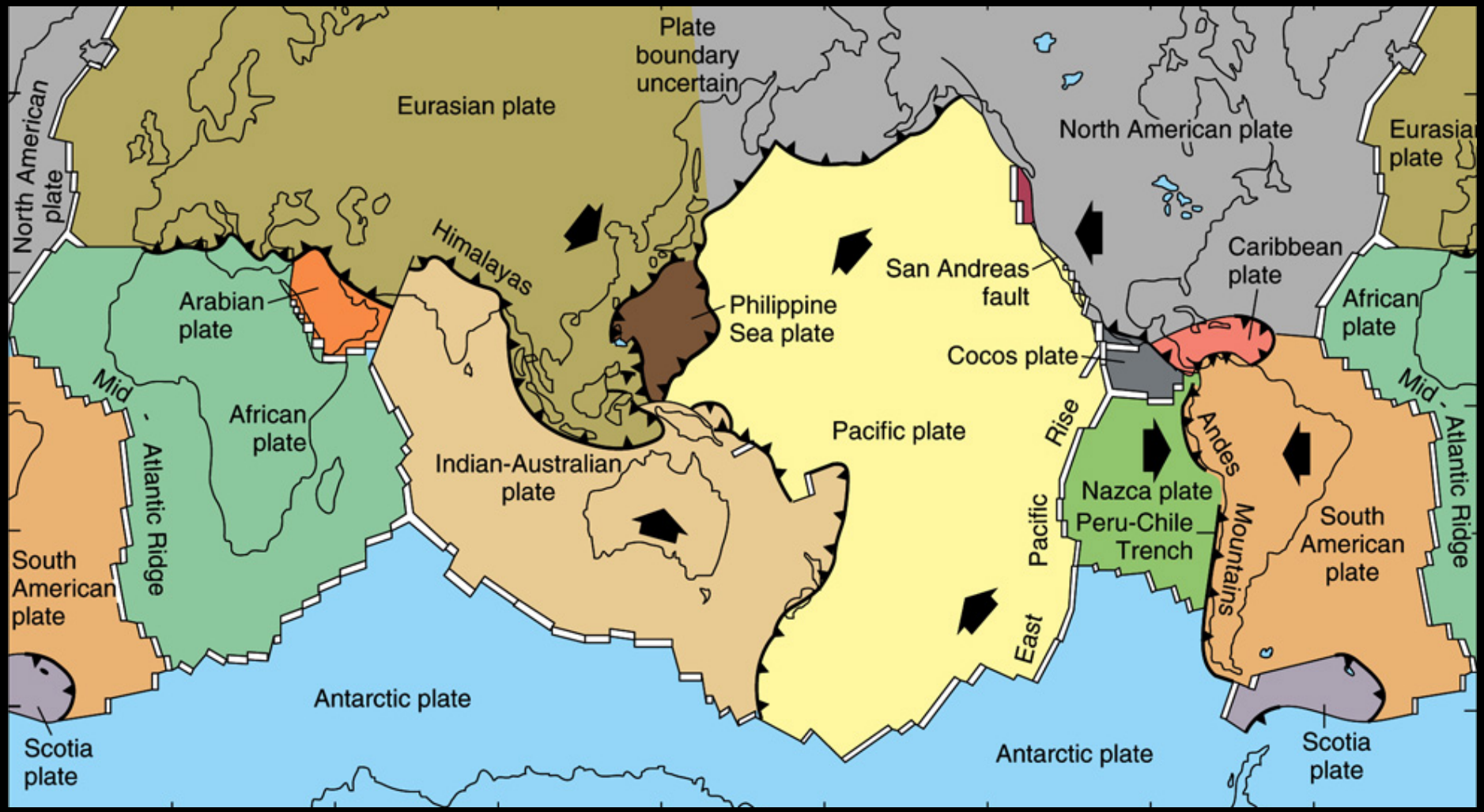
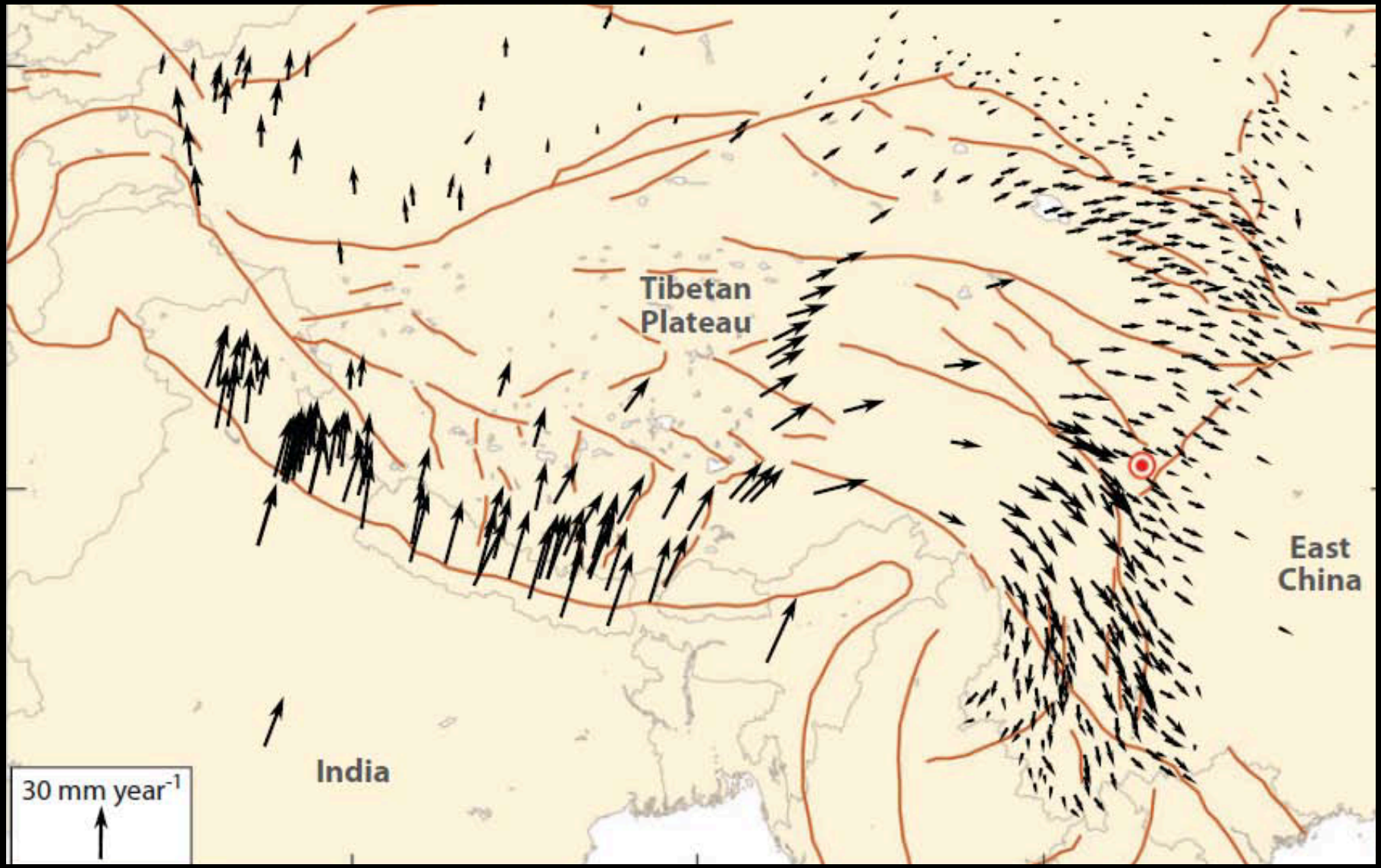
La dynamique interne de la Terre et ses conséquences de surface

