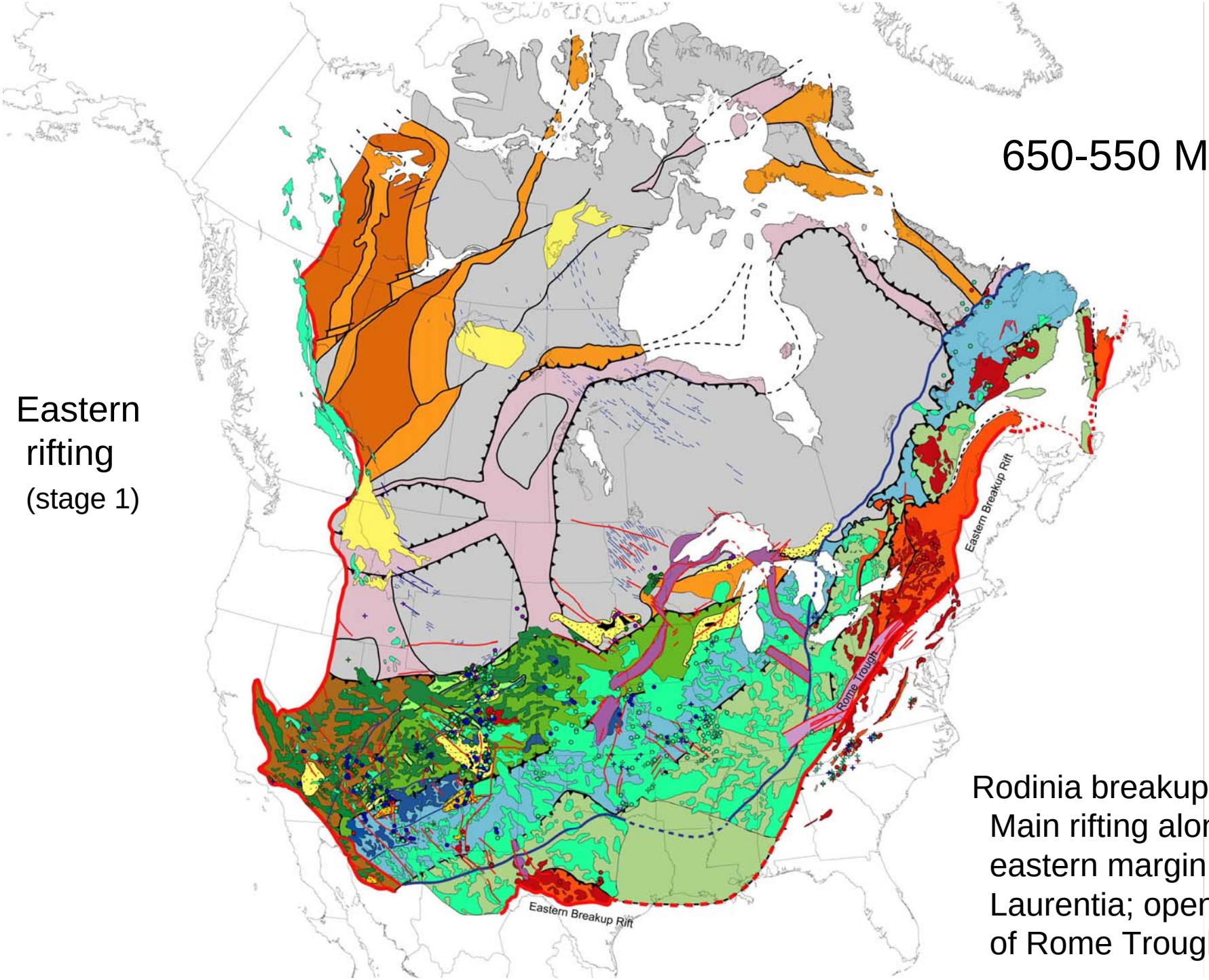


Midcontinent Rift system:
Keweenawan,
Fort Wayne, etc.;
Intrusion of MacKenzie and Animikie dikes


780-680 Ma
Western rifting
Windermere Supergroup
Gunbarrel dikes
Western Breakup Rift
Rodinia breakup:
Rifting along western margin of Laurentia;
Intrusion of Gunbarrel dikes, deposition of Windermere Supergroup

