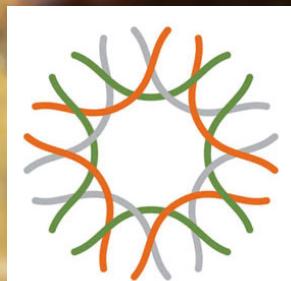




Historical biogeography and biodiversity dynamics of Ponerine ants

Maël DORÉ

ICE 2024 Kyoto
August 29th 2024



CALIFORNIA
ACADEMY OF
SCIENCES

Photo credits: F. Brassard



Ponerinae Subfamily

Top 3 ant subfamily for **diversity**
with 50 genera and ca. **1,400 species**

Predatory ants: include the **trap-jaw ants**
(*Anochetus*, *Odontomachus*)

High diversity of **mandible shapes**
related to **diet specialization**

Plesiomorphic robust morphology

Include the **largest ant species**:
Dinoponera gigantea



Formicinae
3,300 sp.
22%

Myrmicinae
7,200 sp.
48%

Ponerinae
1,400 sp.
10%

Ponerinae Subfamily

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Photo Credits: Magdalena Sorger

Ponerinae Subfamily

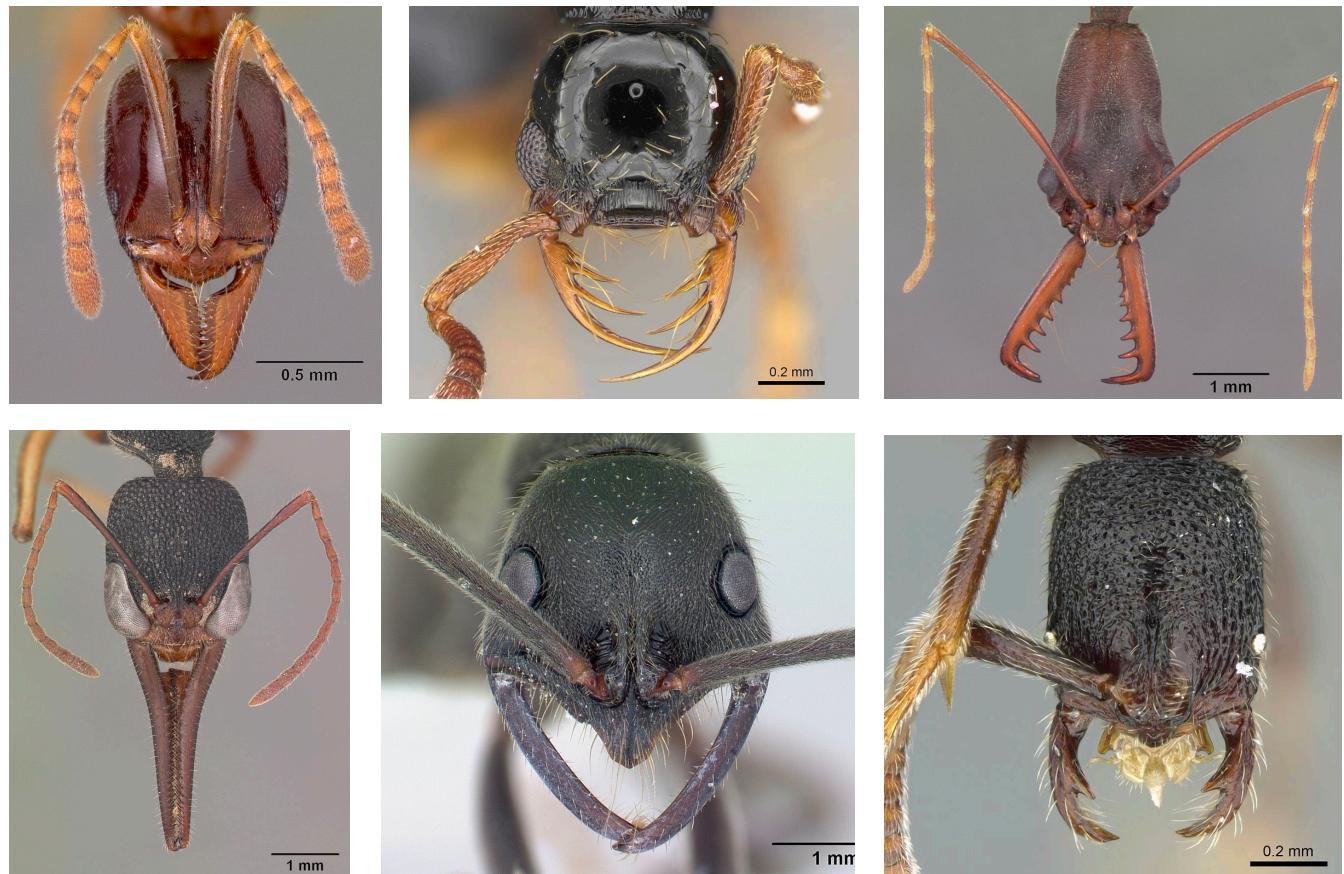
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Source: AntWeb

Ponerinae Subfamily

Photo Credits: Tatyana Kolesnikova

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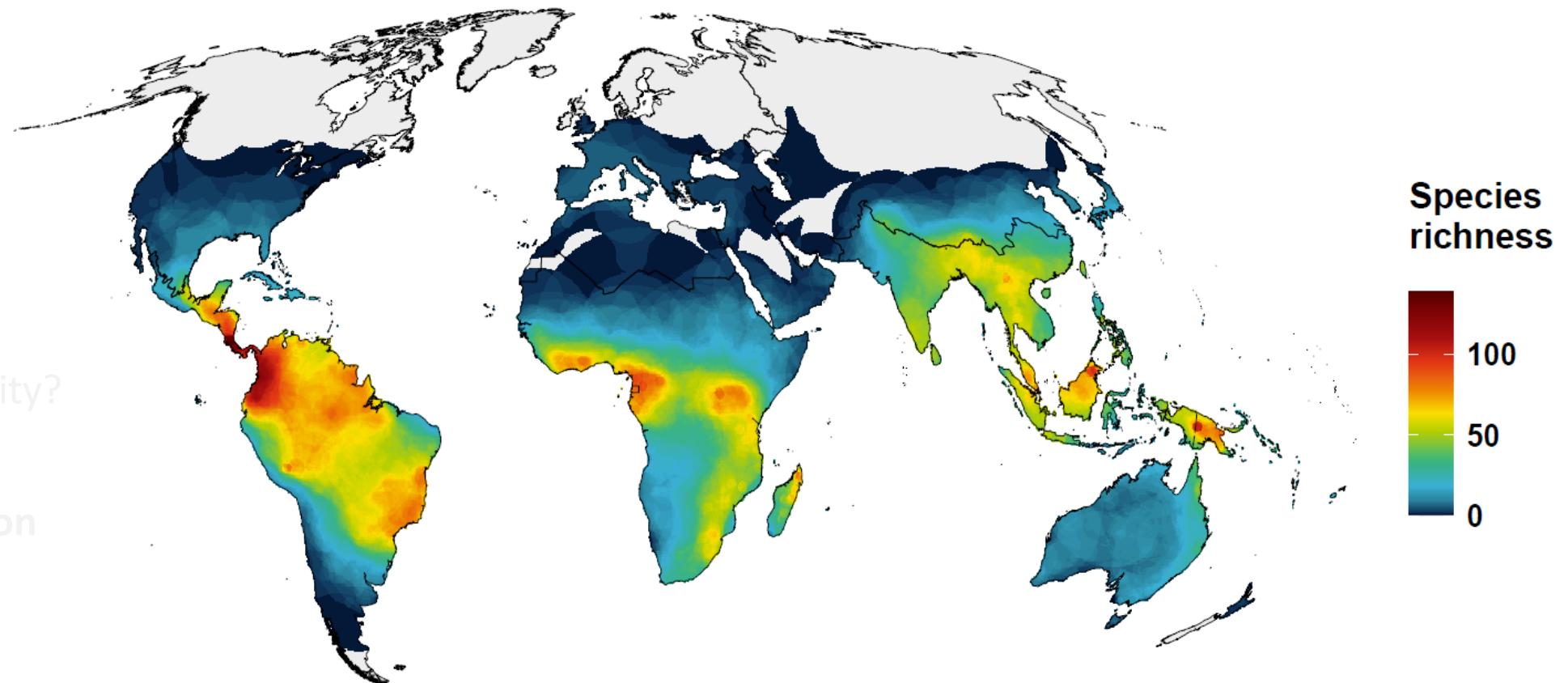


Dinoponera gigantea in Belem, Brazil
Up to 40 mm

Current diversity

Species richness of Ponerinae ants

1/ Origin of the clade?



2/ Source of diversity?

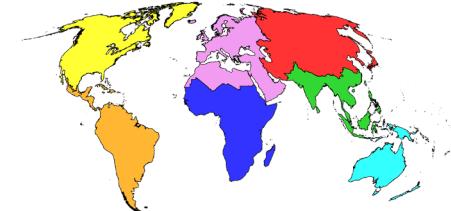
In situ diversification

vs.

Dispersal

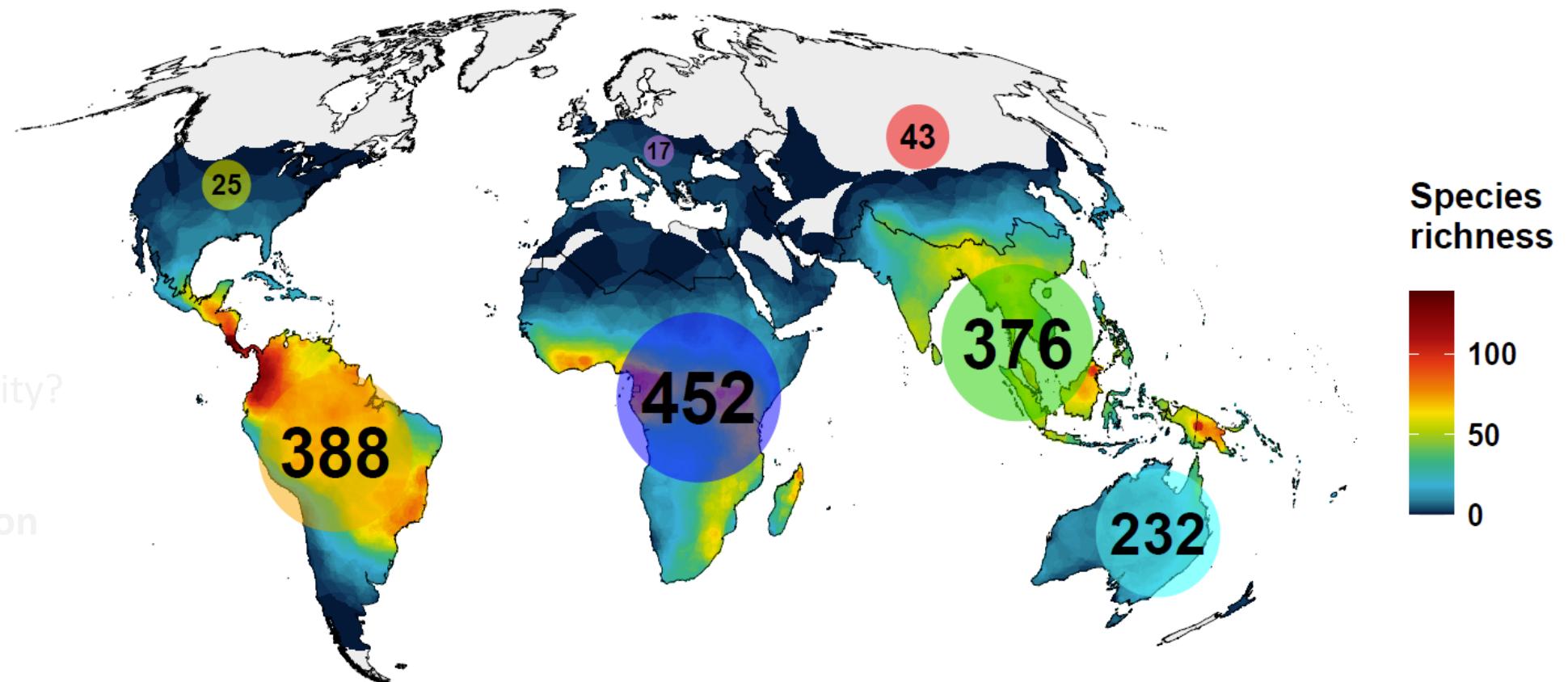
Doré et al., *in prep.*

Current diversity

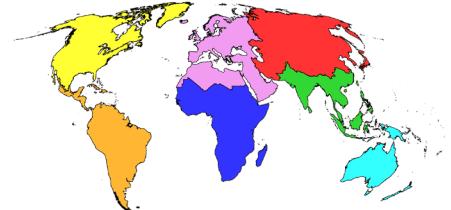


Species richness of Ponerinae ants

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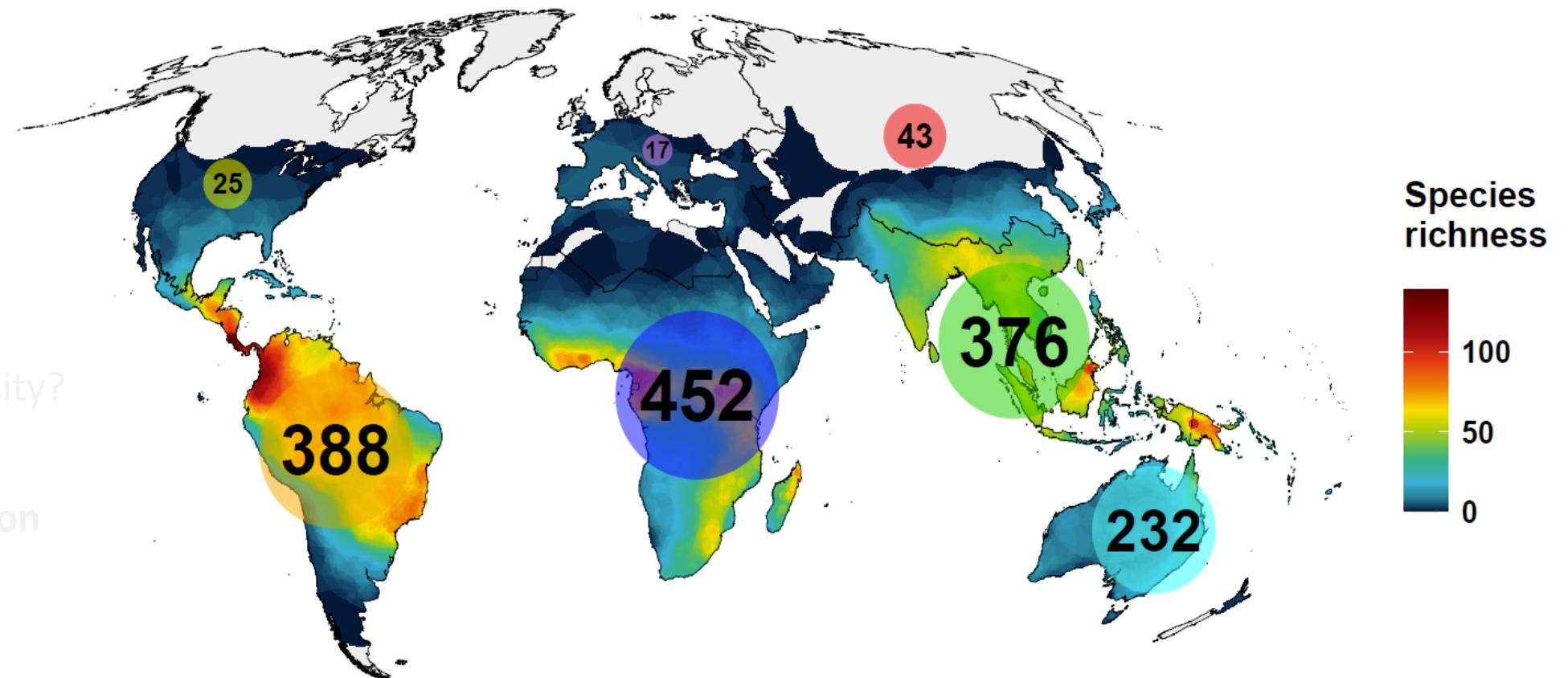


Current diversity



Species richness of Ponerinae ants

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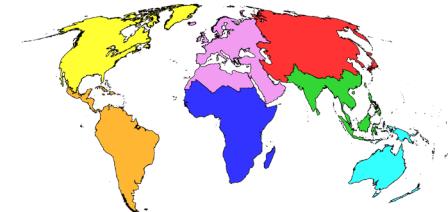
In situ diversification

vs.

Dispersal

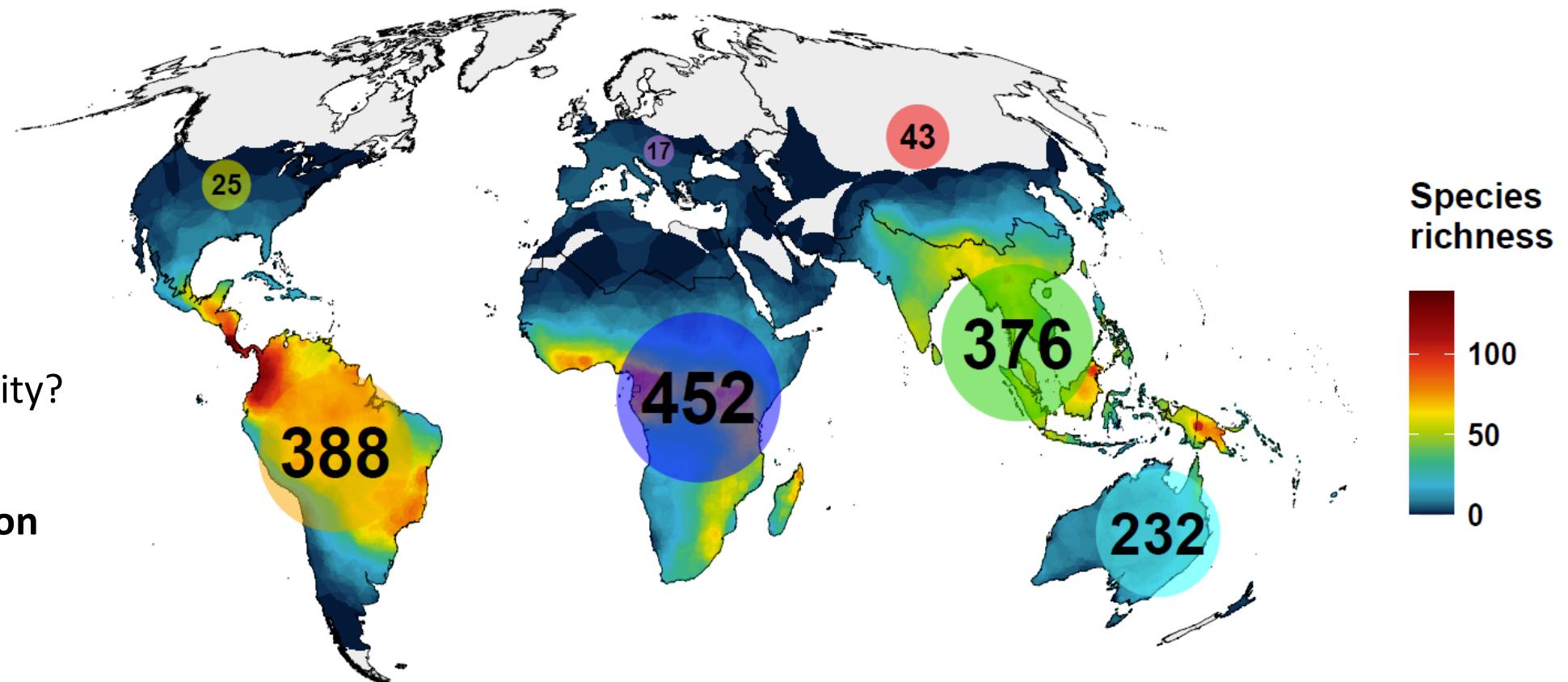
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Current diversity



Species richness of Ponerinae ants

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In situ diversification

vs.