La tectonique des plaques

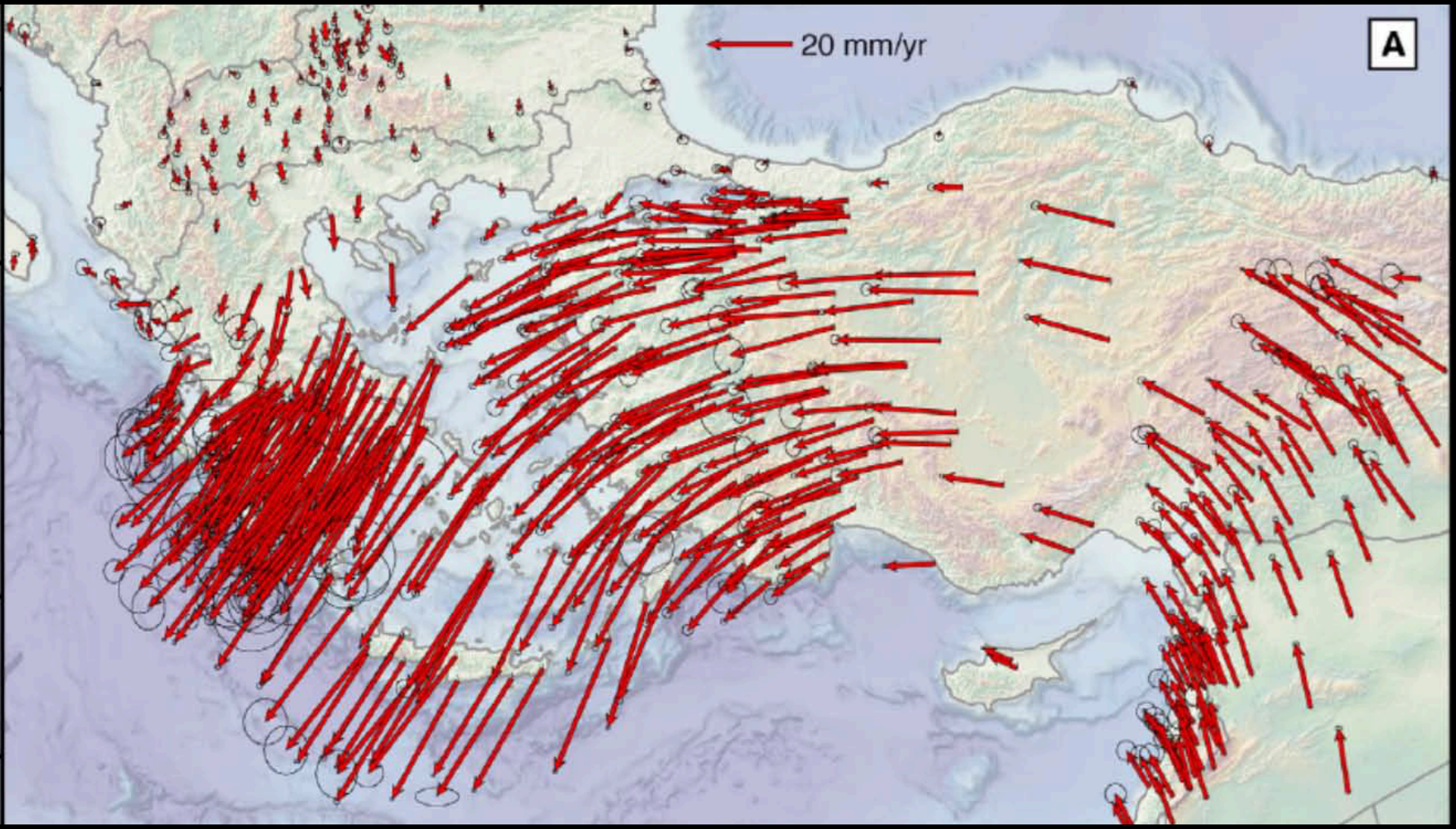


Les vitesses de déplacement

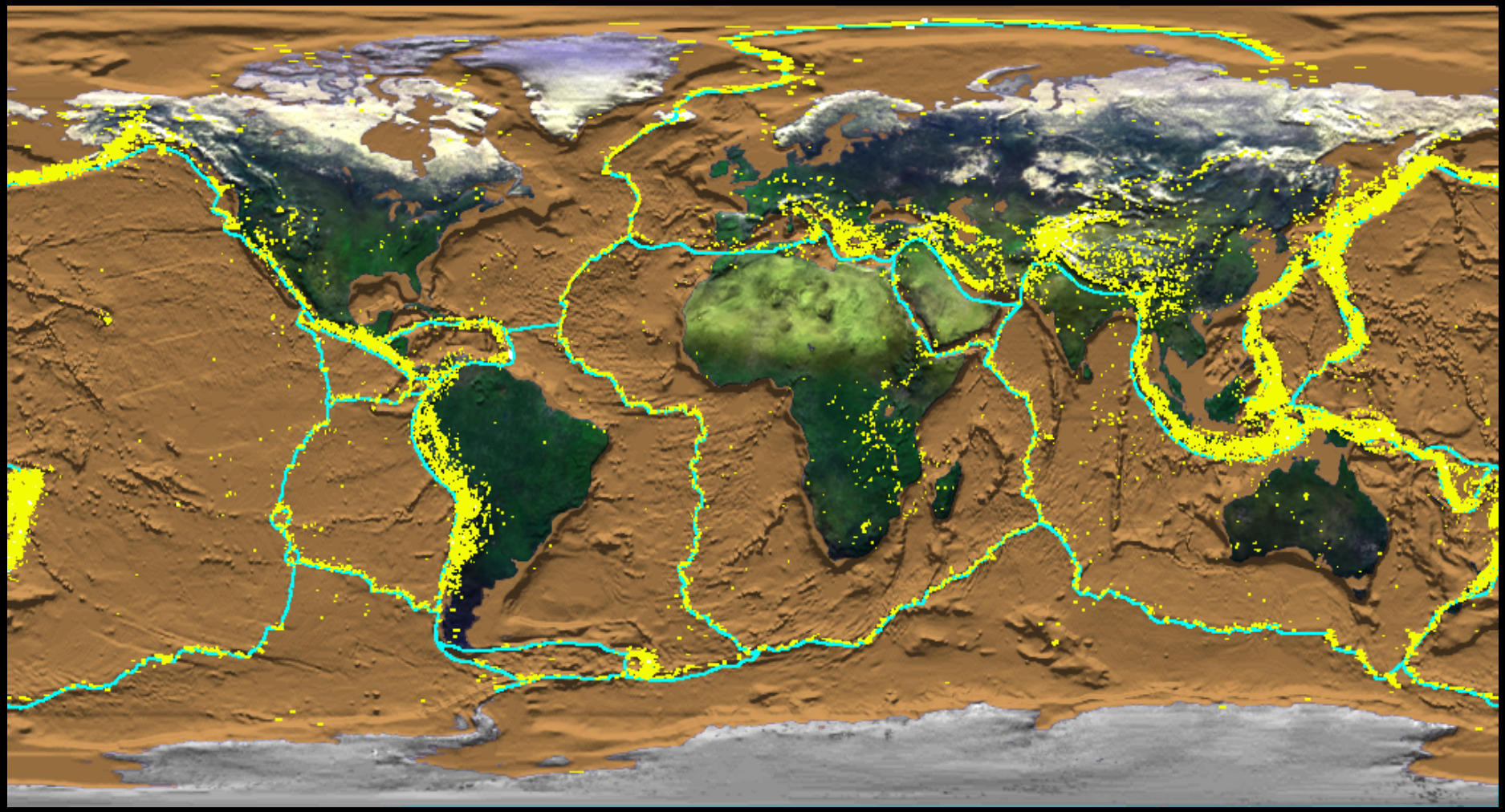
La collision Inde-Asie



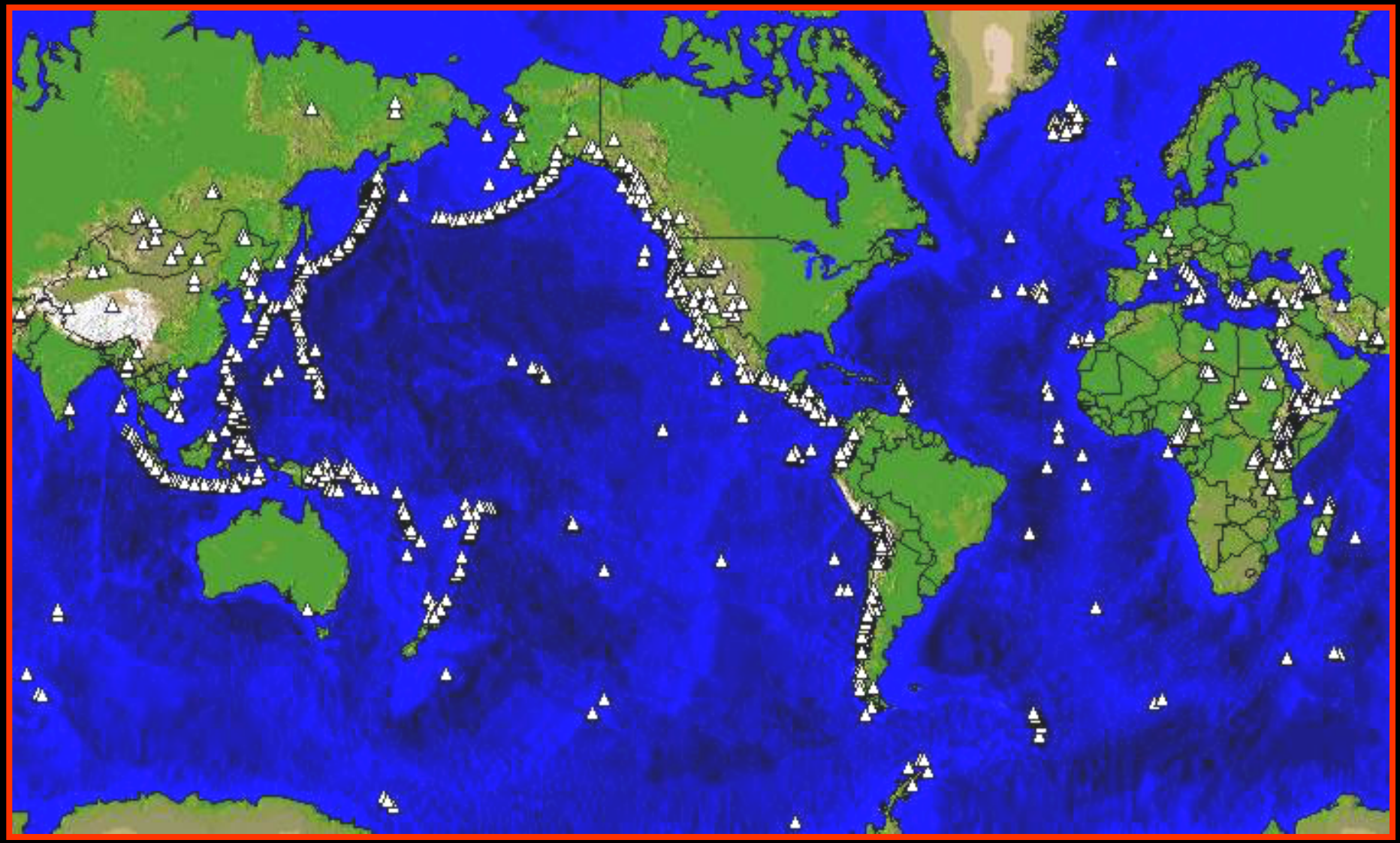
La Turquie et la Grèce



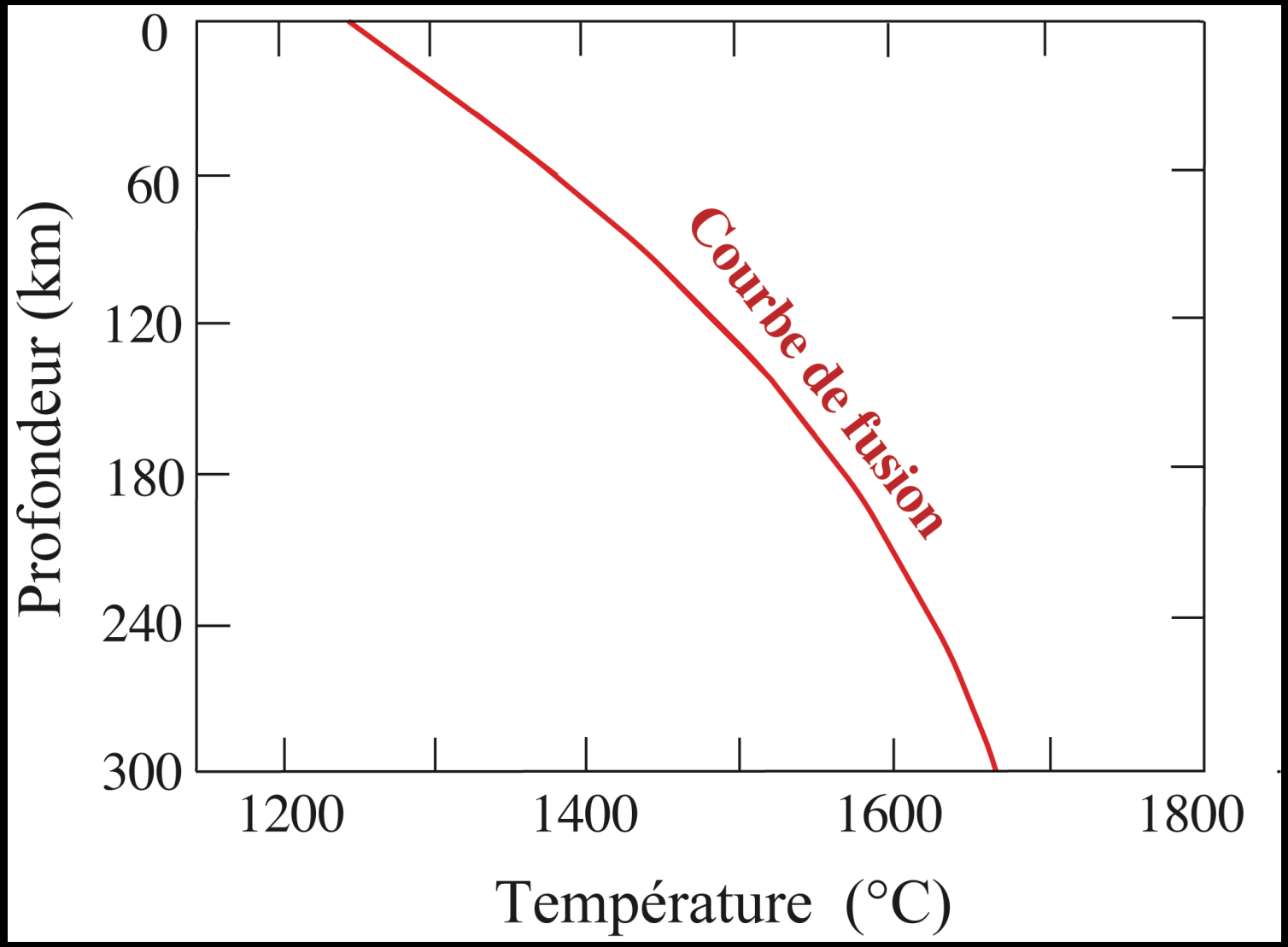
L’activité sismique

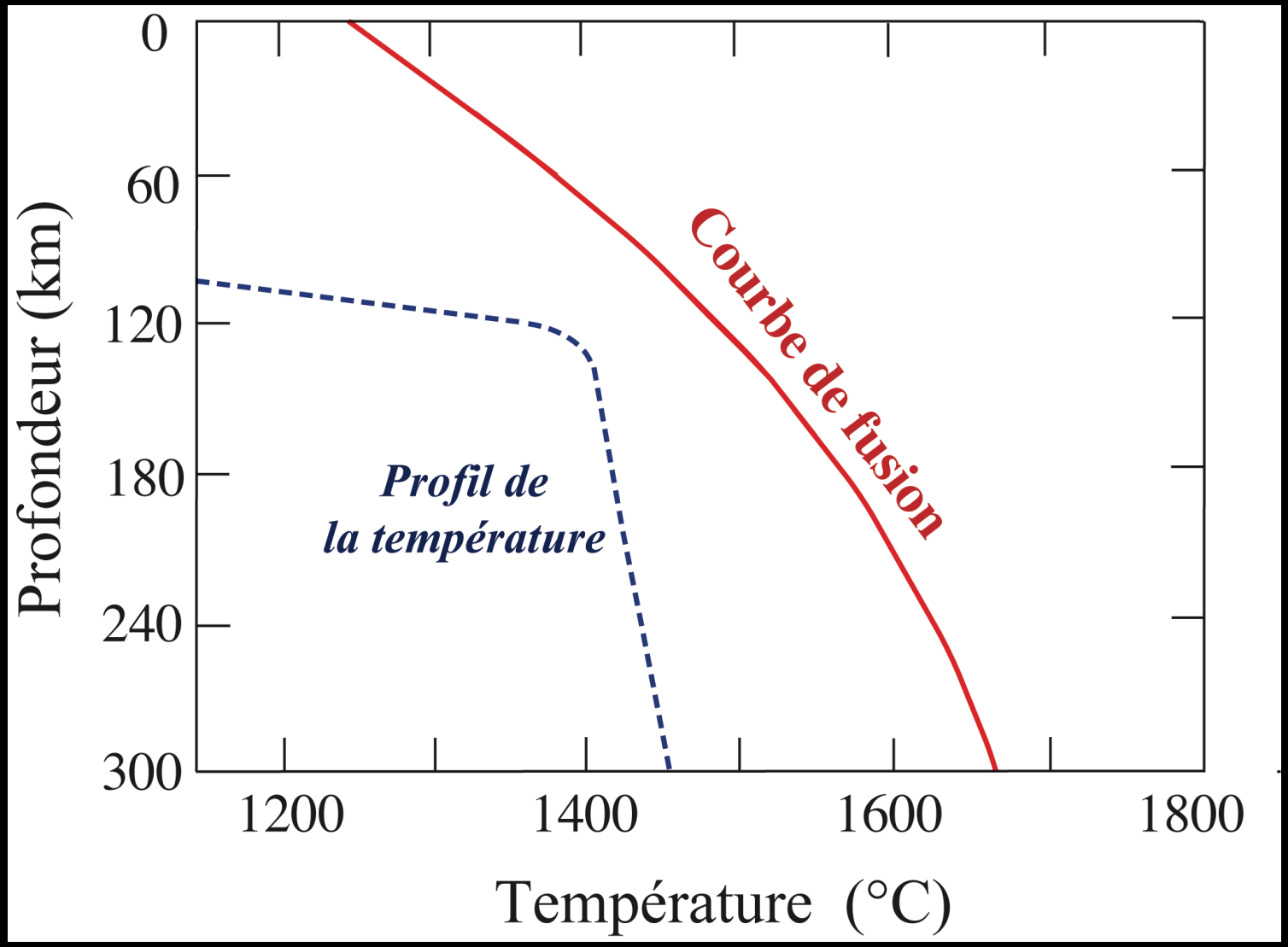


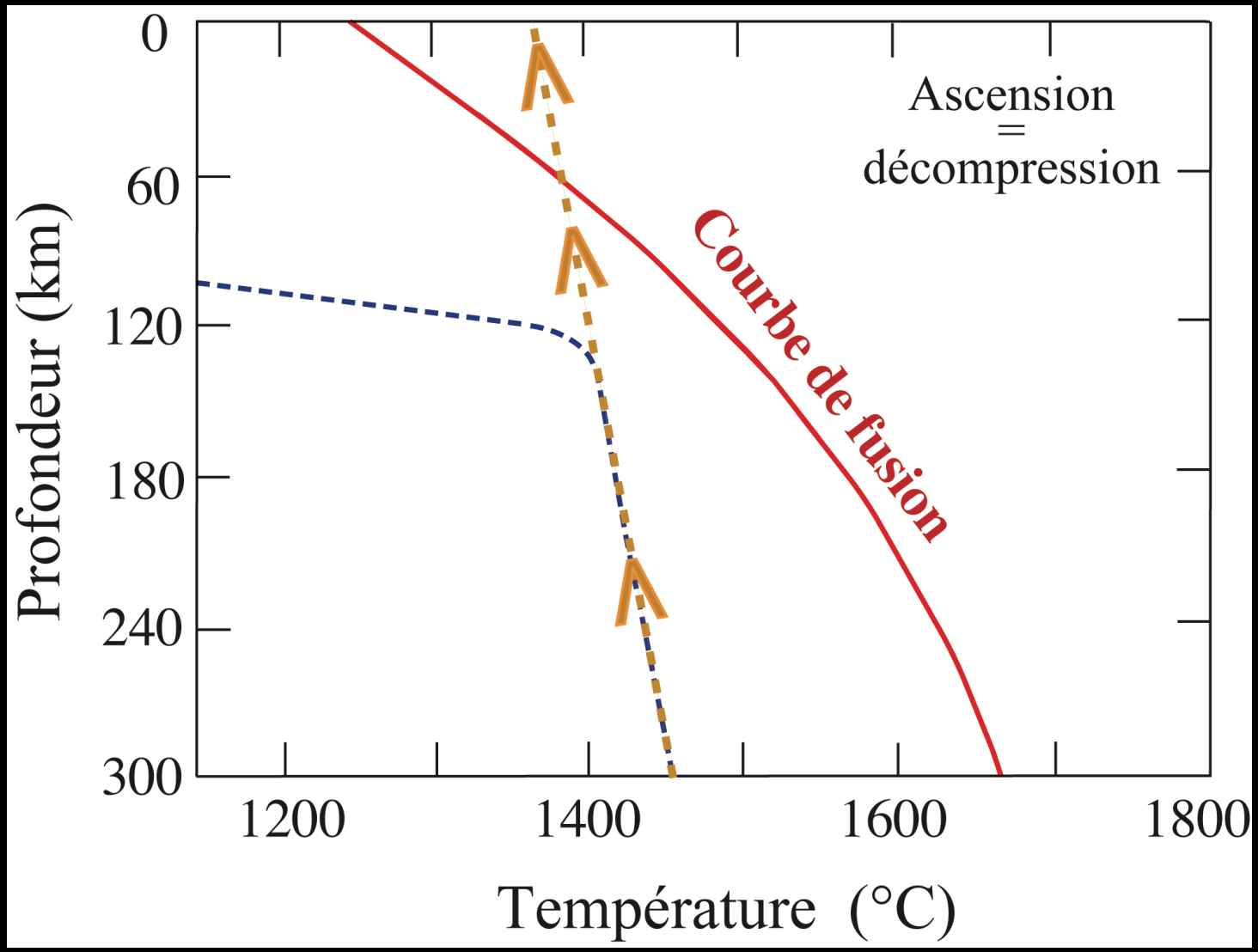
L’activité volcanique

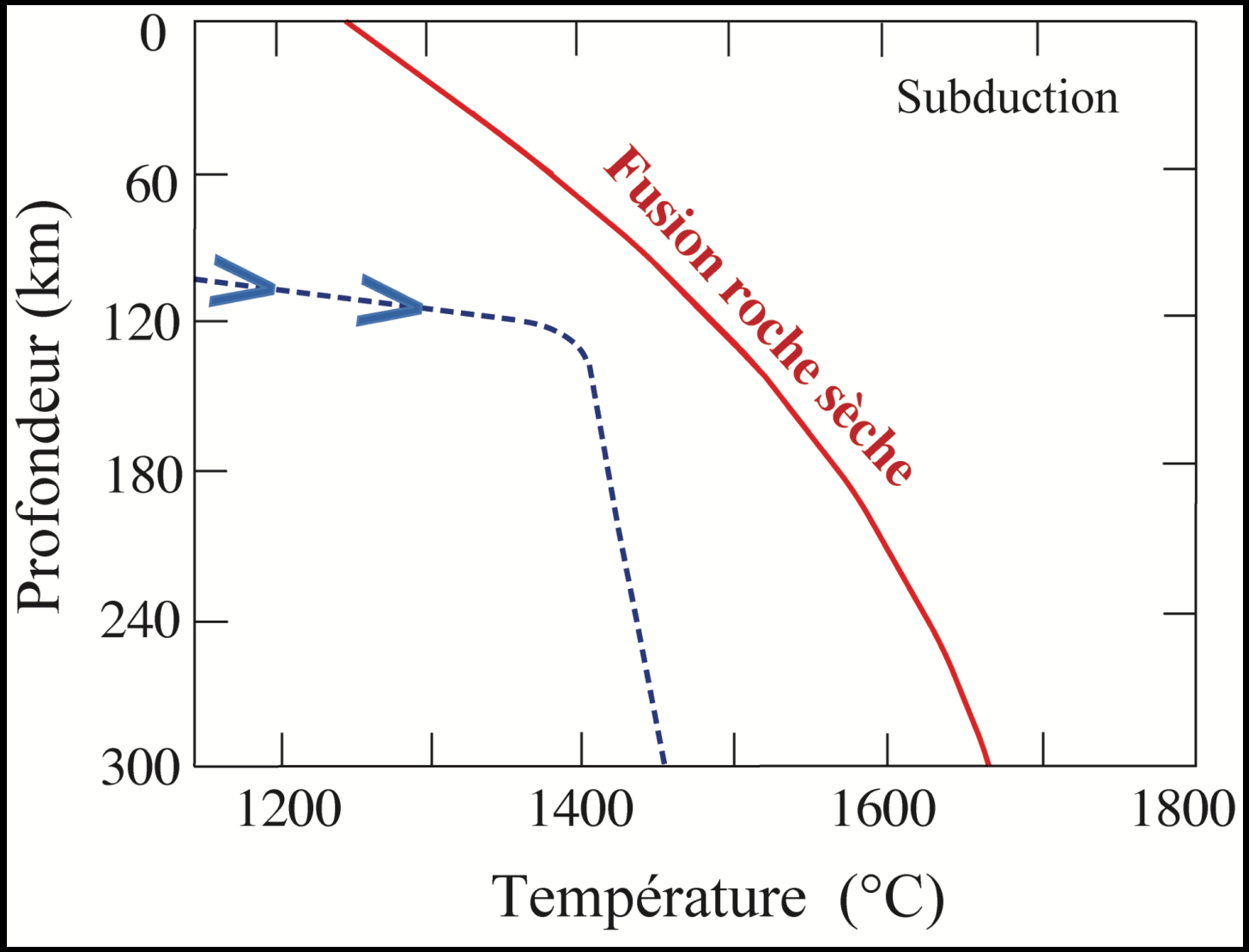


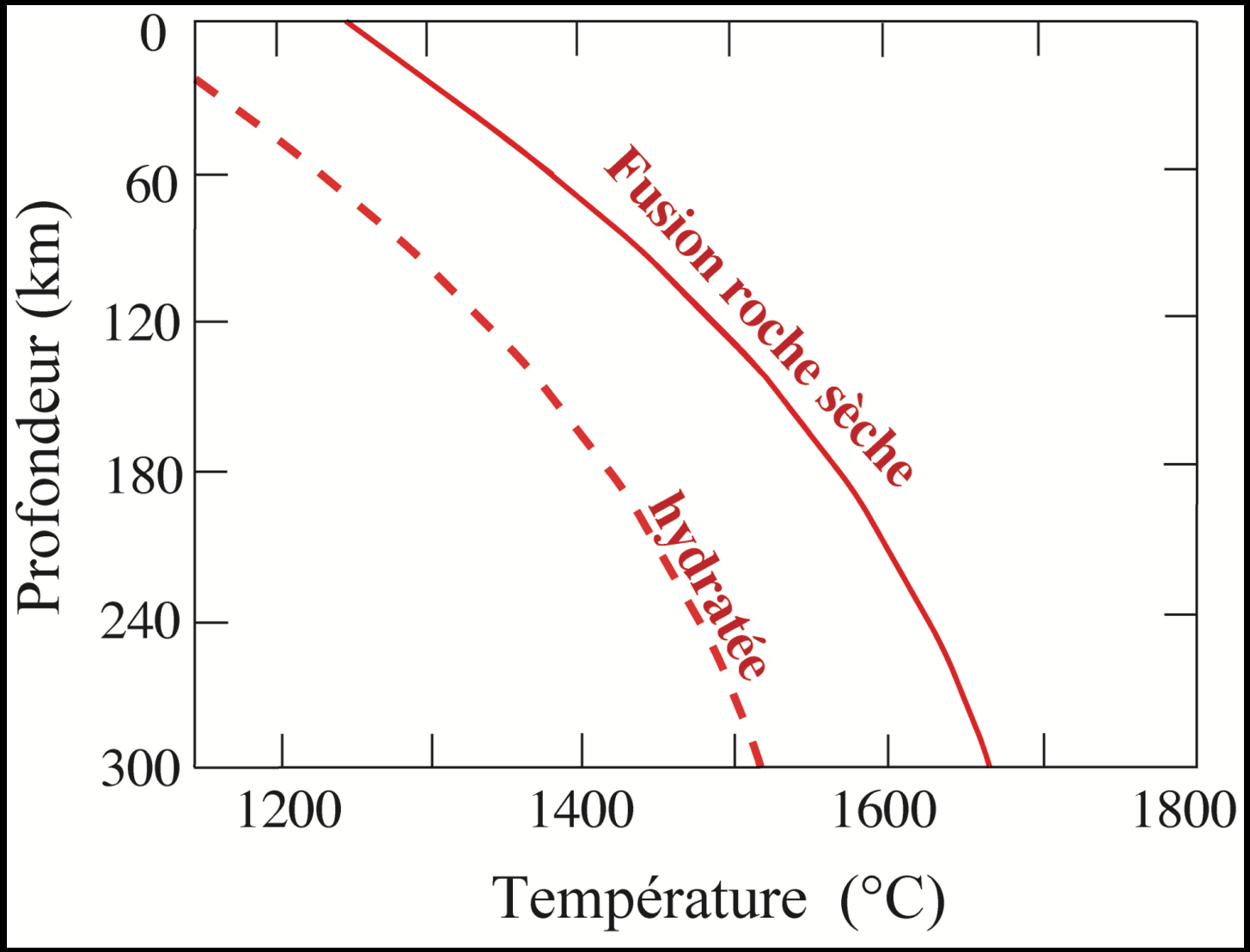
La fusion des roches

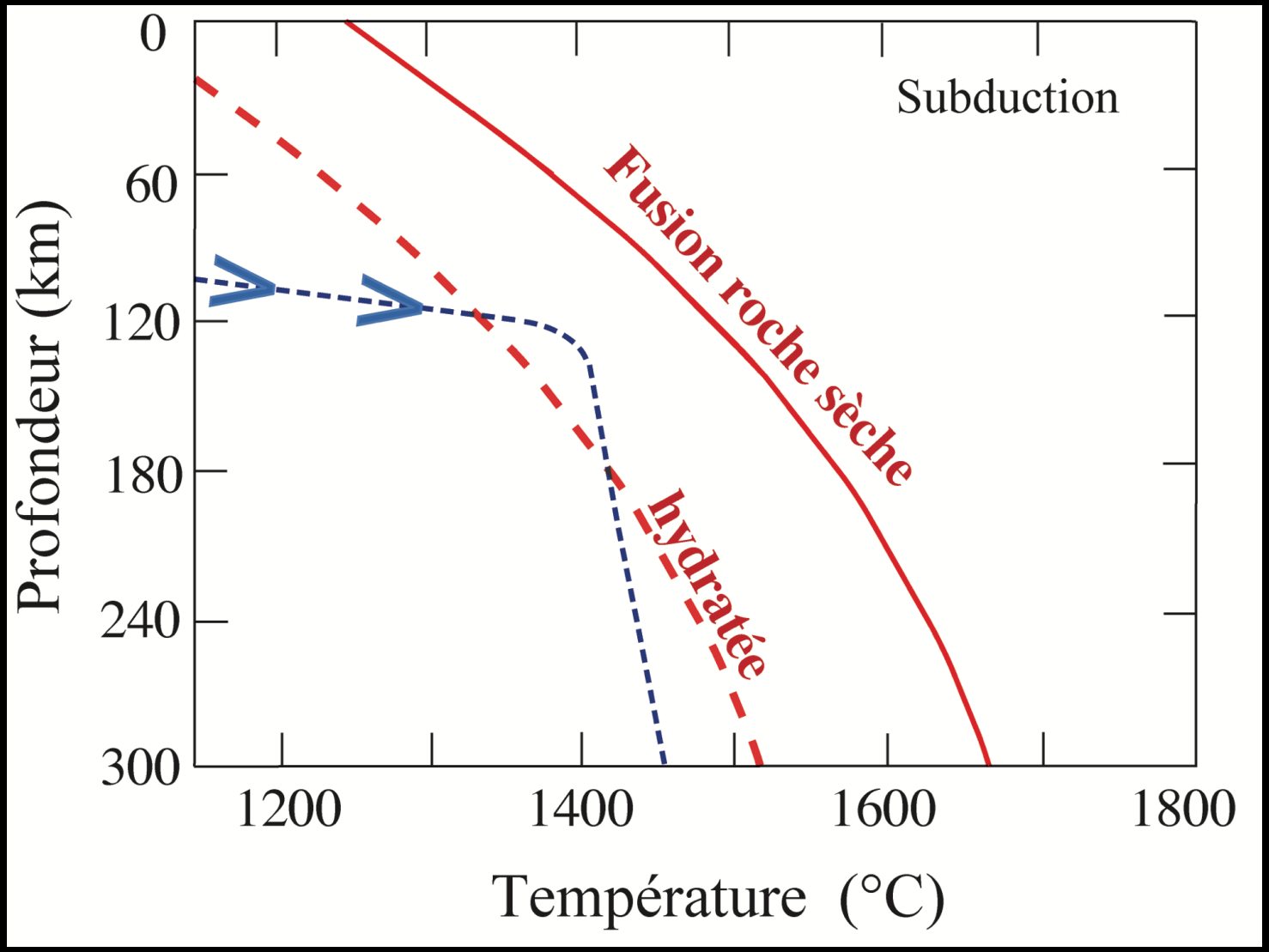


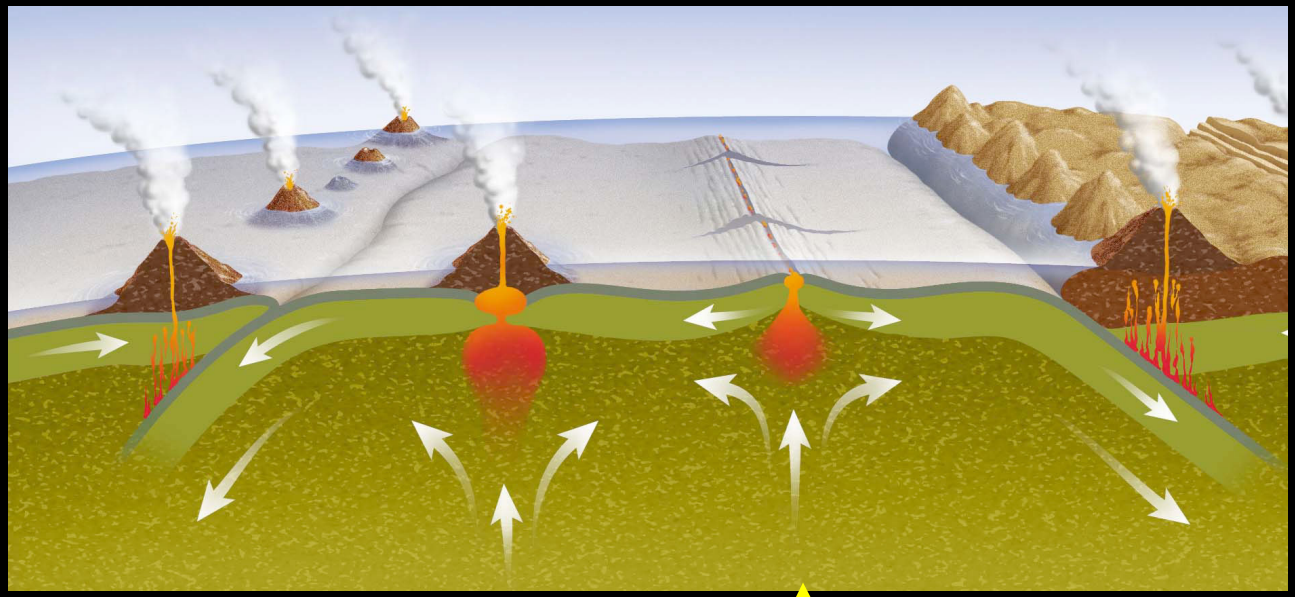

0
60
120
180
240
300
Profondeur (km)
Courbe de fusion
Profil de
la température
1200
1400
1600
1800
Température (°C)


0
60
120
180
240
300
Profondeur (km)
1200
1400
1600
1800
Température (°C)
Ascension
=
décompression
Courbe de fusion

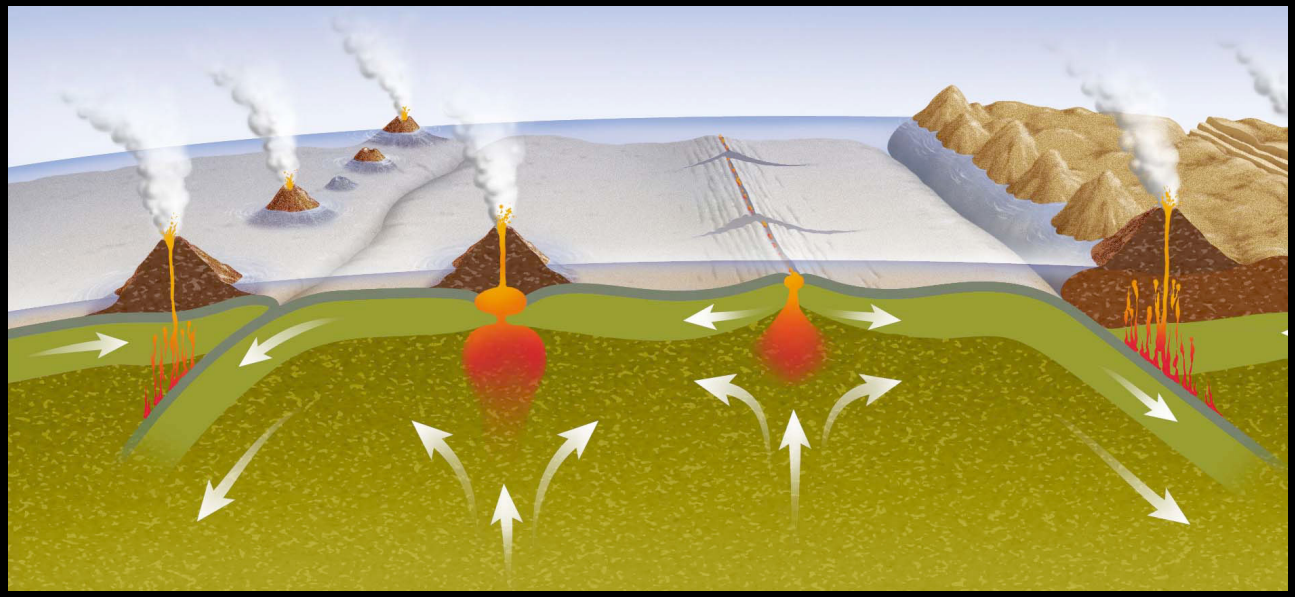

Subduction
Fusion roche sèche
A
A
Profondeur (km)
0
60
120
180
240
300
1200
1400
1600
1800
Température (°C)


0
60
120
180
240
300
Profondeur (km)
1200
1400
1600
1800
Température (°C)
Fusion roche sèche
hydratée

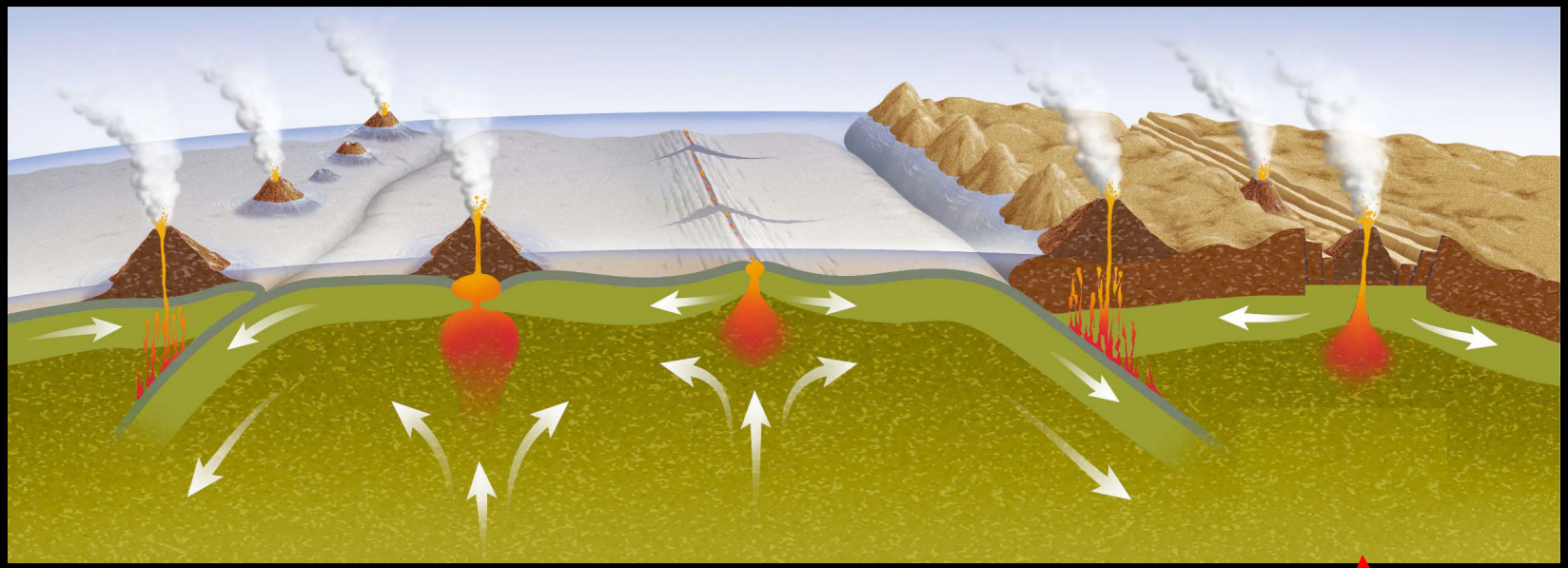

Subduction
Fusion roche sèche
hydratée
A
A
Profondeur (km)
0
60
120
180
240
300
1200
1400
1600
1800
Température (°C)



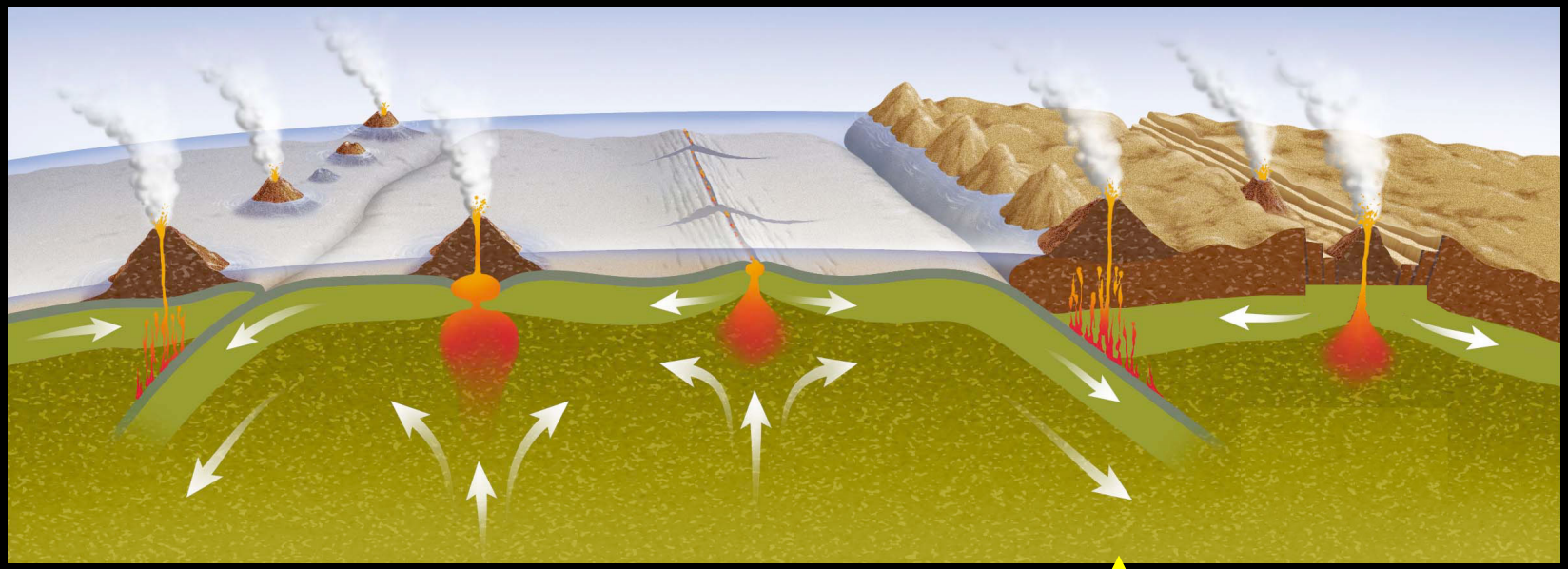
Dorsale océanique



Panache
(“point chaud”)

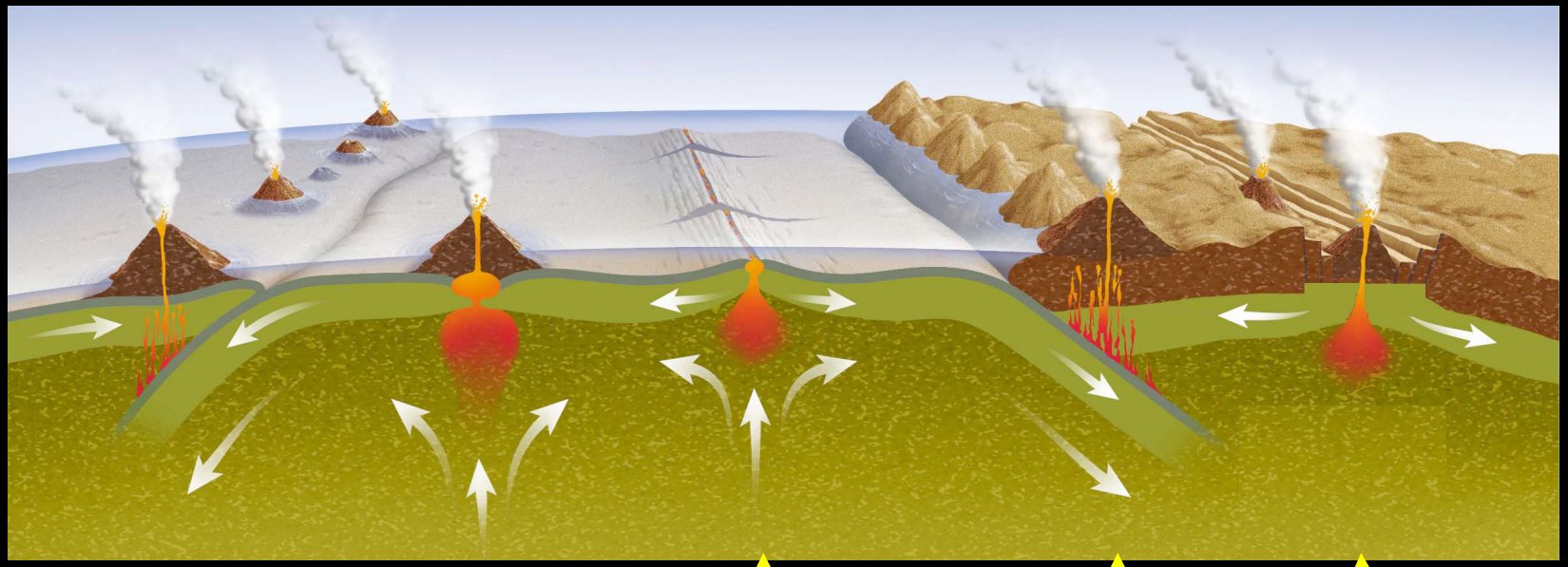


Extension



Subduction

Subduction



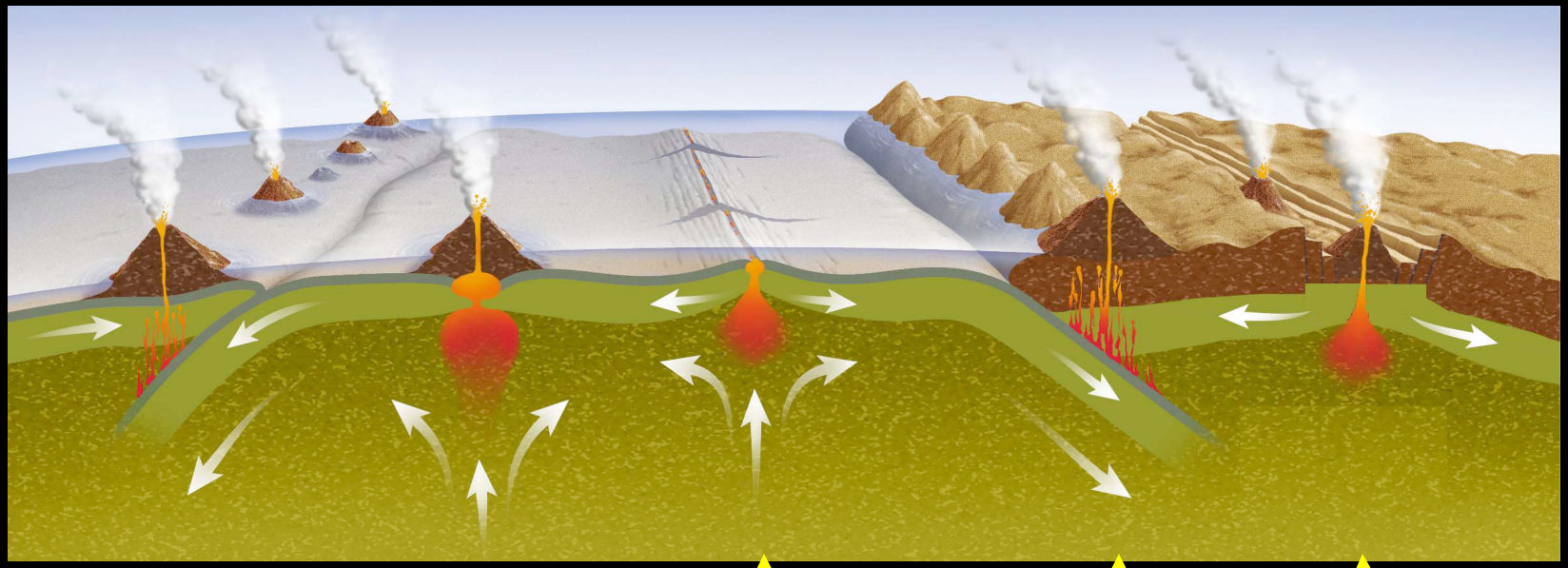
Ex: Japon

Ex: Hawaii,
La Réunion

Dorsale océanique

Ex: chaîne
Des Andes)

Ex: Rhin,
Rift Est-Africain)



Subduction

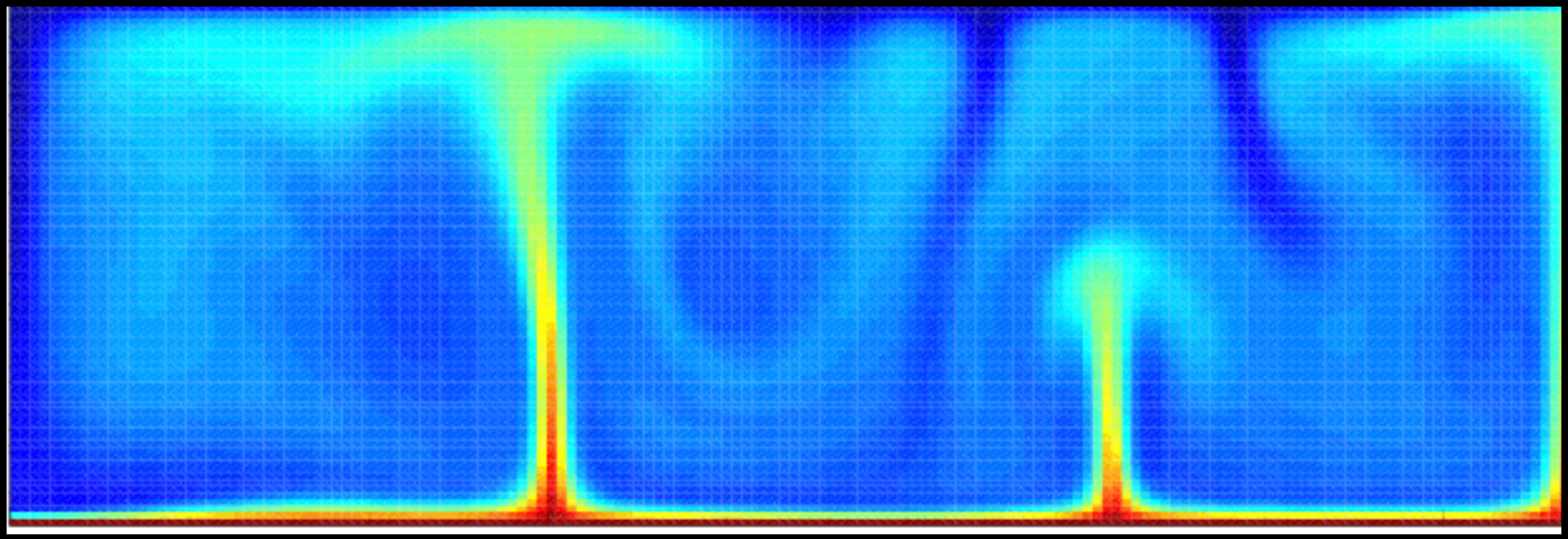
Décompression

Décompression

Subduction

Décompression

Le phénomène moteur: la convection naturelle

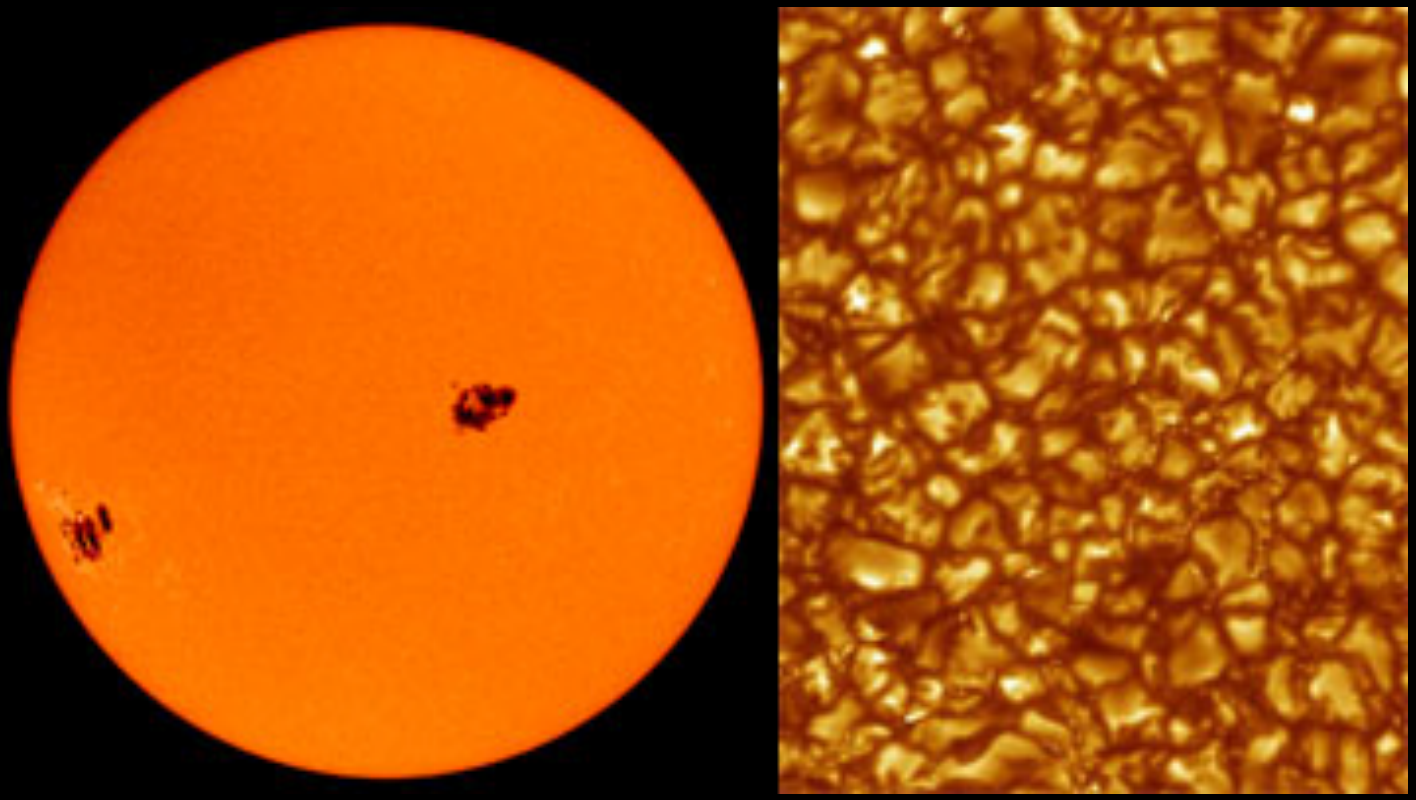


L'énergie nécessaire:

(1) la chaleur initiale (énergie cinétique des astéroïdes)

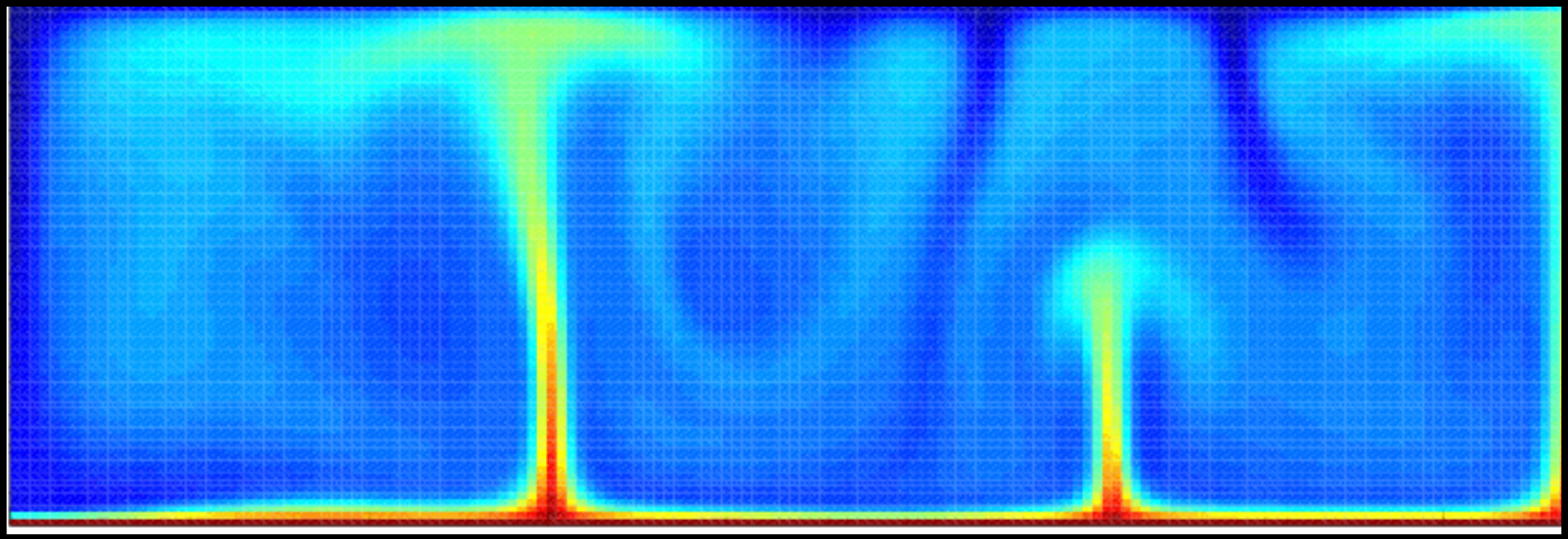
(2) la désintégration des éléments radioactifs