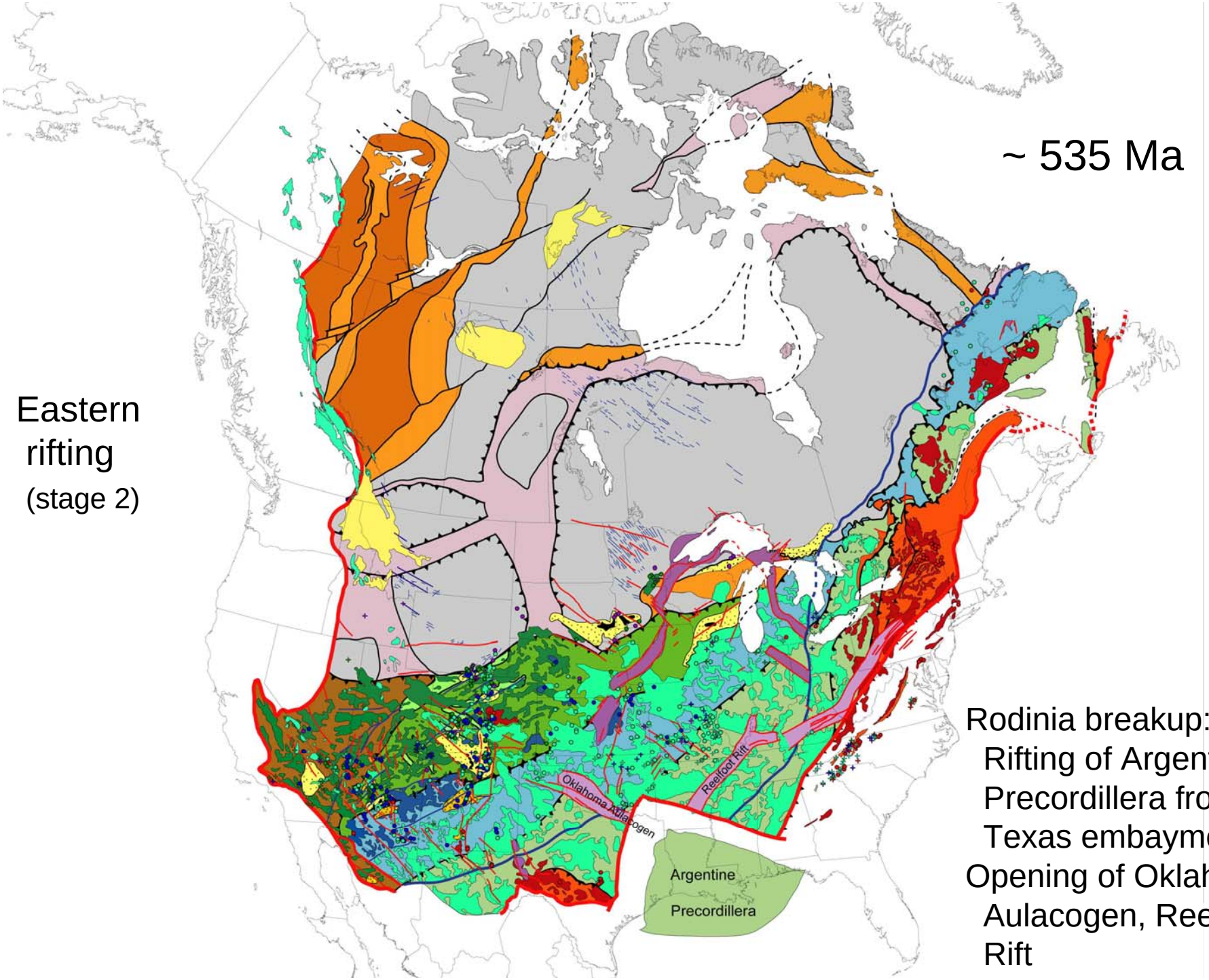
650-550 Ma

Eastern rifting (stage 1)



Rodinia breakup: Main rifting along eastern margin of Laurentia; opening of Rome Trough

Eastern rifting
(stage 2)



Rodinia breakup:
Rifting of Argentine Precordillera from Texas embayment;
Opening of Oklahoma Aulacogen, Reelfoot Rift

But, none of this is happening in isolation . . .