Dispersal

Doré et al., *in prep.*

Phylogenomic methods

Doré et al., *in prep.*

Taxa sampling: 789 species (51.4%)
among all 50 Genera (100%)

Molecular data: 2,365 **UCE loci** = 1.05 M sites

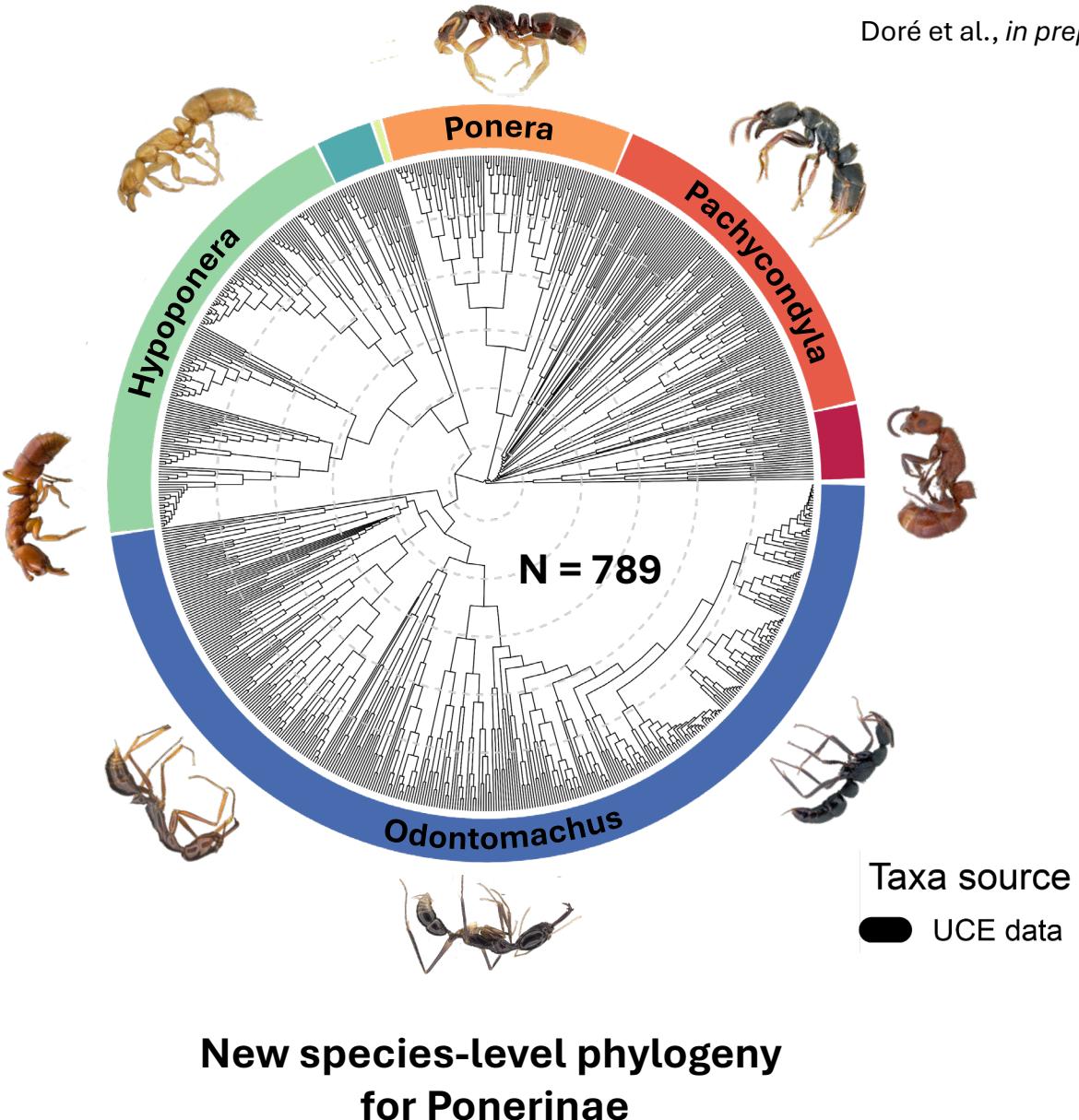
Phylogenetic inferences: ML in **IQ-Tree**
with **SWSC partitioning**

Sensitivity analyses:

Inference method x Loci filtering x
Partitioning scheme x Divergence dating

Grafting of missing species:

Impute all 745 valid species with no UCE data using
available taxonomic and geographic information



Phylogenomic methods

Doré et al., *in prep.*

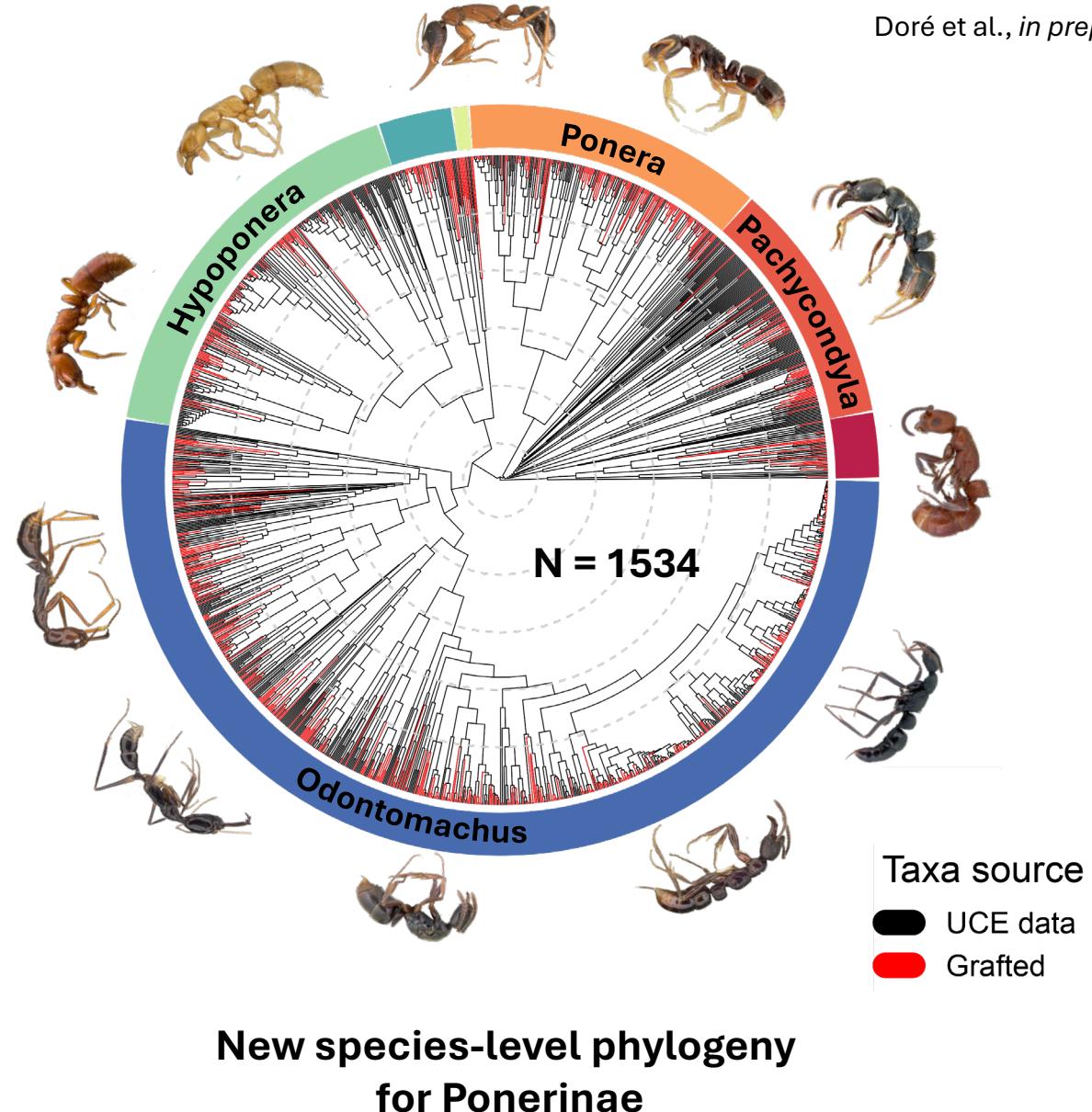
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Biogeographic data

Occurrence sources:

- AntWeb (62,301 records)
- GABI/AntMap (93,557 records)

Bioregions as defined in AntWeb

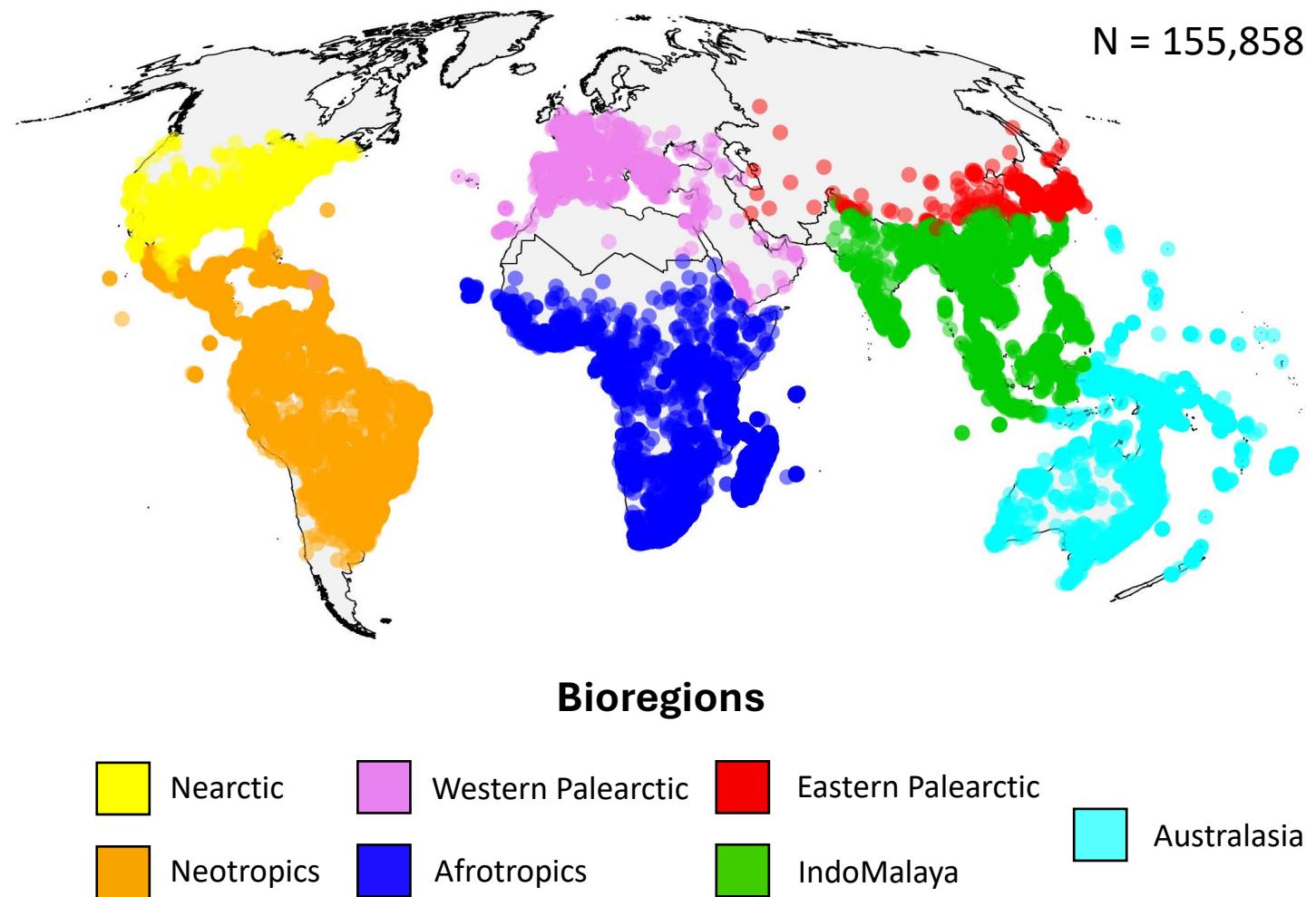
Data curation:

- Automatic and visual checks
 - *CoordinateCleaner* (Zizka et al., 2019)
- Geogazeeting
 - *geoBoundaries* (Runfola et al., 2020)
- Accuracy estimates

Final database: 155,858 records

- 105,574 records from GPS
- 50,284 records from locality

Occurrences of Ponerinae ants



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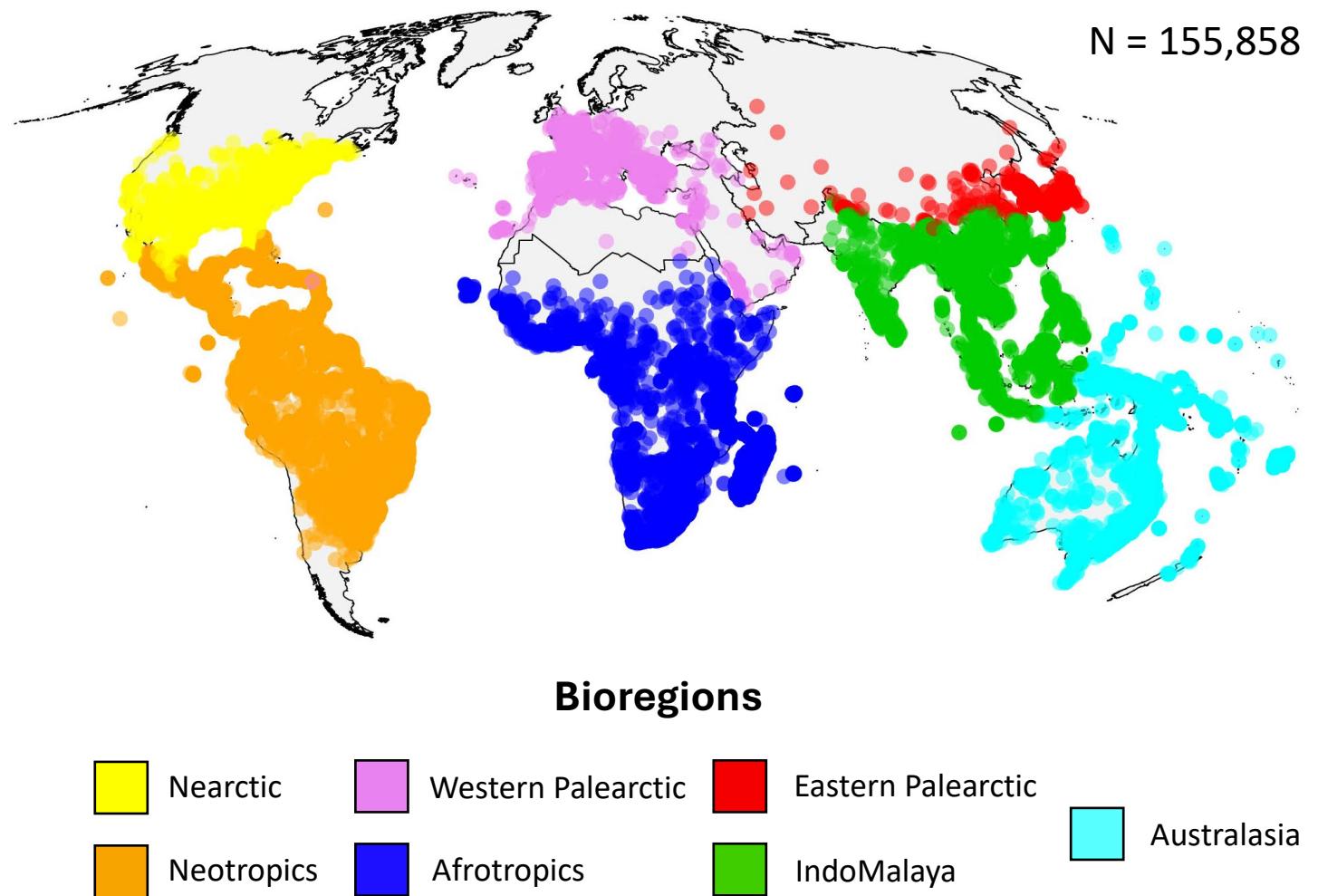
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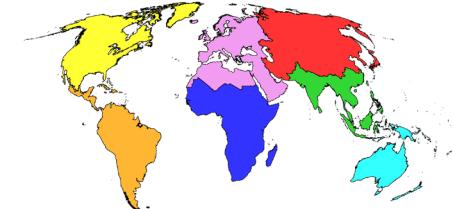
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Occurrences of Ponerinae ants



Biogeographic methods



BioGeoBEARS framework:

- DIVALIKE, DEC, DIVALIKE + J, DEC + J
- Model selection based on AICc
- Best model = **Time-stratified DEC + J**

Model of continental connectivity

Ancestral Range Estimates (ARE):

- Marginal likelihoods of node ranges

Biogeographic Stochastic Mapping (BSM):

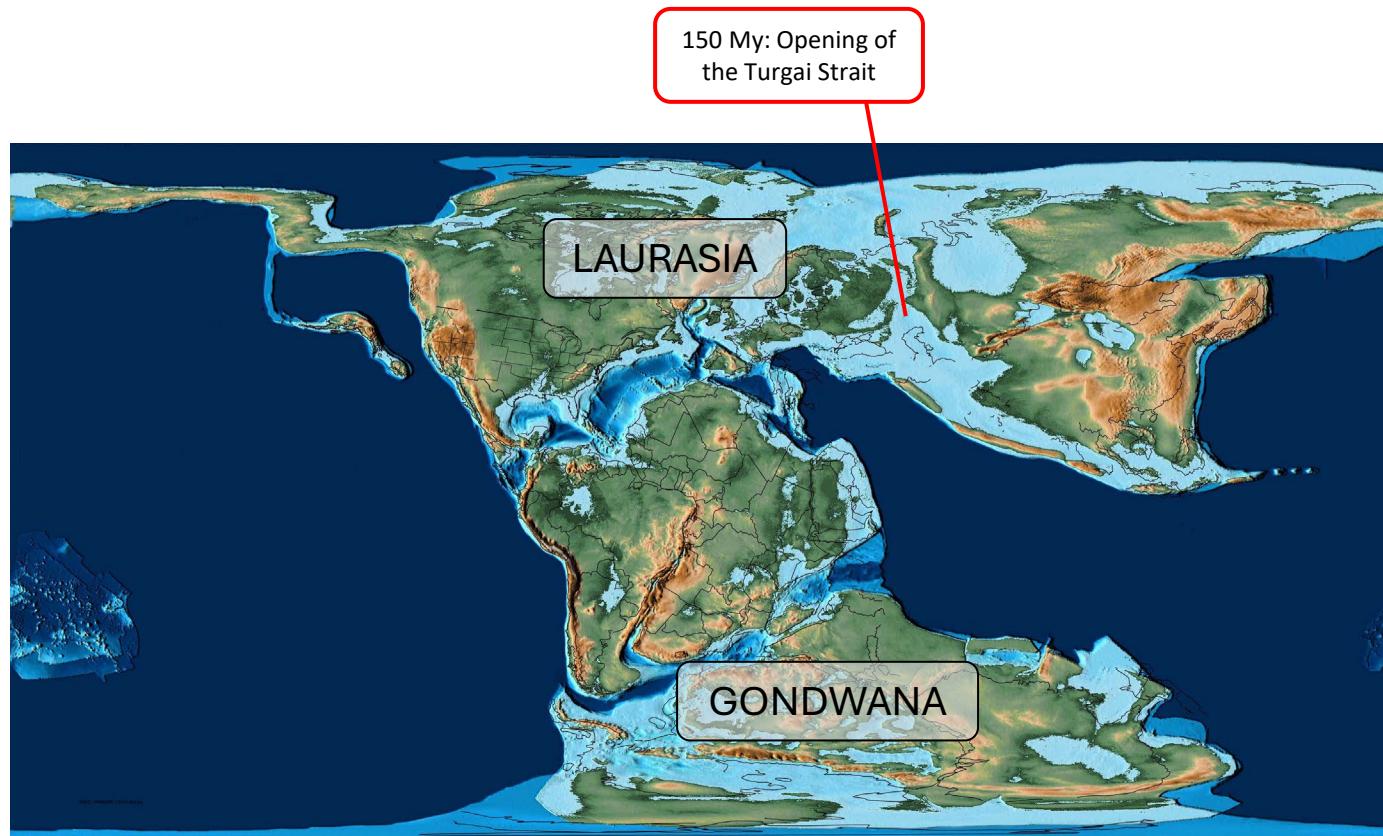
- Simulation of biogeographic histories compatible with ancestral ranges estimates
- Summary statistics across 1000 BSM

Model comparison

	DEC+J	DIVALIKE+J	DIVALIKE	DEC
logLk	-2154	-2205	-4391	-4467
# params	3	3	2	2
AICc	4313	4416	8787	8939
Δ AICc	0	103	4474	4626
Akaike weights	100 %	0 %	0 %	0 %
d	0.007	0.008	0.030	0.024
e	0.000	0.000	0.019	0.020
y	0.994	0.991	1.000	1.000
v	0.994	0.991	1.000	1.000
s	0.994	-	-	1.000
j	0.019	0.018	-	-

Doré et al., *in prep.*

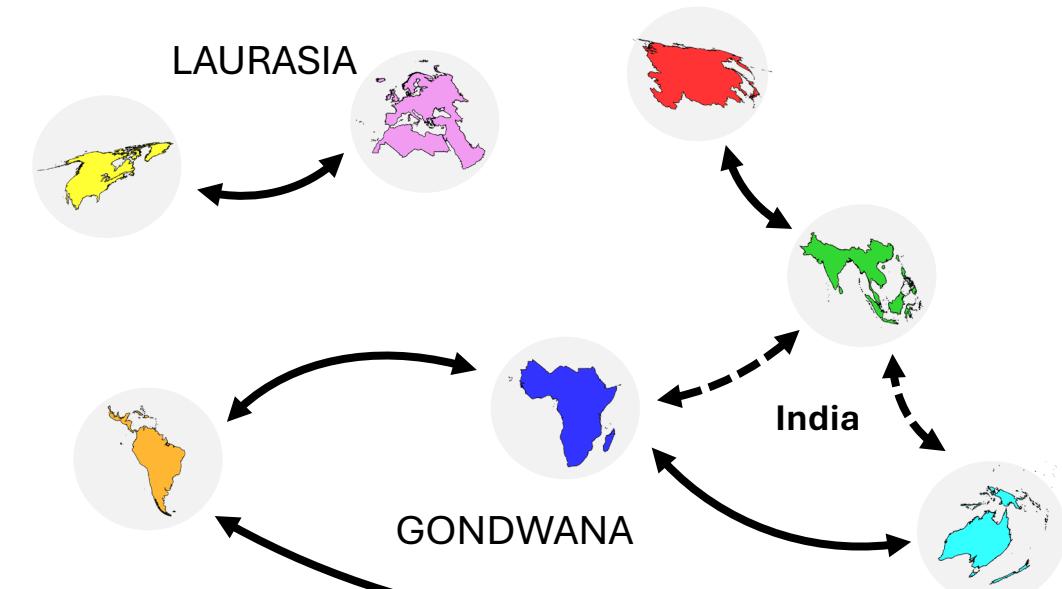
Biogeographic methods



Source: PALEOMAP Project by C. Scotese

Early Cretaceous

145.0 My



Early Cretaceous

Late Cretaceous

Paleo.

Eocene

Oligo.