Phénomène à l'œuvre dans quasiment tous les systèmes naturels de grandes dimensions

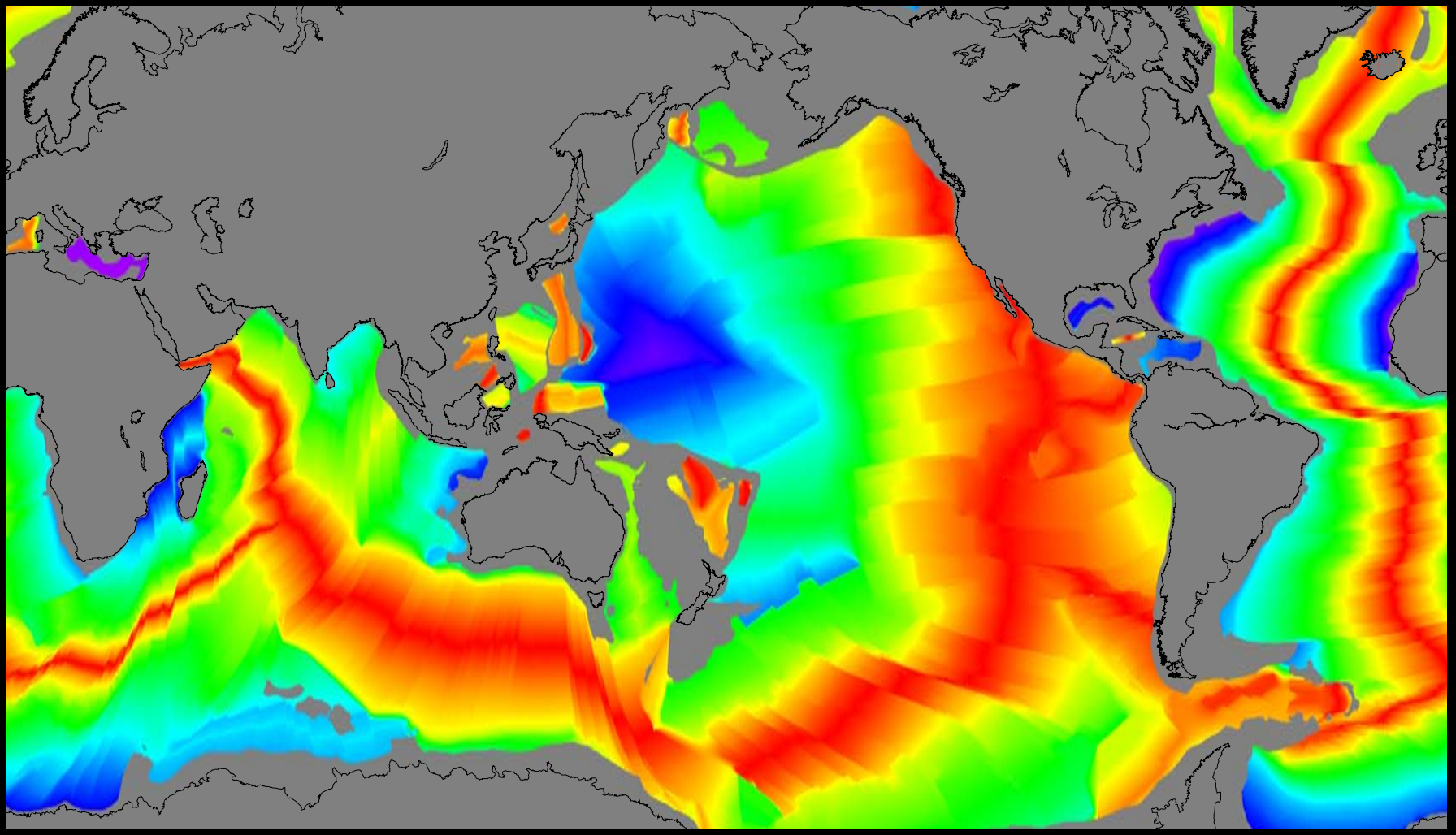


Dans le soleil

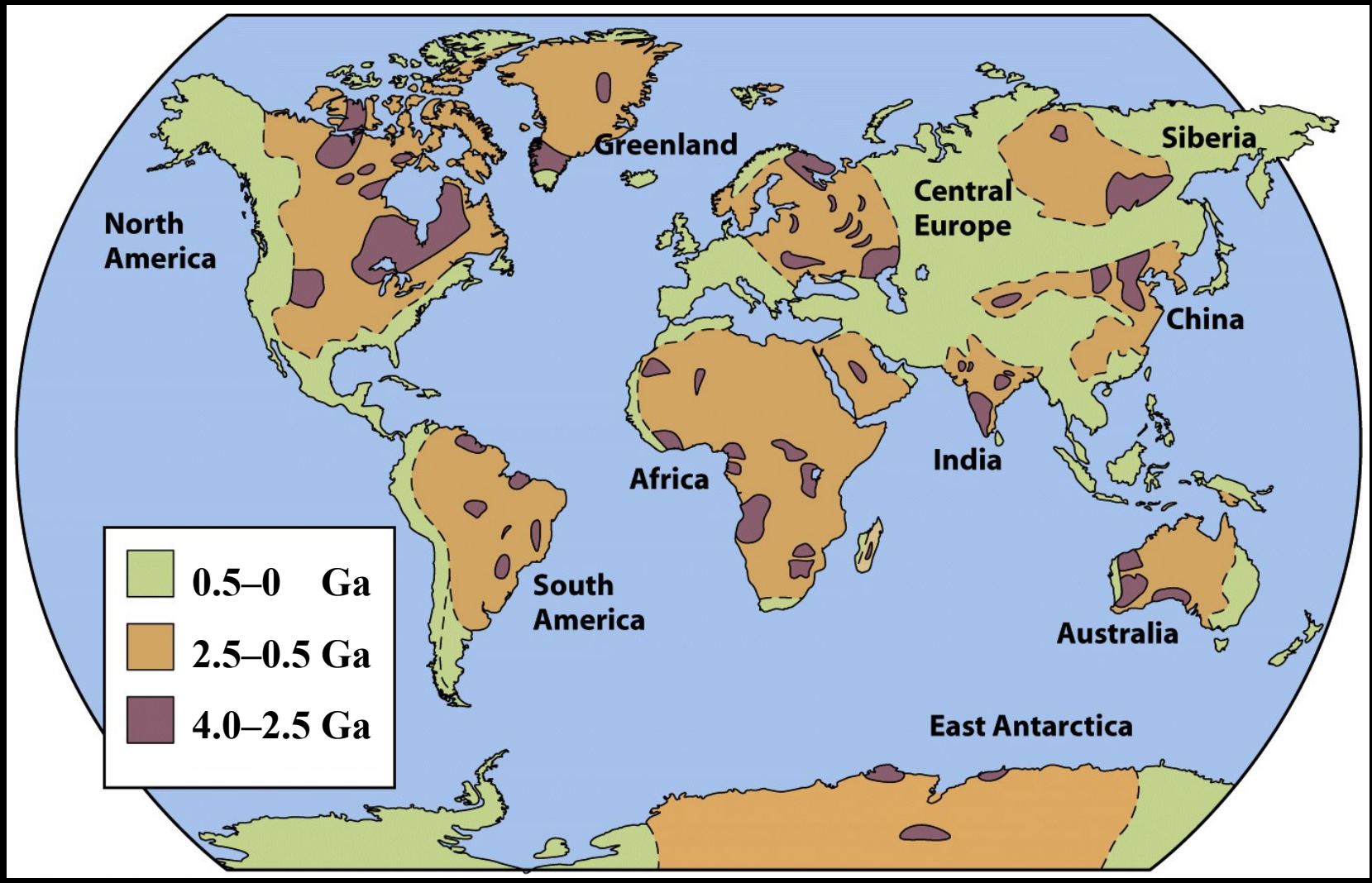
Quelles en sont les conséquences à long terme ?



Des fonds océaniques constamment renouvelés

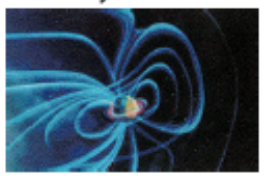


La création de matière continentale



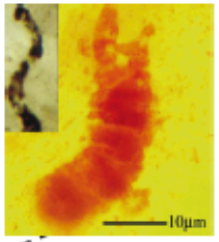
1ers océans

Dynamo?

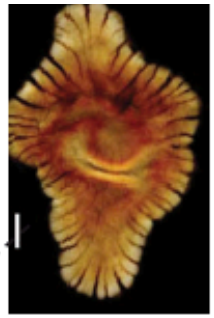


Naissance

1ère bactérie



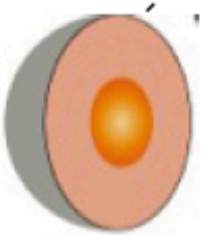
1er organisme multi-cellulaire



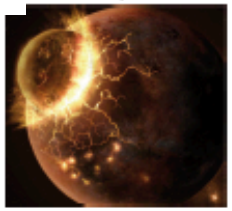
1ers êtres vivants
Composants solides

Cyanobactéries photosynthèse

4.56 4.0 3.0 2.0 1.0 0 Ga



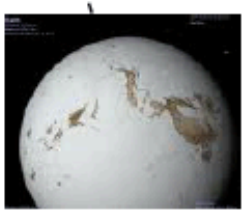
Noyau



Formation Lune

Roche la plus ancienne

Sédiments les + anciens



1er âge glaciaire

O_2

Oxydation atmosphère

Il y a ≈ 4.3 Ga,
il y avait déjà des océans.

Preuves géologiques:
roches sédimentaires, laves en coussins.

La vie apparaît à ≈ 3.8 Ga

North Pole, Australie
(3.5 Ga)

Aujourd'hui
(Shark Bay, Australie)

Tapis algaires, stromatolites

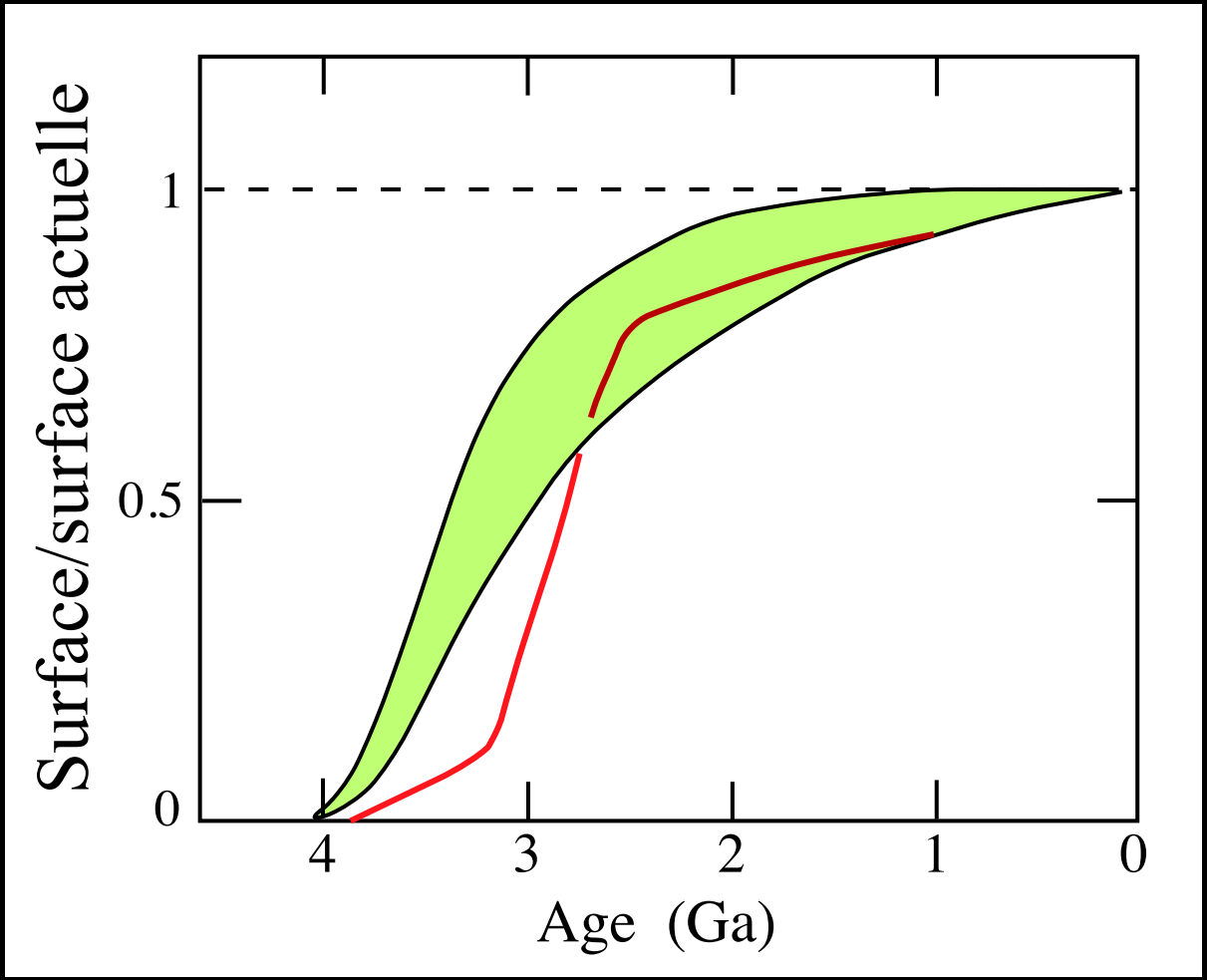
Les continents sont aussi apparus très tôt

La Terre à 4.3 Ga

Les plus vieilles roches

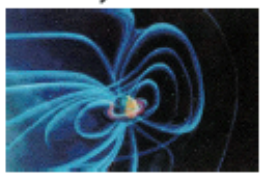
Nuvvuaggittuq (≈ 4.3 Ga)

Croissance des continents



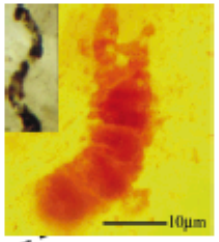
1ers océans

Dynamo?

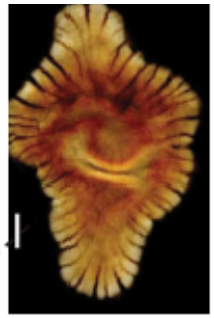


Naissance

1ère bactérie



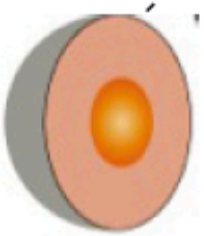
1er organisme multi-cellulaire



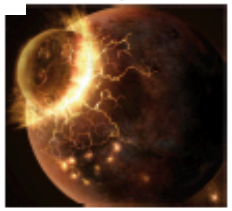
1ers êtres vivants
Composants solides

Cyanobactéries photosynthèse

4.56 4.0 3.0 2.0 1.0 0 Ga



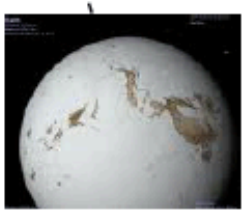
Noyau



Formation Lune

Roche la plus ancienne

Sédiments les + anciens



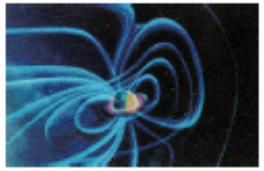
1er âge glaciaire

O_2

Oxydation atmosphère

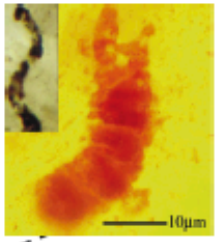
1ers océans

Dynamo?

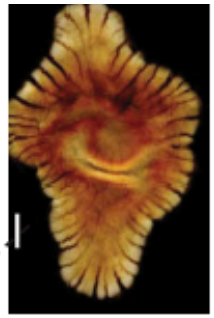


Naissance

1ère bactérie



1er organisme multi-cellulaire

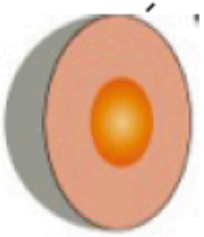


1ers êtres vivants
Composants solides

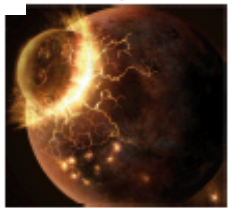
Cyanobactéries photosynthèse

4.56 — 4.0 — 3.0 — 2.0 — 1.0 — 0 Ga

CROISSANCE DES CONTINENTS



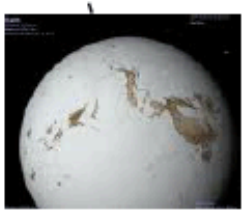
Noyau



Formation Lune

Roche la plus ancienne

Sédiments les + anciens



1er âge glaciaire

O_2

Oxydation atmosphère

Protocontinents = arcs insulaires et …

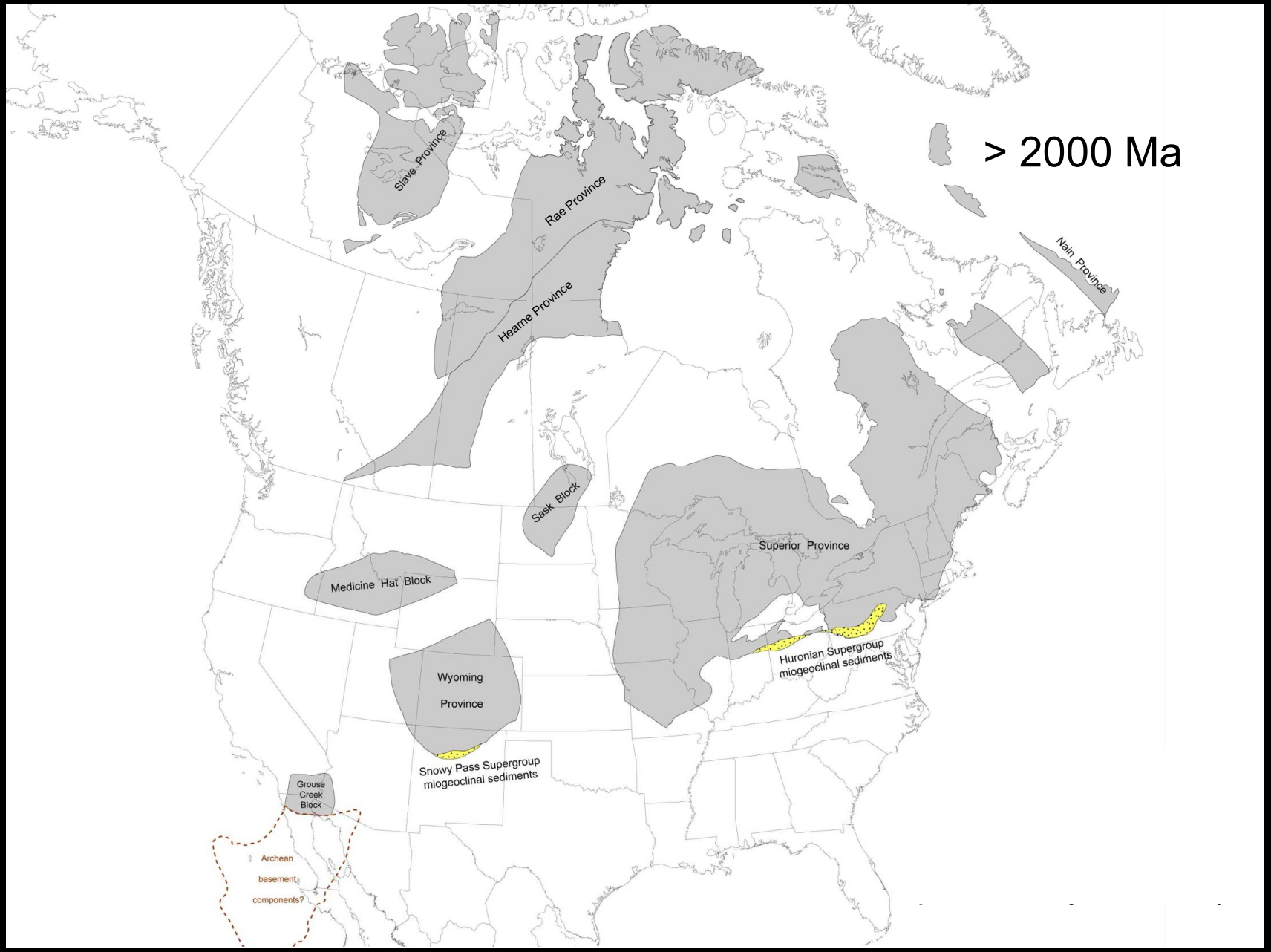
Java

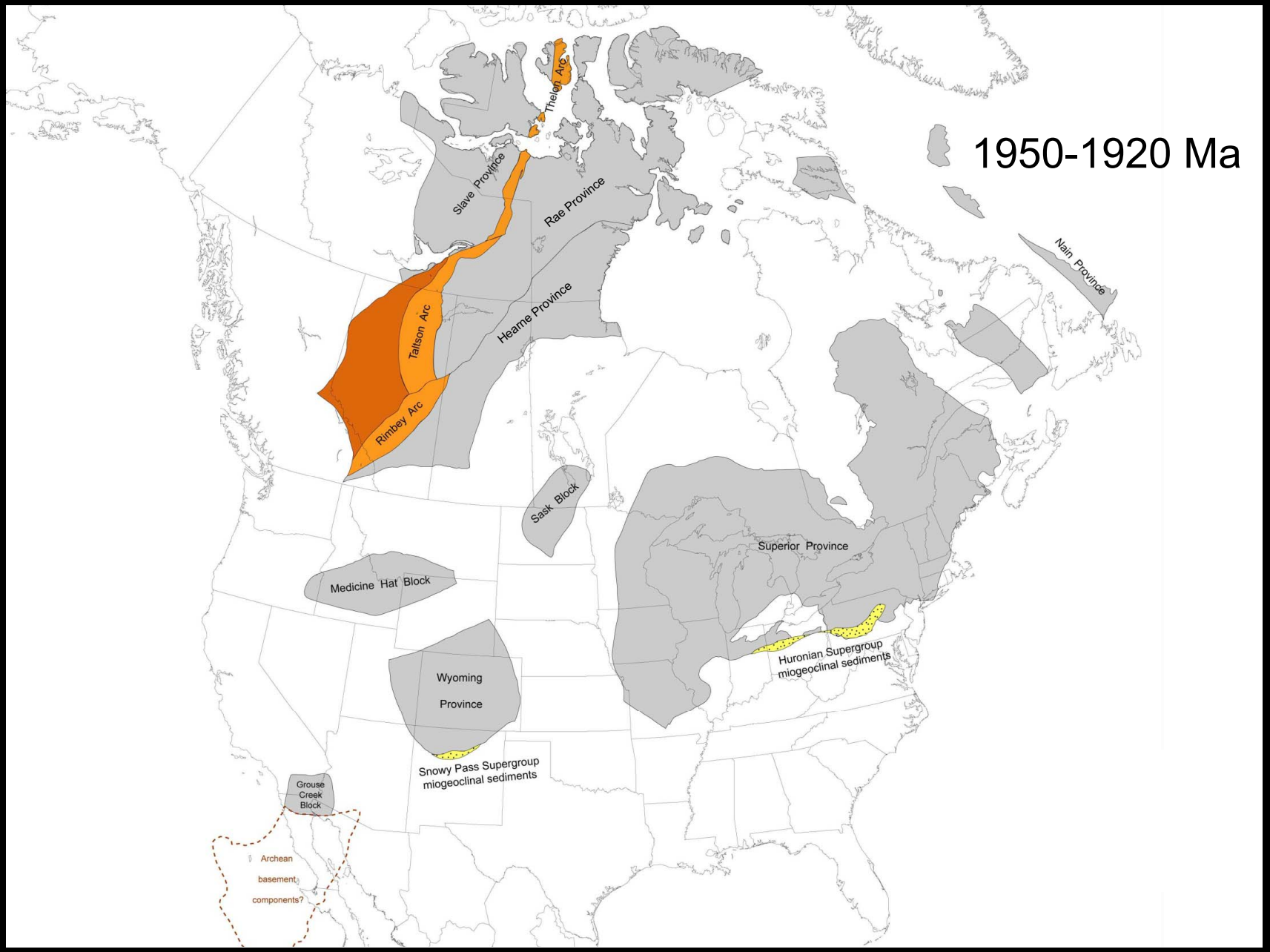
Aléoutiennes

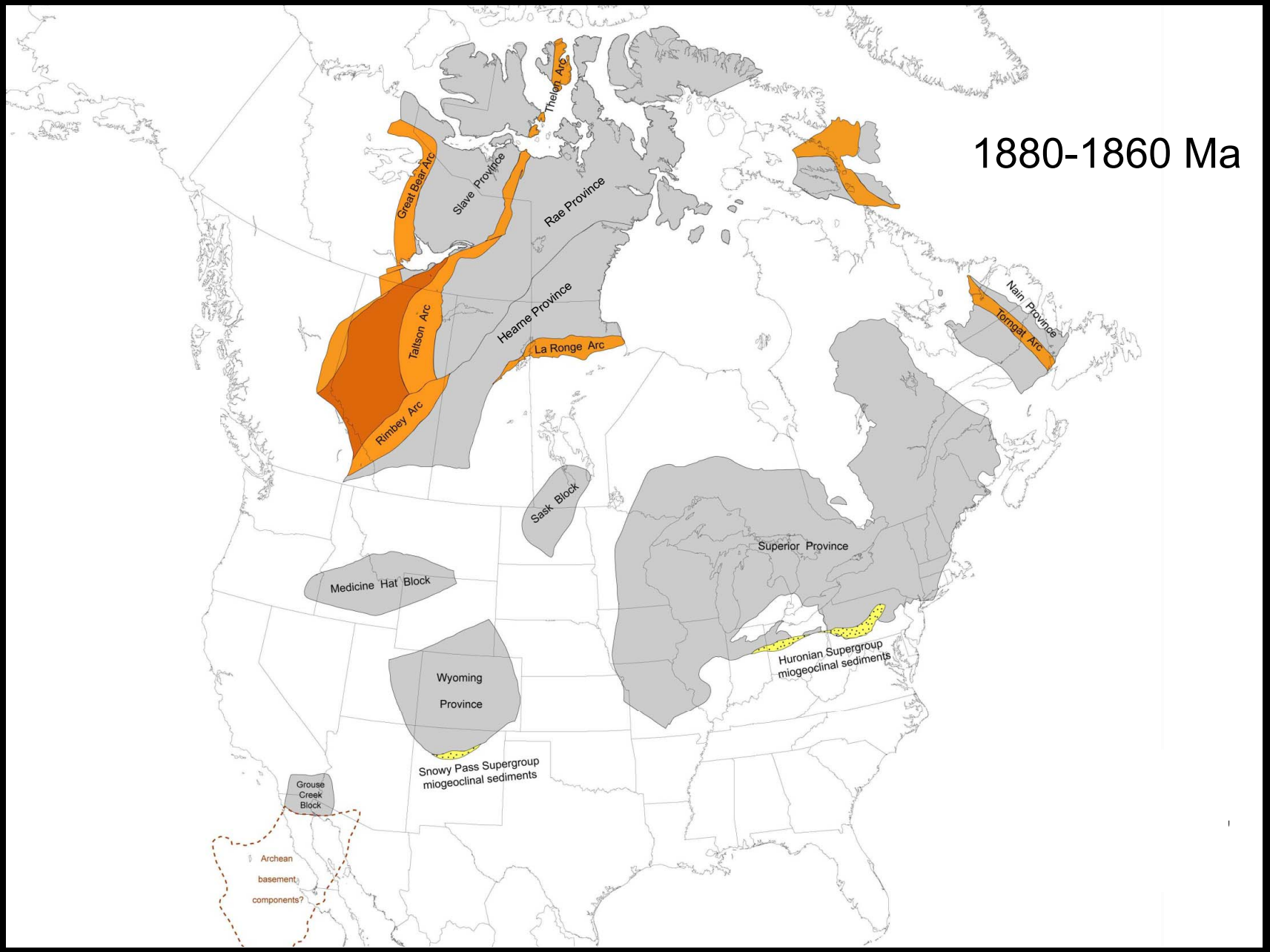
… îles océaniques

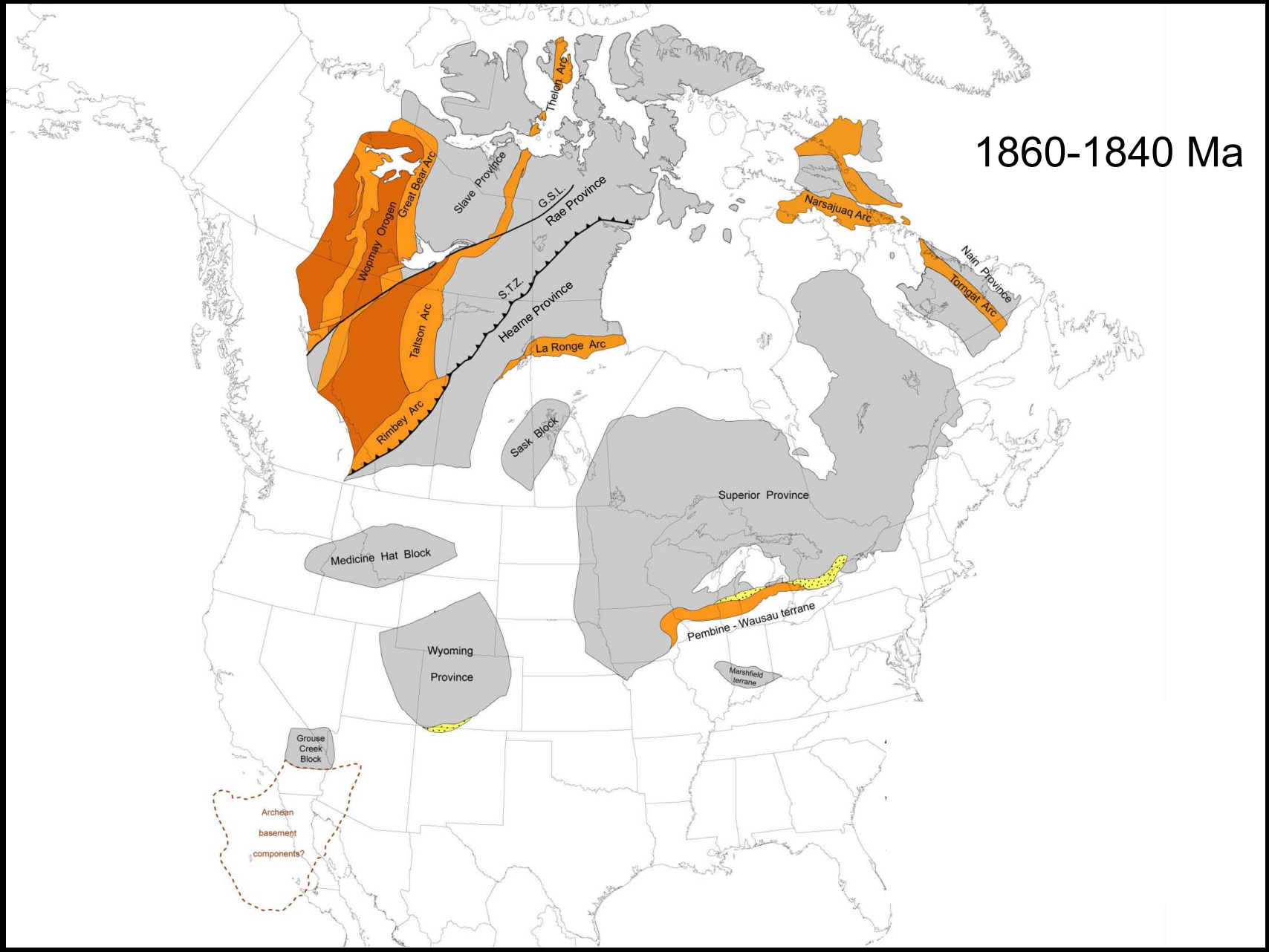
Croissance continentale: centrifuge, par addition de ceintures

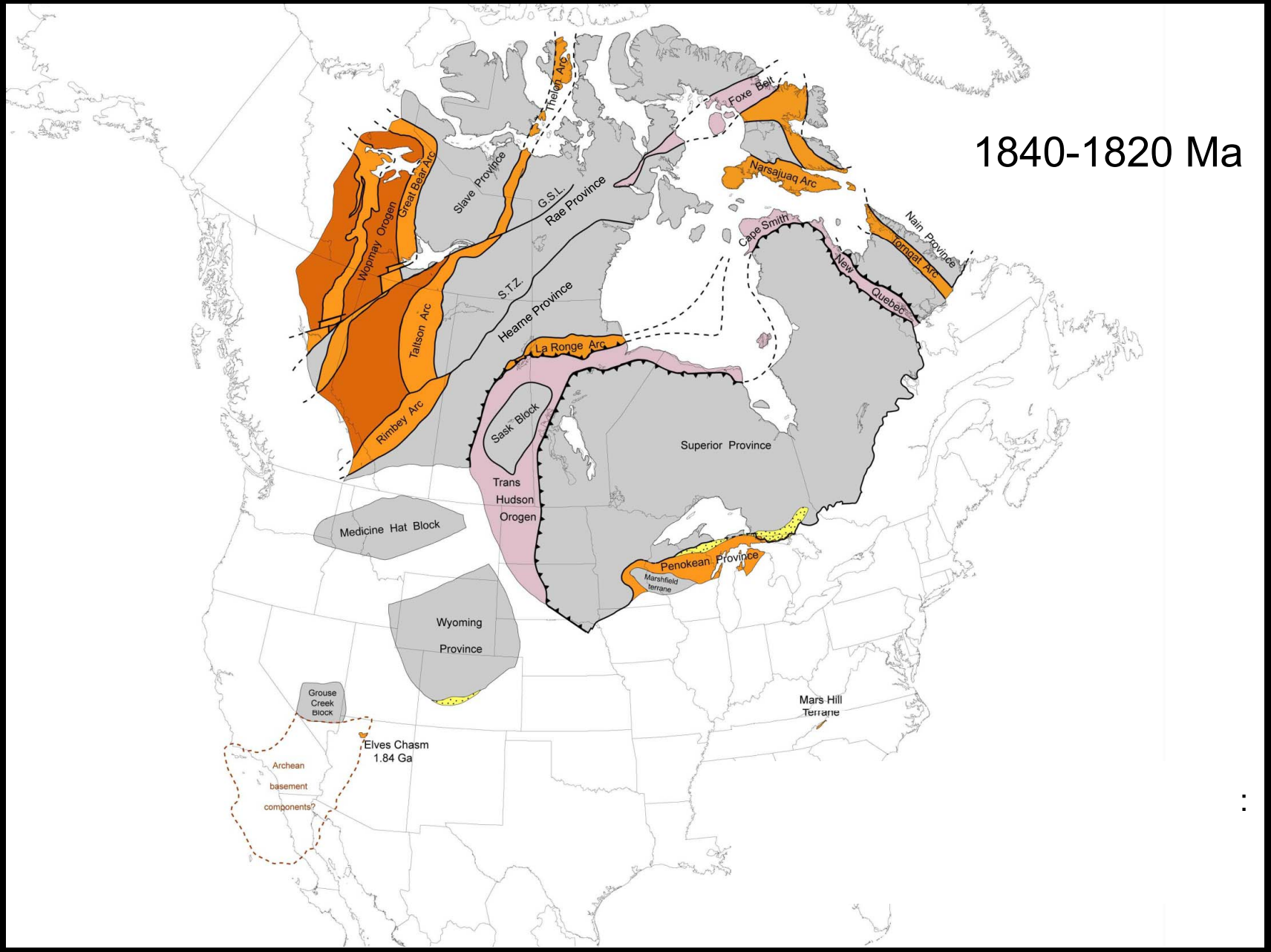
La croissance du continent Nord-Américain

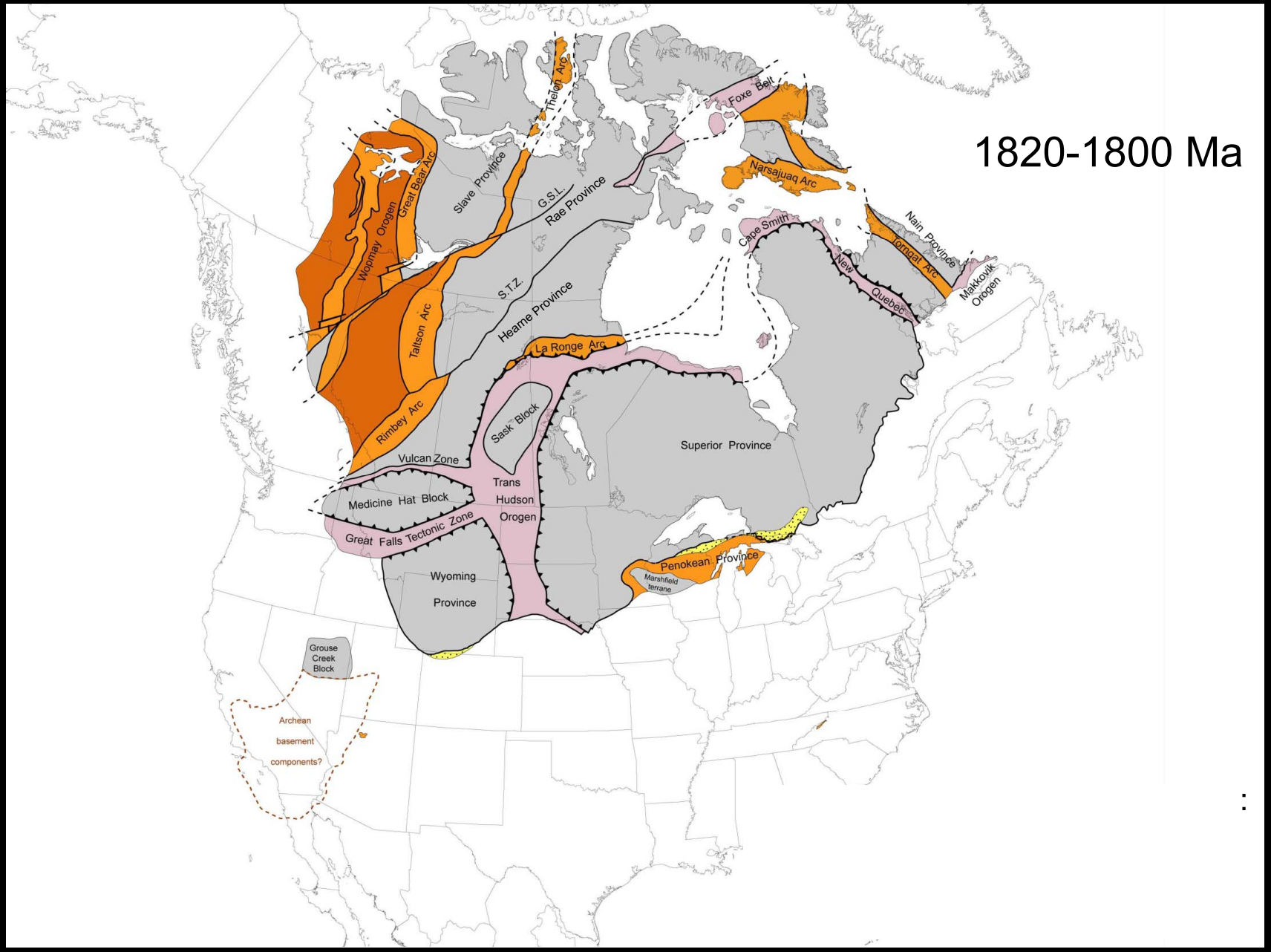

> 2000 Ma
Slave Province
Rae Province
Hearne Province
Nain Province
Sask Block
Superior Province
Medicine Hat Block
Huronian Supergroup miogeoclinal sediments
Wyoming Province
Snowy Pass Supergroup miogeoclinal sediments
Grouse Creek Block
Archean basement components?

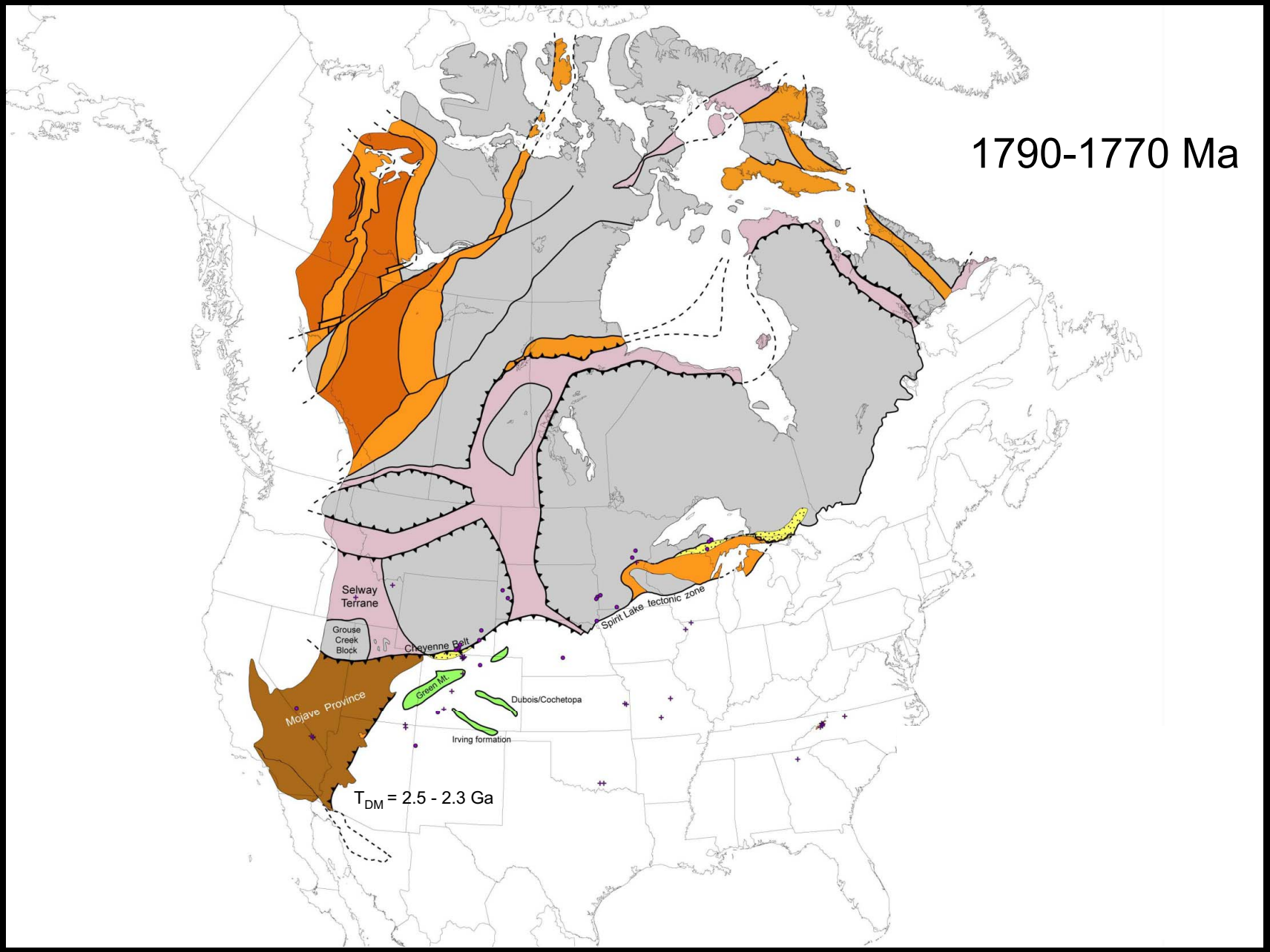

1950-1920 Ma
Thelon Arc
Slave Province
Rae Province
Hearne Province
Taltson Arc
Rimbey Arc
Nain Province
Sask Block
Superior Province
Medicine Hat Block
Huronian Supergroup miogeoclinal sediments
Wyoming Province
Snowy Pass Supergroup miogeoclinal sediments
Grouse Creek Block
Archean basement components?

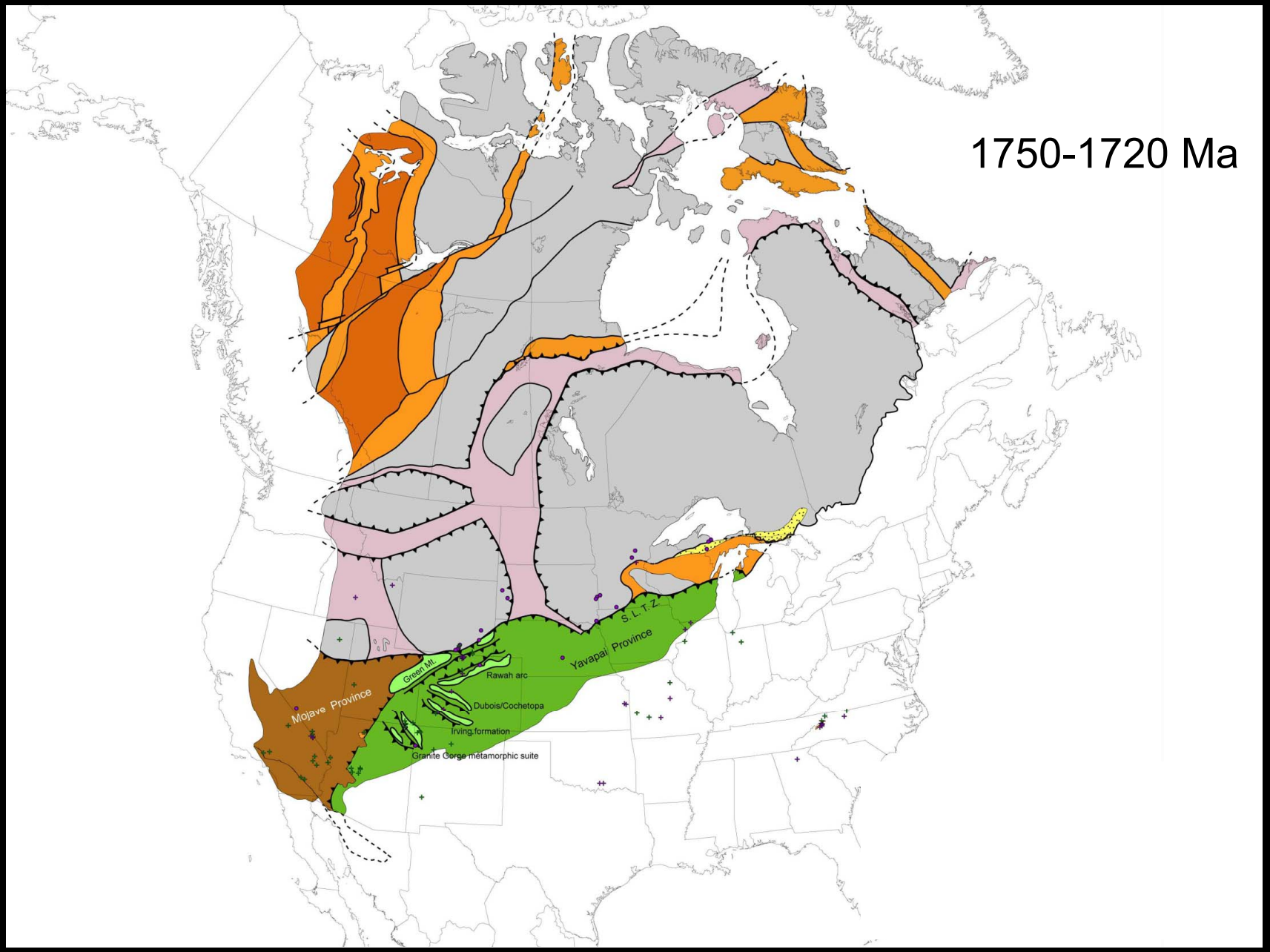

1880-1860 Ma
Thelon Arc
Great Bear Arc
Slave Province
Rae Province
Hearne Province
Taltson Arc
La Ronge Arc
Rimbey Arc
Nain Province
Torngat Arc
Sask Block
Superior Province
Medicine Hat Block
Huronian Supergroup miogeoclinal sediments
Wyoming Province
Snowy Pass Supergroup miogeoclinal sediments
Grouse Creek Block
Archean basement components?

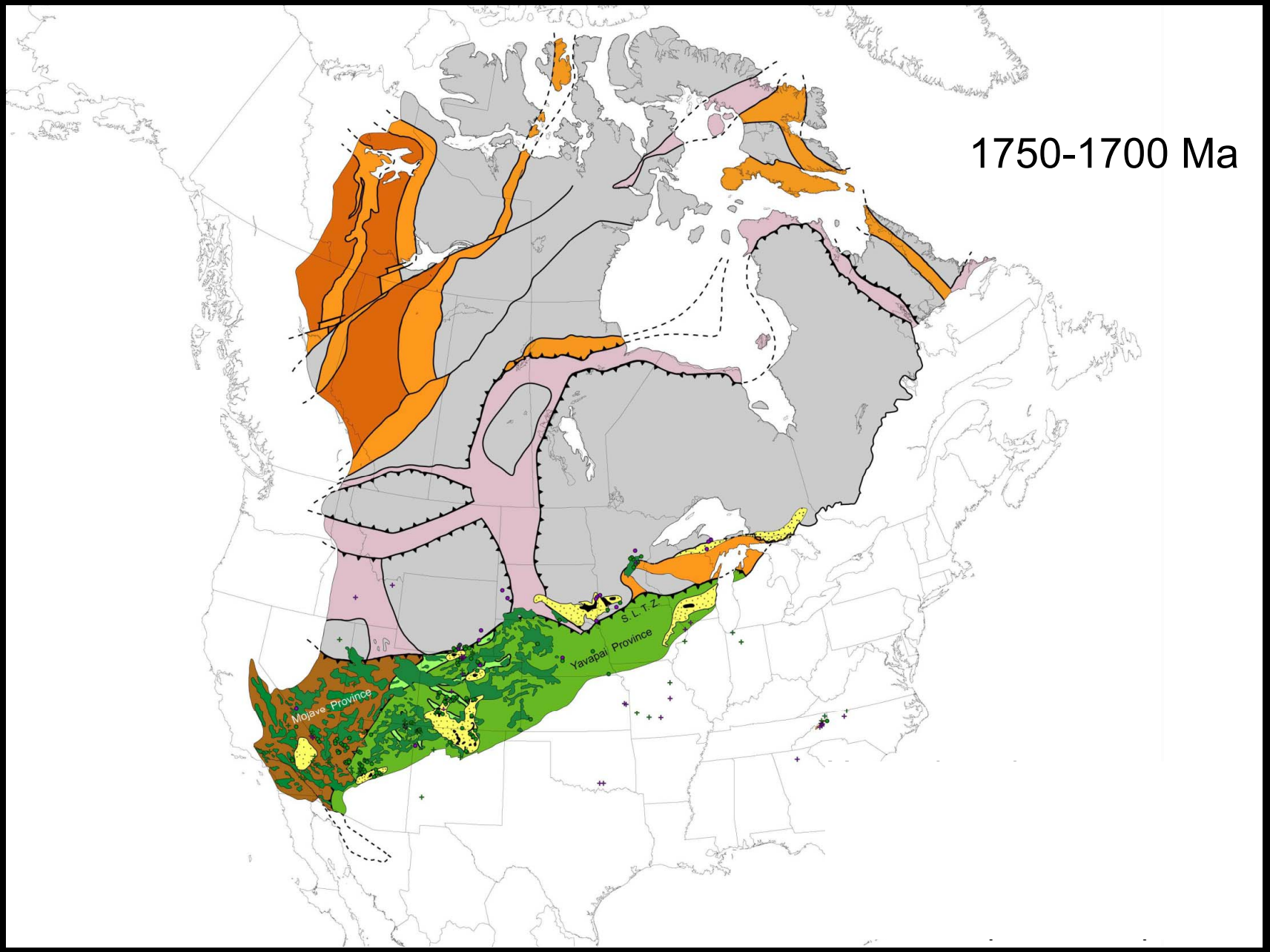

1860-1840 Ma
Thelon Arc?
Slave Province
Great Bear Arc
Wopmay Orogen
G.S.L.
Rae Province
S.T.Z.
Hearne Province
Taltson Arc
Rimbey Arc
La Ronge Arc
Sask Block
Narsajuaq Arc
Nain Province
Torngat Arc
Superior Province
Medicine Hat Block
Pembine - Wausau terrane
Wyoming
Province
Marshfield
terrane
Grouse
Creek
Block
Archean
basement
components?

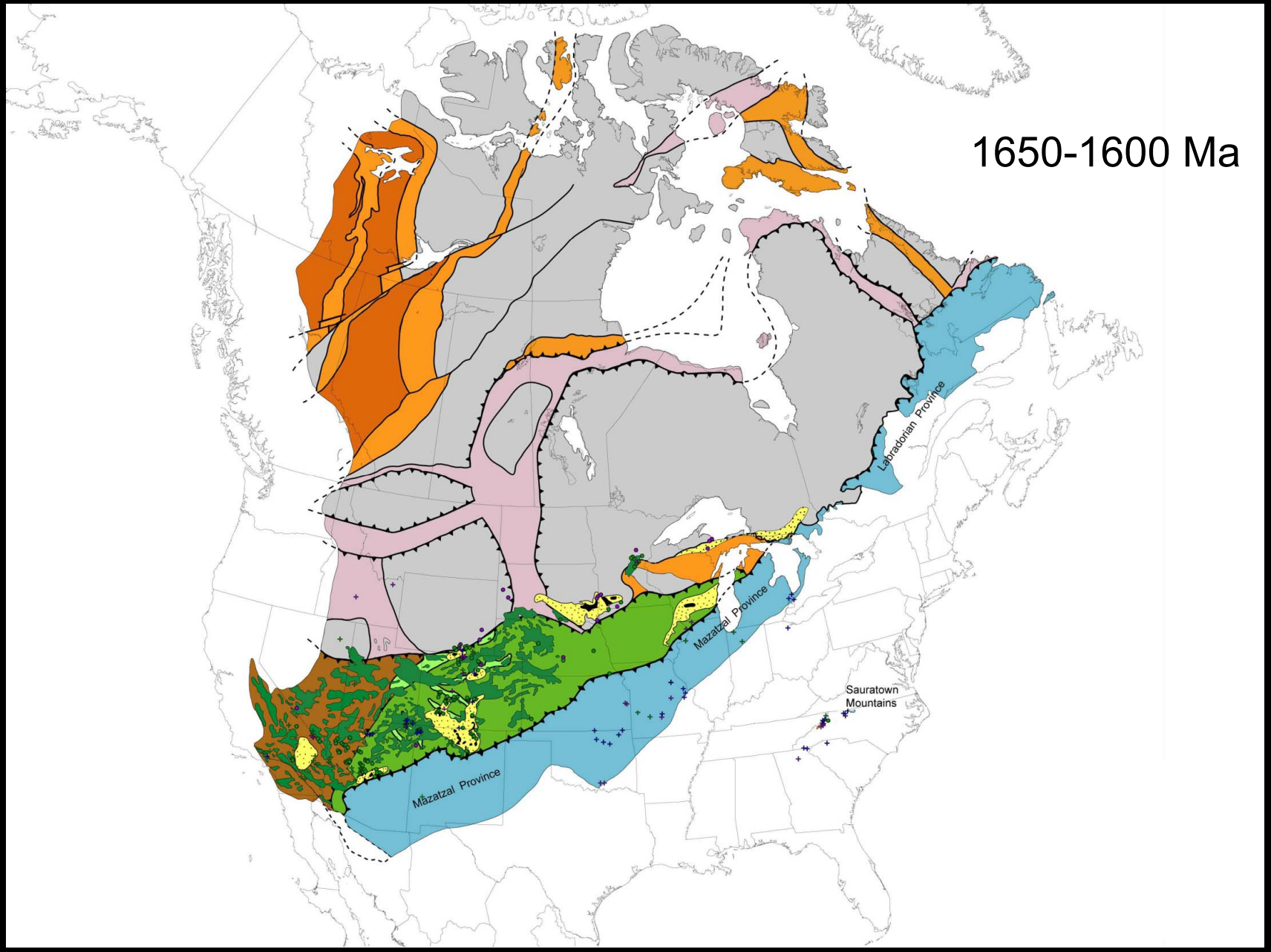

1840-1820 Ma
Thelon Arc
Foxe Belt
Slave Province
G.S.L.
Rae Province
Great Bear Arc
Wopmay Orogen
Natsajuaq Arc
Cape Smith
Nain Province
Torngat Arc
New Quebec
S.T.Z.
Hearne Province
Taltson Arc
La Ronge Arc
Rimbey Arc
Sask Block
Superior Province
Trans Hudson Orogen
Medicine Hat Block
Penokean Province
Marshfield terrane
Wyoming Province
Grouse Creek Block
Mars Hill Terrane
Elves Chasm 1.84 Ga
Archean basement components?

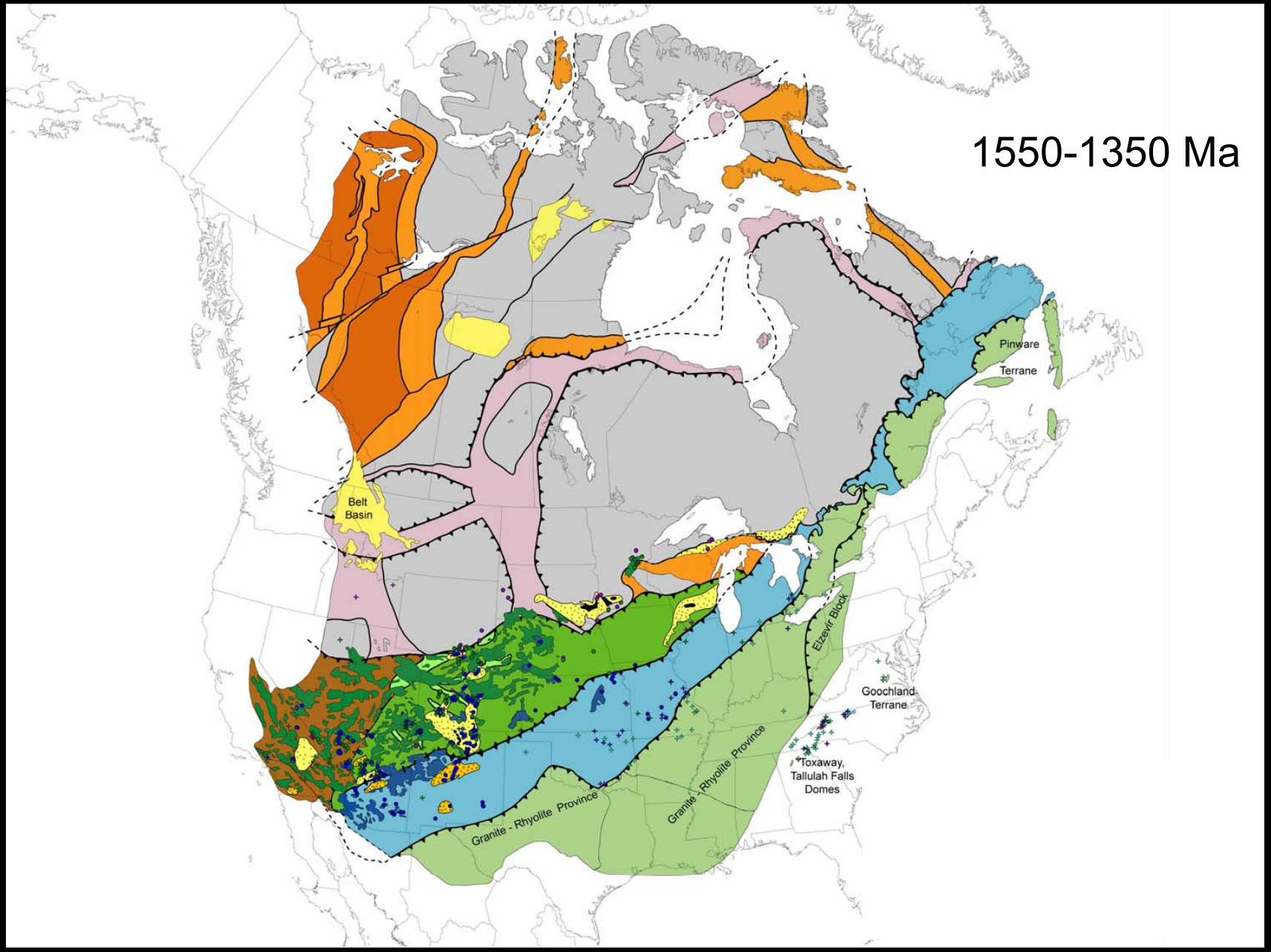

1820-1800 Ma
Thelon Arc
Foxe Belt
Slave Province
G.S.L.
Rae Province
Great Bear Arc
Wopmay Orogen
Narsajuaq Arc
Cape Smith
Nain Province
Torngat Arc
Makkovik Orogen
New Quebec
S.T.Z.
Hearne Province
Taltson Arc
La Ronge Arc
Rimbey Arc
Sask Block
Superior Province
Vulcan Zone
Trans Hudson Orogen
Medicine Hat Block
Great Falls Tectonic Zone
Penokean Province
Marshfield terrane
Wyoming Province
Grouse Creek Block
Archean basement components?

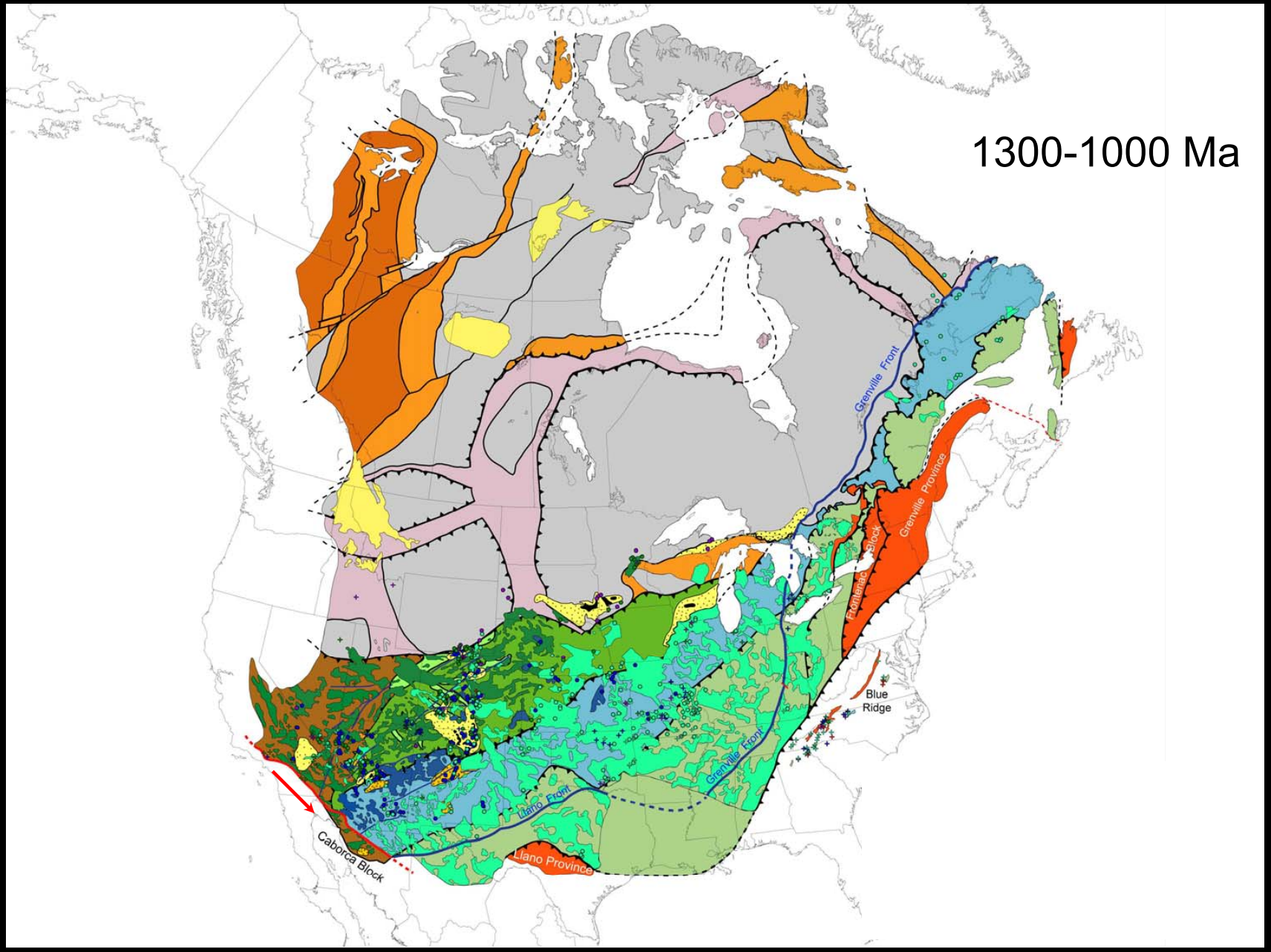

1790-1770 Ma
Selway Terrane
Grouse Creek Block
Cheyenne Belt
Green Mt.
Dubois/Cochetopa
Irving formation
Mojave Province
Spirit Lake tectonic zone
T_{DM} = 2.5 - 2.3 Ga