Miocene

PPHo

145.0

100.5

66.0

55.8

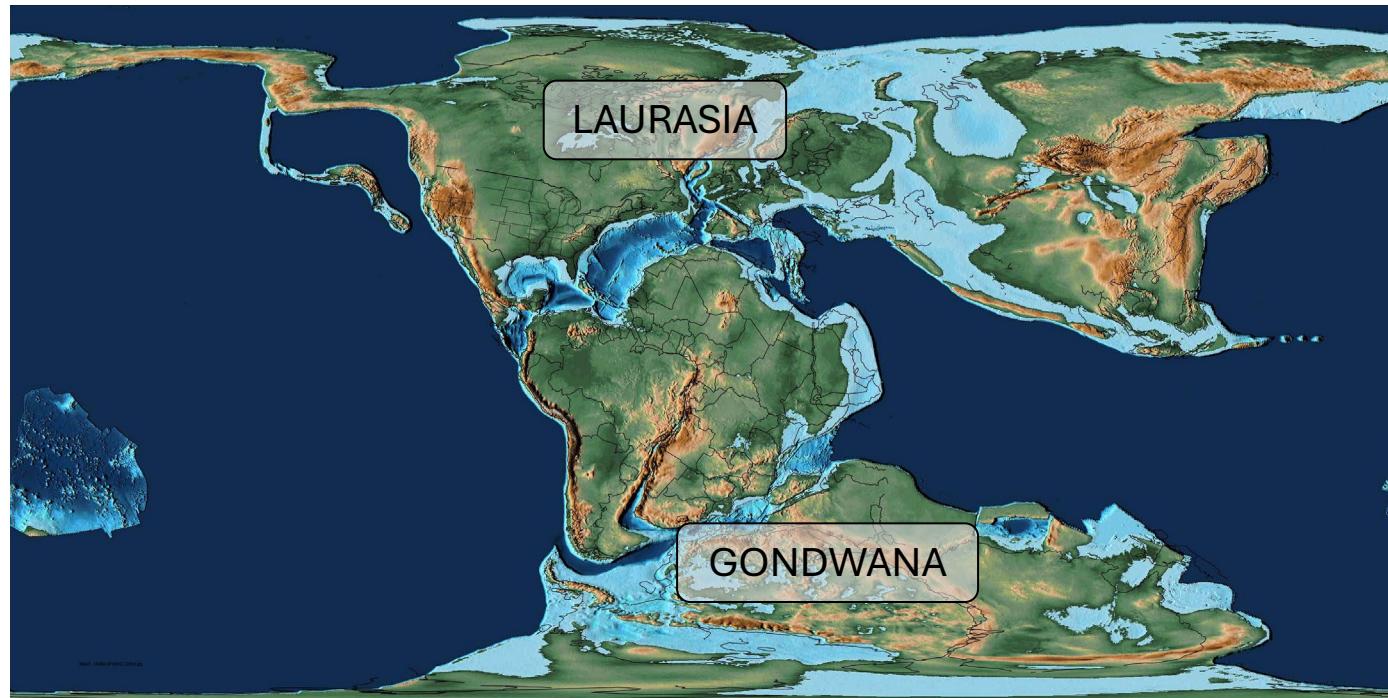
33.9

23.0

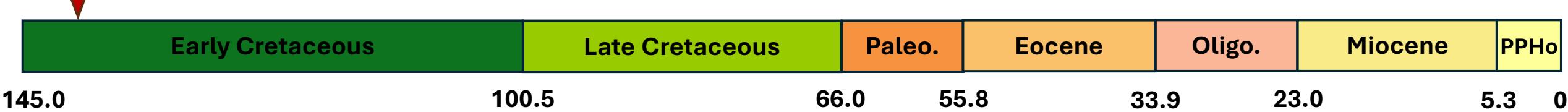
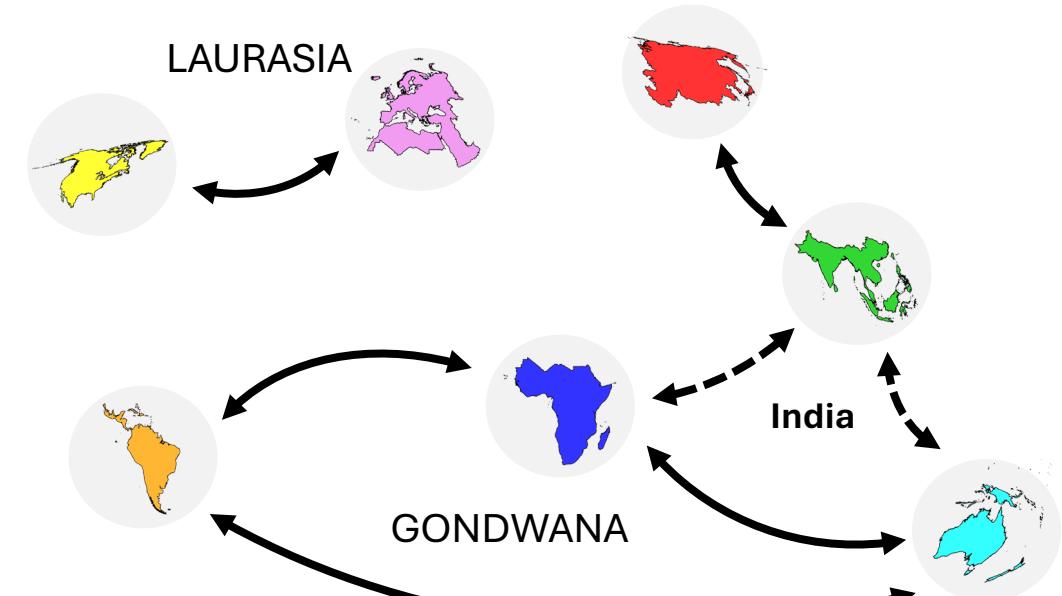
5.3 0

Biogeographic methods

Early Cretaceous
140.0 My

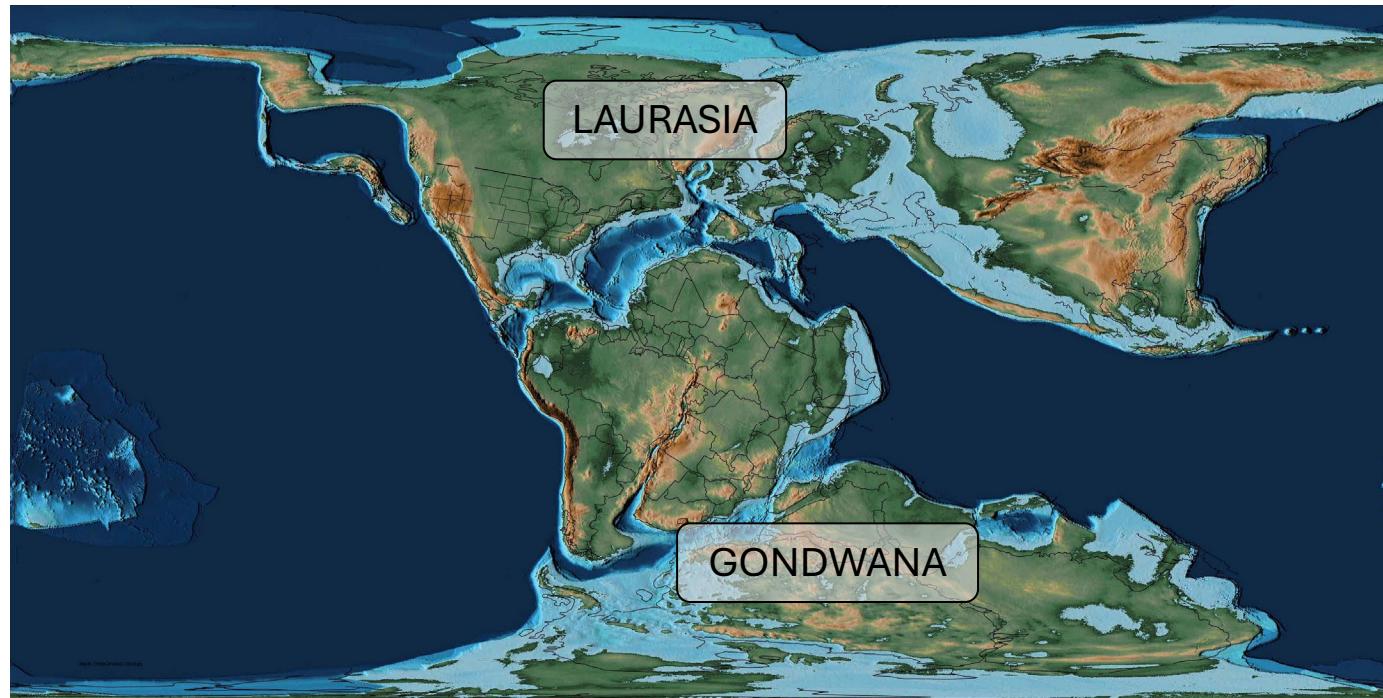


Source: PALEOMAP Project by C. Scotese

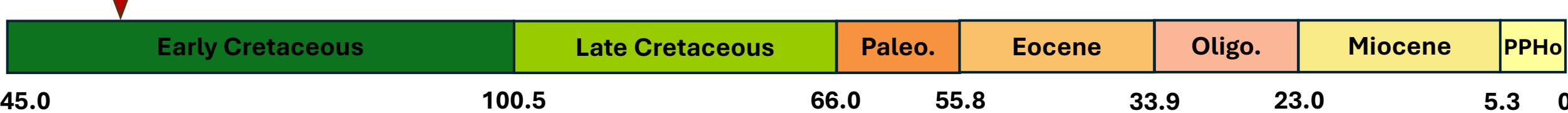
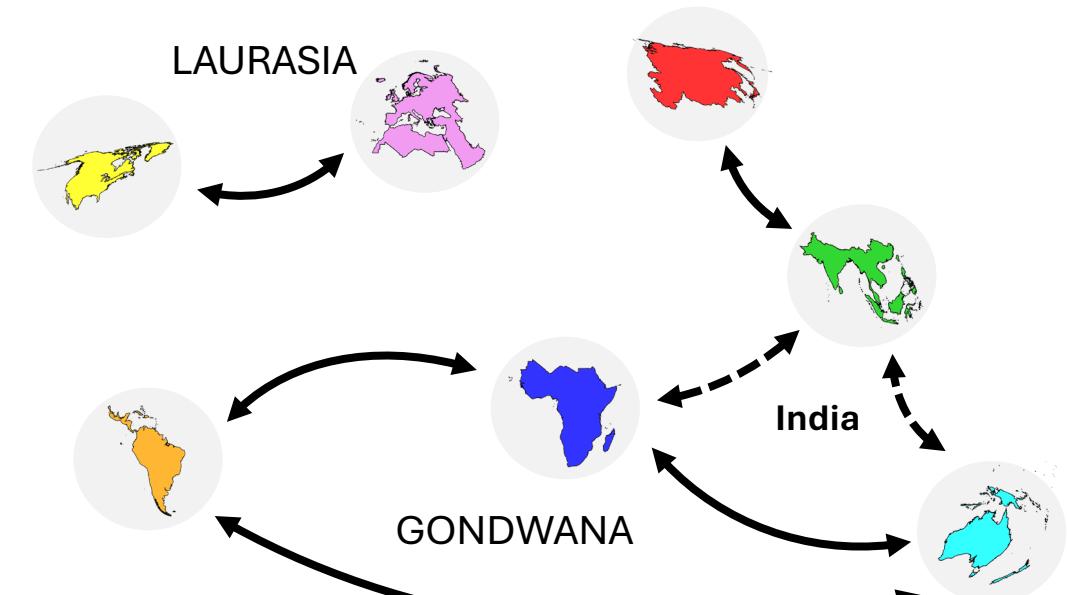


Biogeographic methods

Early Cretaceous
135.0 My

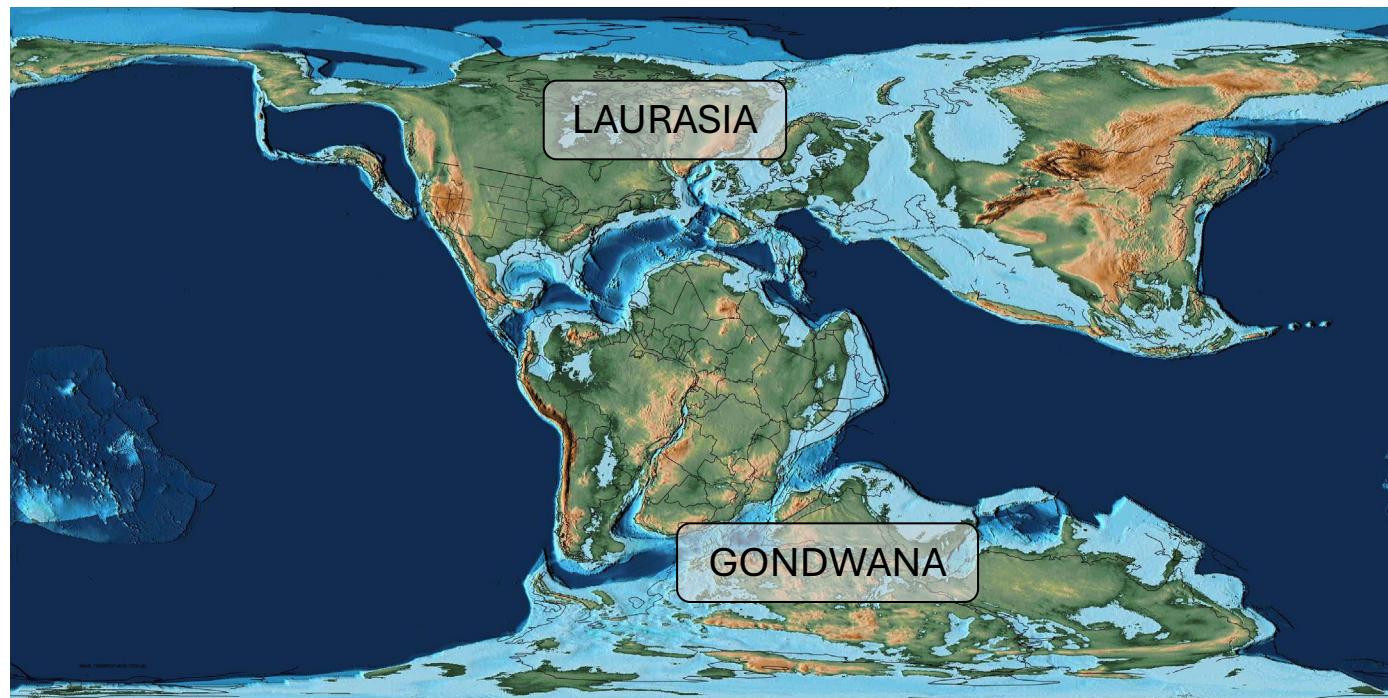


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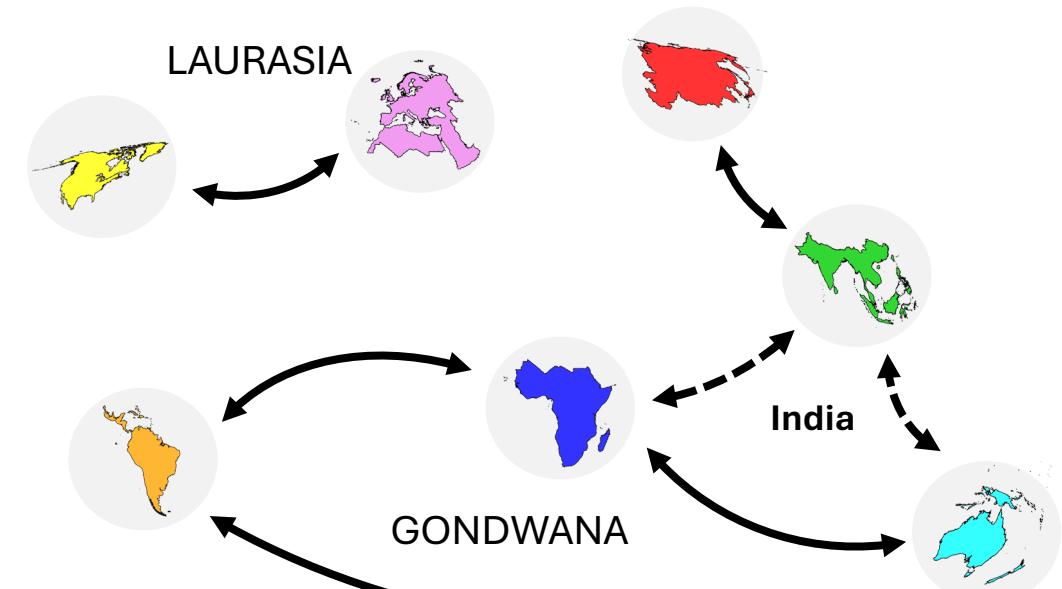


Biogeographic methods

Early Cretaceous
130.0 My



Source: PALEOMAP Project by C. Scotese



Early Cretaceous

Late Cretaceous

Paleo.

Eocene

Oligo.

Miocene

PPHo

145.0

100.5

66.0

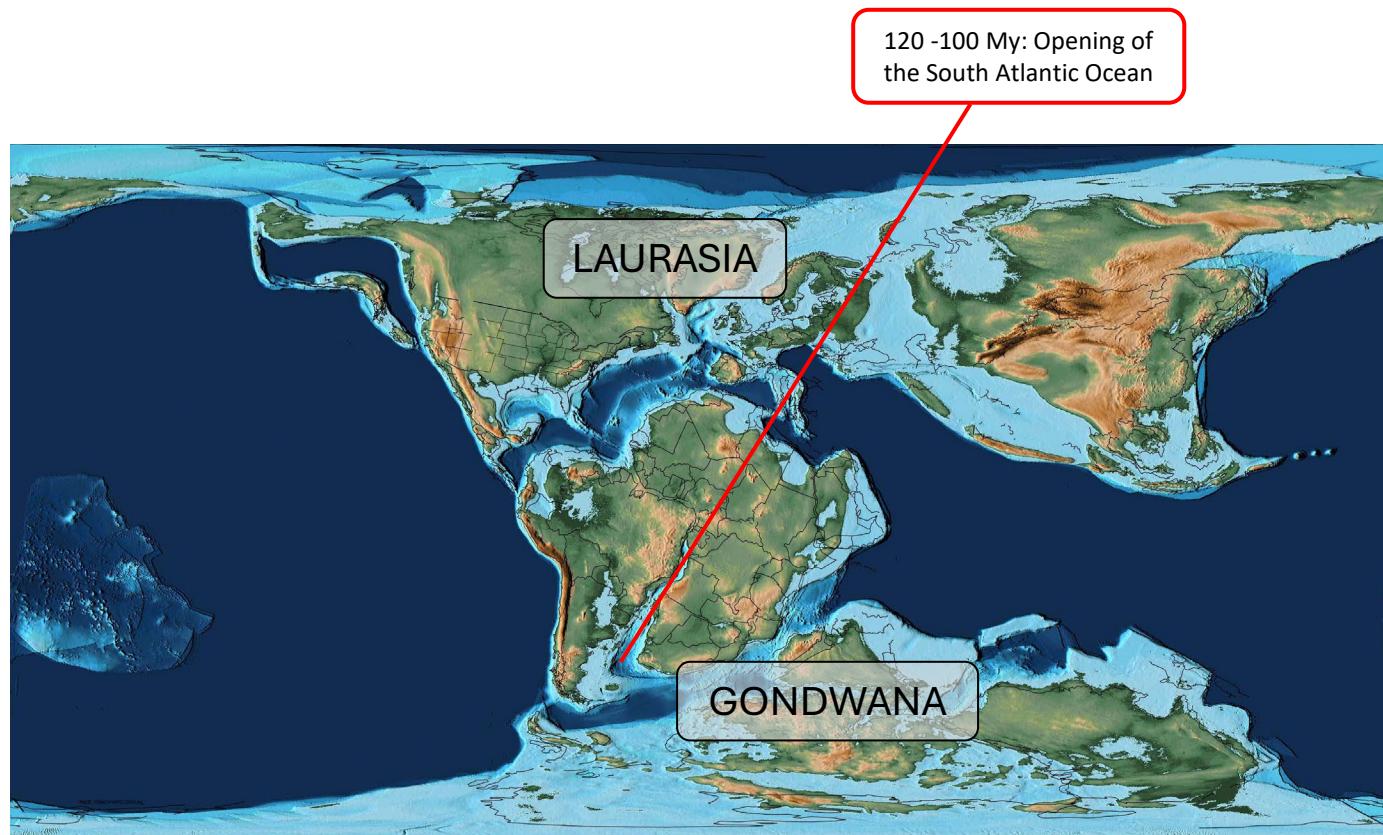
55.8

33.9

23.0

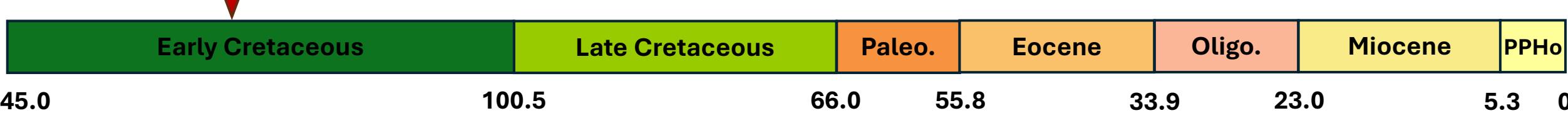
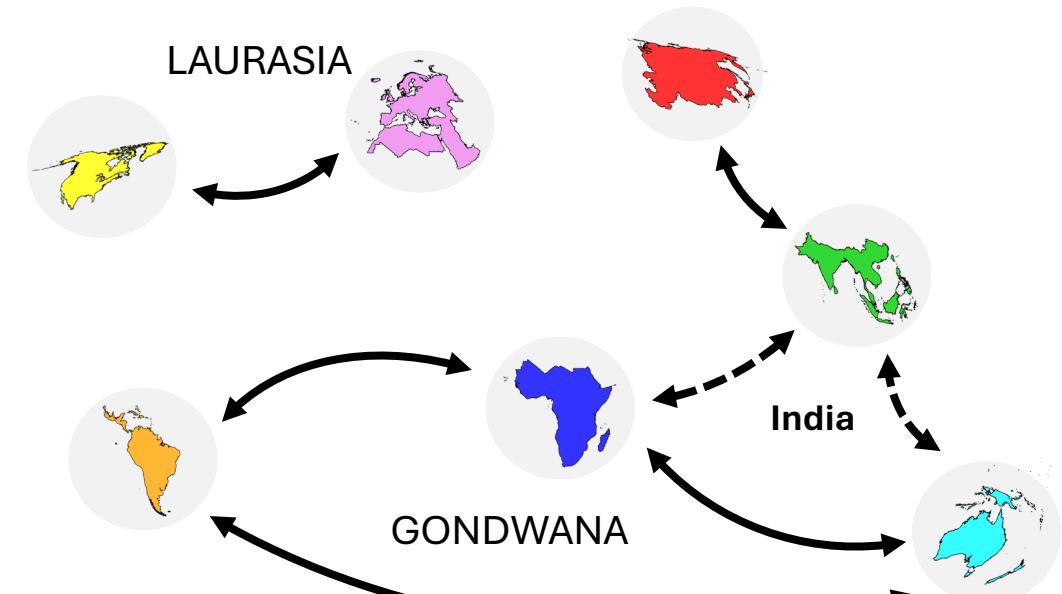
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Biogeographic methods

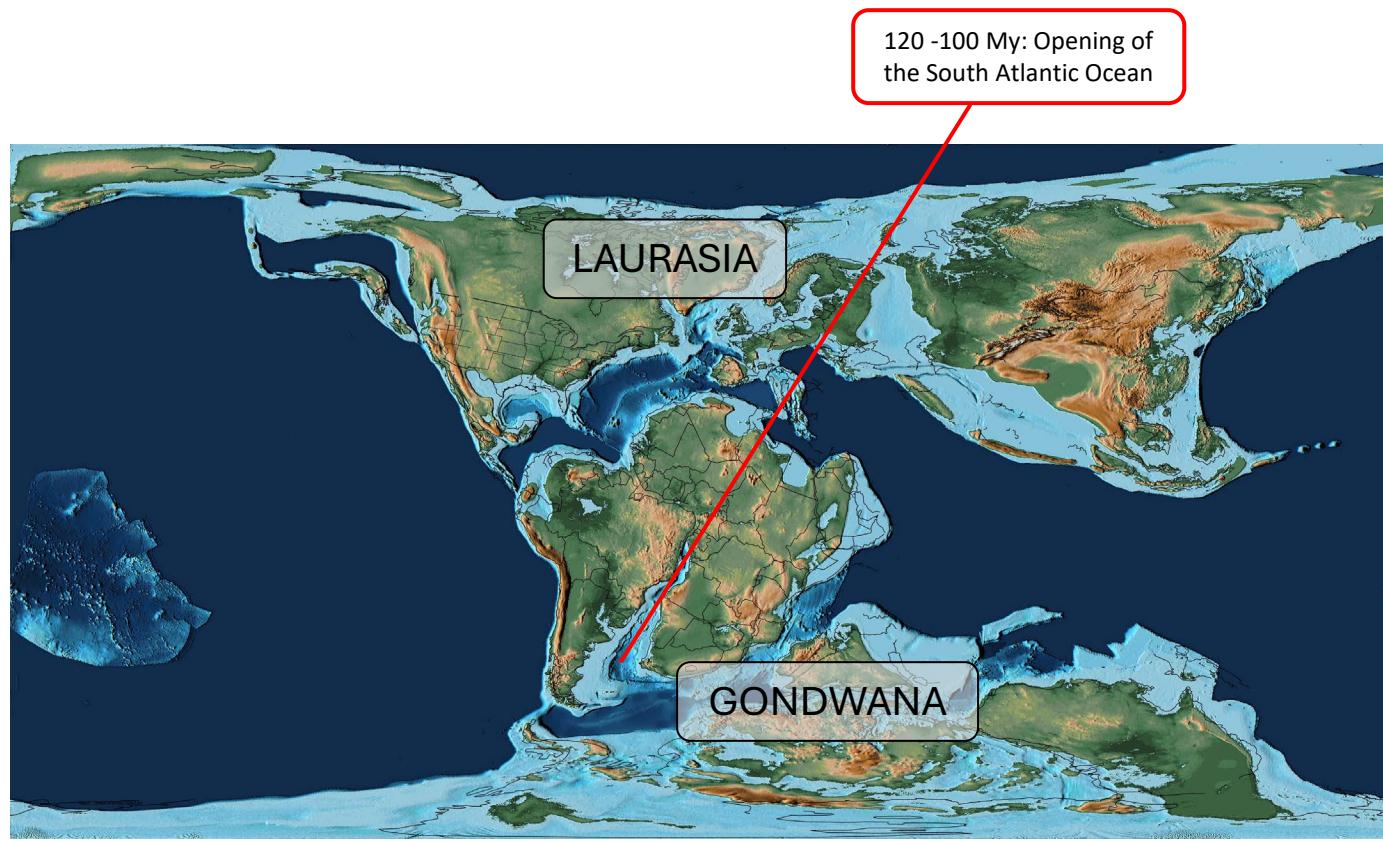


Source: PALEOMAP Project by C. Scotese

Early Cretaceous
125.0 My

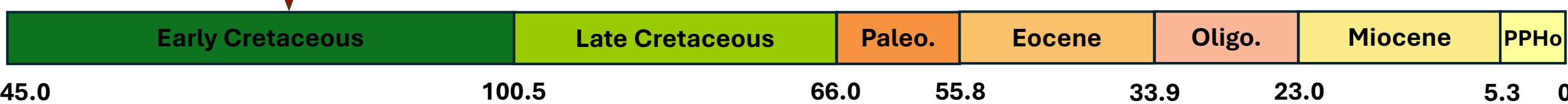
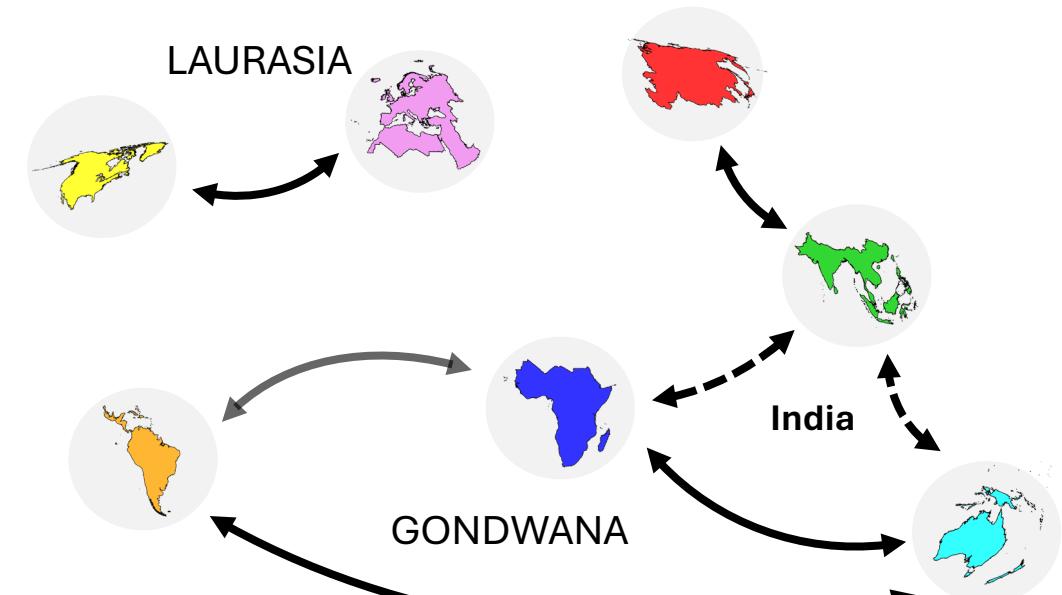


Biogeographic methods

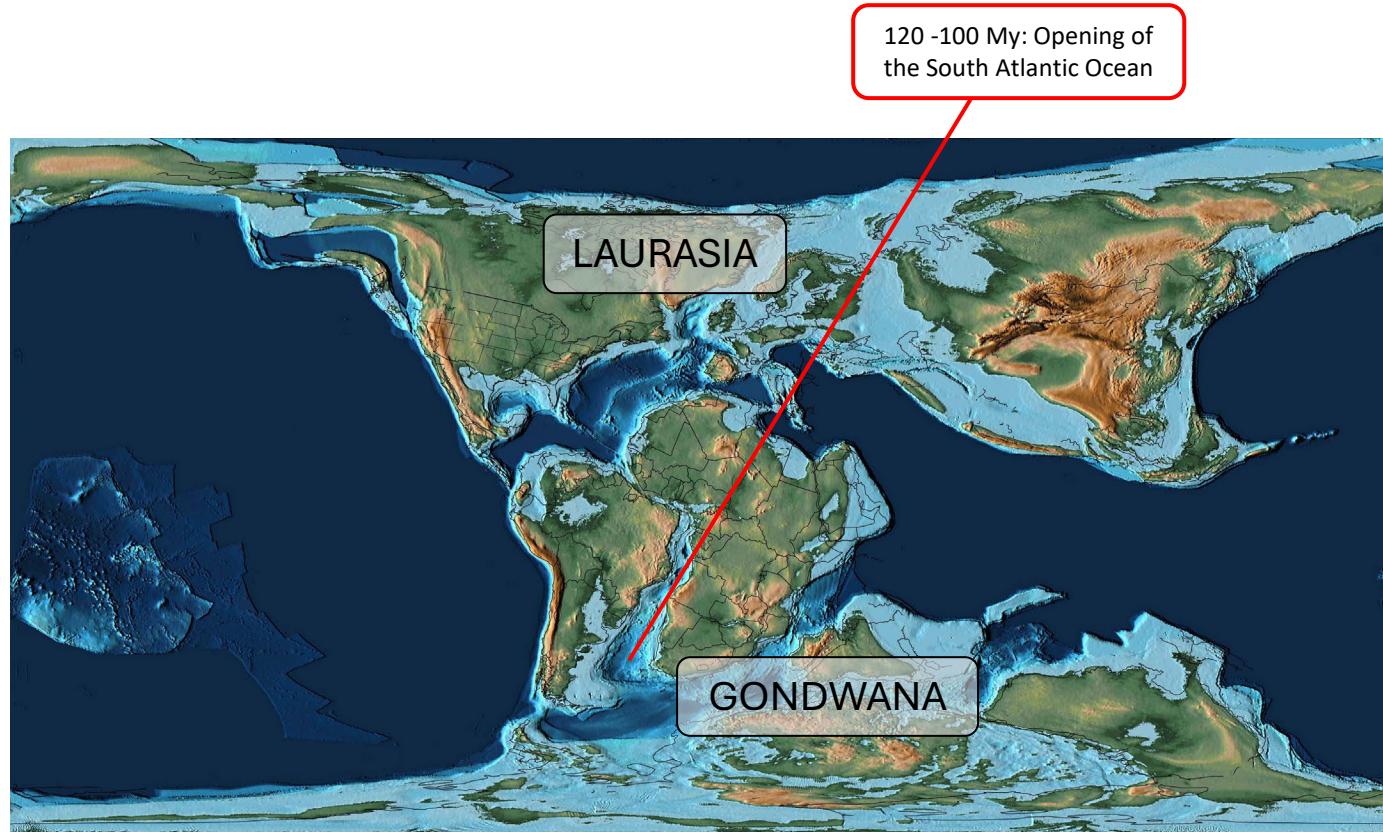


Source: PALEOMAP Project by C. Scotese

Early Cretaceous
120.0 My



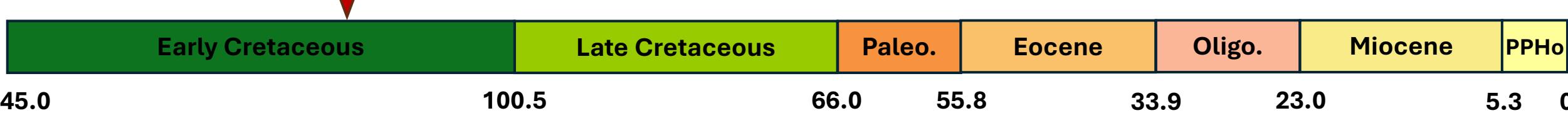
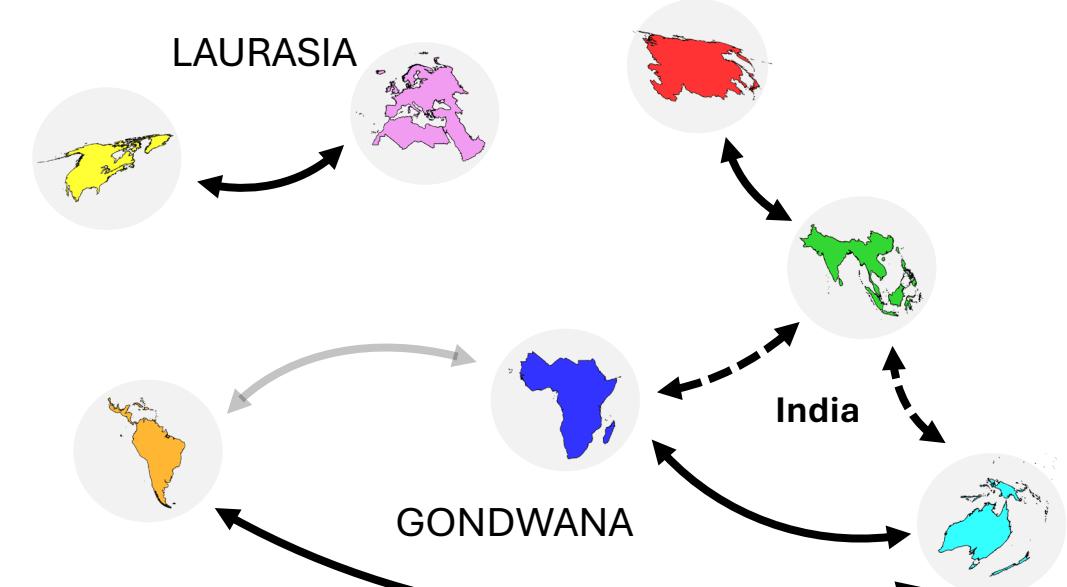
Biogeographic methods



Source: PALEOMAP Project by C. Scotese

Early Cretaceous

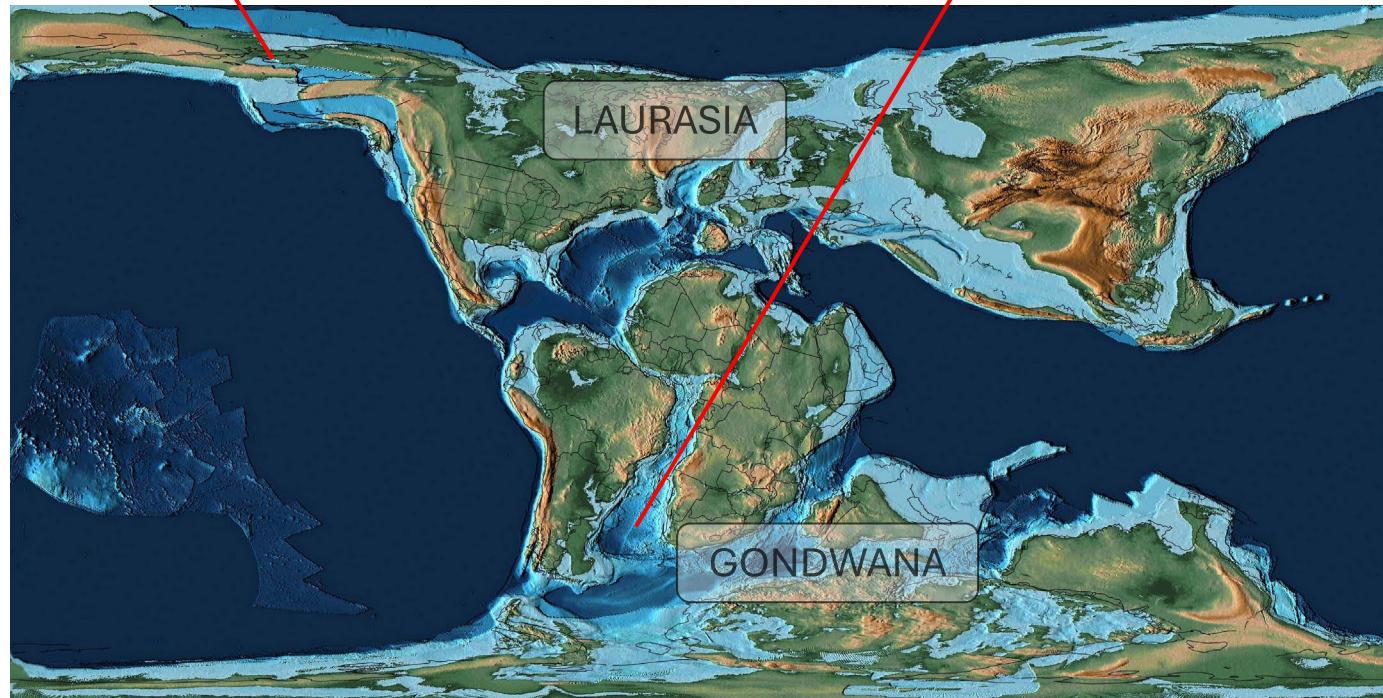
115.0 My



Biogeographic methods

110 - 80 My: Bering land bridge opens

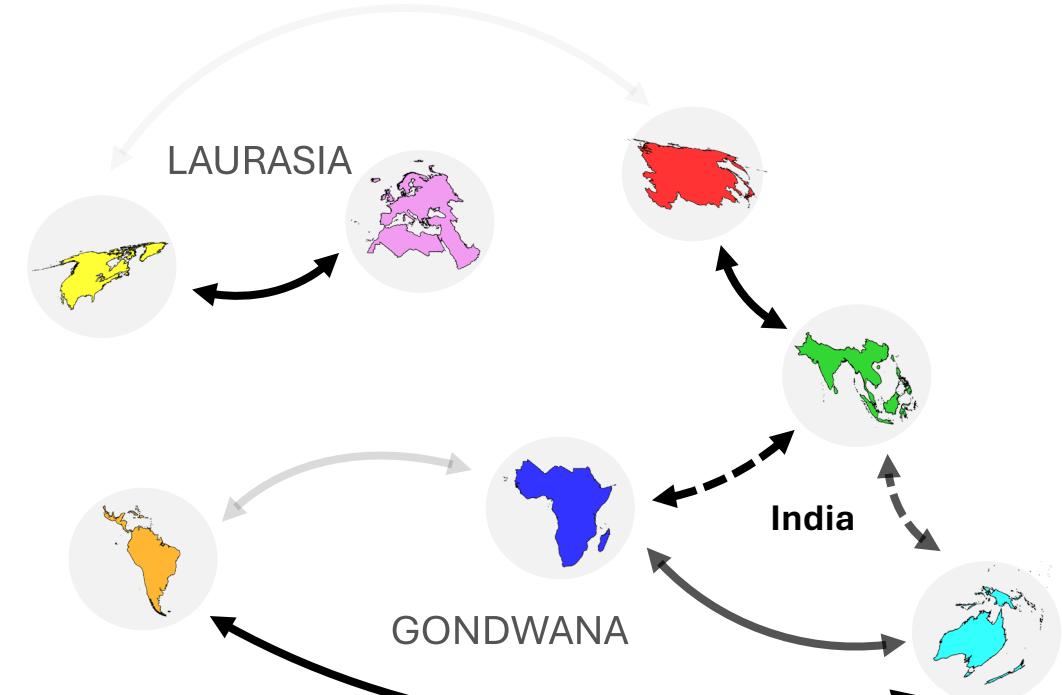
120 -100 My: Opening of the South Atlantic Ocean



Source: PALEOMAP Project by C. Scotese

Early Cretaceous

110.0 My



Early Cretaceous

Late Cretaceous

Paleo.

Eocene

Oligo.

Miocene

PPHo

145.0

100.5

66.0

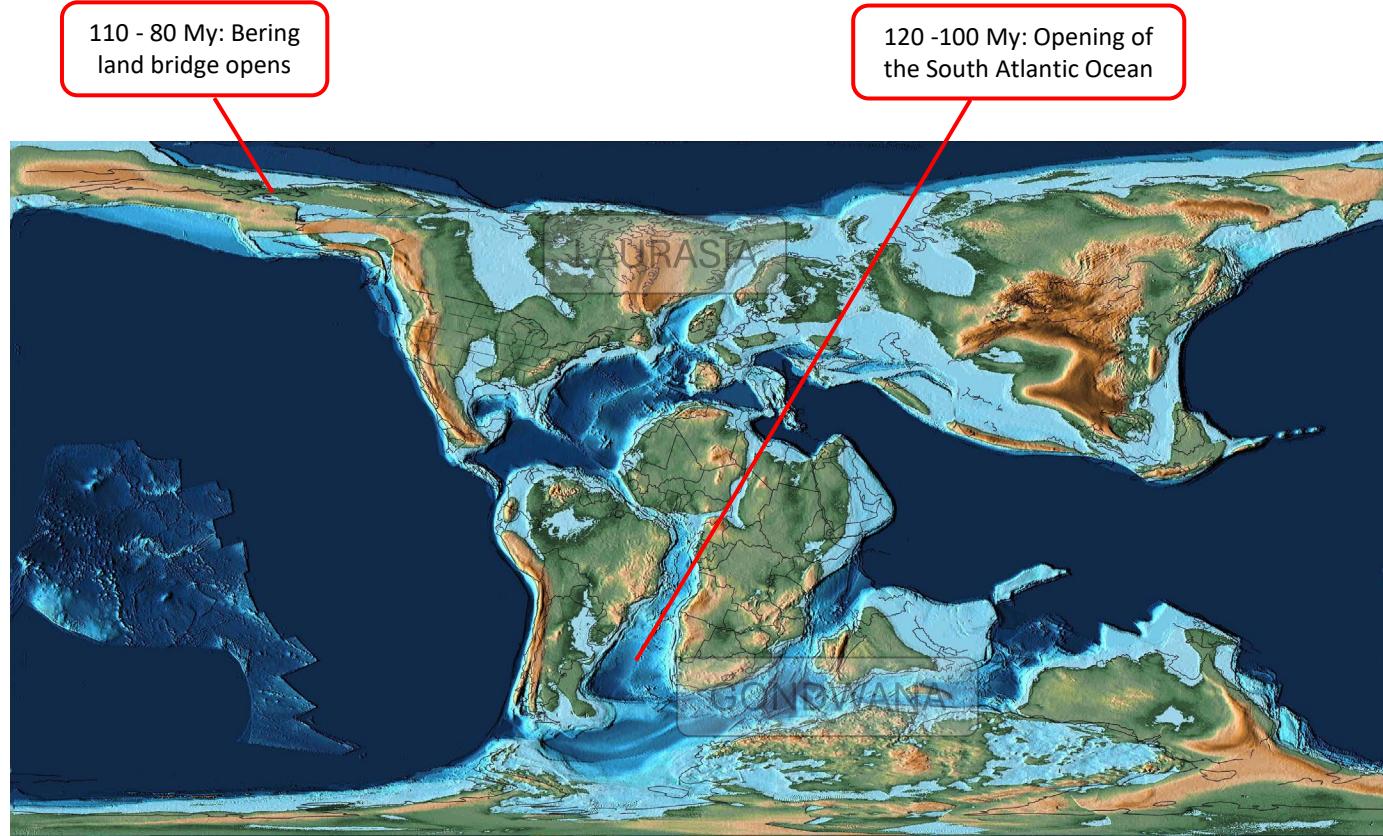
55.8

33.9

23.0

5.3 0

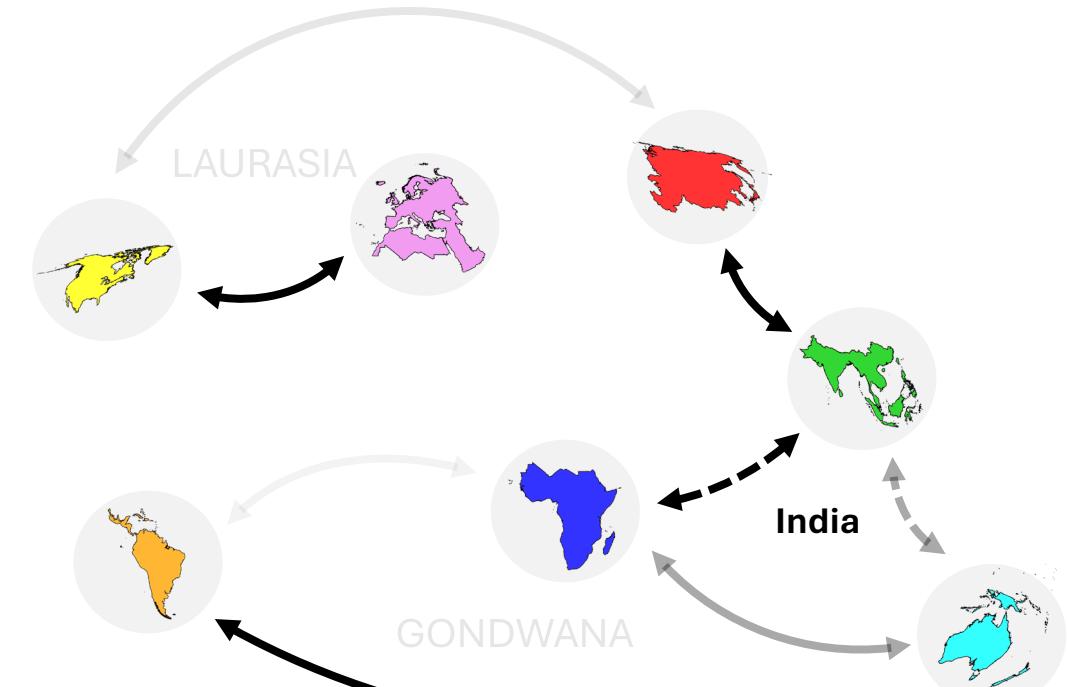
Biogeographic methods



Source: PALEOMAP Project by C. Scotese

Early Cretaceous

105.0 My



Early Cretaceous

Late Cretaceous

Paleo.