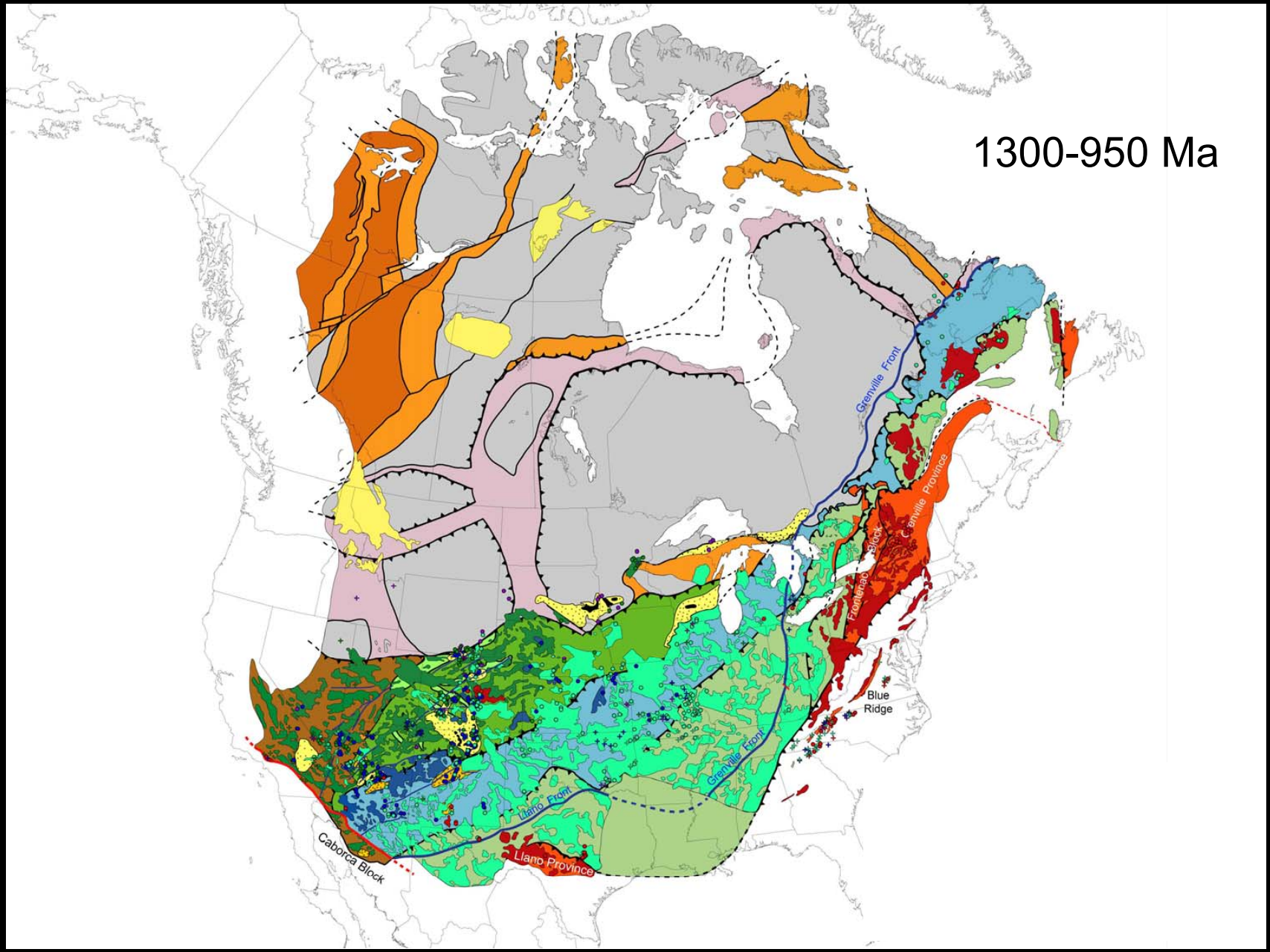

1750-1720 Ma
S. L. T. Z.
Yavapai Province
Mojave Province
Green Mt.
Rawah arc
Dubois/Cochetopa
Irving formation
Granite Gorge metamorphic suite

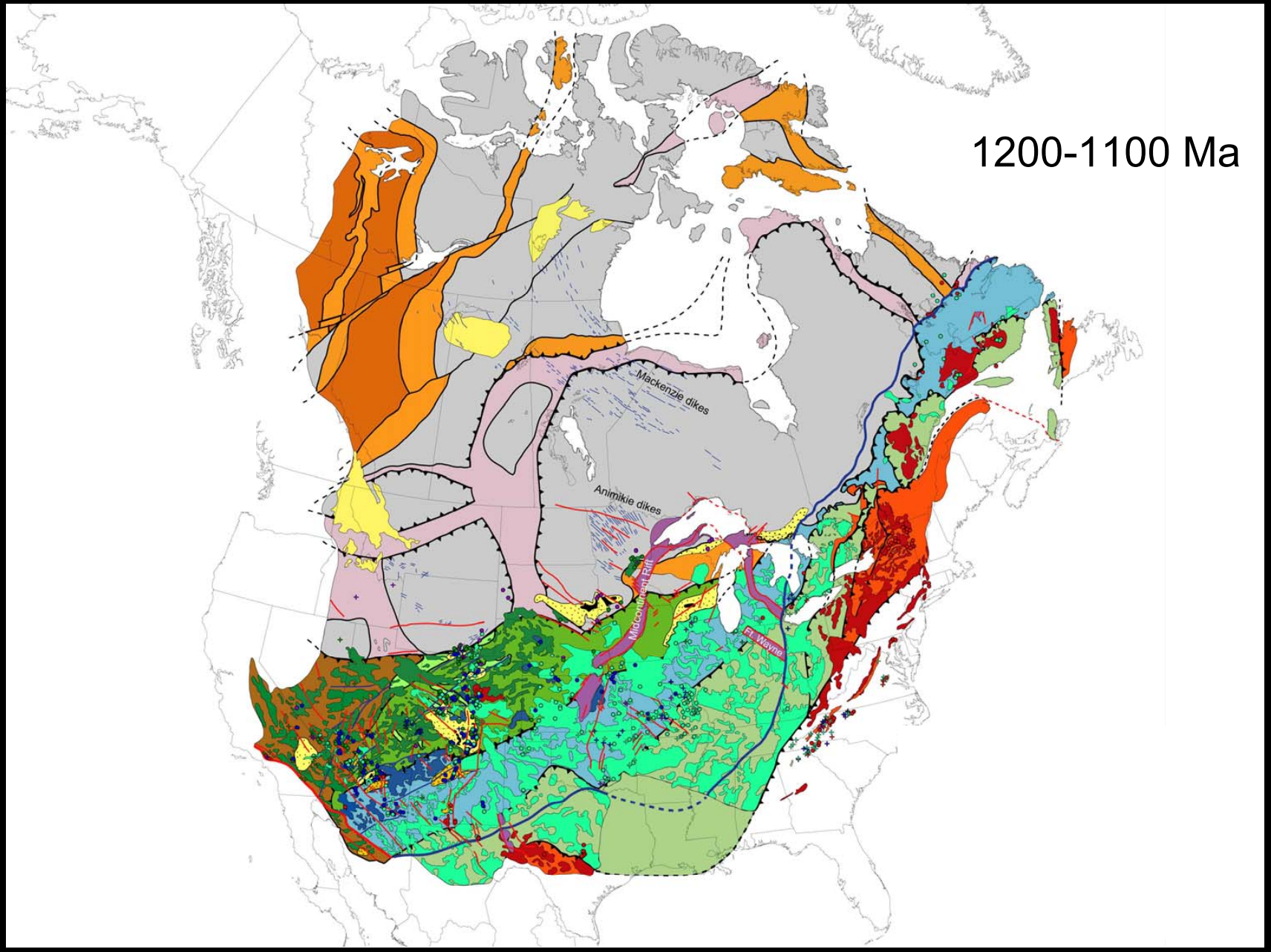

1750-1700 Ma
S. L. T. Z.
Yavapai Province
Mojave Province

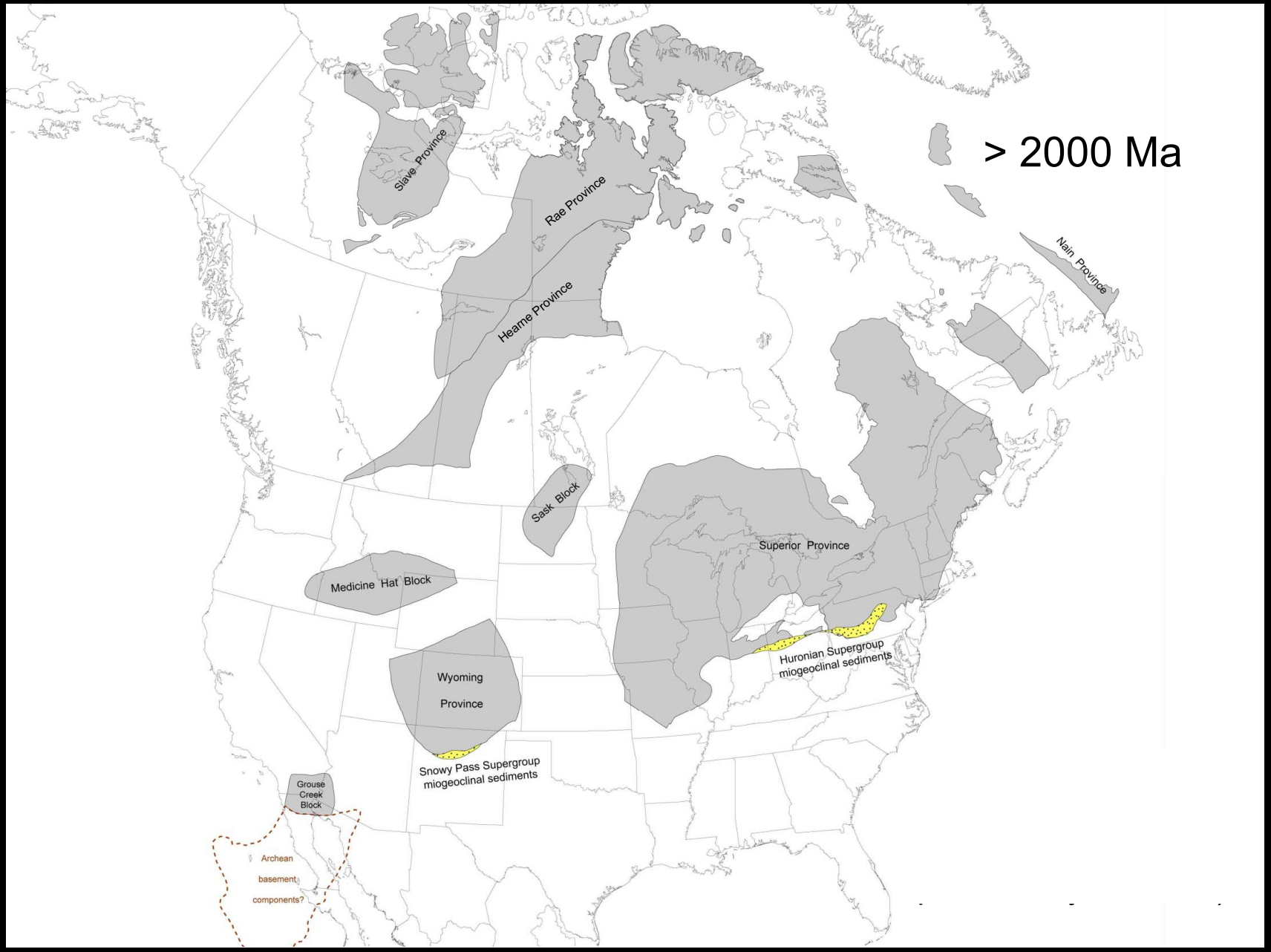

1650-1600 Ma
Labradorian Province
Mazatzal Province
Mazatzal Province
Sauratown Mountains

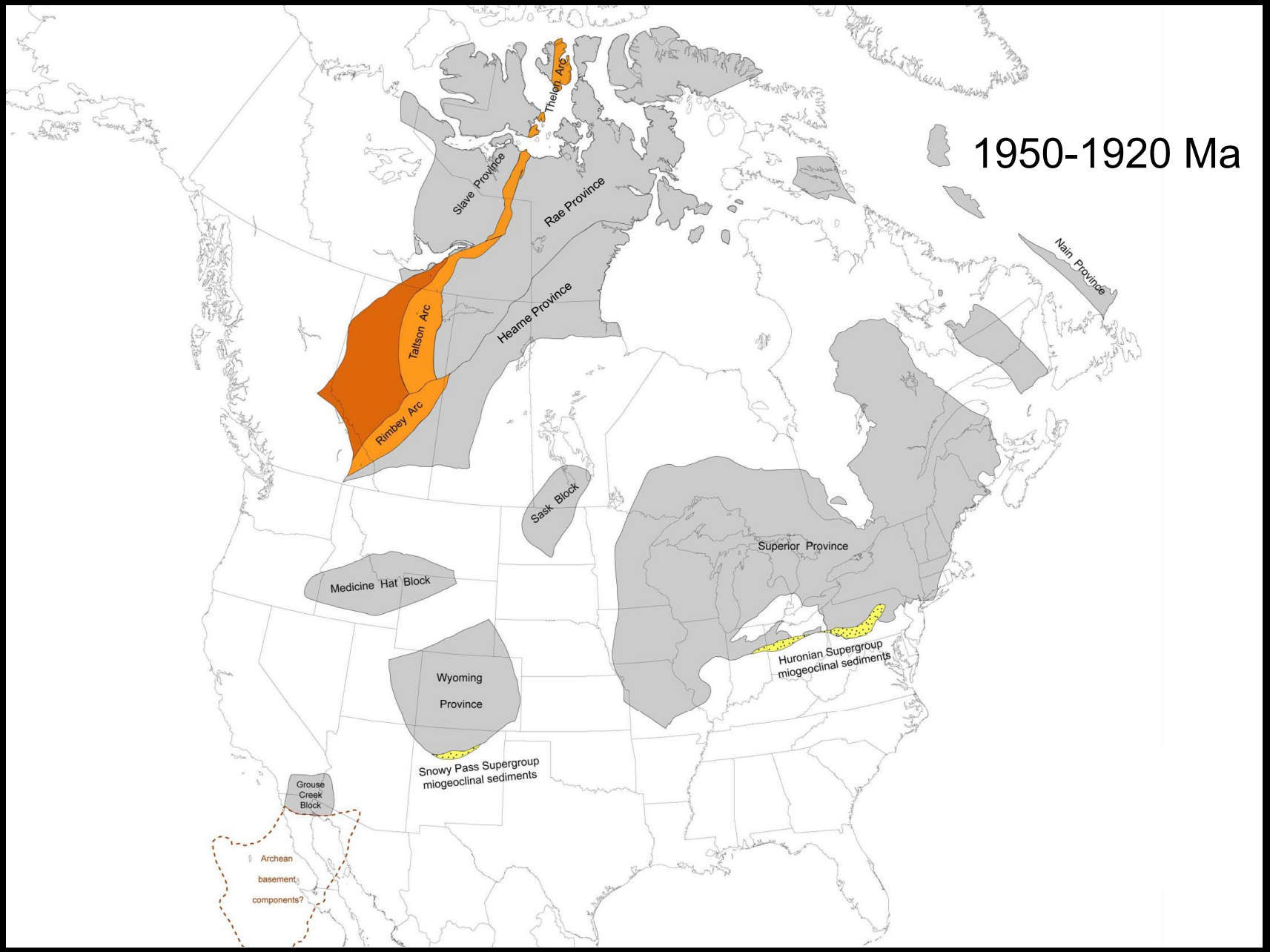

1550-1350 Ma
Pinware
Terrane
Belt
Basin
Elzevir Block
Goochland
Terrane
Toxaway,
Tallulah Falls
Domes
Granite - Rhyolite Province
Granite - Rhyolite Province

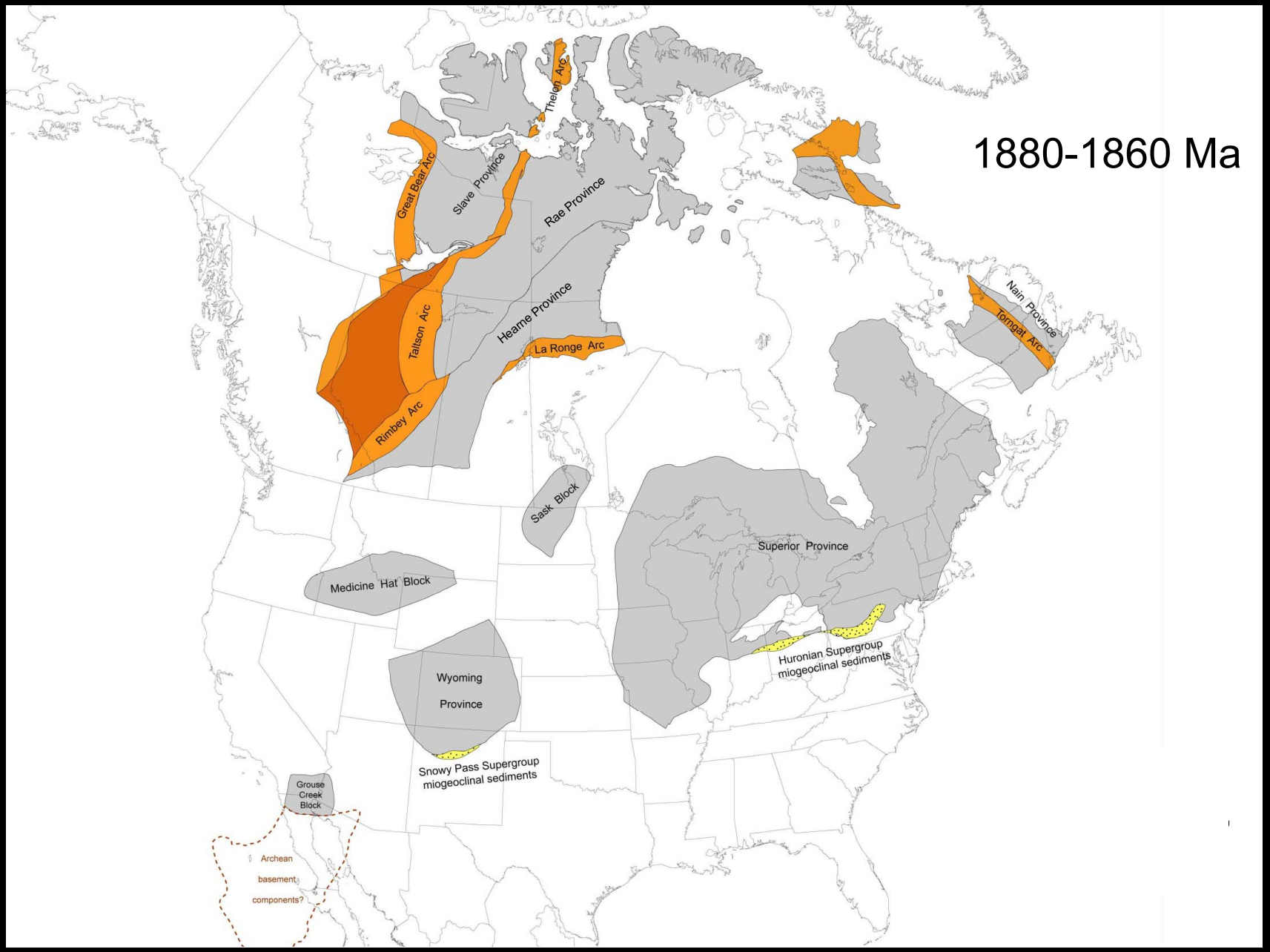

1300-1000 Ma
Grenville Front
Grenville Province
Frontenac Terrane
Blue Ridge
Grenville Front
Llano Front
Llano Province
Caborca Block

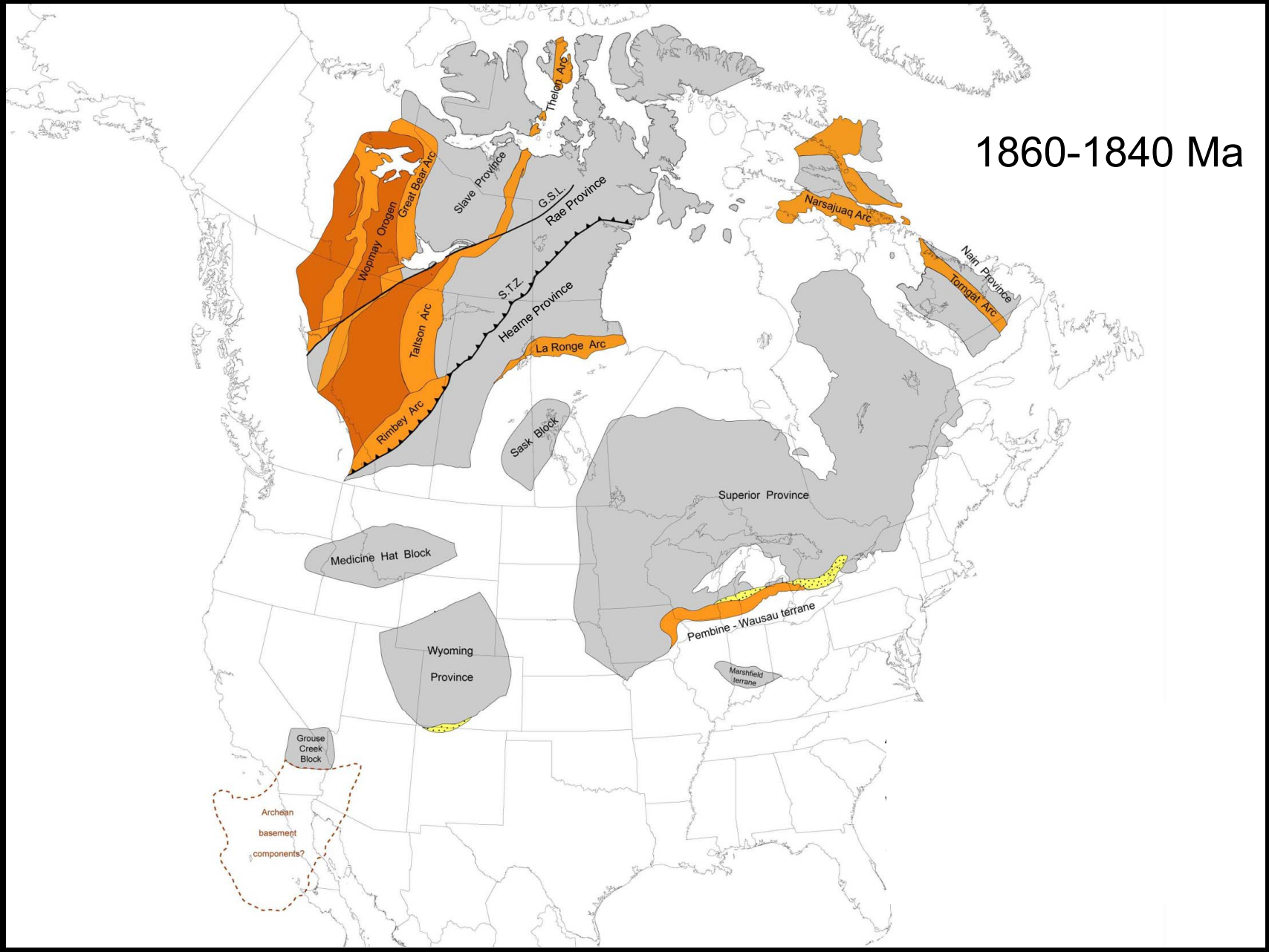

1300-950 Ma
Grenville Front
Grenville Province
Frontenac Block
Blue Ridge
Grenville Front
Llano Front
Llano Province
Caborca Block

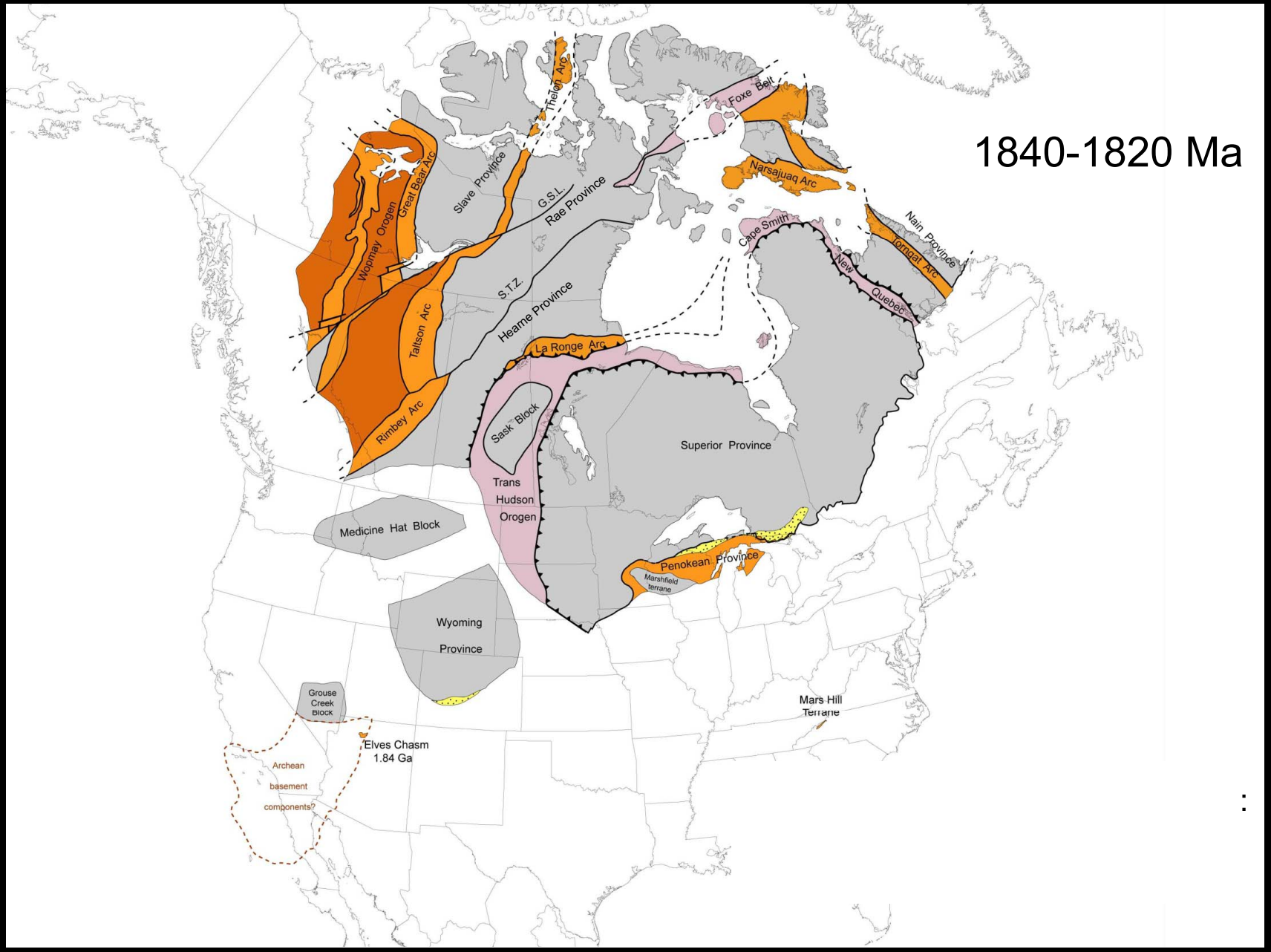

1200-1100 Ma
Mackenzie dikes
Animikie dikes
Midcontinent Rift
Ft. Wayne

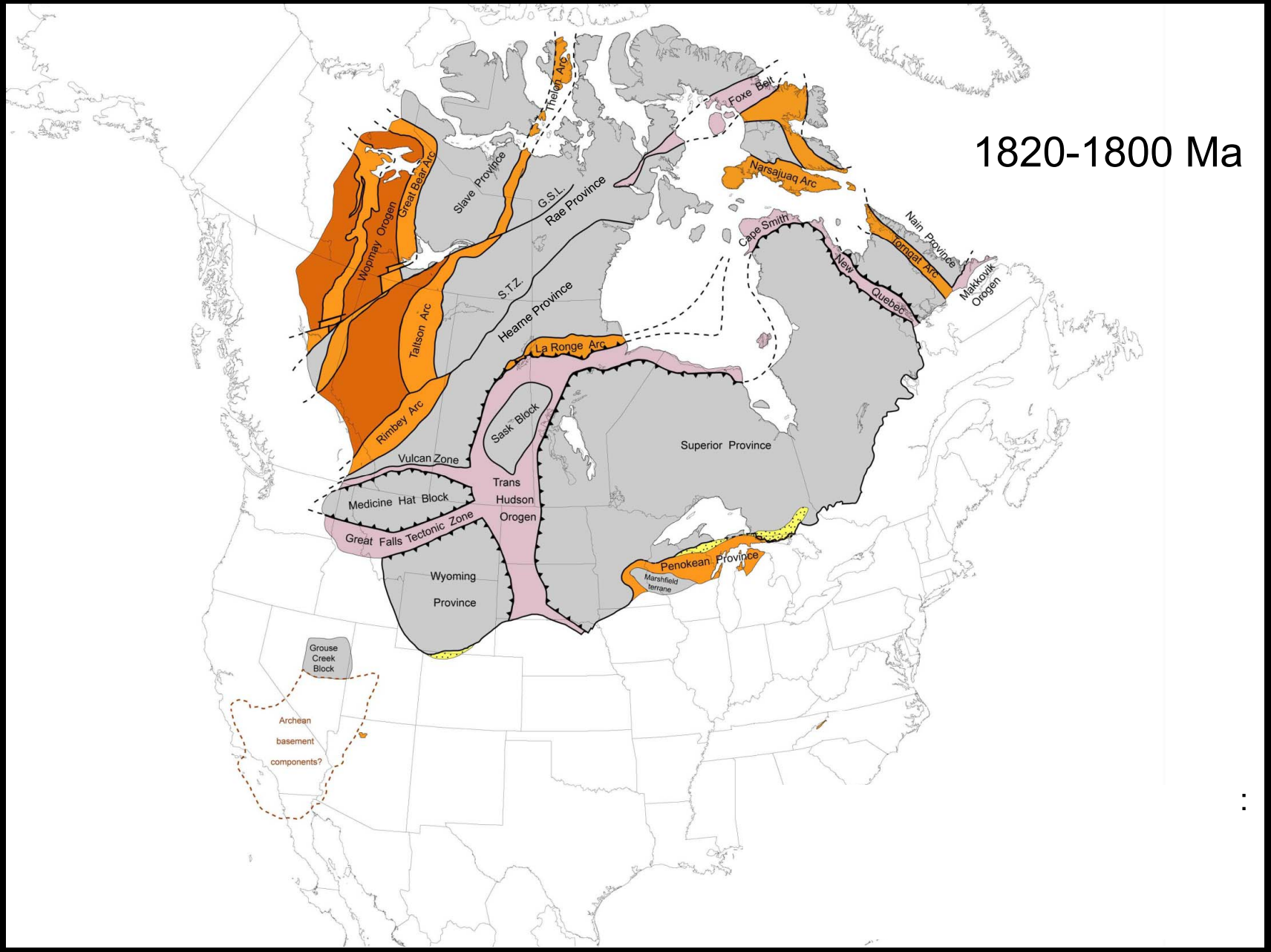

> 2000 Ma
Slave Province
Rae Province
Hearne Province
Nain Province
Sask Block
Superior Province
Medicine Hat Block
Huronian Supergroup miogeoclinal sediments
Wyoming Province
Snowy Pass Supergroup miogeoclinal sediments
Grouse Creek Block
Archean basement components?

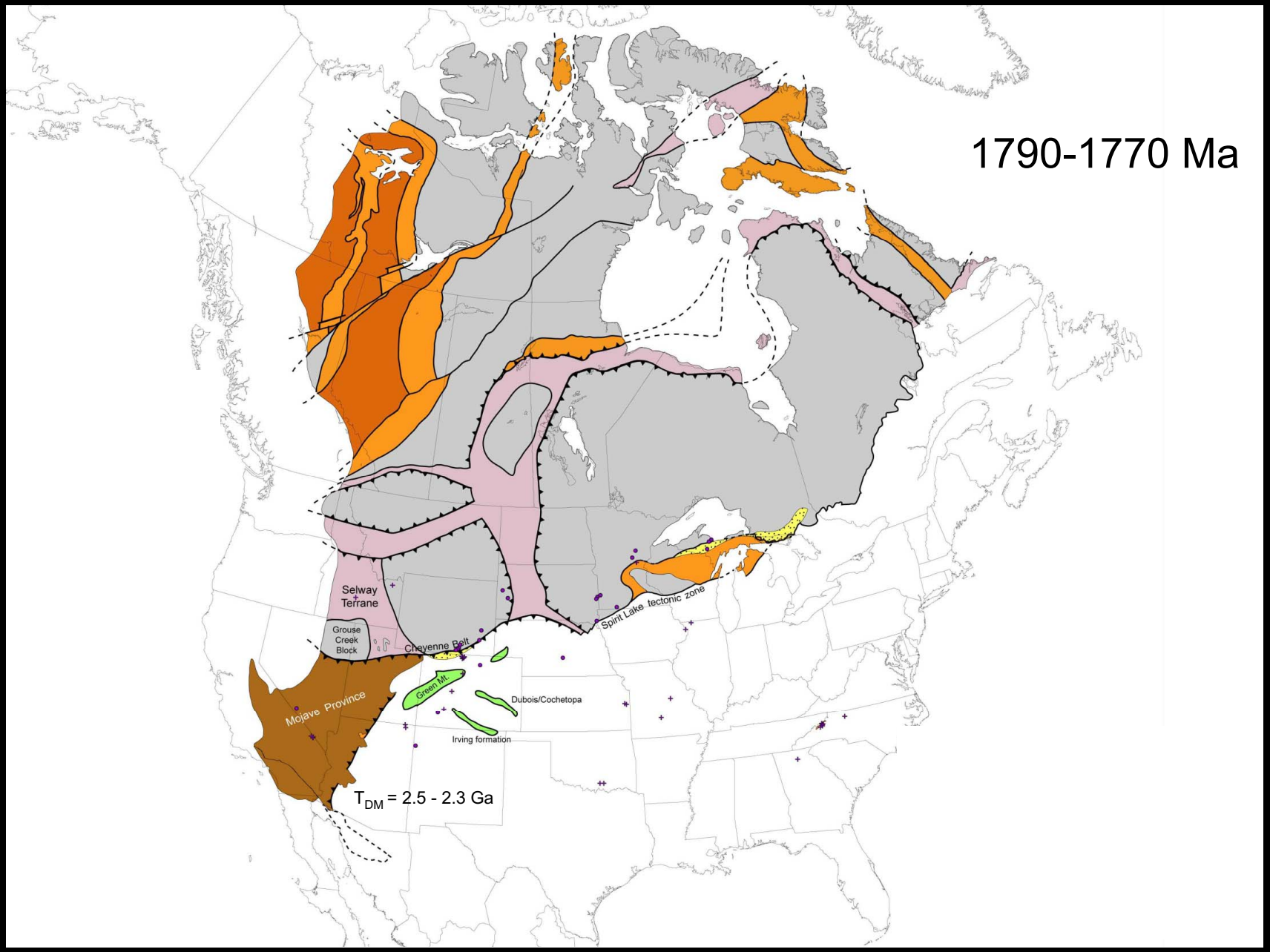

1950-1920 Ma
Thelon Arc
Slave Province
Rae Province
Hearne Province
Taltson Arc
Rimbey Arc
Nain Province
Sask Block
Superior Province
Medicine Hat Block
Huronian Supergroup miogeoclinal sediments
Wyoming Province
Snowy Pass Supergroup miogeoclinal sediments
Grouse Creek Block
Archean basement components?