Eocene

Oligo.

Miocene

PPHo

145.0

100.5

66.0

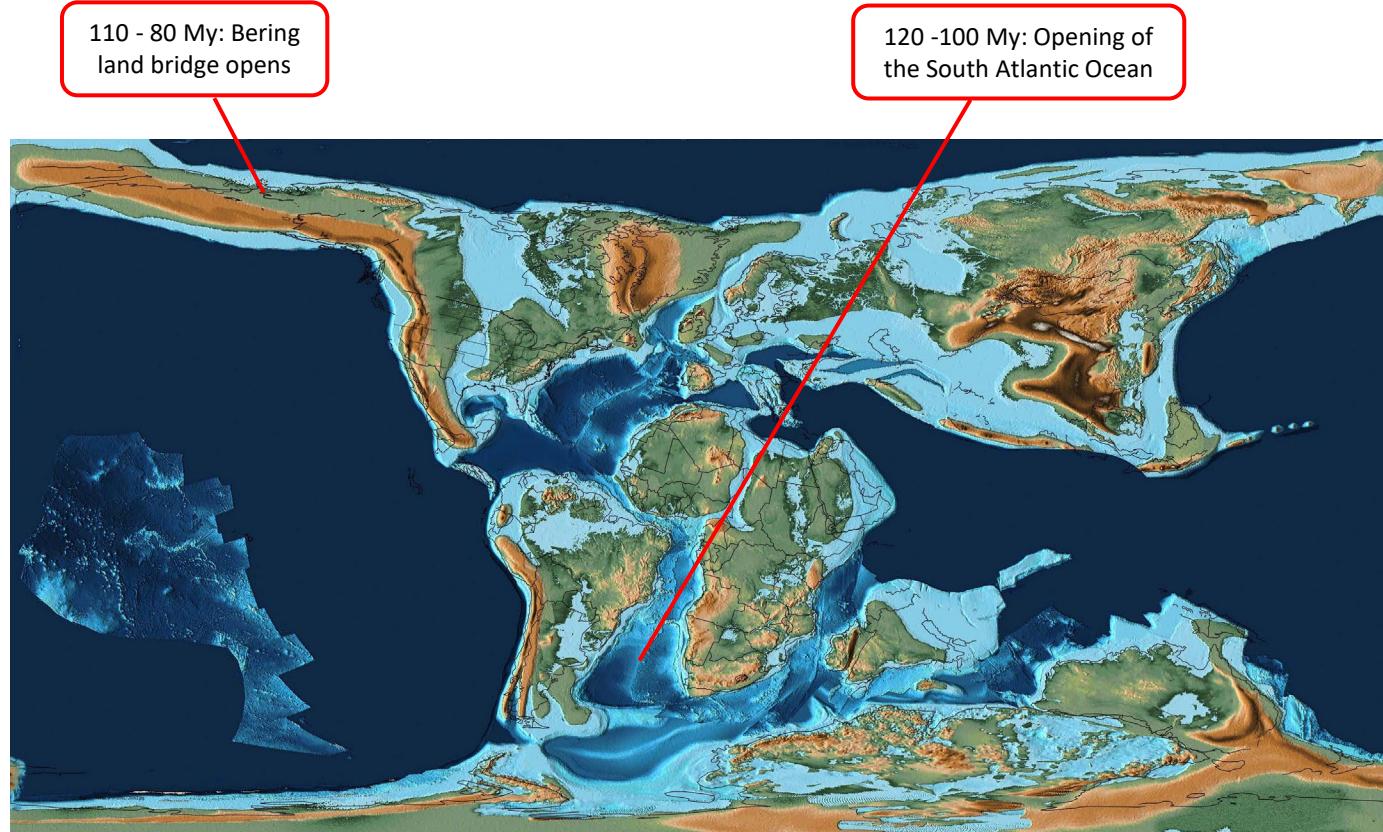
55.8

33.9

23.0

5.3 0

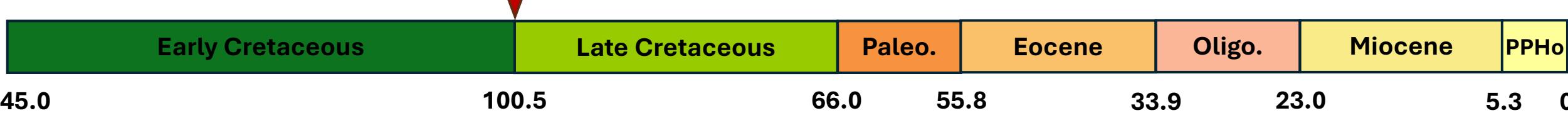
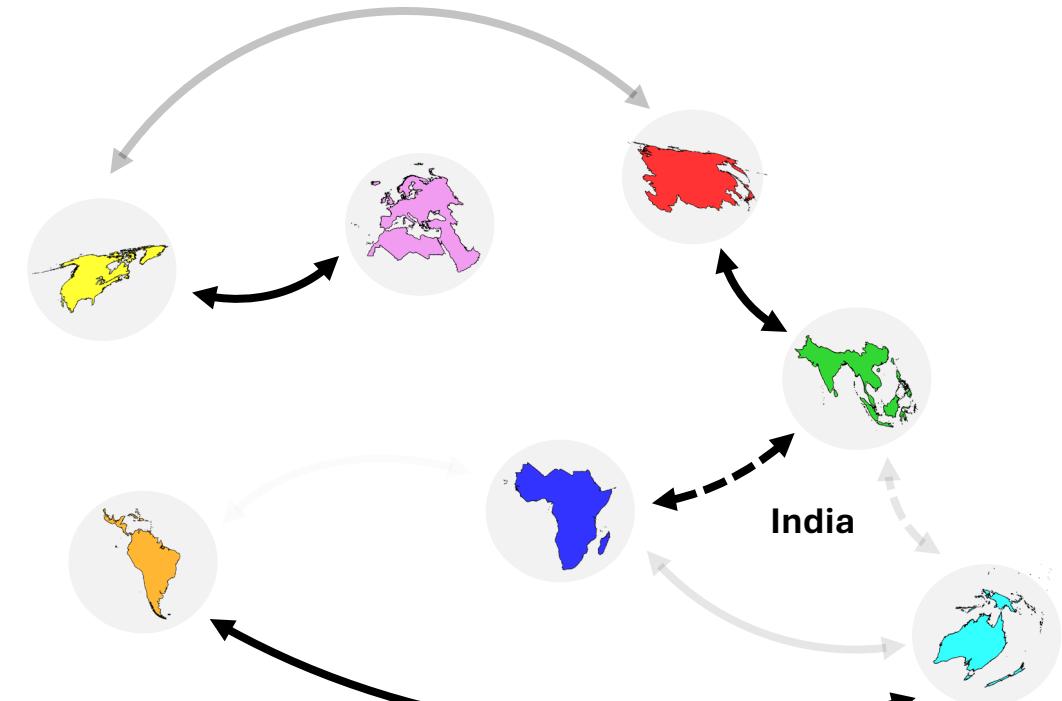
Biogeographic methods



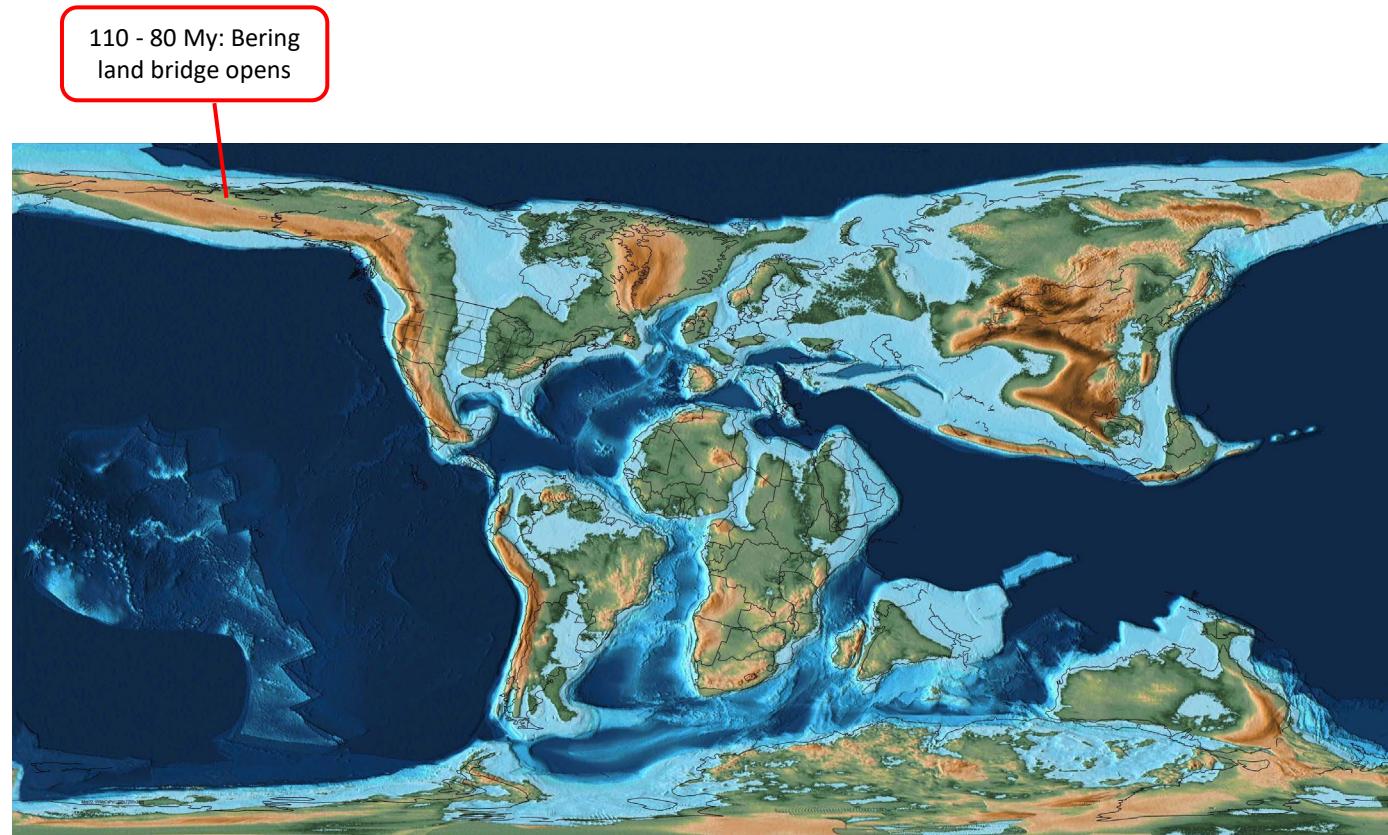
Source: PALEOMAP Project by C. Scotese

Early to Late Cretaceous

100.5 My



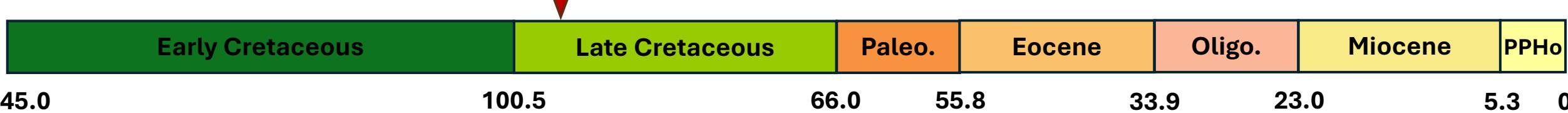
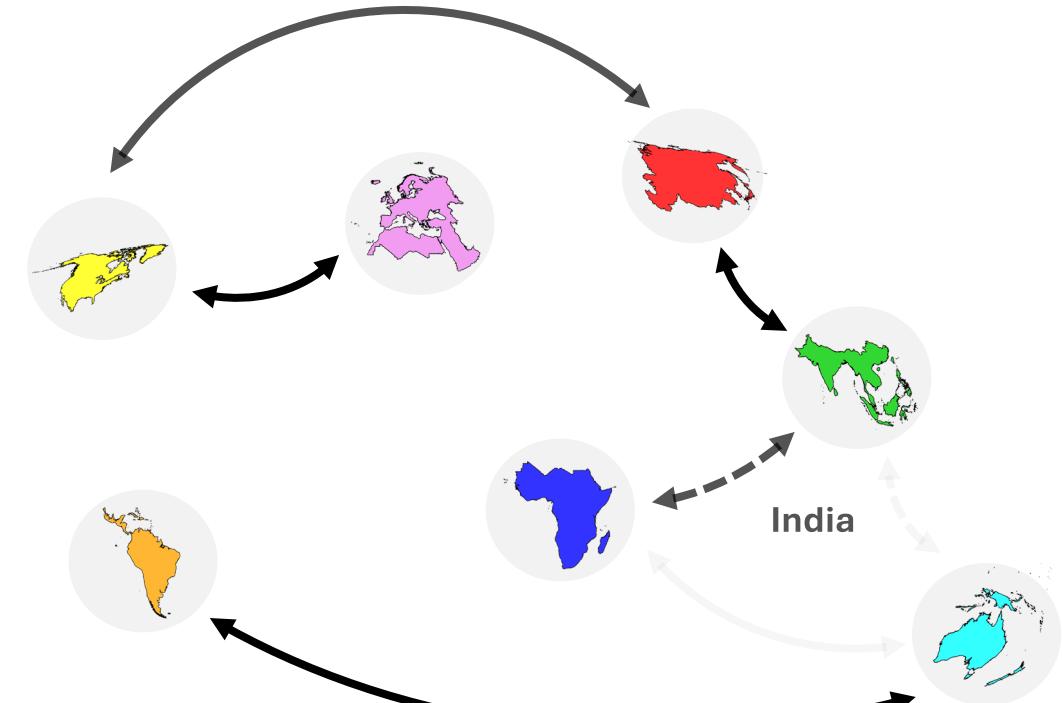
Biogeographic methods



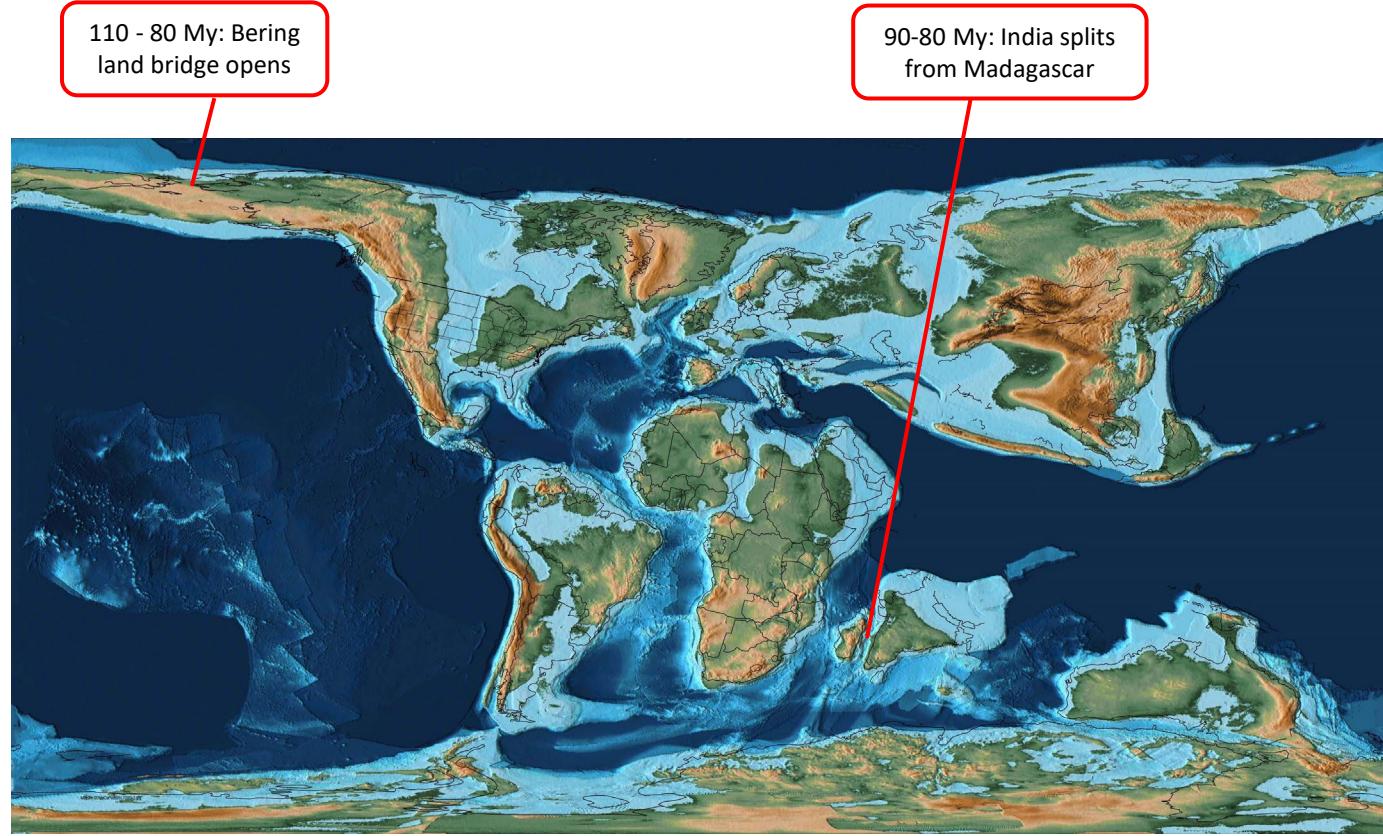
Source: PALEOMAP Project by C. Scotese

Late Cretaceous

95.0 My

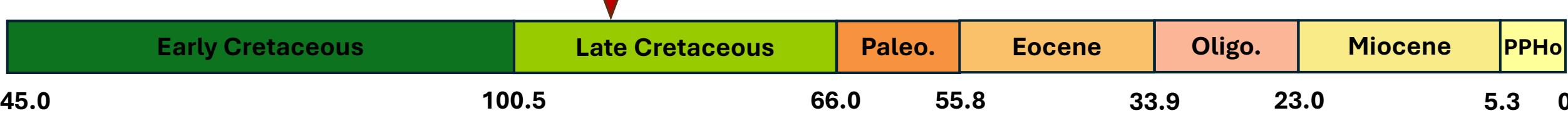
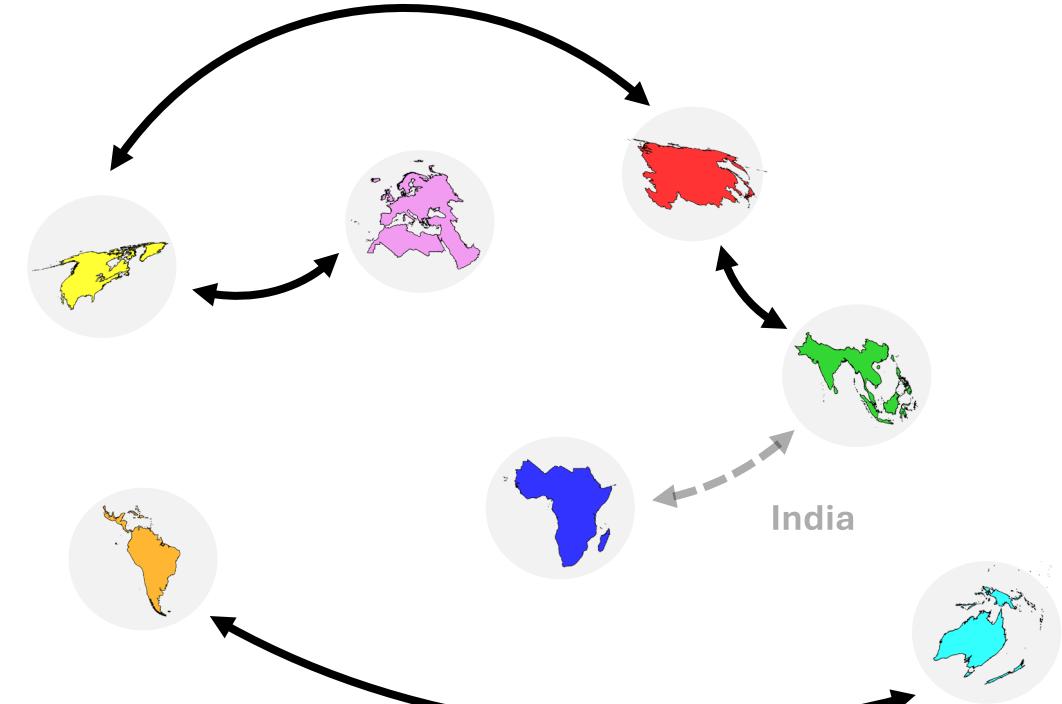


Biogeographic methods

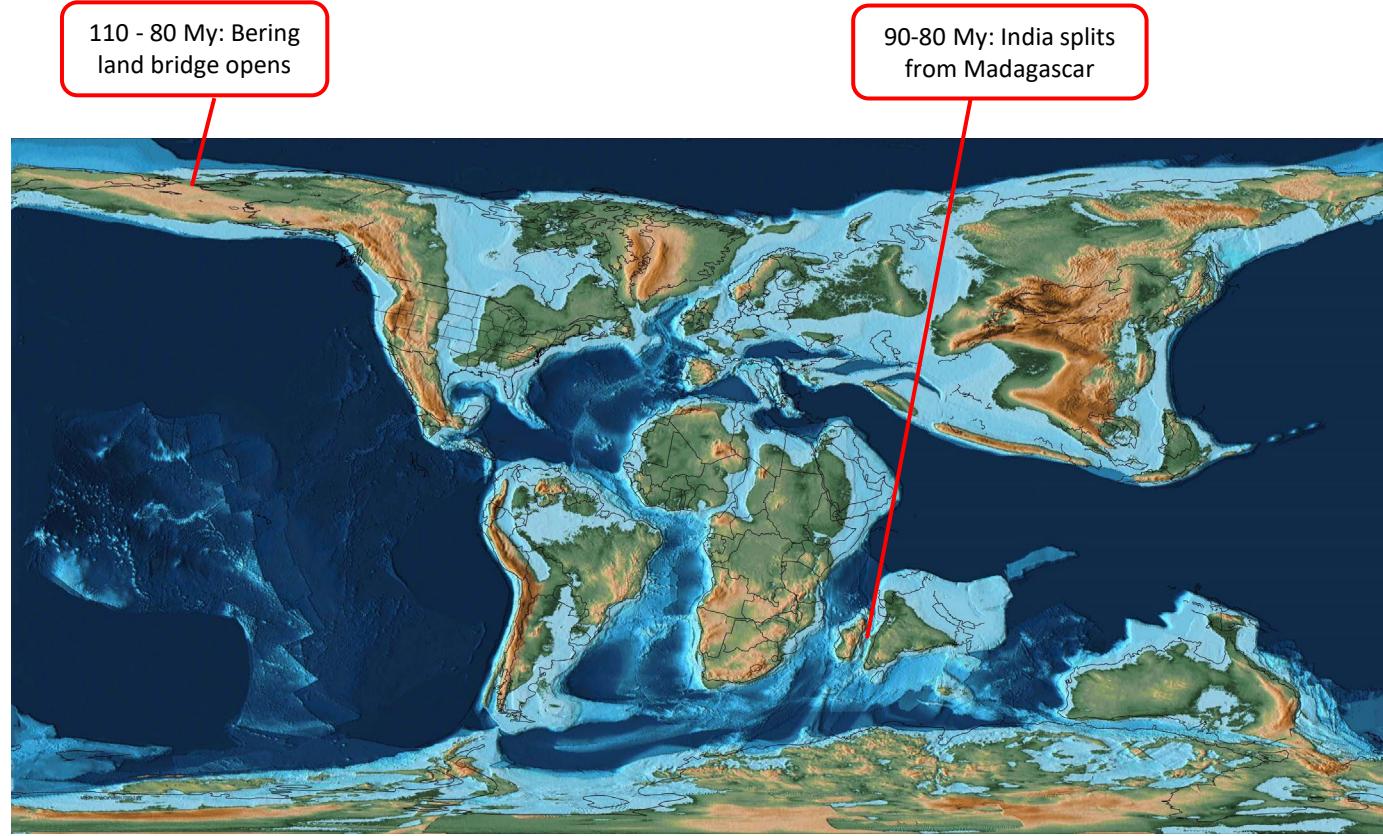


Late Cretaceous

90.0 My



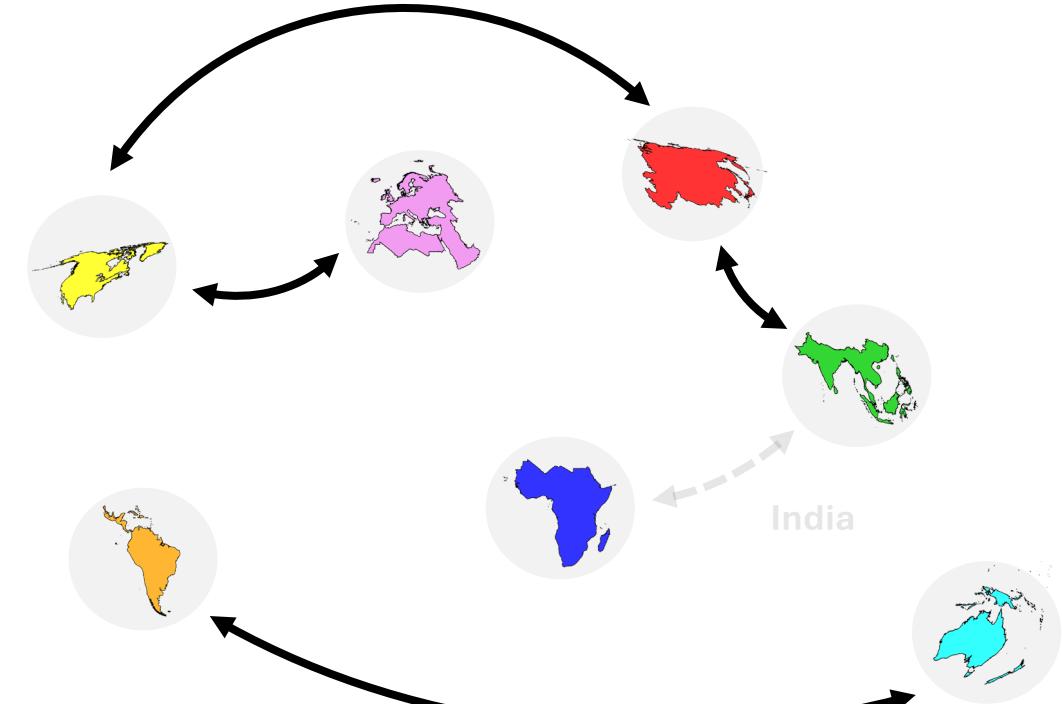
Biogeographic methods



Source: PALEOMAP Project by C. Scotese

Late Cretaceous

85.0 My



Early Cretaceous

Late Cretaceous

Paleo.

Eocene

Oligo.

Miocene

PPHo

145.0

100.5

66.0

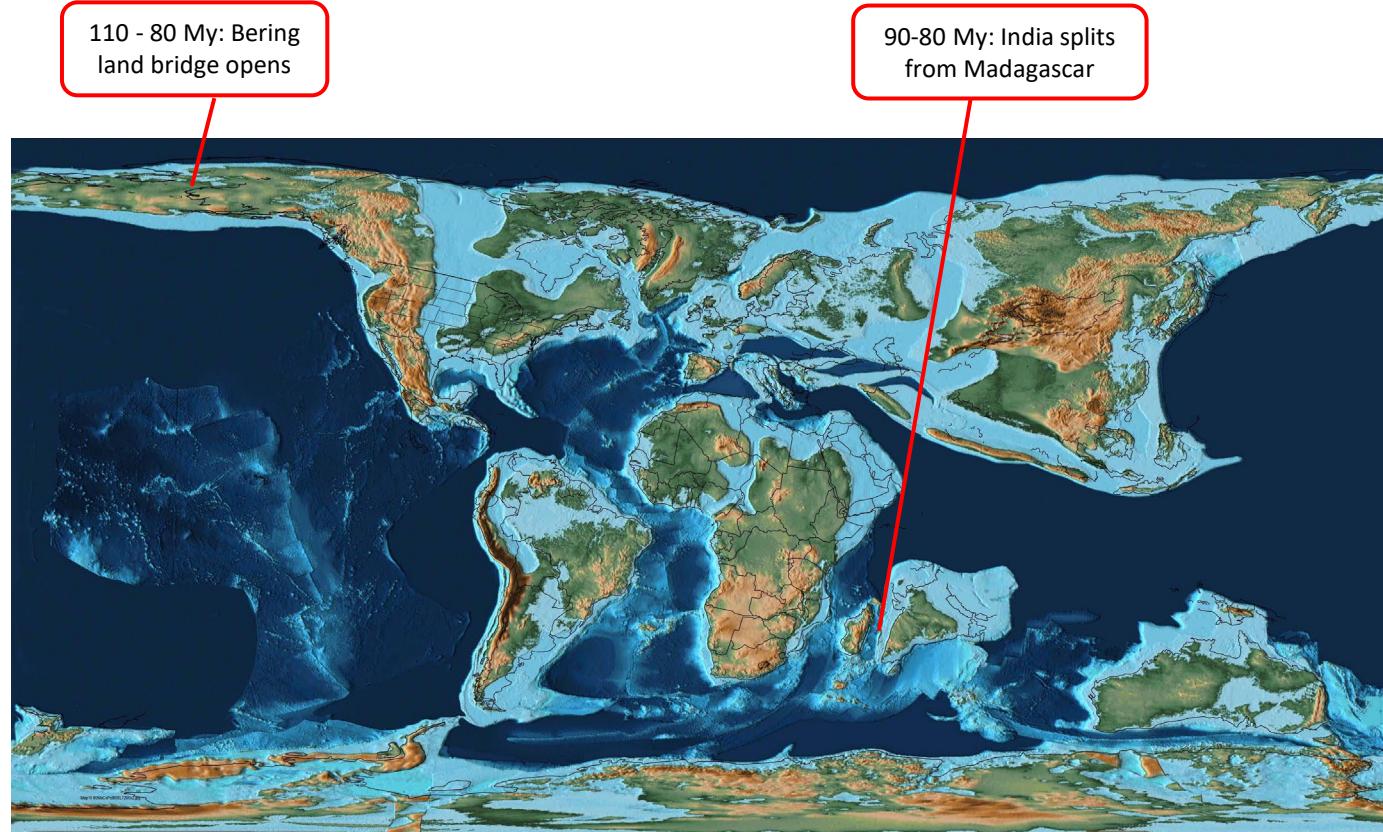
55.8

33.9

23.0

5.3 0

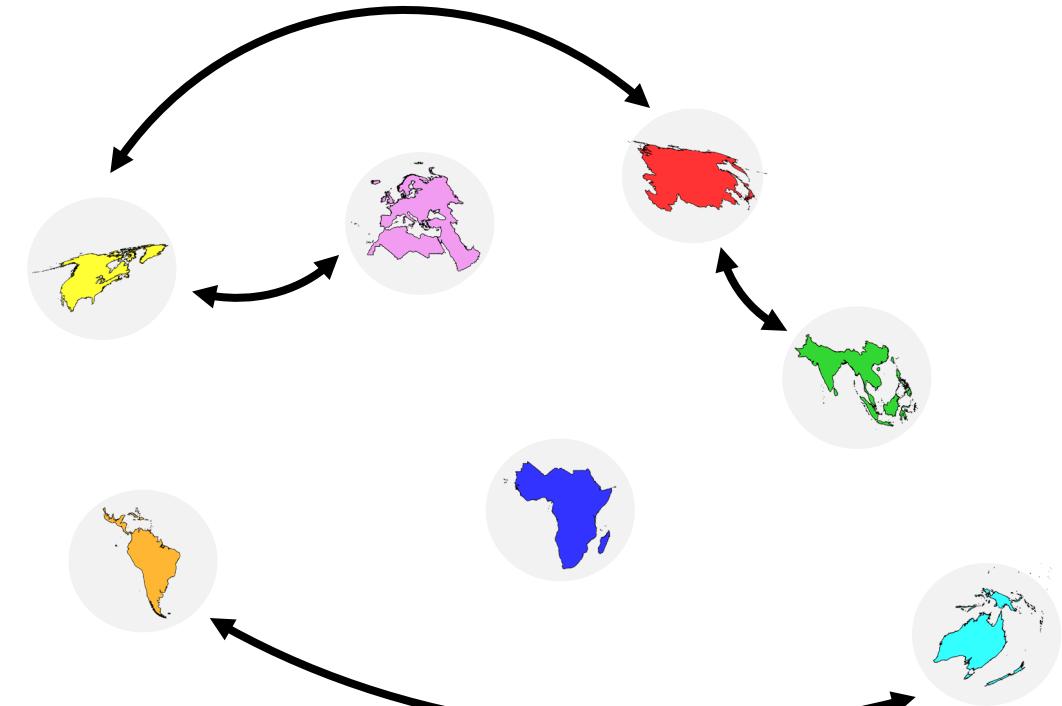
Biogeographic methods



Source: PALEOMAP Project by C. Scotese

Late Cretaceous

80.0 My



Early Cretaceous

Late Cretaceous

Paleo.

Eocene

Oligo.

Miocene

PPHo

145.0

100.5

66.0

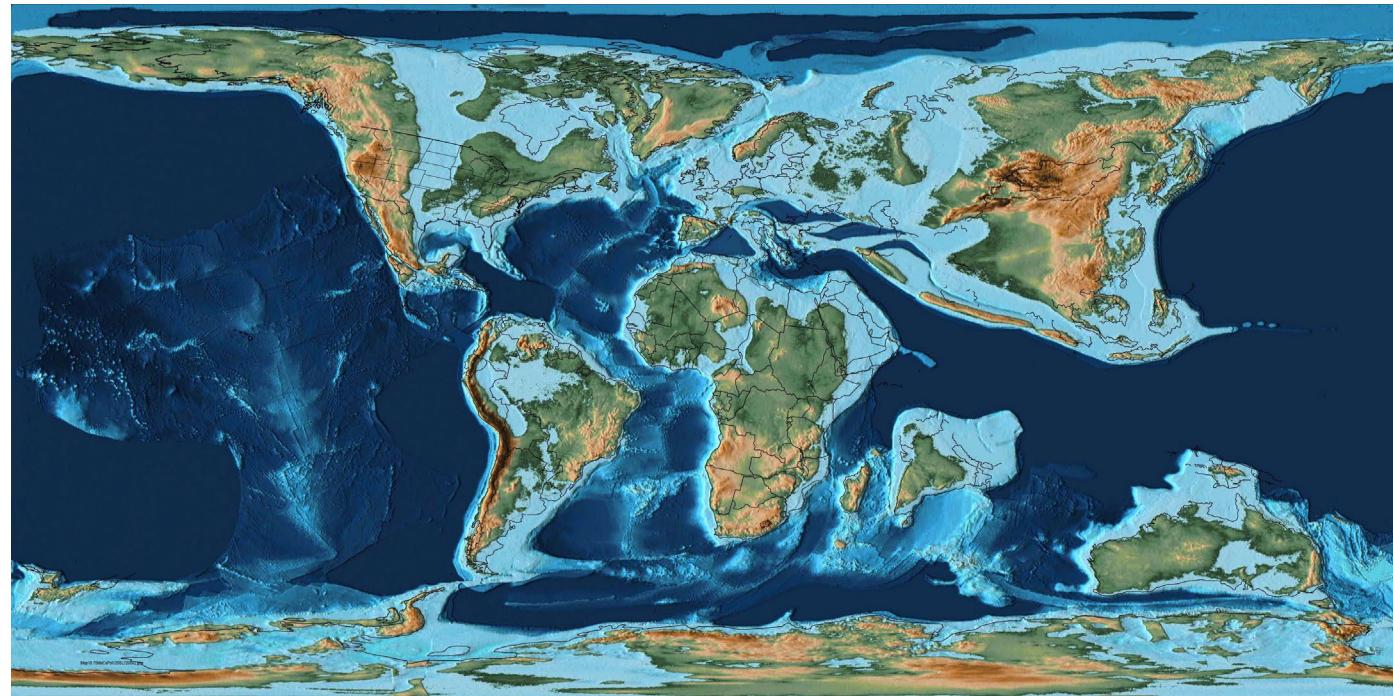
55.8

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23.0

5.3 0

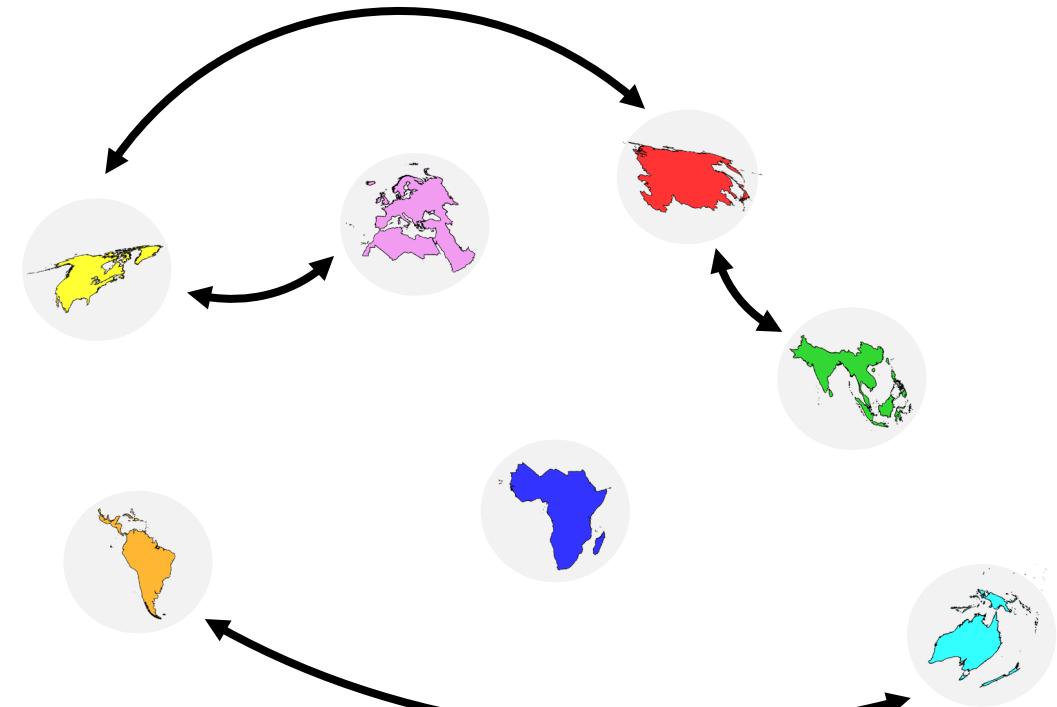
Biogeographic methods



Source: PALEOMAP Project by C. Scotese

Late Cretaceous

75.0 My



Early Cretaceous

Late Cretaceous

Paleo.

Eocene

Oligo.

Miocene

PPHo

145.0

100.5

66.0

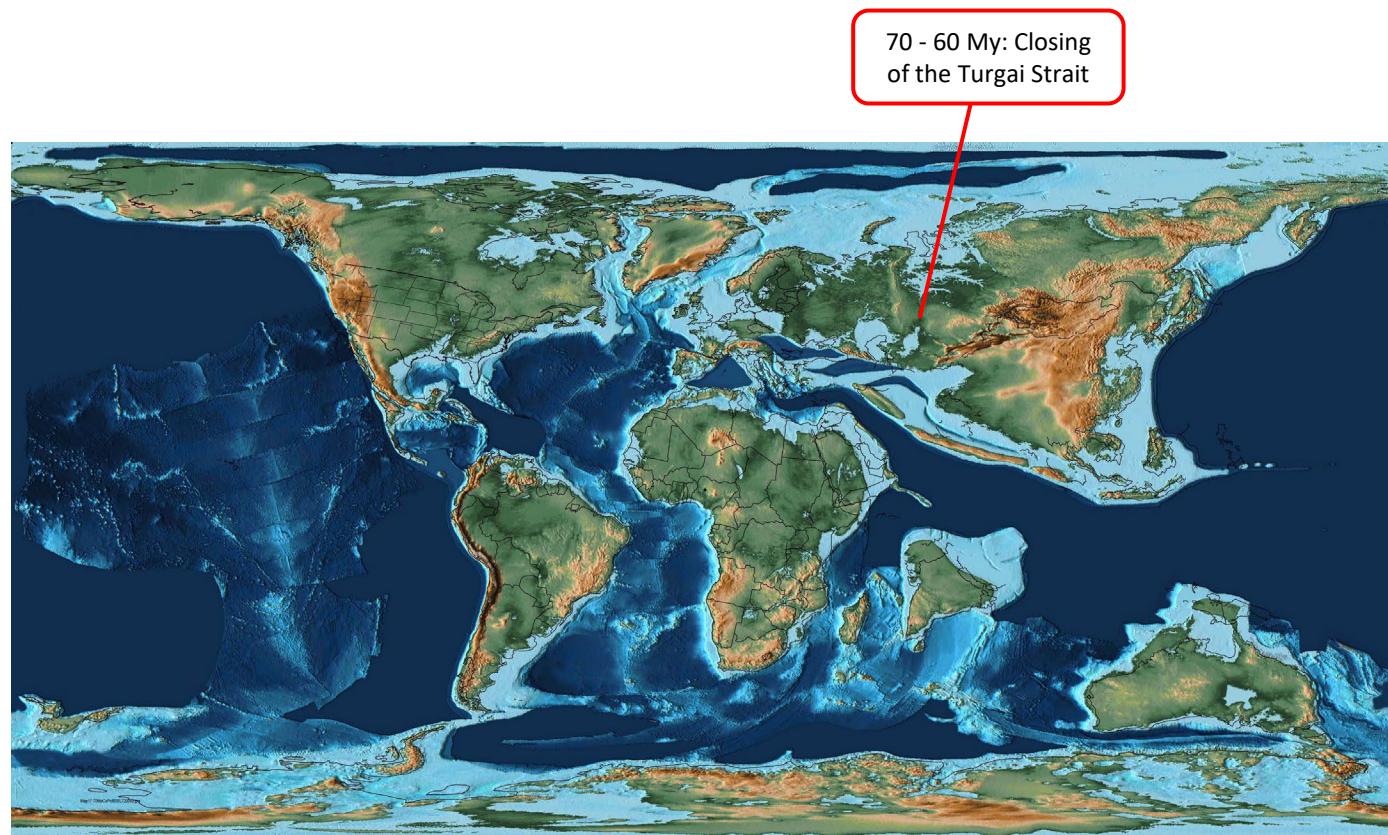
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33.9

23.0

5.3 0

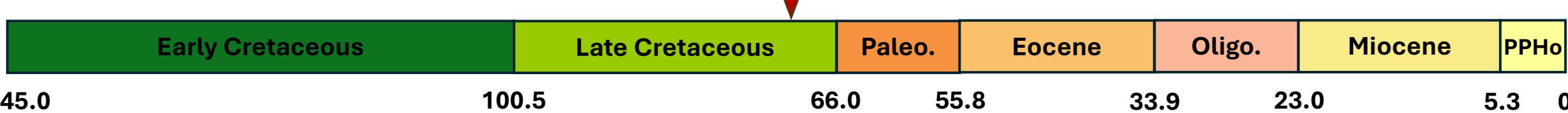
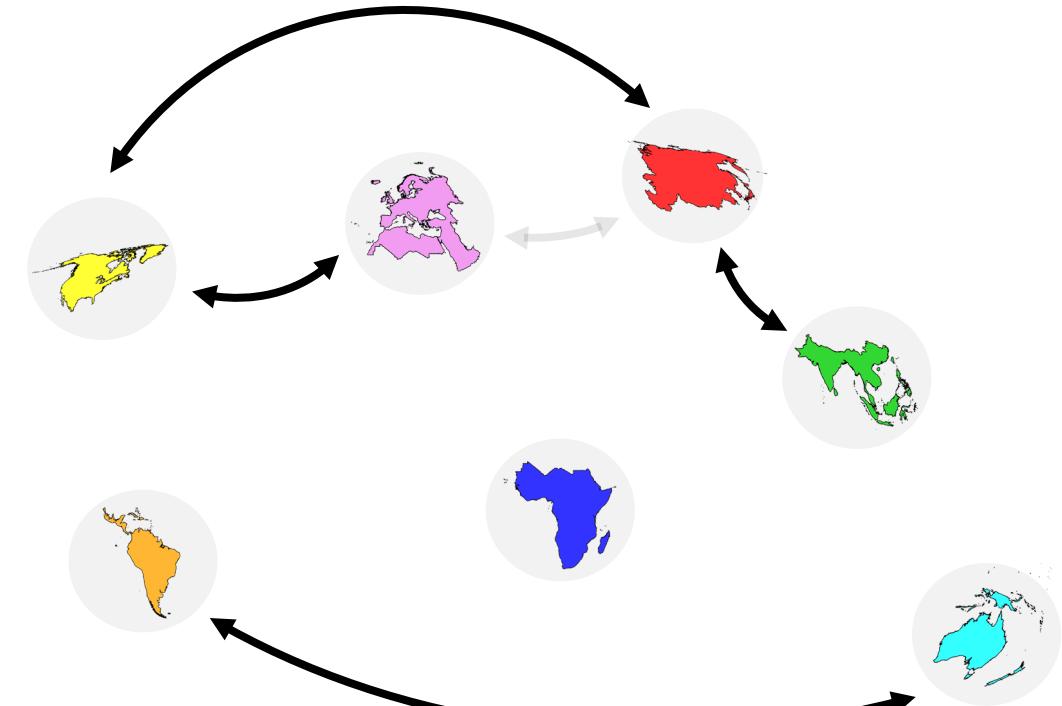
Biogeographic methods