1880-1860 Ma
Thelon Arc
Great Bear Arc
Slave Province
Rae Province
Hearne Province
Taltson Arc
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?


1860-1840 Ma
Thelon Arc?
Slave Province
Great Bear Arc
Wopmay Orogen
G.S.L.
Rae Province
S.T.Z.
Hearne Province
Taltson 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?


1840-1820 Ma
Thelon Arc
Foxe Belt
Slave Province
G.S.L.
Rae Province
Great Bear Arc
Wopmay Orogen
Natsajuaq Arc
Cape Smith
Nain Province
Torngat Arc
New Quebec
S.T.Z.
Hearne Province
Taltson Arc
La Ronge Arc
Rimbey Arc
Sask Block
Superior Province
Trans Hudson Orogen
Medicine Hat Block
Penokean Province
Marshfield terrane
Wyoming Province
Grouse Creek Block
Mars Hill Terrane
Elves Chasm 1.84 Ga
Archean basement components?


1820-1800 Ma
Thelon Arc
Foxe Belt
Slave Province
G.S.L.
Rae Province
Great Bear Arc
Wopmay Orogen
Narsajuaq Arc
Cape Smith
Nain Province
Torngat Arc
Makkovik Orogen
New Quebec
S.T.Z.
Hearne Province
Taltson Arc
La Ronge Arc
Rimbey Arc
Sask Block
Superior Province
Vulcan Zone
Trans Hudson Orogen
Medicine Hat Block
Great Falls Tectonic Zone
Penokean Province
Marshfield terrane
Wyoming Province
Grouse Creek Block
Archean basement components?


1790-1770 Ma
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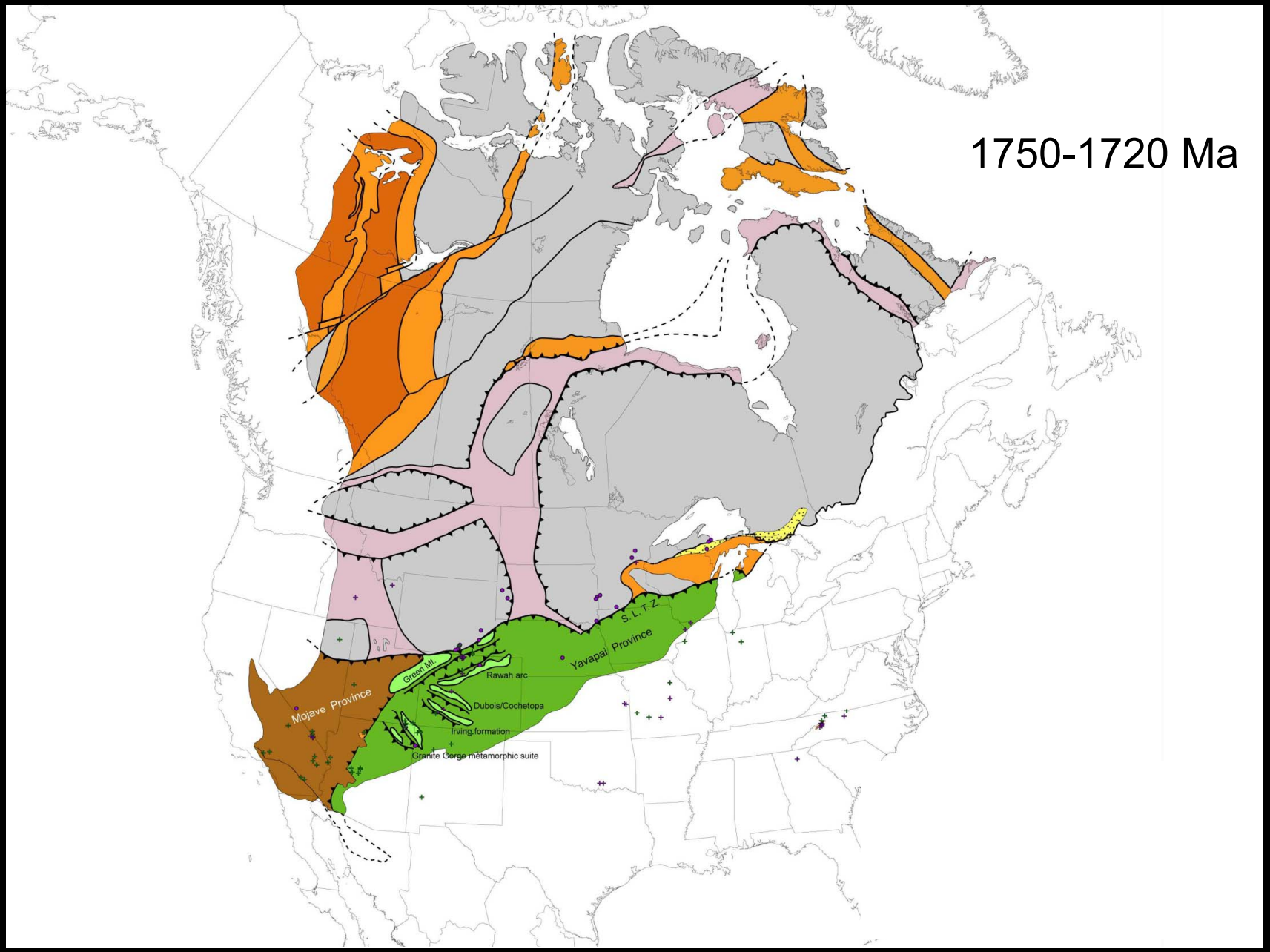
Grouse Creek Block
Cheyenne Belt
Green Mt.
Dubois/Cochetopa
Irving formation
Mojave Province
Spirit Lake tectonic zone
T_{DM} = 2.5 - 2.3 Ga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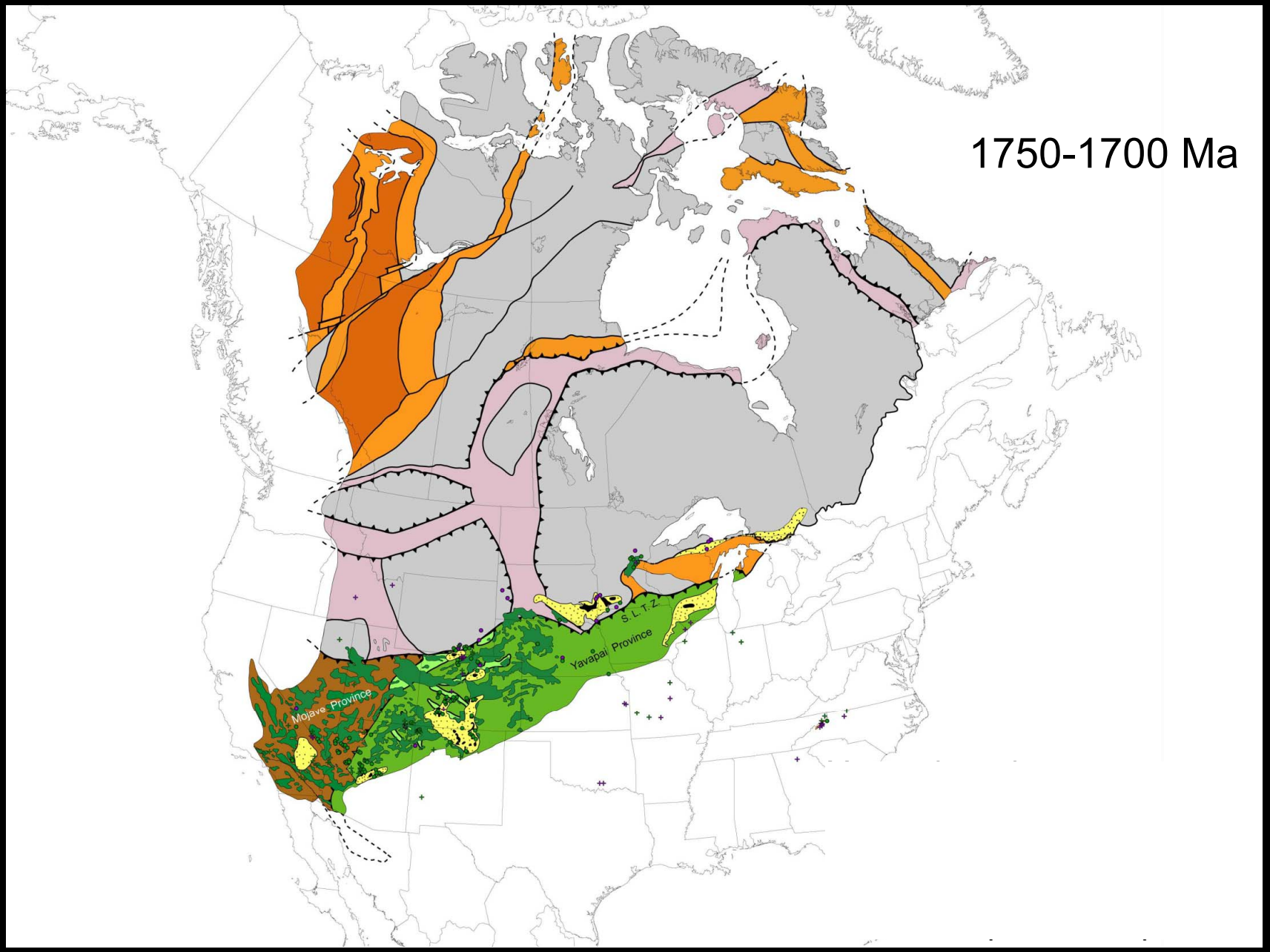
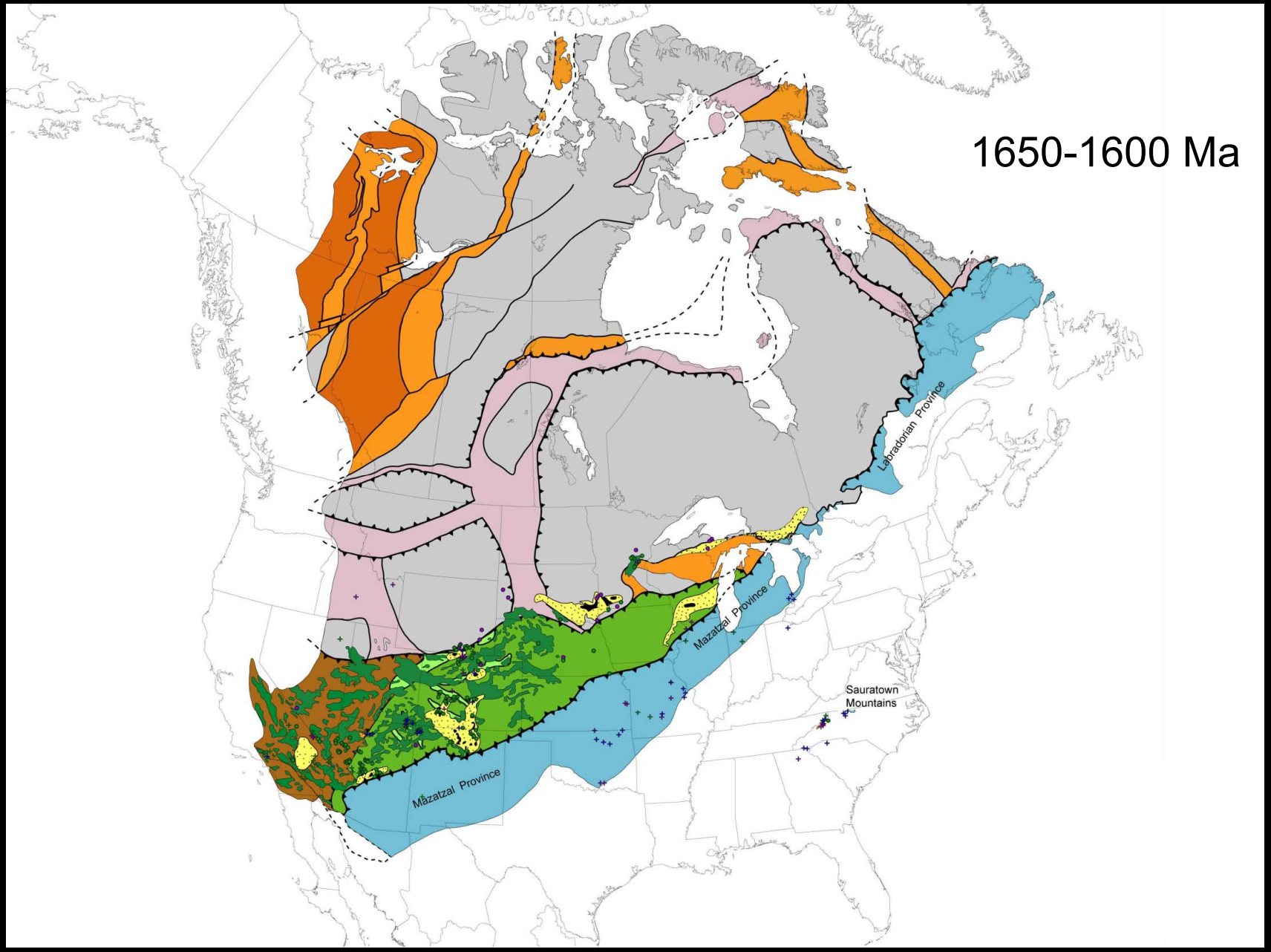
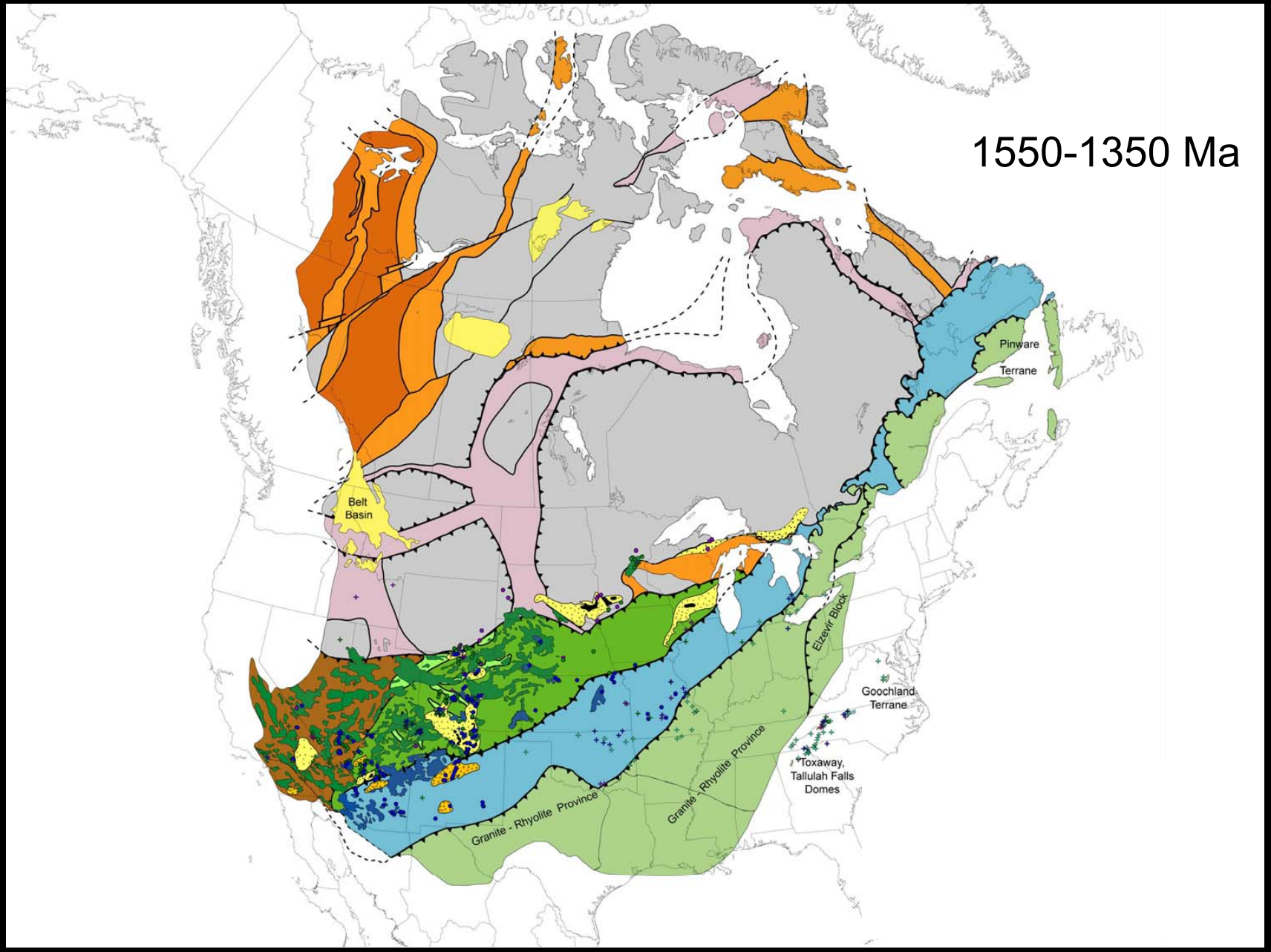
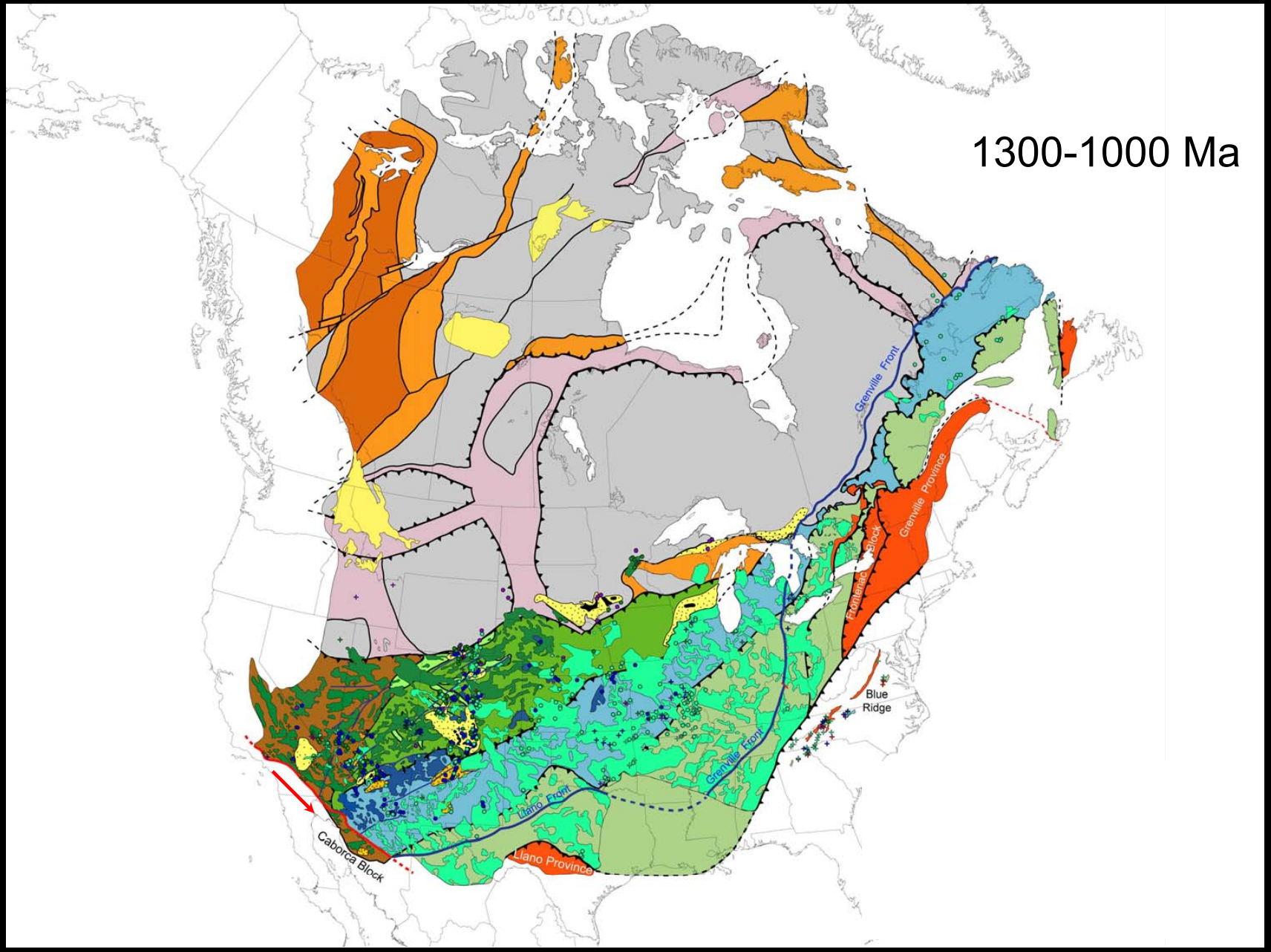
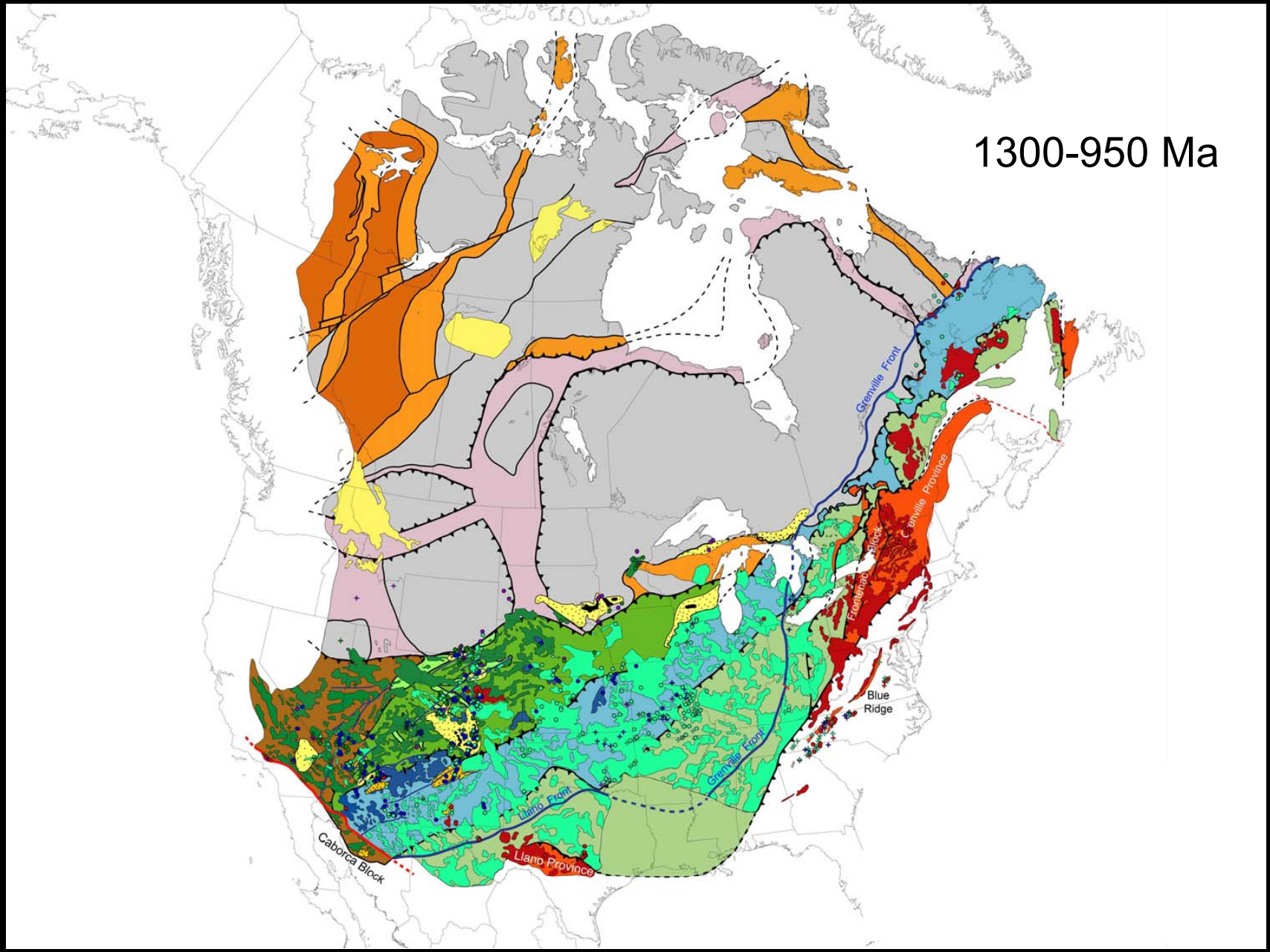
Granite Gorge metamorphic suite

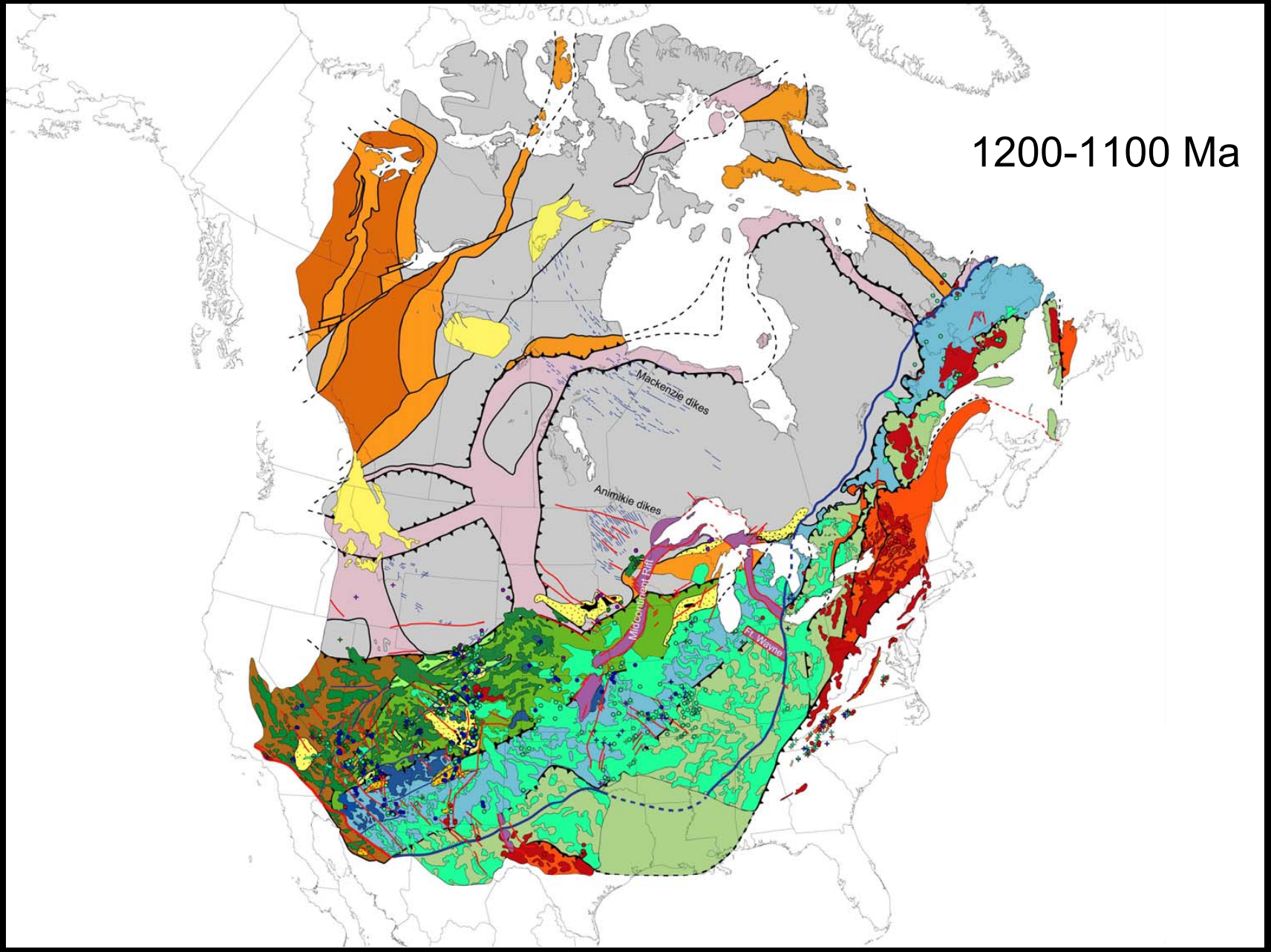

1750-1700 Ma
S. L. T. Z.
Yavapai Province
Mojave Province


1650-1600 Ma
Labradorian Province
Mazatzal Province
Mazatzal Province
Sauratown Mountains

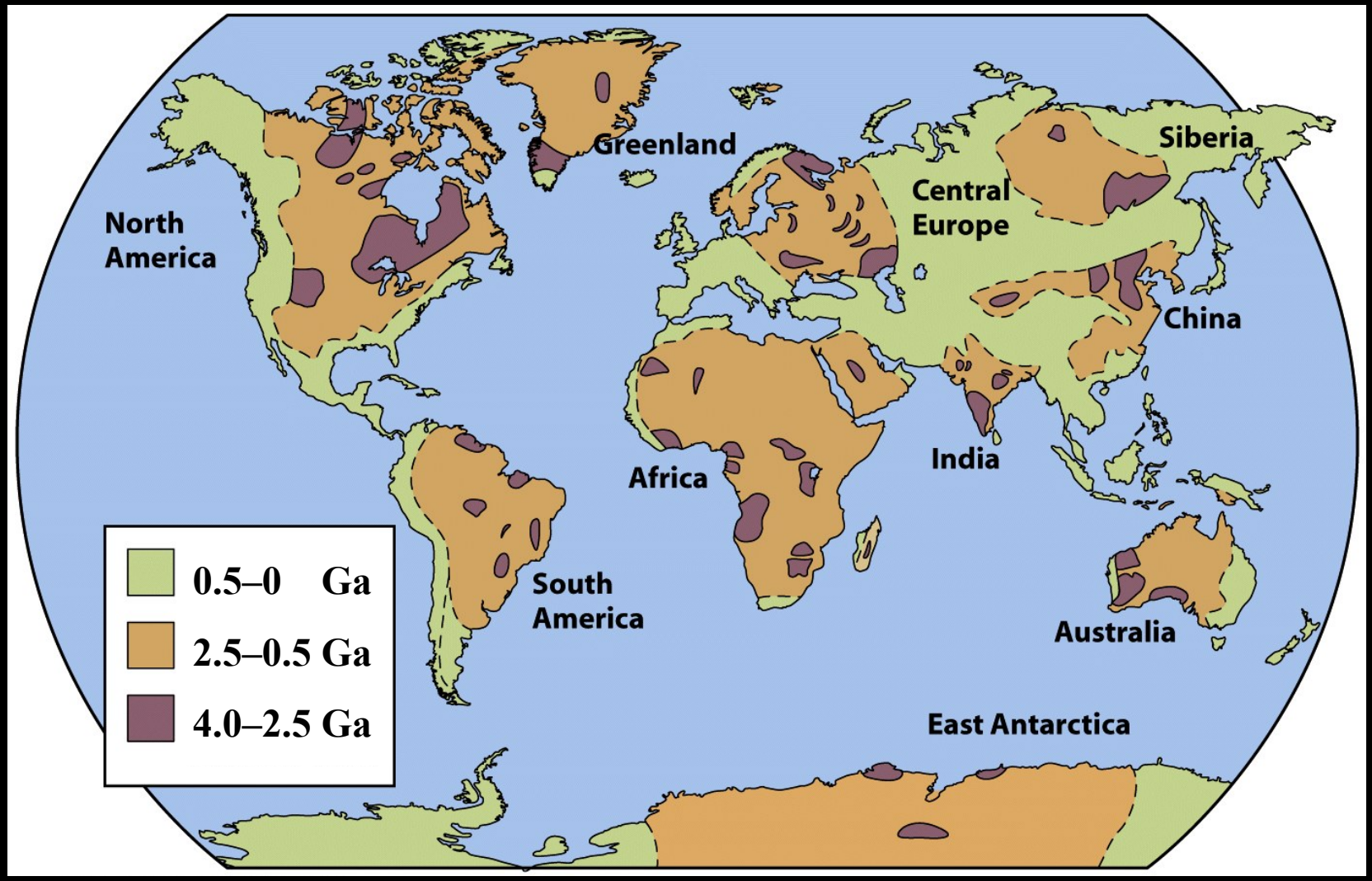

1550-1350 Ma
Pinware
Terrane
Belt
Basin
Elzevir Block
Goochland
Terrane
Toxaway,
Tallulah Falls
Domes
Granite - Rhyolite Province
Granite - Rhyolite Province