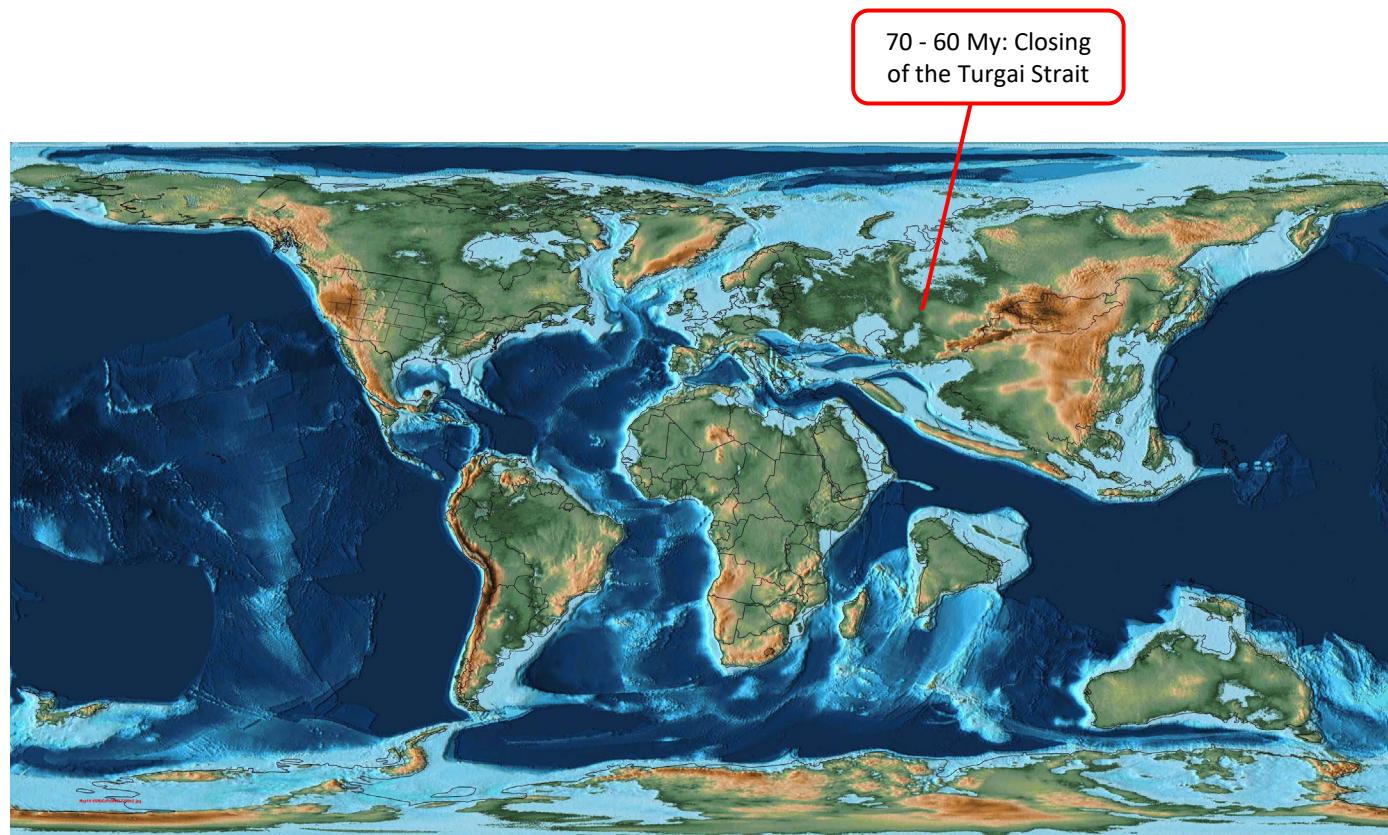
Source: PALEOMAP Project by C. Scotese

Late Cretaceous

70.0 My



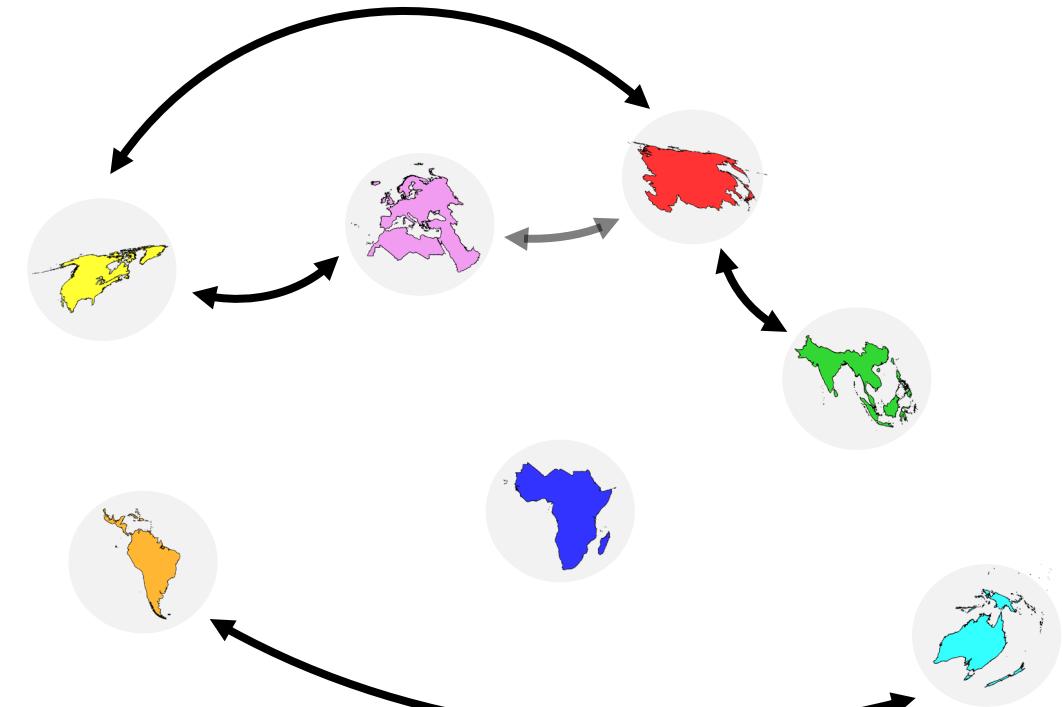
Biogeographic methods



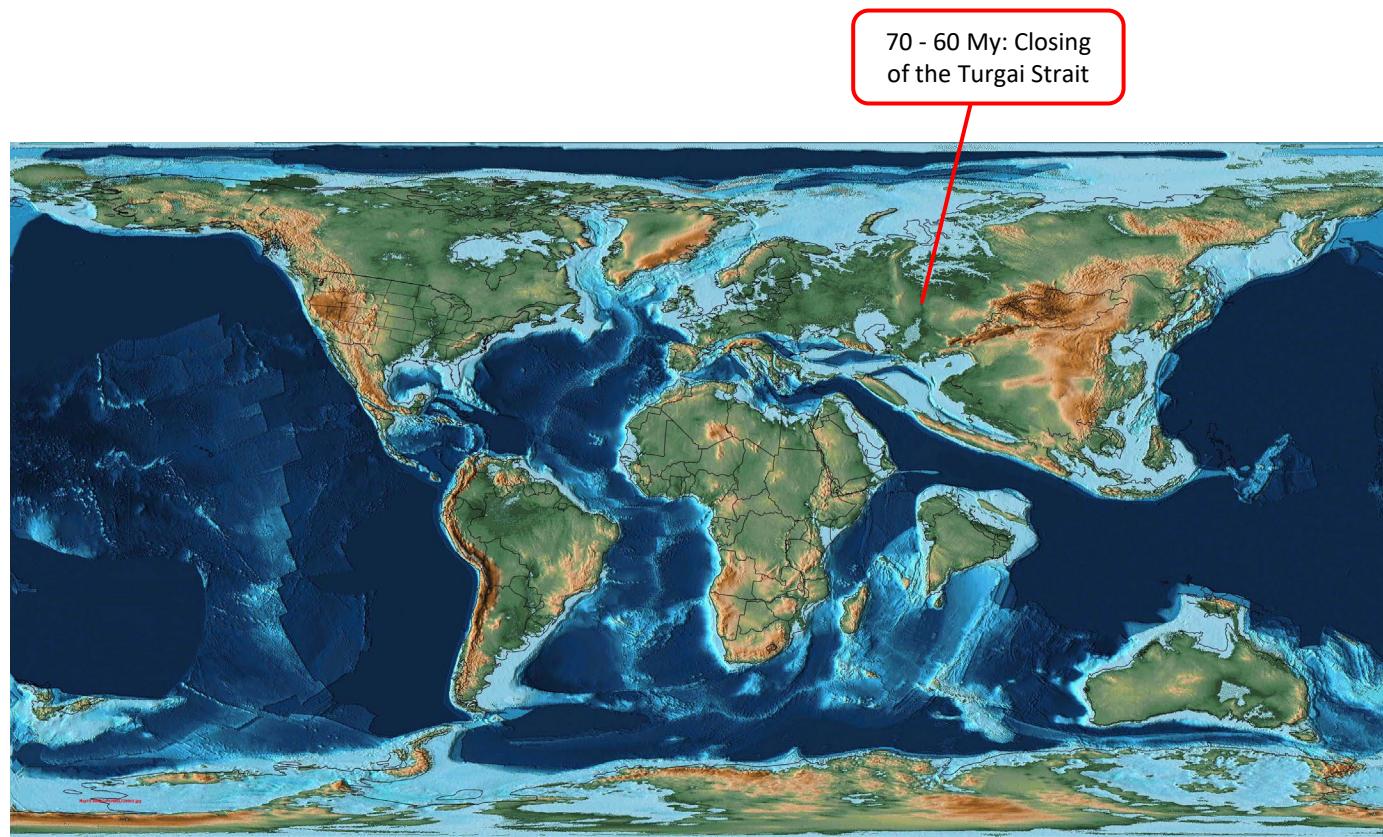
Source: PALEOMAP Project by C. Scotese

Late Cretaceous to Paleocene

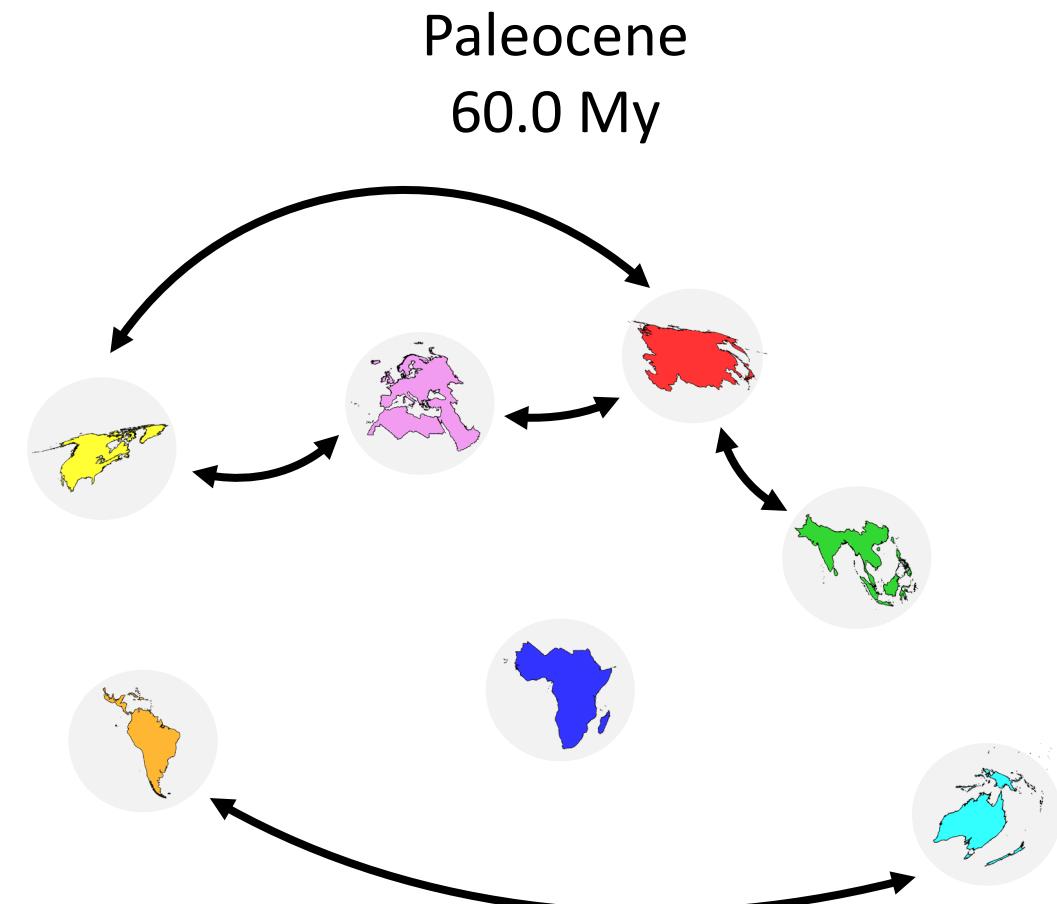
66.0 My



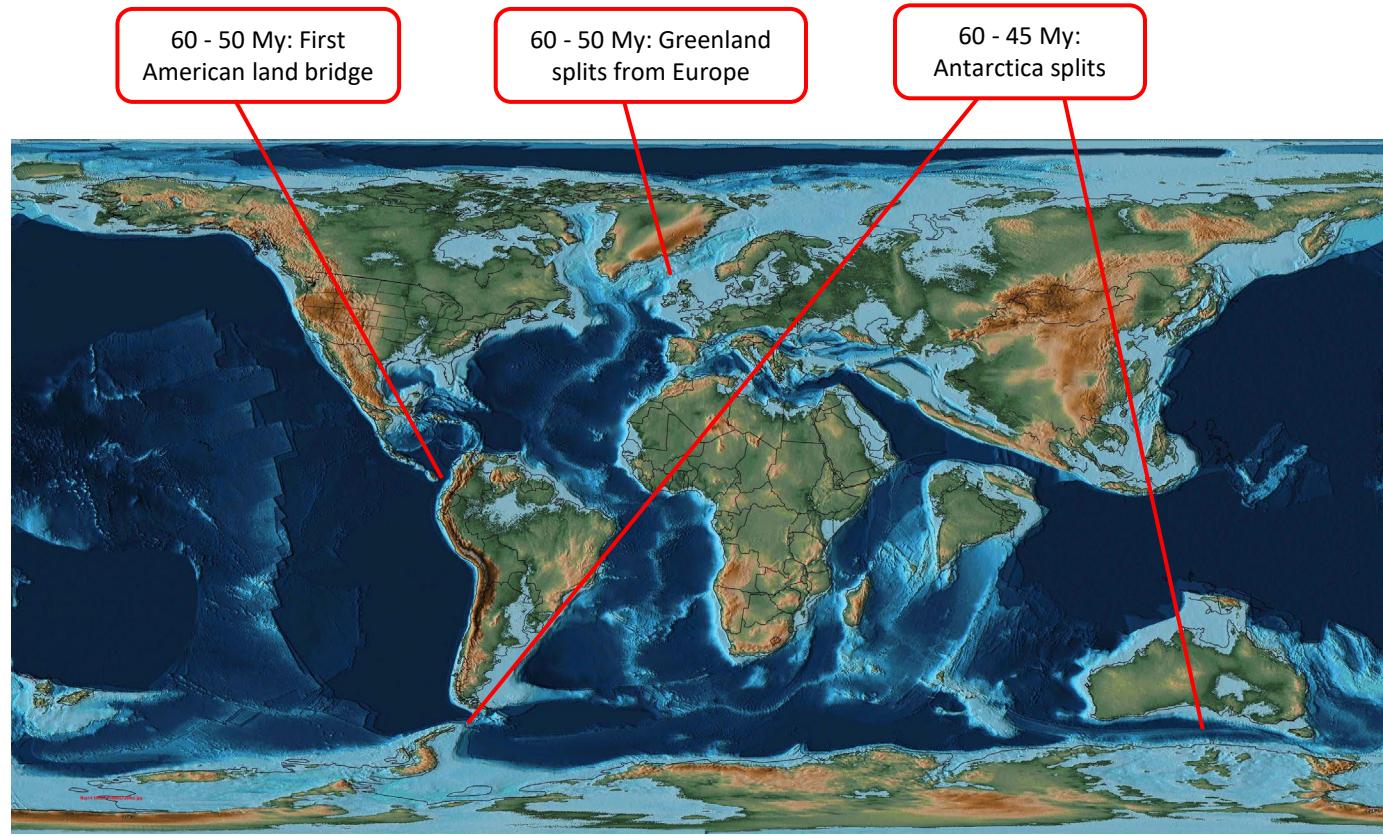
Biogeographic methods



Source: PALEOMAP Project by C. Scotese



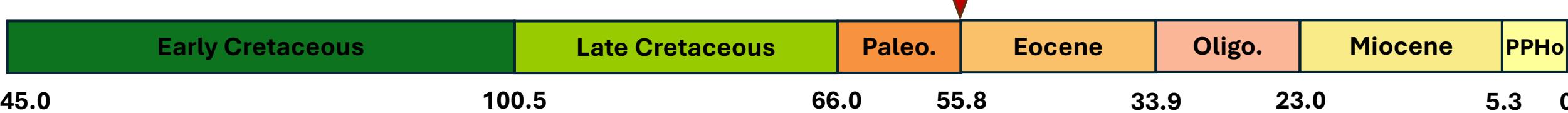
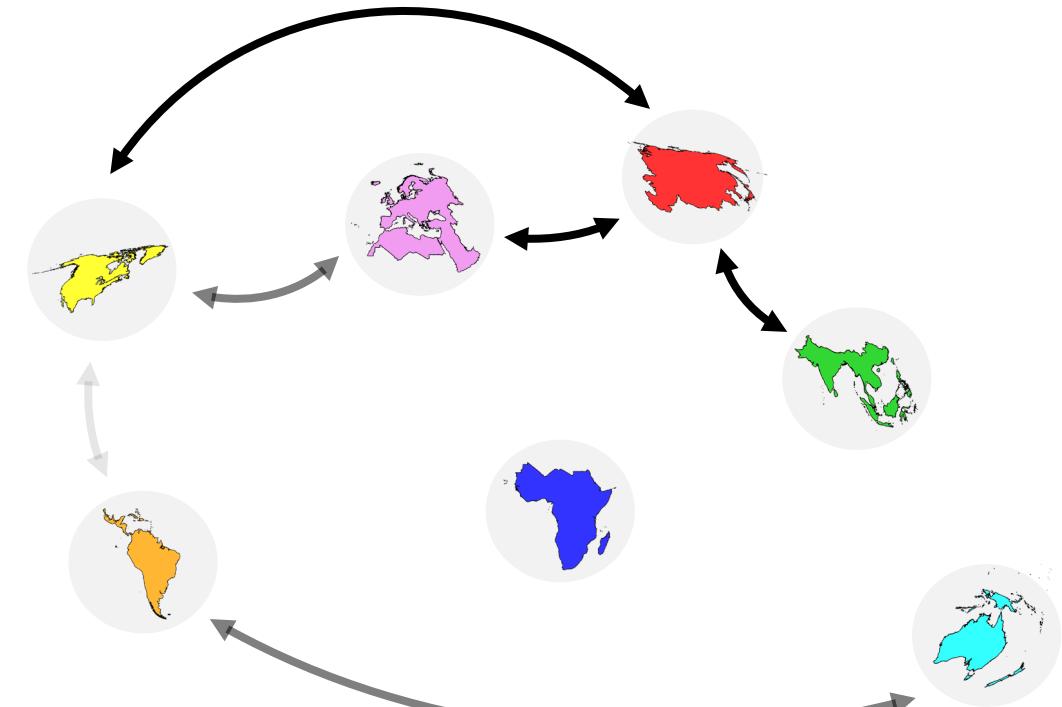
Biogeographic methods