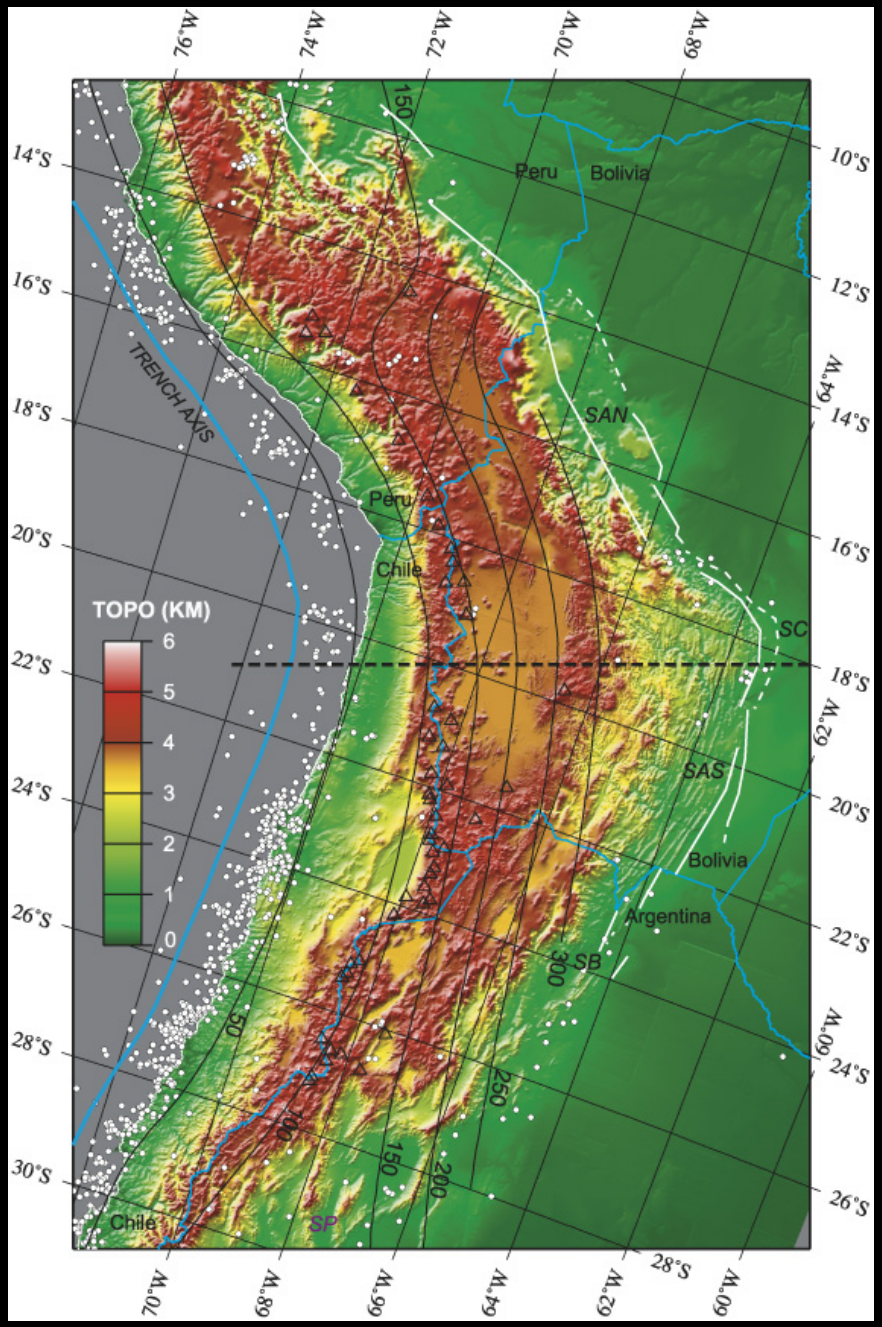

1300-1000 Ma
Grenville Front
Grenville Province
Frontenac Terrane
Blue Ridge
Grenville Front
Llano Front
Llano Province
Caborca Block


1300-950 Ma
Grenville Front
Grenville Province
Frontenac Block
Blue Ridge
Grenville Front
Llano Front
Llano Province
Caborca Block


1200-1100 Ma
Mackenzie dikes
Animikie dikes
Midcontinent Rift
Ft. Wayne

Age des continents



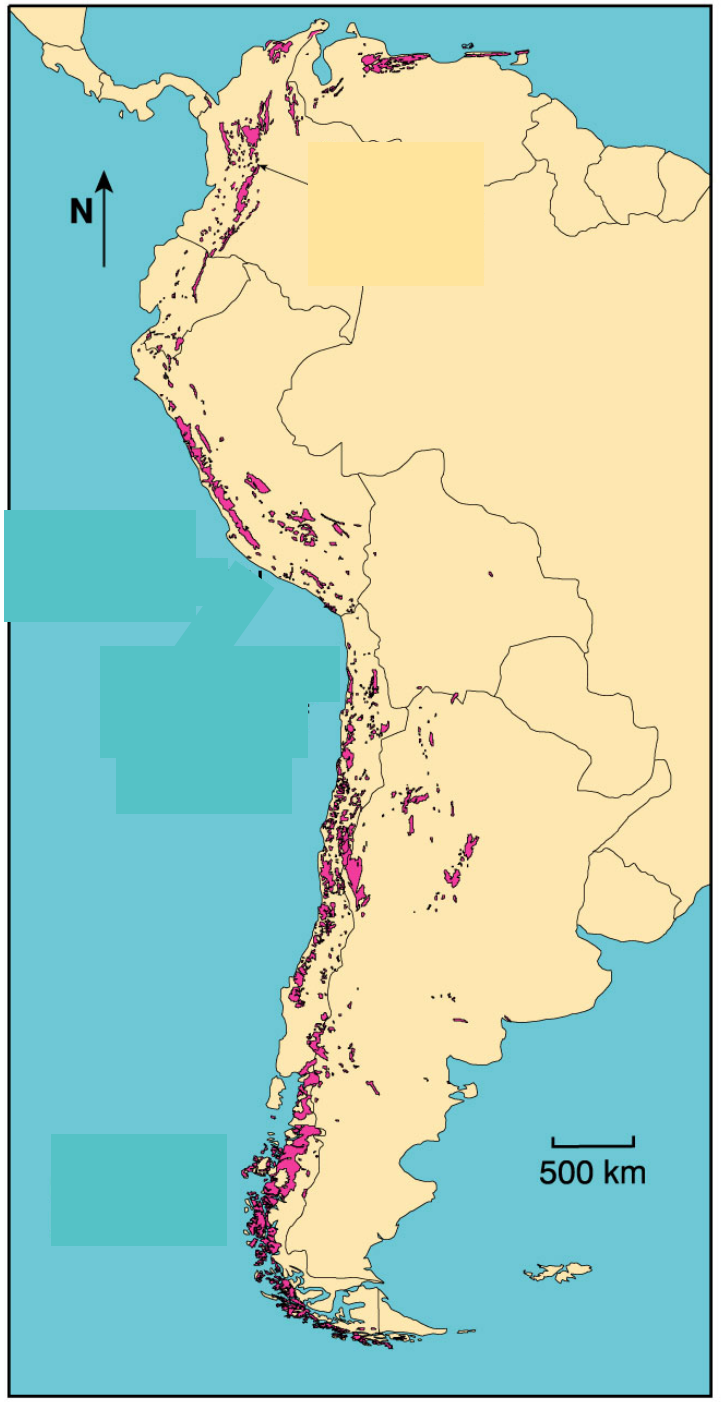


Cordillère des Andes

Altitude ~ 6km

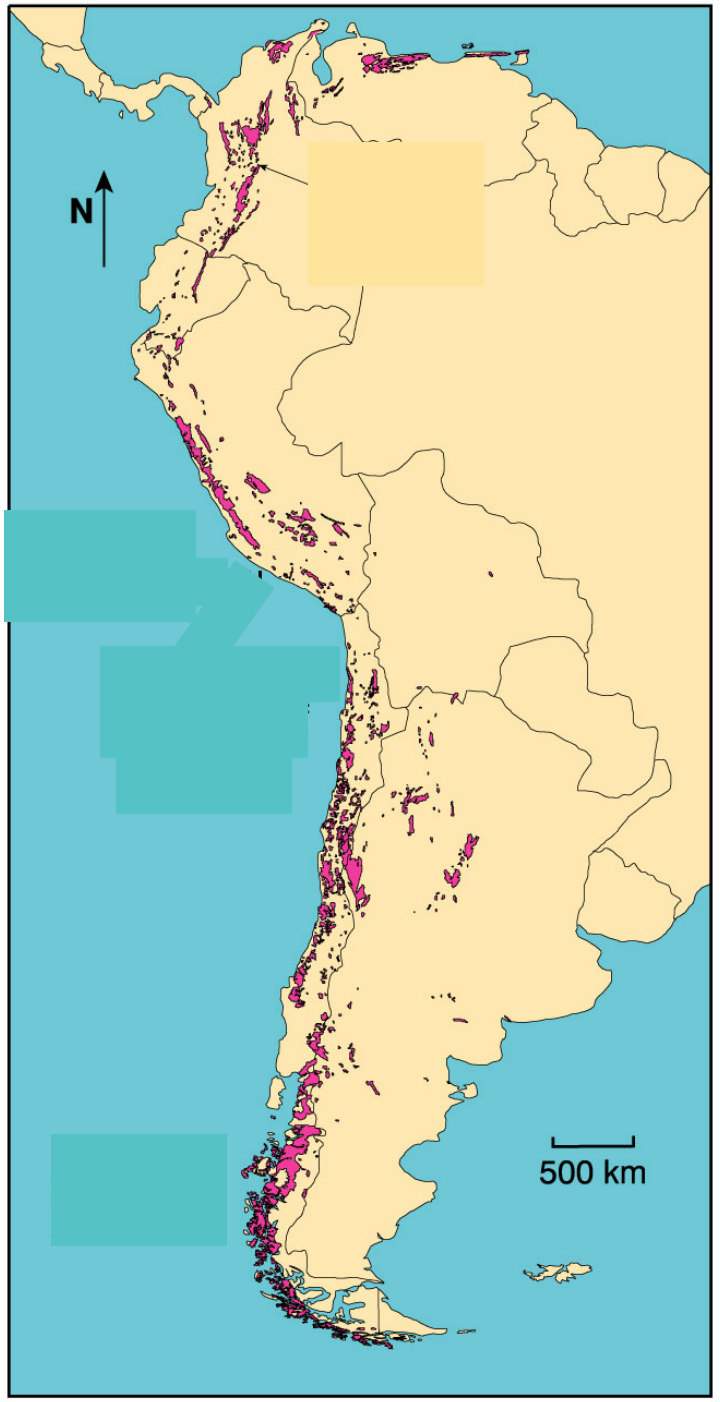
Croûte épaisse
(60-70 km au lieu de 40 km)
Addition de magmas “juvéniles”
(nouvelle croûte)

Taux de fabrication ≈
50 km^3/Ma/km



Taux de fabrication ≈
50 km³/Ma/km

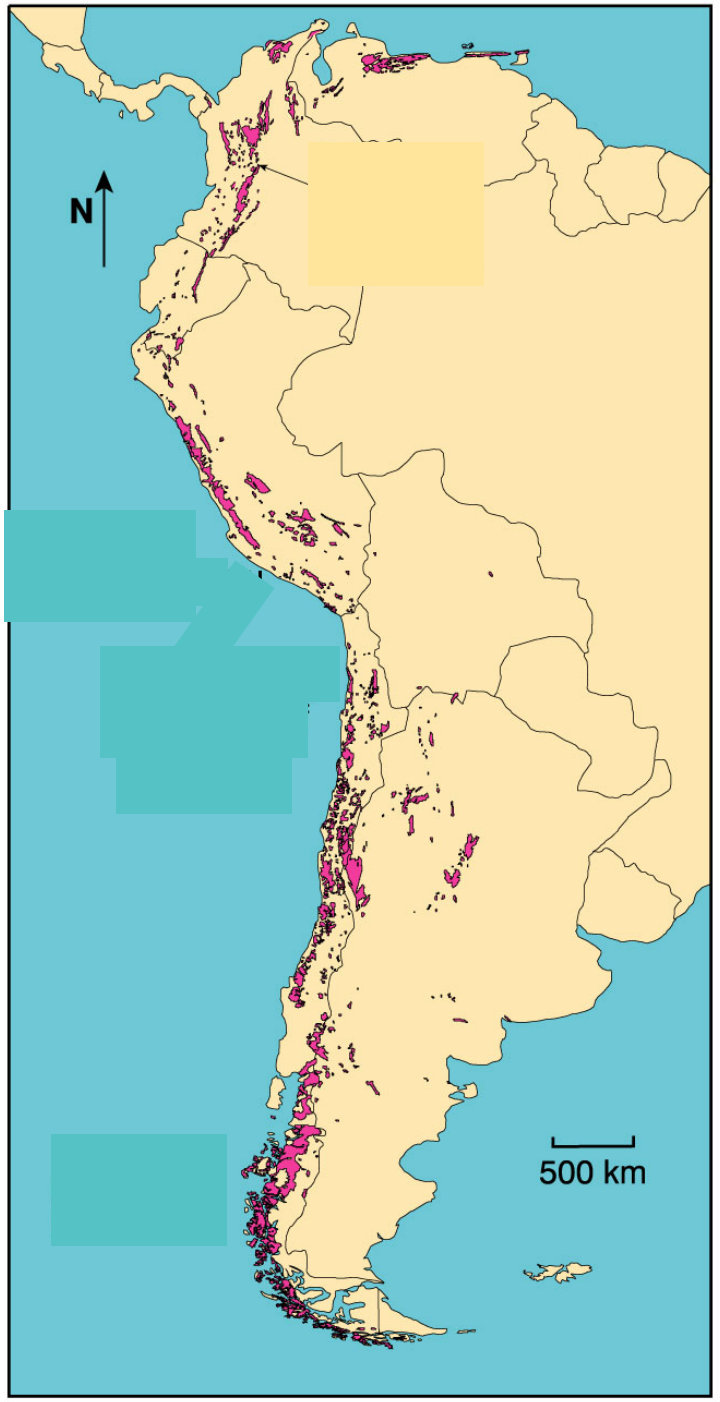
soit
une ceinture de 125 km de large
ajoutée en 100 Ma.



Taux de fabrication ≈
50 km³/Ma/km

soit
une ceinture de 125 km de large
ajoutée en 100 Ma.

≈ 1500 km de large en 1 Ga
pour la seule cordillère des Andes.

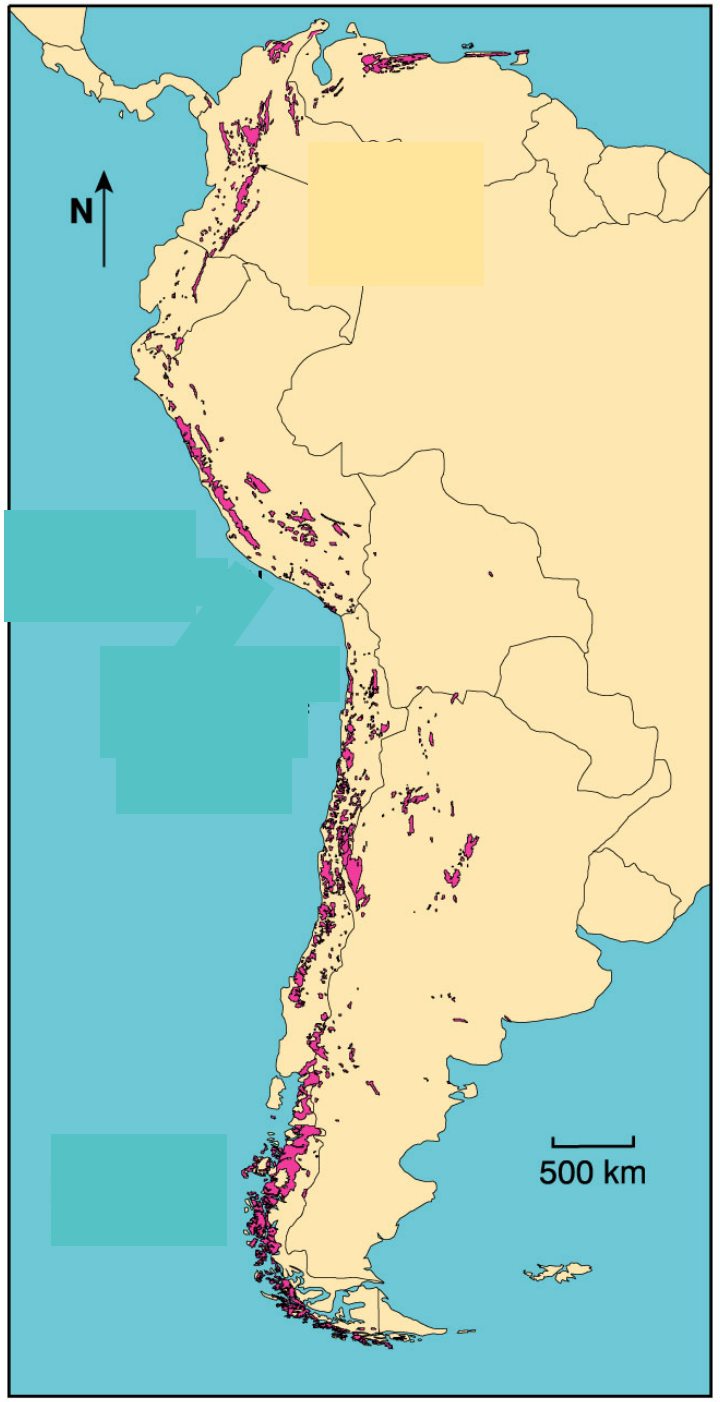


Taux de fabrication ≈
50 km^3/Ma/km

soit
une ceinture de 125 km de large
ajoutée en 100 Ma.

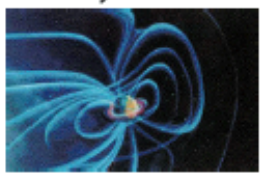
≈ 1500 km de large en 1 Ga
pour la seule cordillère des Andes.

Depuis le début,
l'activité magmatique/volcanique
a construit (au moins)
3.5 x 10^8 km^2 de surface continentale
70% de la surface terrestre



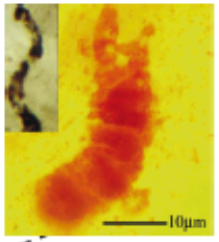
1ers océans

Dynamo?

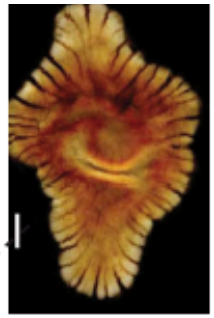


Naissance

1ère bactérie



1er organisme multi-cellulaire

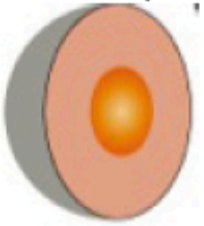


1ers êtres vivants
Composants solides

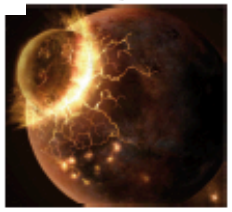
Cyanobactéries
photosynthèse

4.56 4.0 3.0 2.0 1.0 0 Ga

CROISSANCE DES CONTINENTS



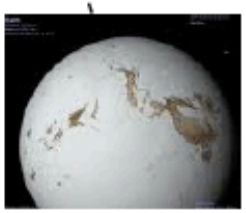
Noyau



Formation
Lune

Roche
la plus
ancienne

Sédiments
les + anciens

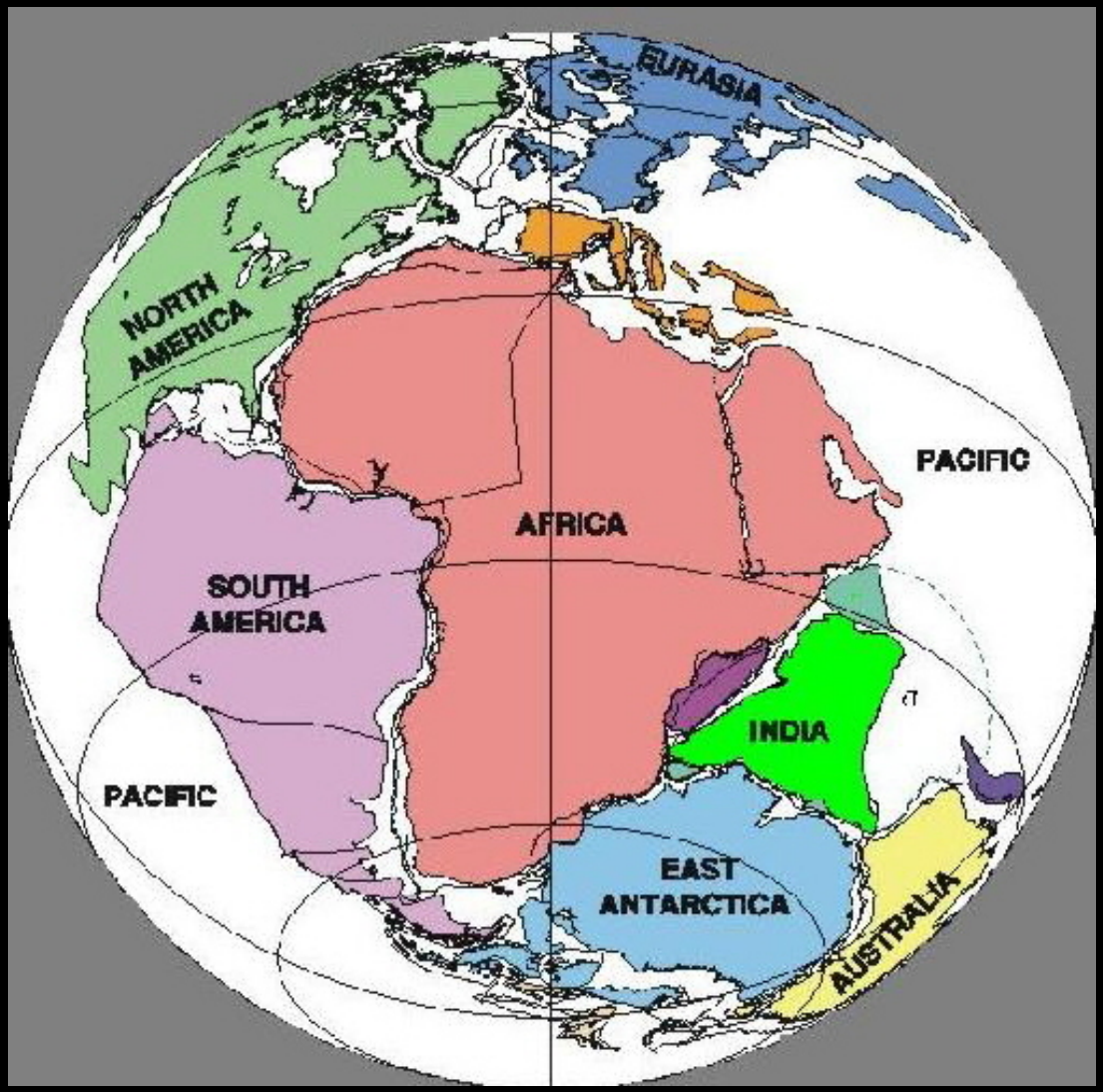


1er
âge glaciaire

O_2

Oxydation
atmosphère

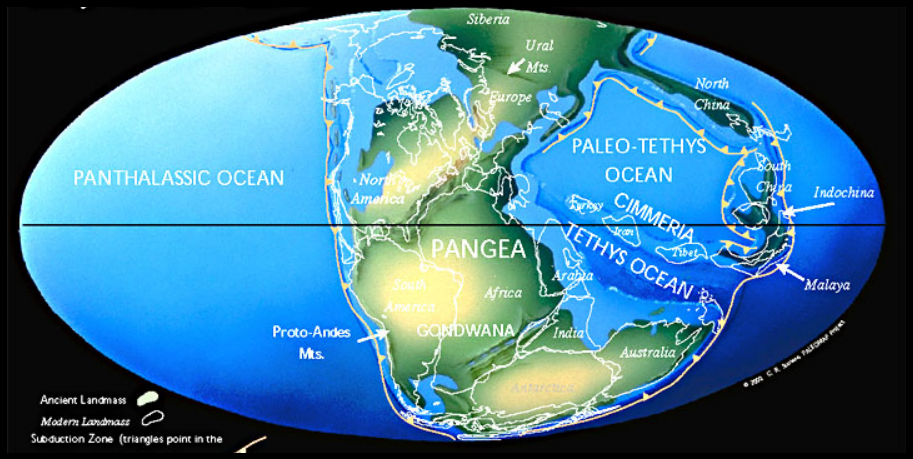
Formation et démembrement des supercontinents



Supercontinents

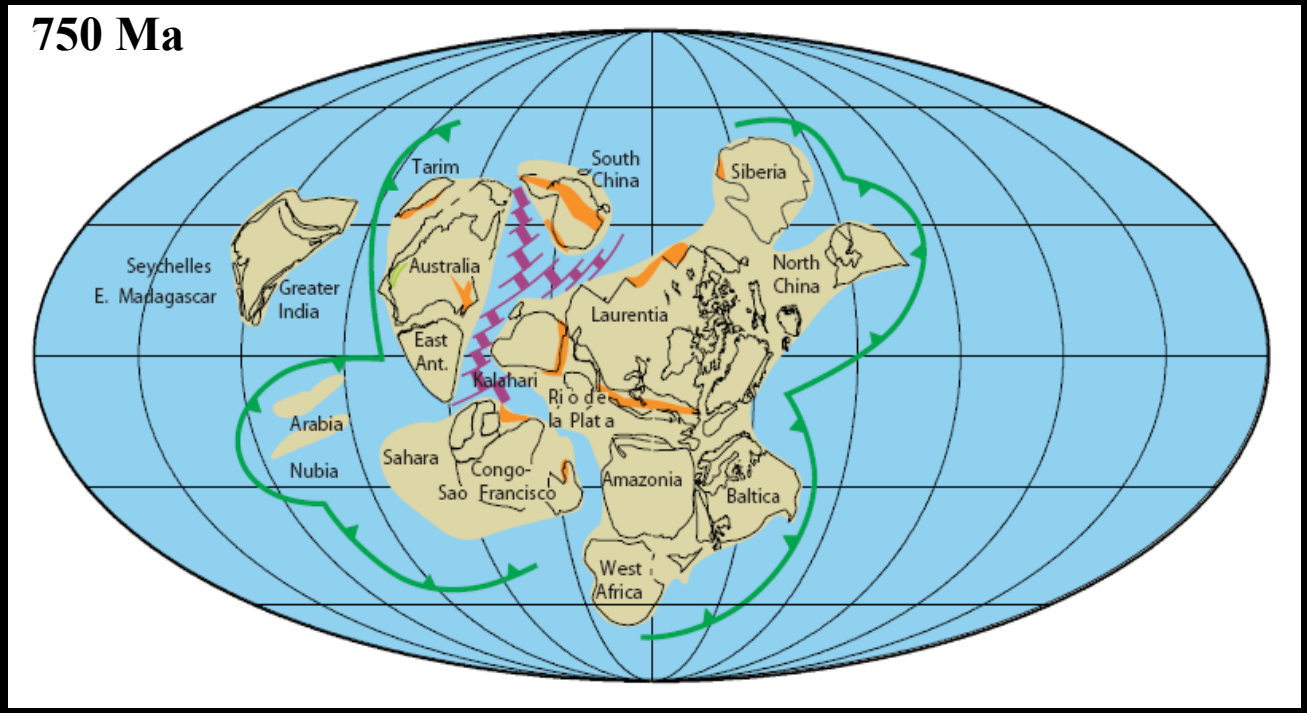
SUPERCONTINENT	PHASE	INTERVALLE (Ga)	DUREE (Ma)
Kenorland (Superia)	Assembl.	2.8-2.5	300
	Stable	2.5-2.4	100
	Démemb.	2.4-2.0	400
Columbia (Nuna)	Assembl.	2.0-1.8	200
	Stable	1.8-1.6	200
	Démemb.	1.6-1.2	400
Rodinia	Assembl.	1.2-1.0	200
	Stable	1.0-0.75	250
	Démem.	0.75-0.6	150
Pannotia	Assembl.	0.6-0.56	40
	Stable	0.56-0.54	20
	Démemb.	0.54-0.43	110
Pangée	Assembl.	0.43-0.25	180
	Stable	0.25-0.175	75
	Démemb.	0.175-0	175

Pangée (330 - 180 Ma)

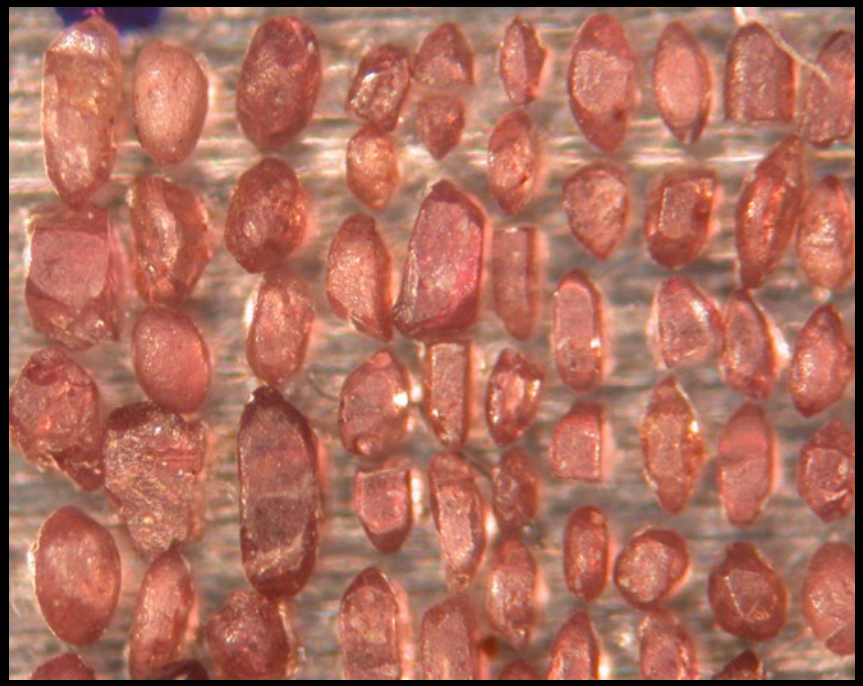


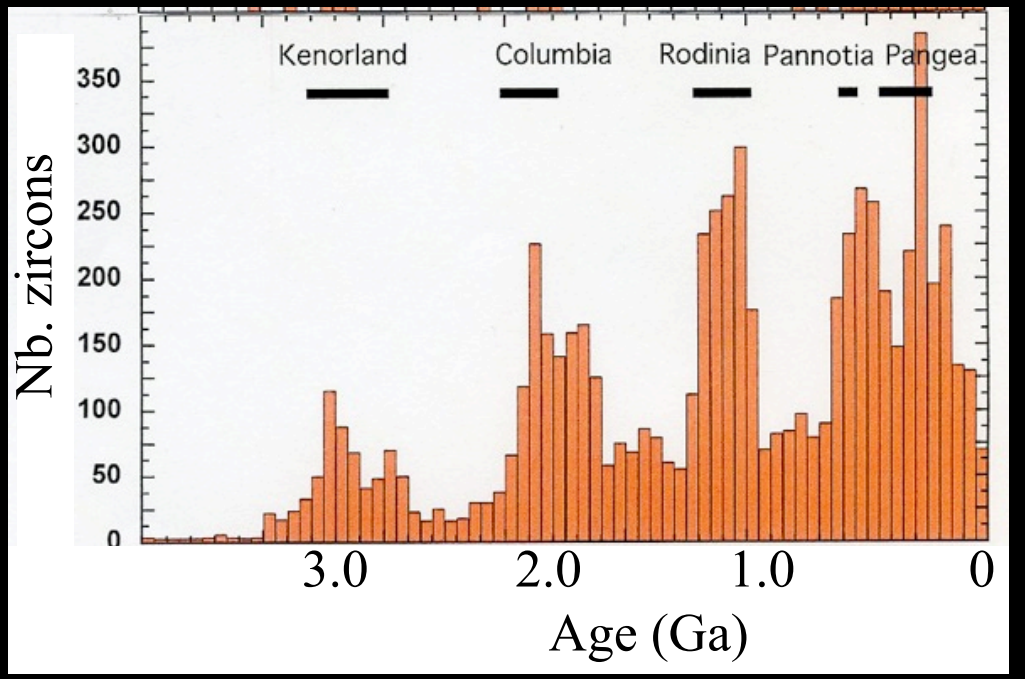
Pangée (330 - 180 Ma)

Rodinia (900 - 750 Ma)



Les zircons sont indestructibles

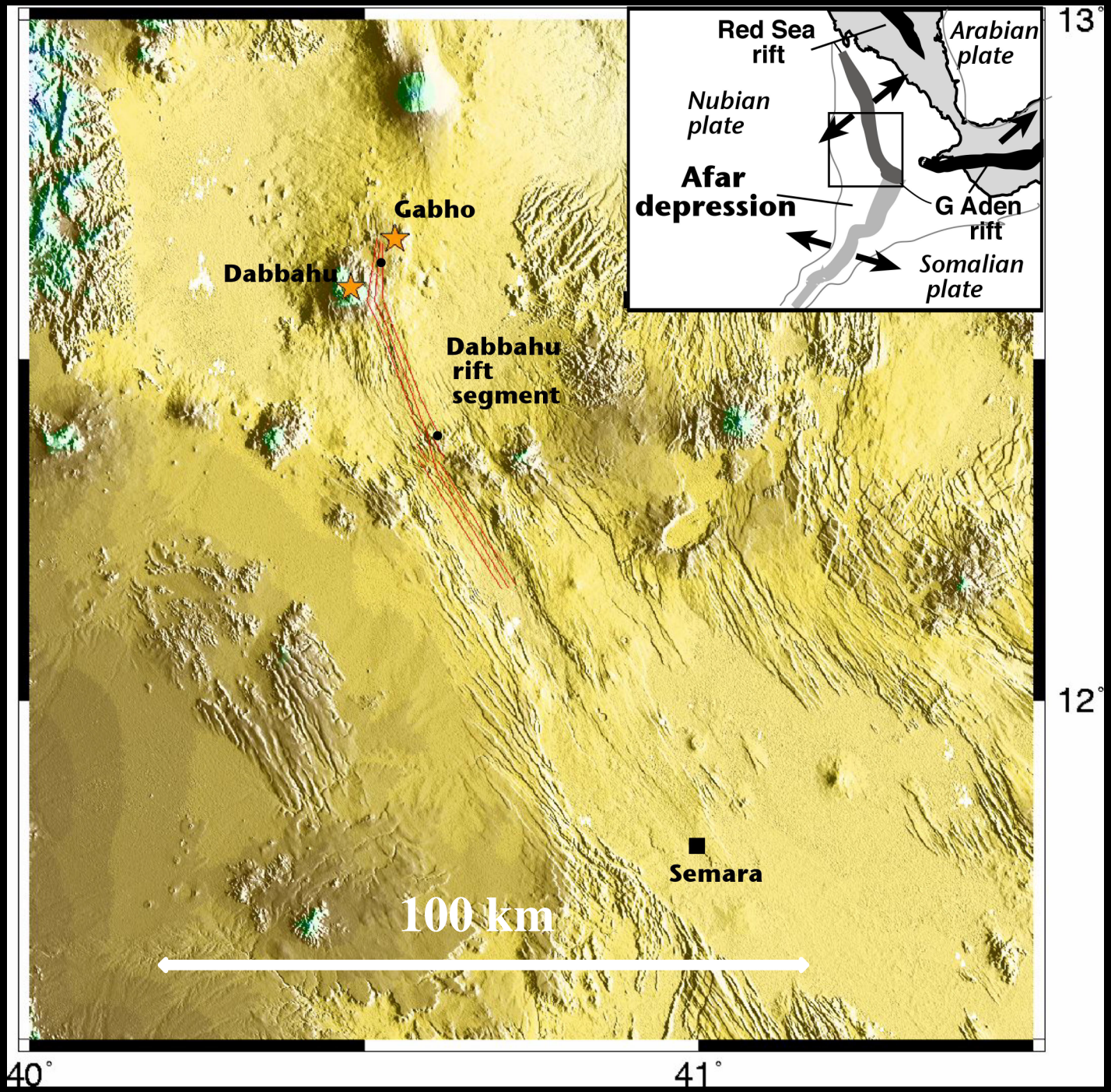




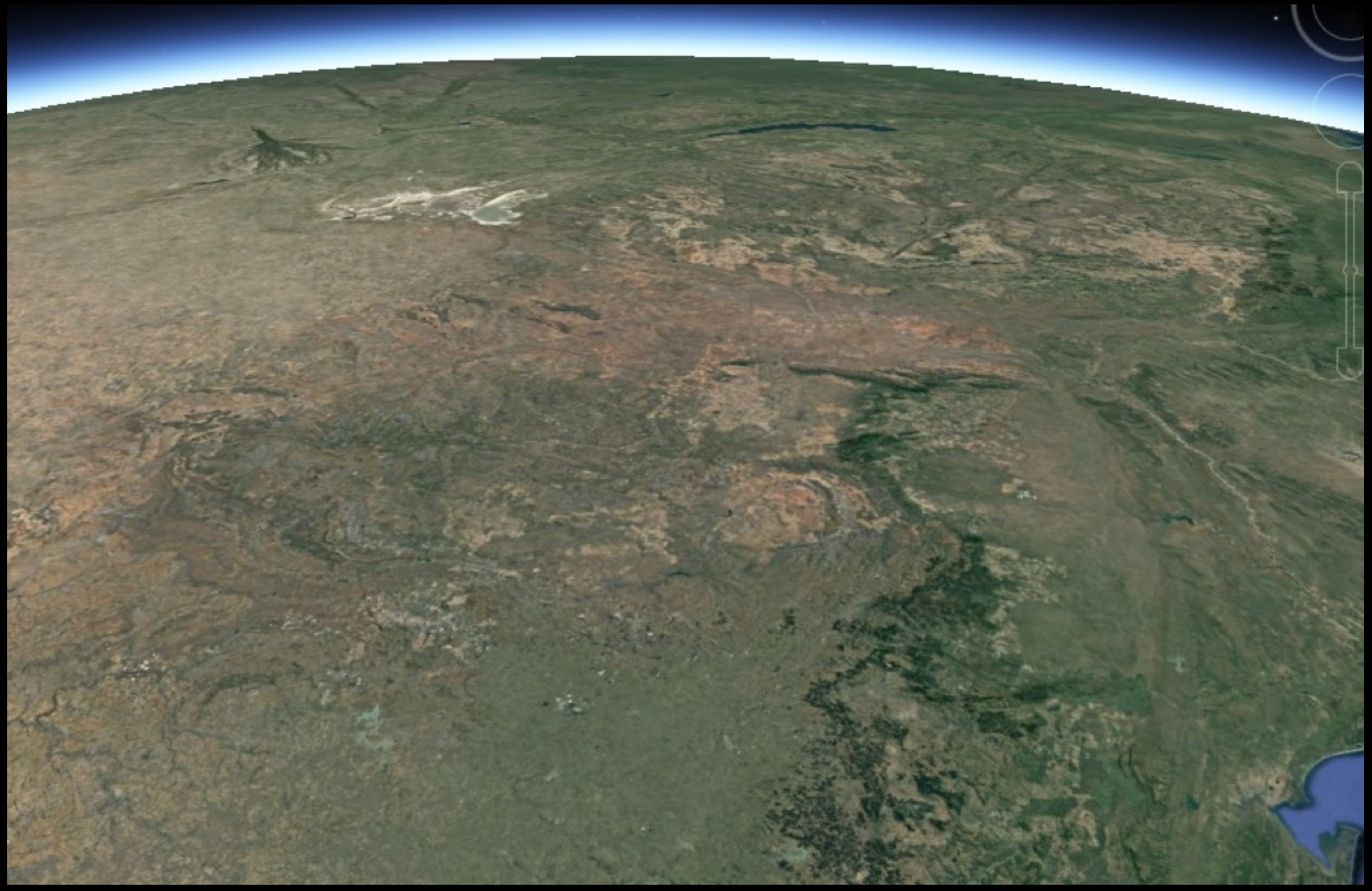
Les cicatrices des continents

Eruption
de Dabbahu
(Afars)
2005

Ouverture
d'une fissure
de 60 km
de long



Le “Great Dyke” du Zimbabwe



Great Dyke, Zimbabwe

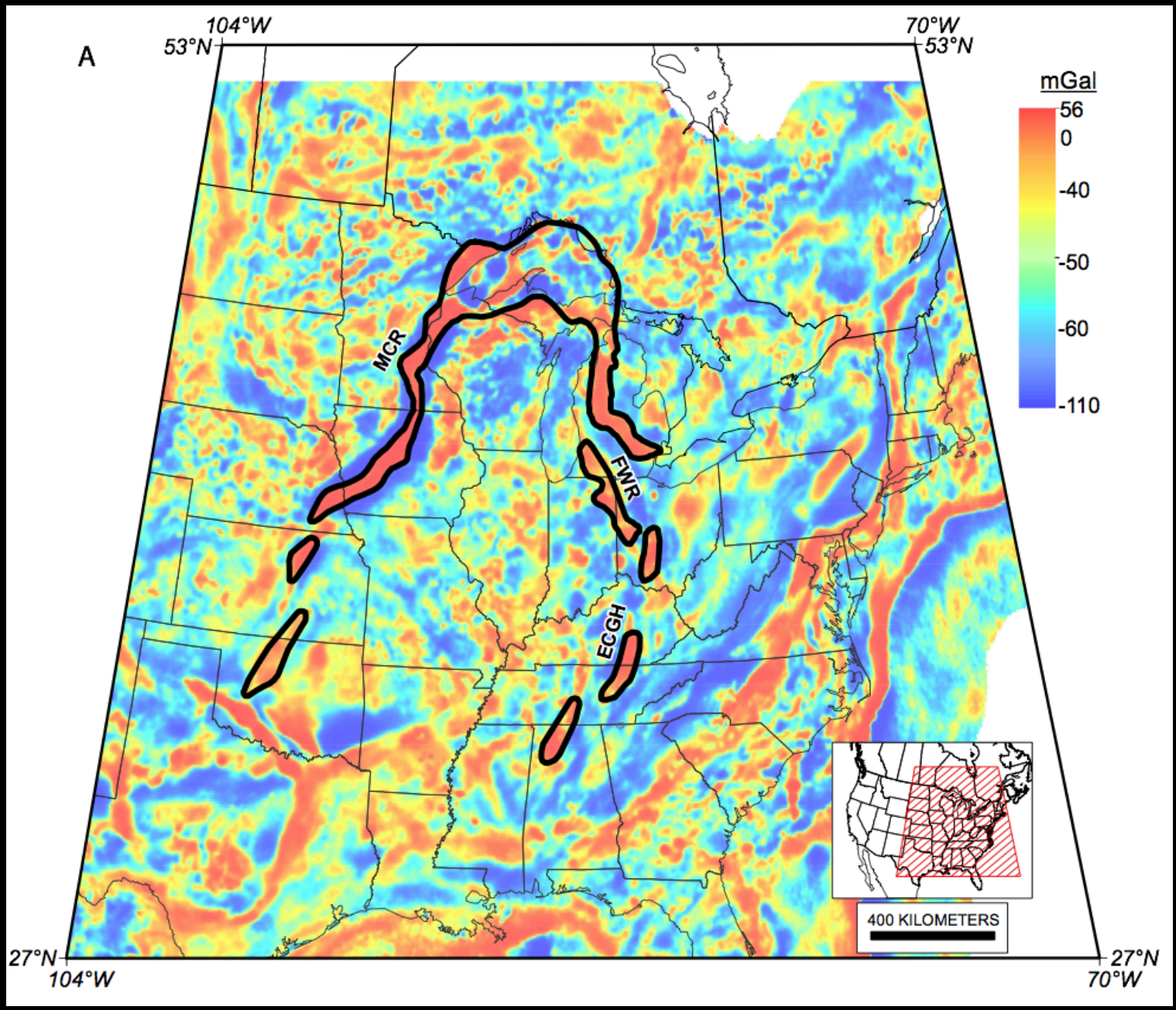
2.6 Gyr old
550 km long
15 km wide


ZAMBIA
GREAT DYKE
Victoria Falls
Hartley Platinum
Harare
MOZAMBIQUE
ZIMBABWE
Ngezi Platinum
Unki
BOTSWANA
Bulawayo
Mimosa
AFRICA
Zimbabwe
SOUTH AFRICA

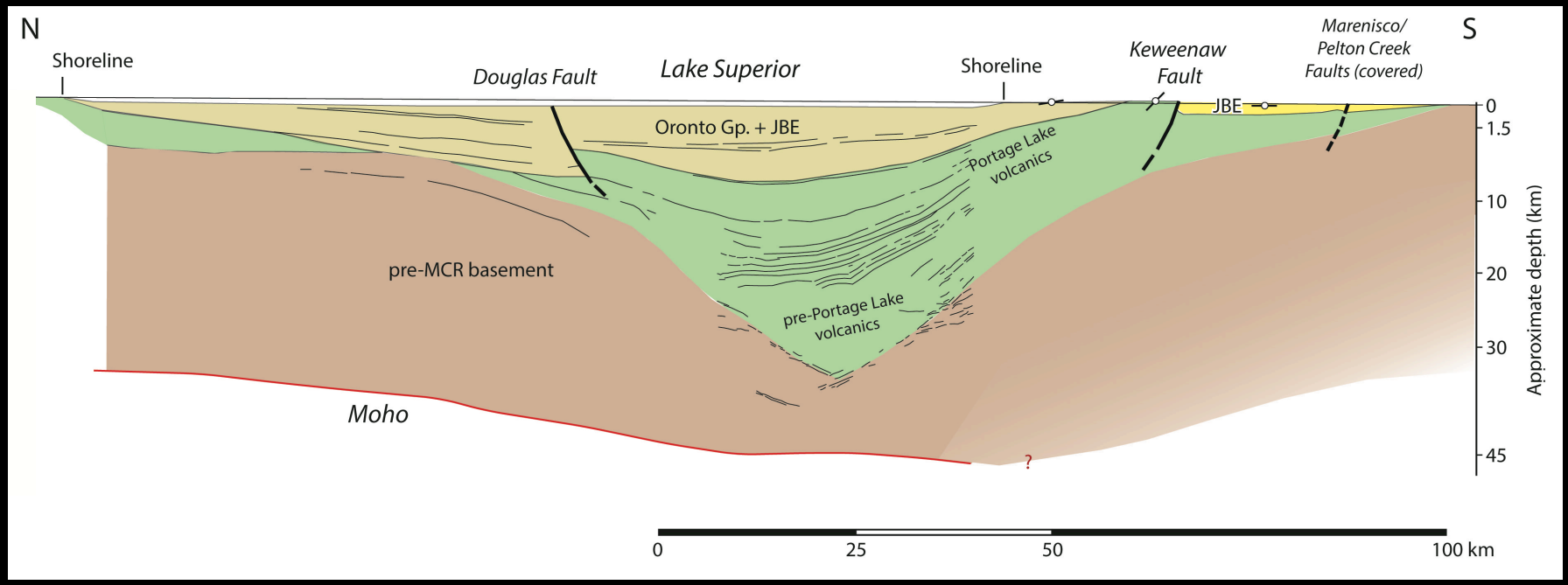
Le rift mi-continental (Keweenawan, 1 Ga)

Bord du Lac Supérieur

Anomalies du champ de pesanteur

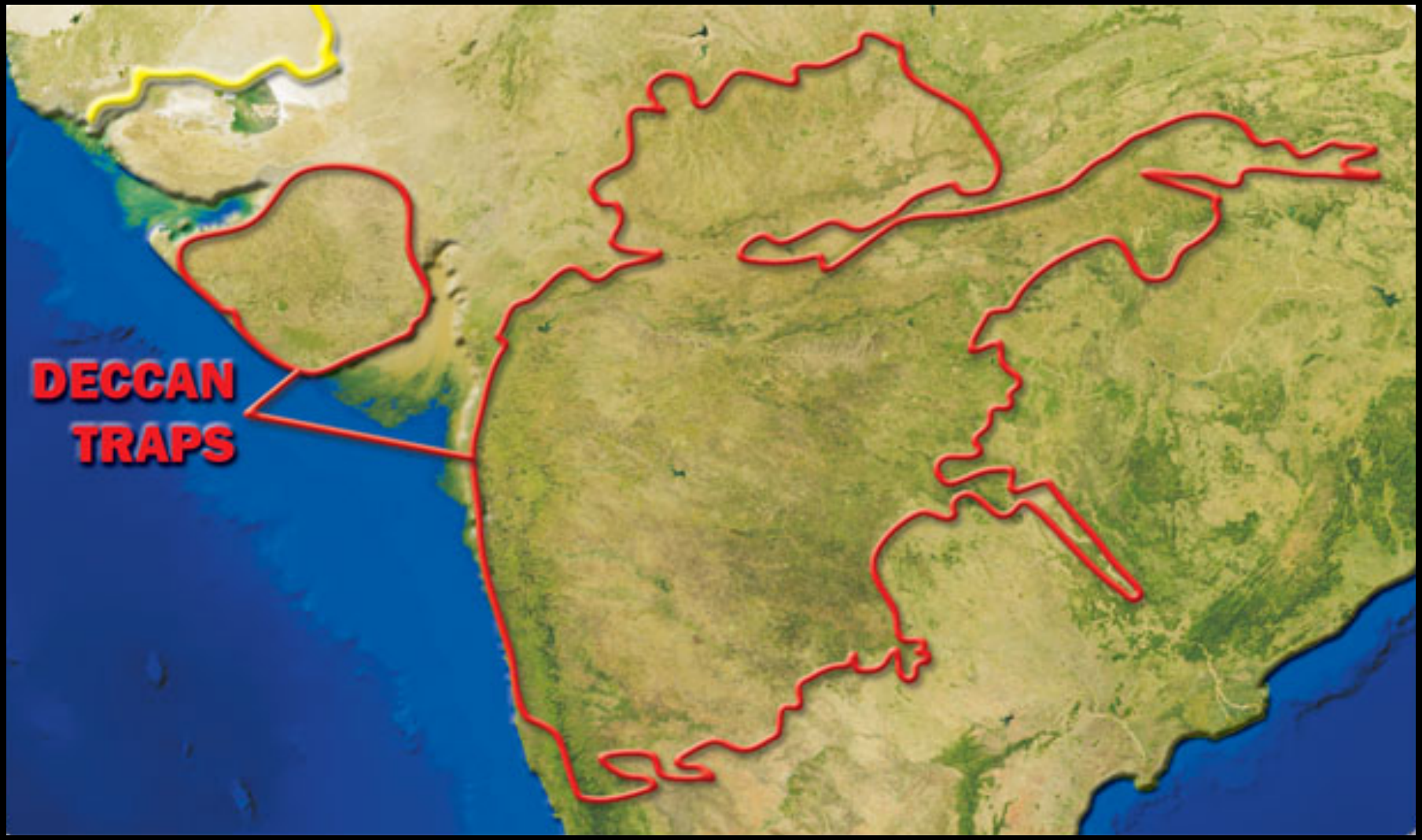


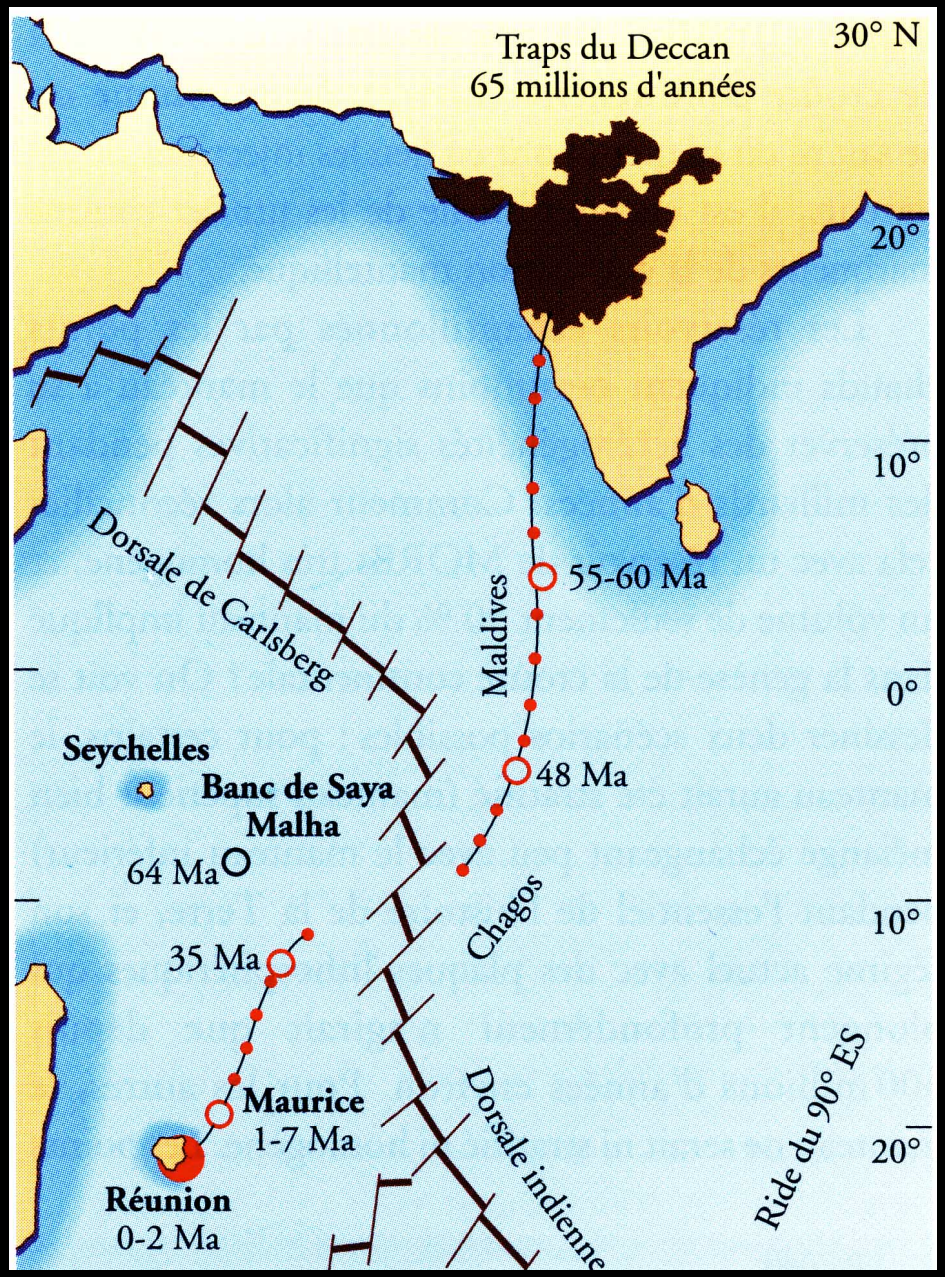
- ~2500 km de long et 150-200 km de large


N
S
Shoreline
Douglas Fault
Lake Superior
Shoreline
Keweenaw Fault
Marenisco/ Pelton Creek Faults (covered)
JBE
Oronto Gp. + JBE
Portage Lake volcanics
pre-MCR basement
pre-Portage Lake volcanics
Moho
?
0
1.5
10
20
30
45
Approximate depth (km)
0
25
50
100 km

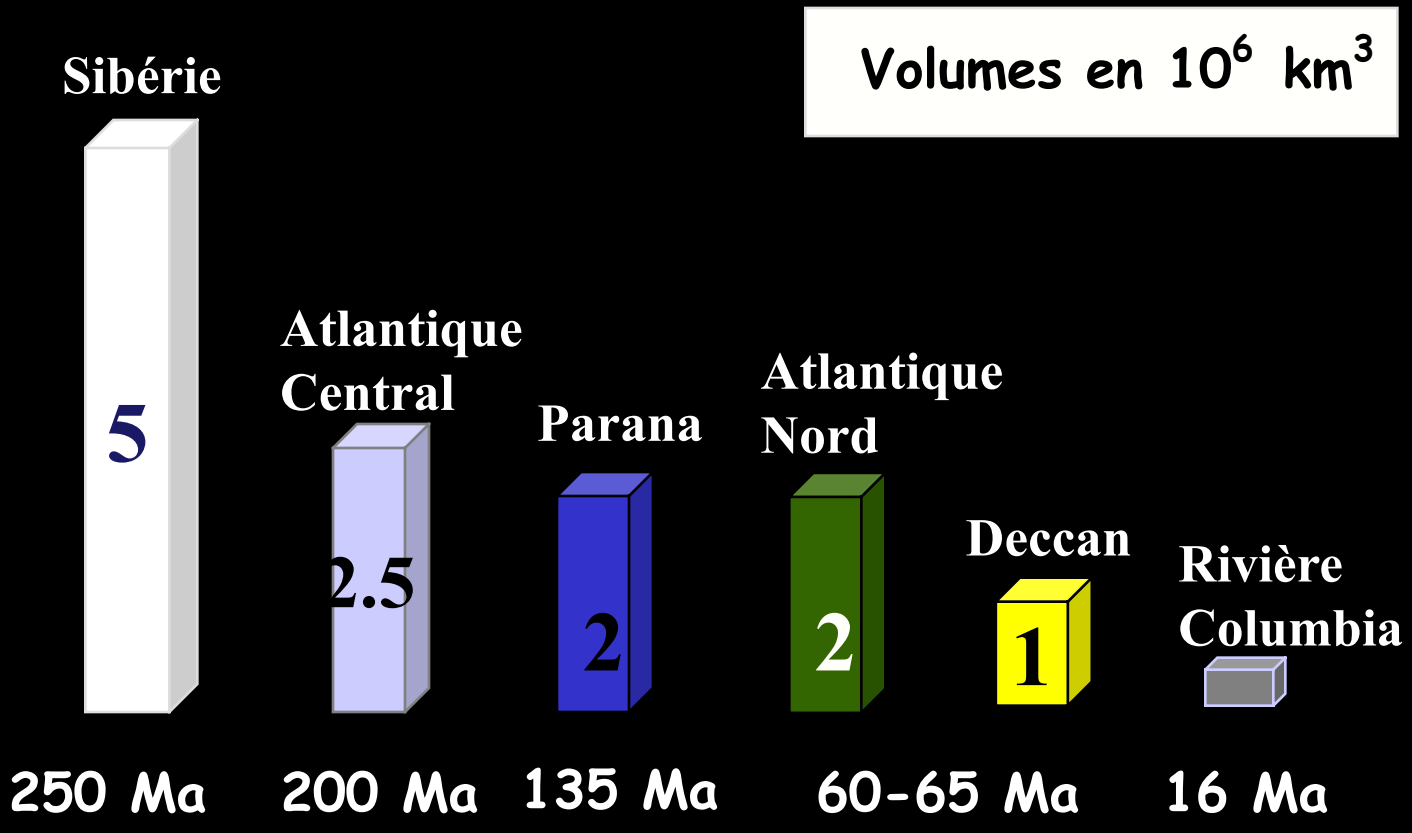
Les provinces basaltiques (traps)

Les traps du Deccan (Ouest de l'Inde)

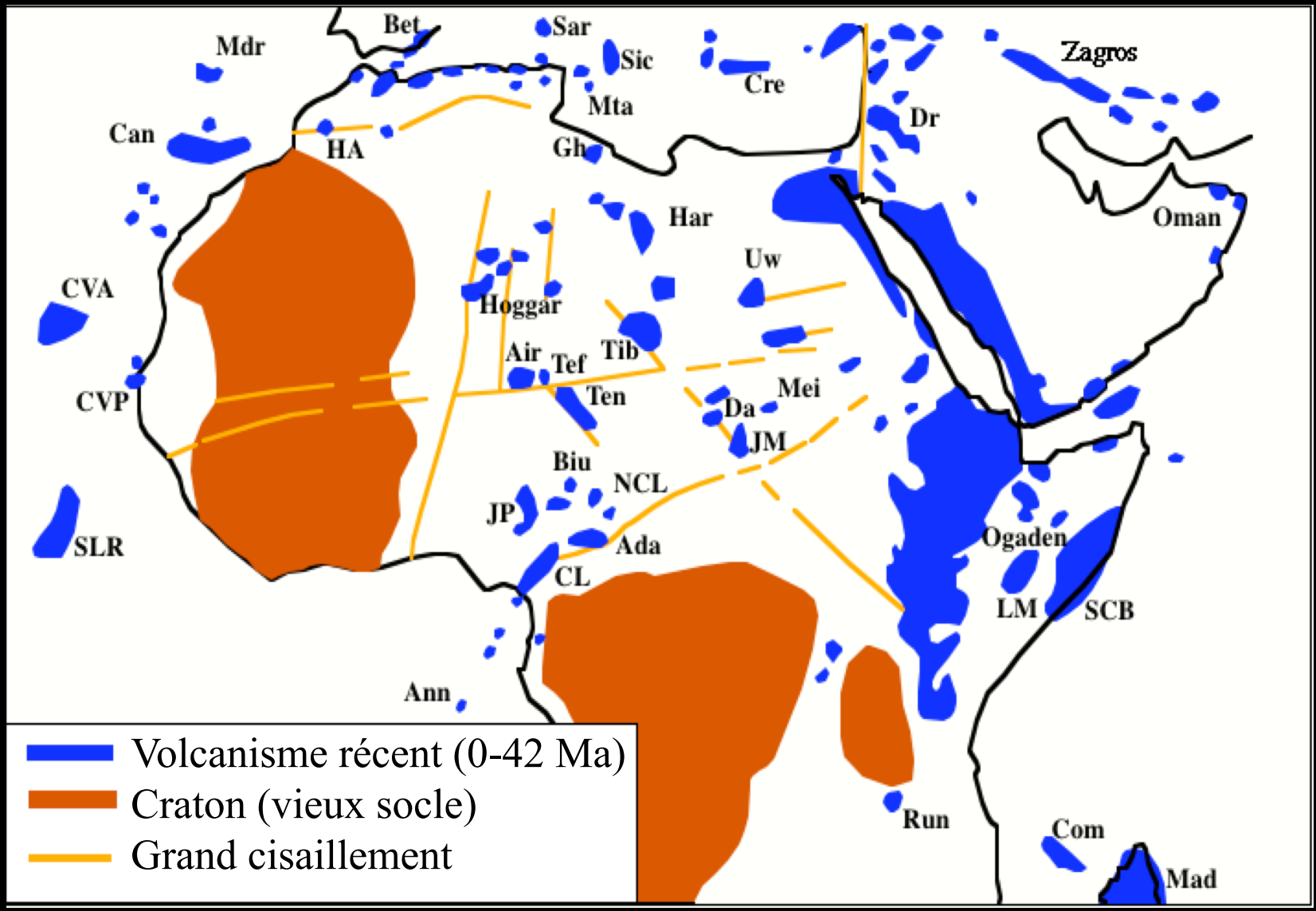

DECCAN
TRAPS


Traps du Deccan
65 millions d'années
30° N
20°
10°
0°
10°
20°
Dorsale de Carlsberg
Maldives
55-60 Ma
48 Ma
Seychelles
Banc de Saya
Malha
64 Ma
Chagos
35 Ma
Maurice
1-7 Ma
Réunion
0-2 Ma
Dorsale indienne
Ride du 90° ES

Les grandes provinces basaltiques

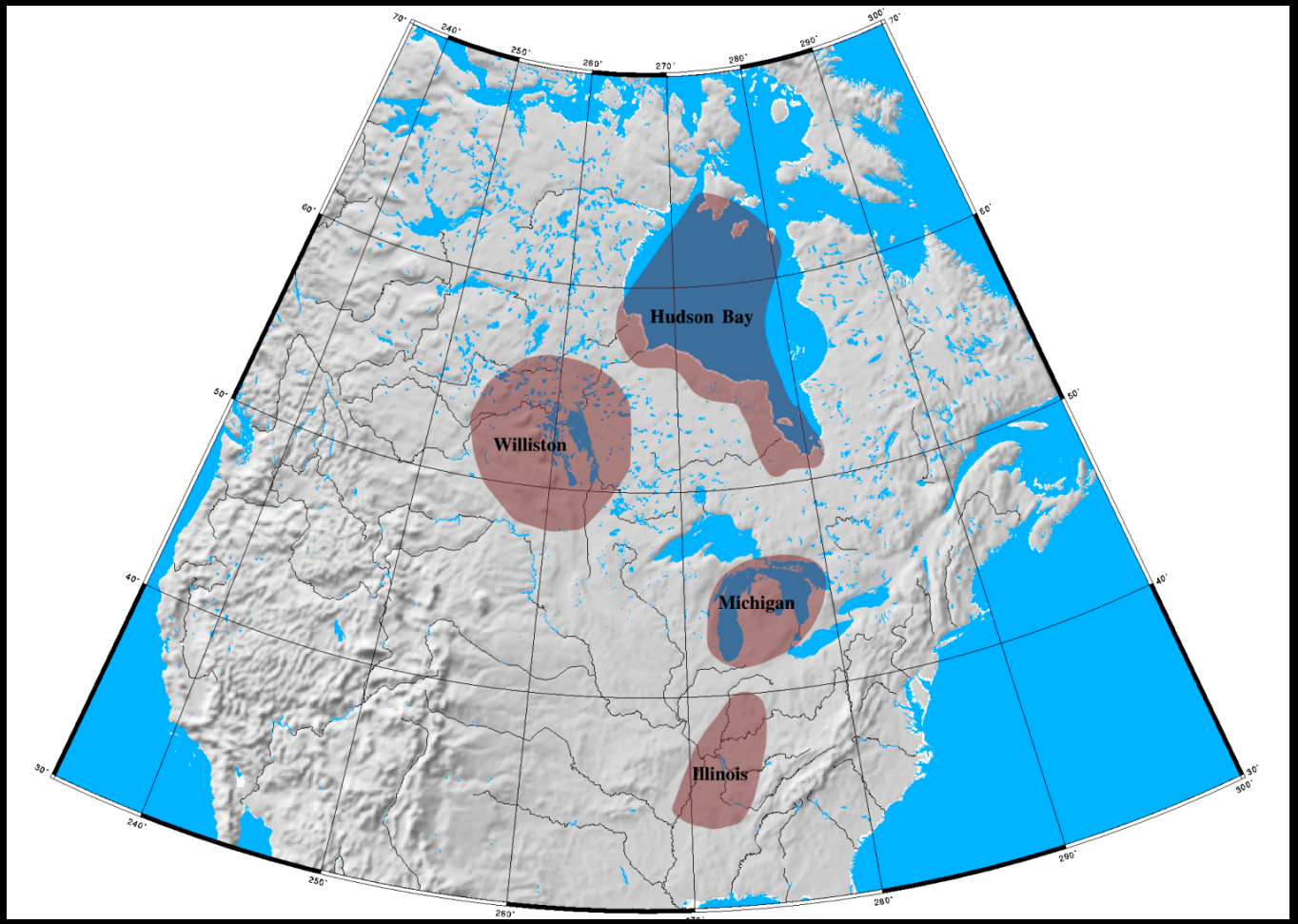


L'activité magmatique/volcanique Africaine



La Terre
évolue
et change
continuellement.

North America



Four intracratonic basins formed simultaneously (all ca. 500 Ma)