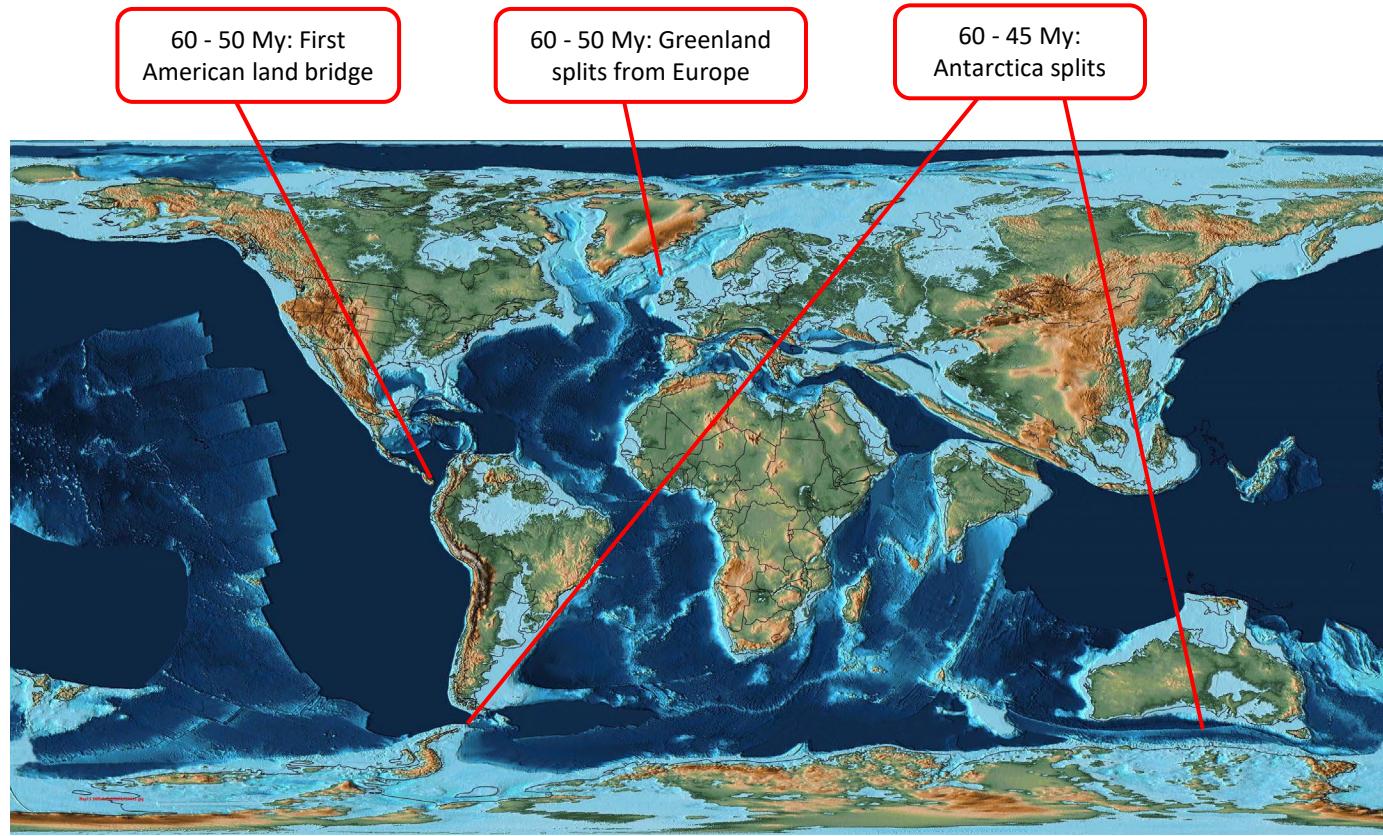
Source: PALEOMAP Project by C. Scotese

Paleocene to Eocene

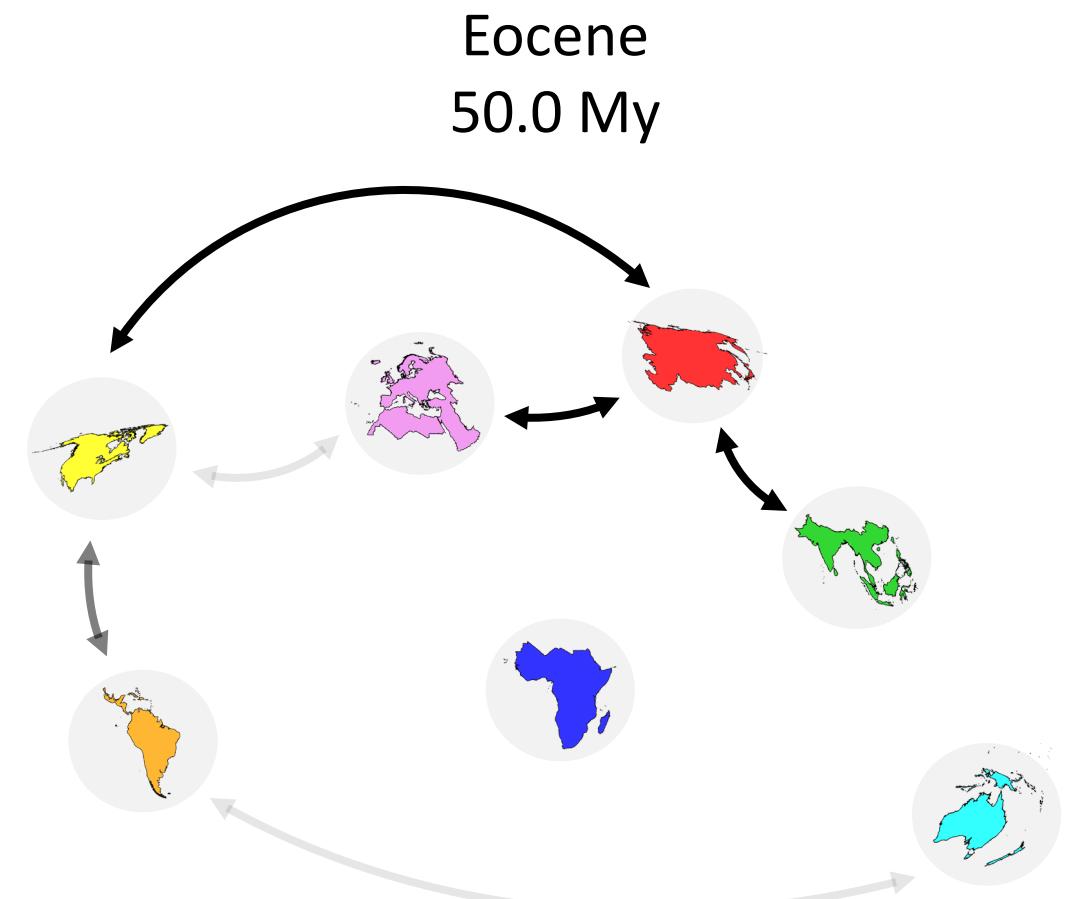
55.8 My



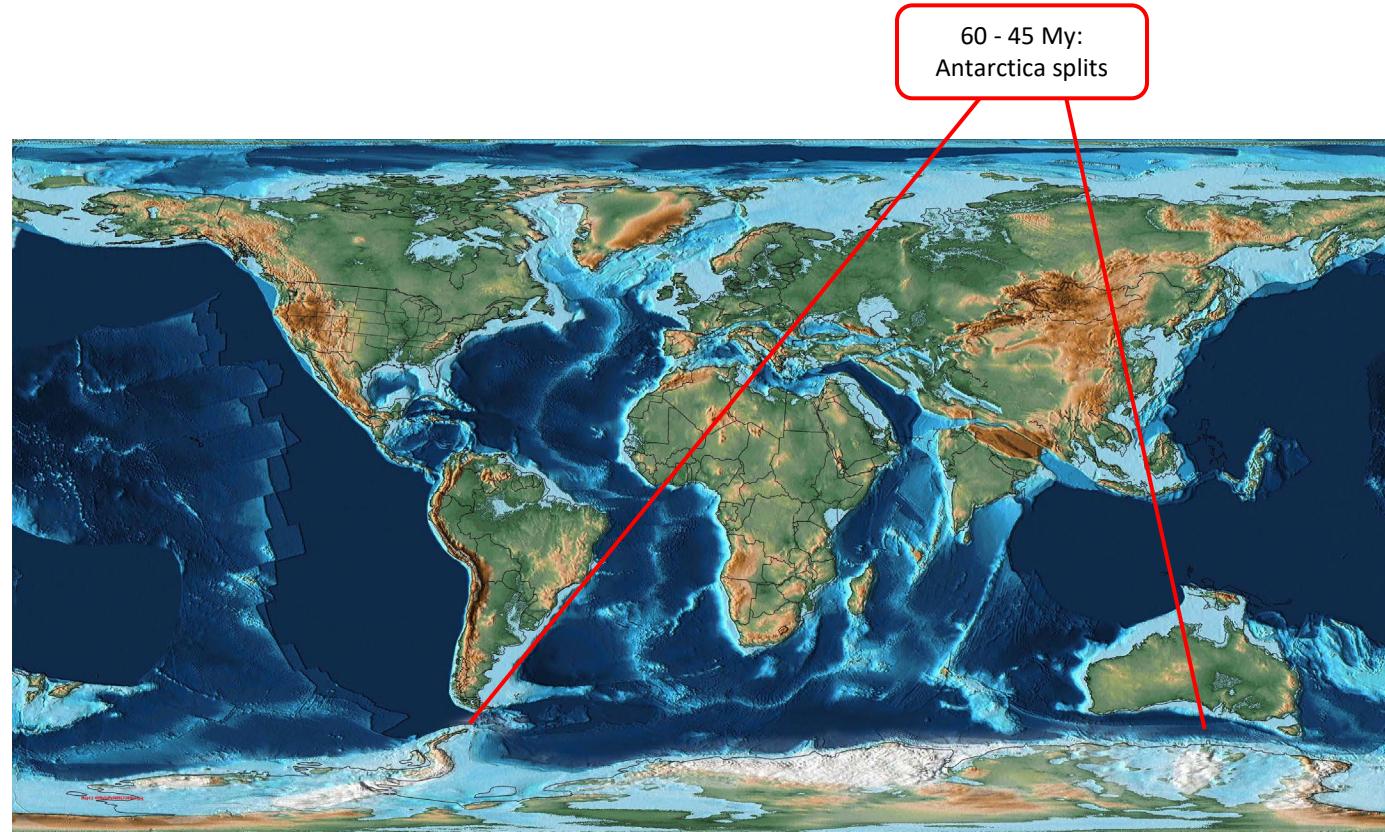
Biogeographic methods



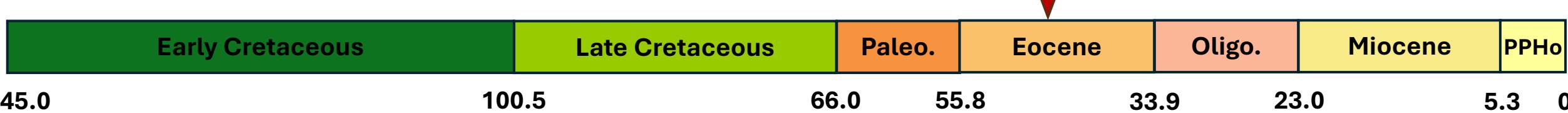
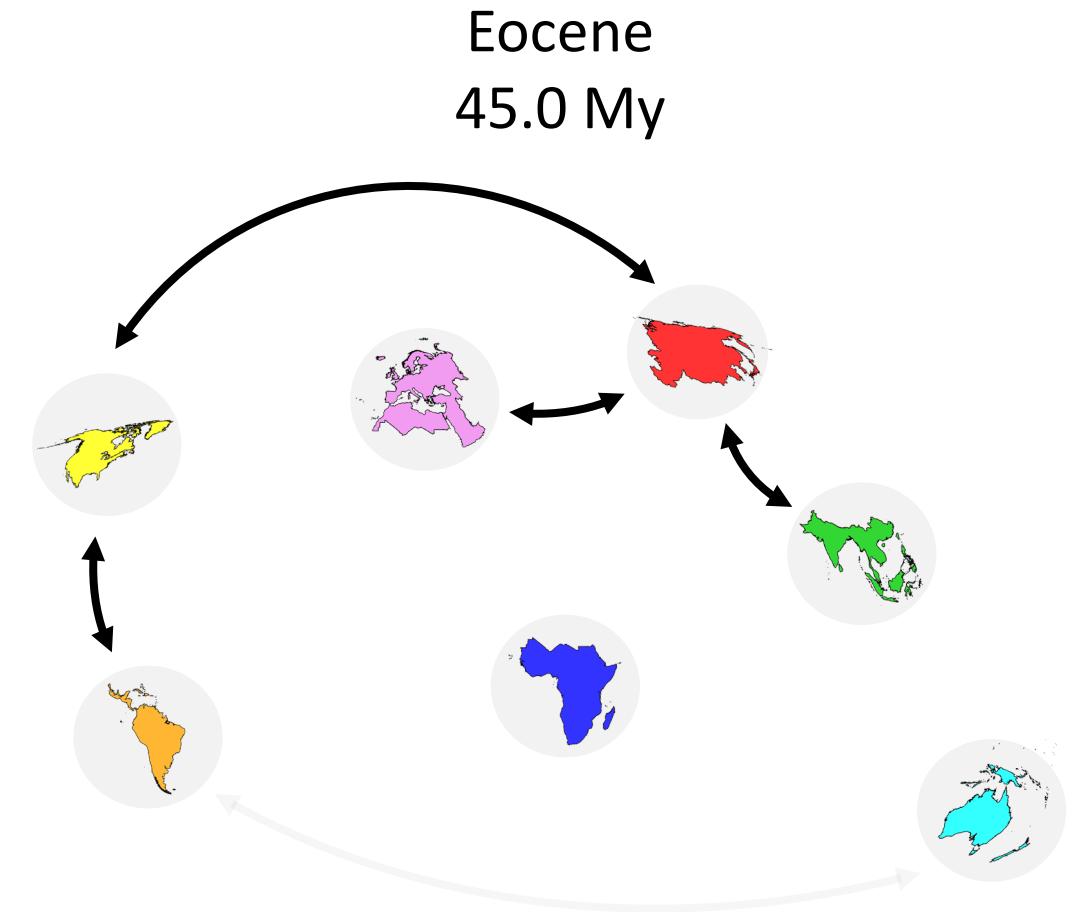
Source: PALEOMAP Project by C. Scotese



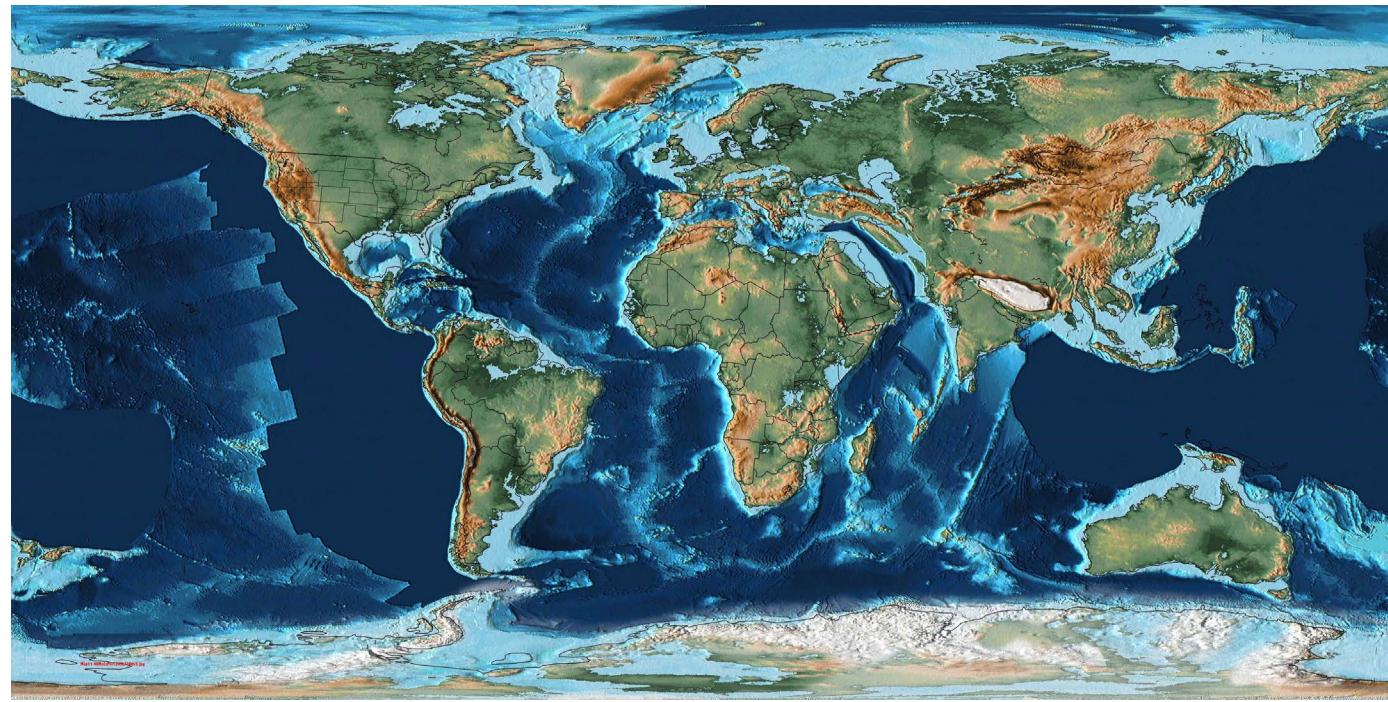
Biogeographic methods



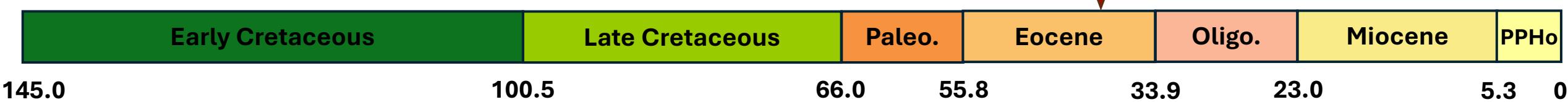
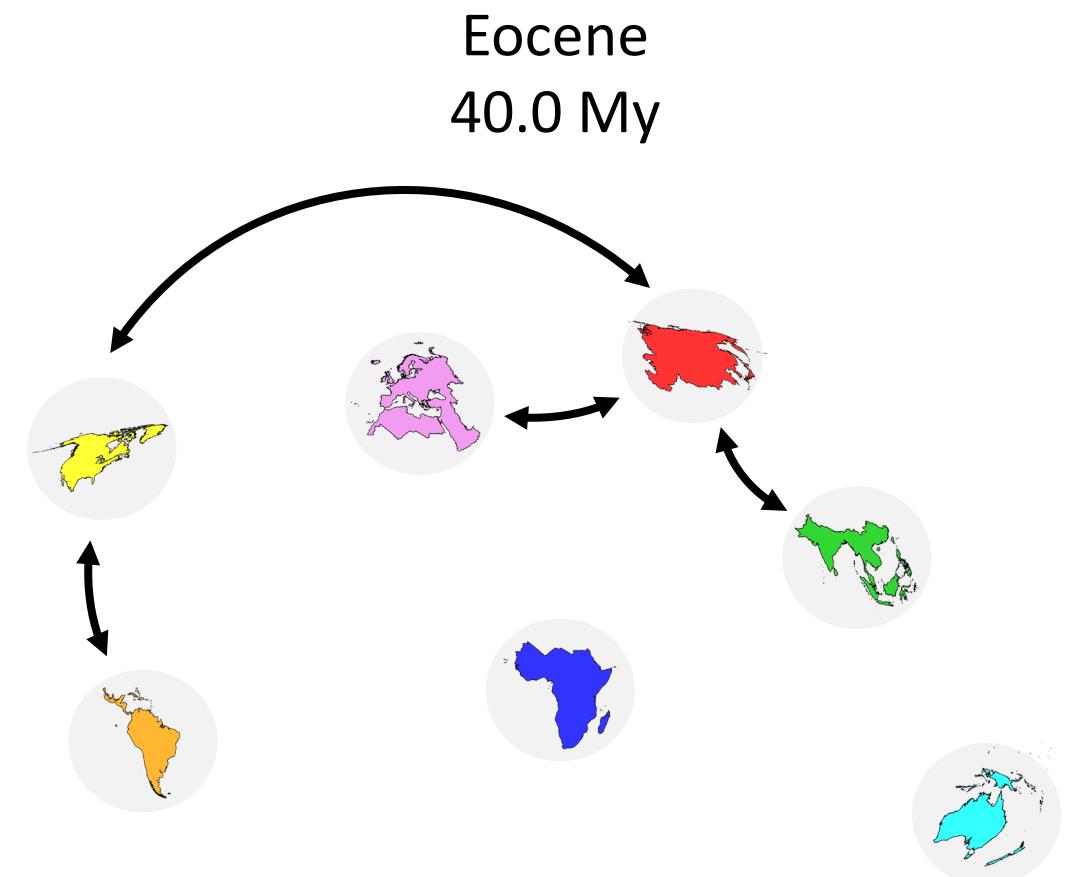
Source: PALEOMAP Project by C. Scotese



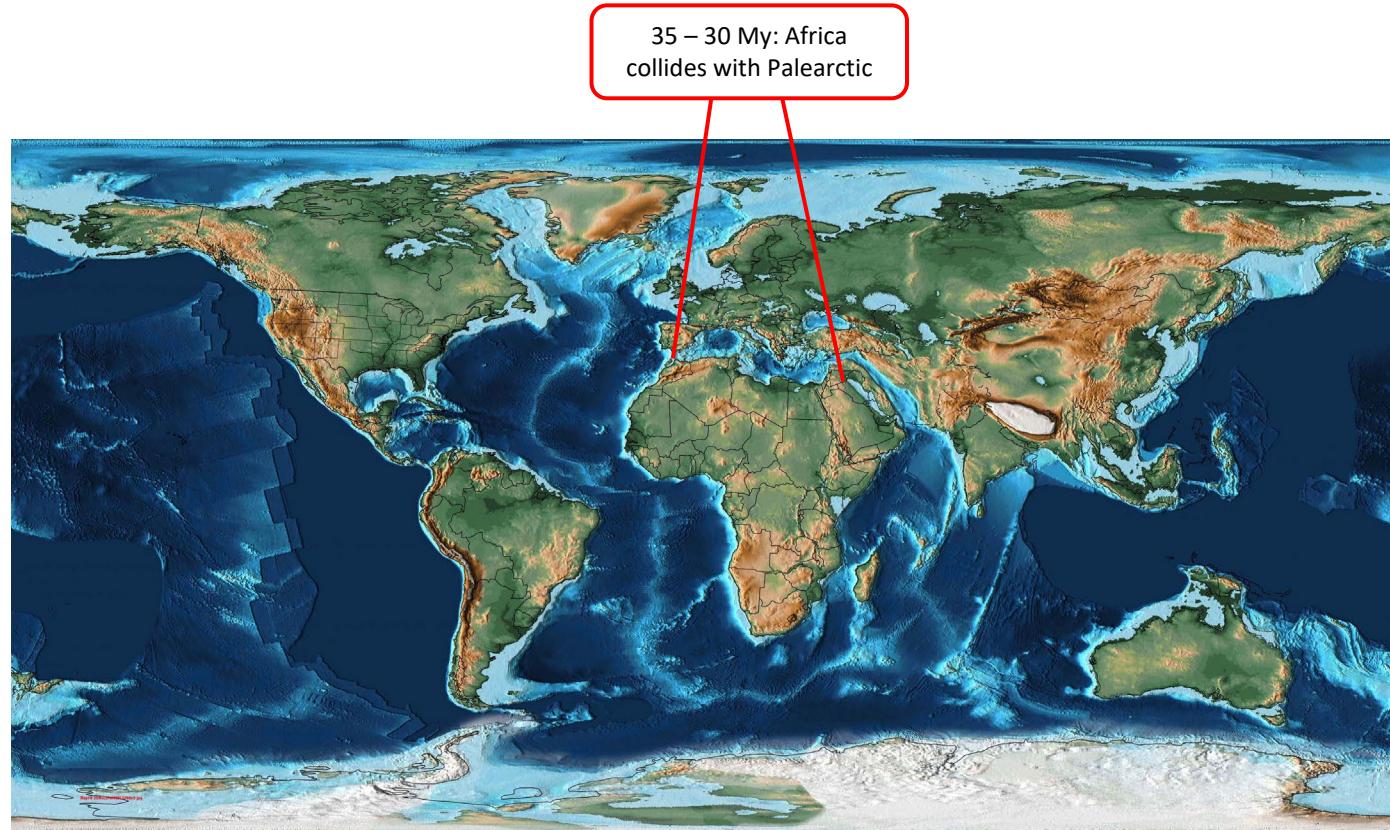
Biogeographic methods



Source: PALEOMAP Project by C. Scotese



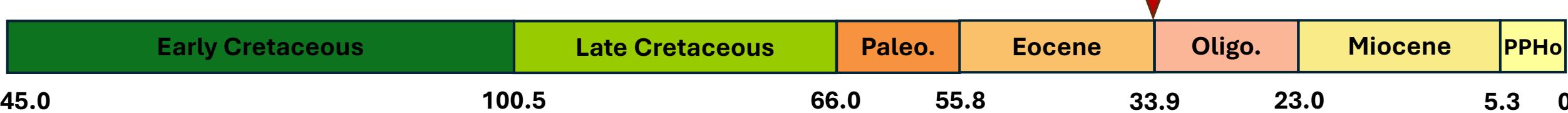
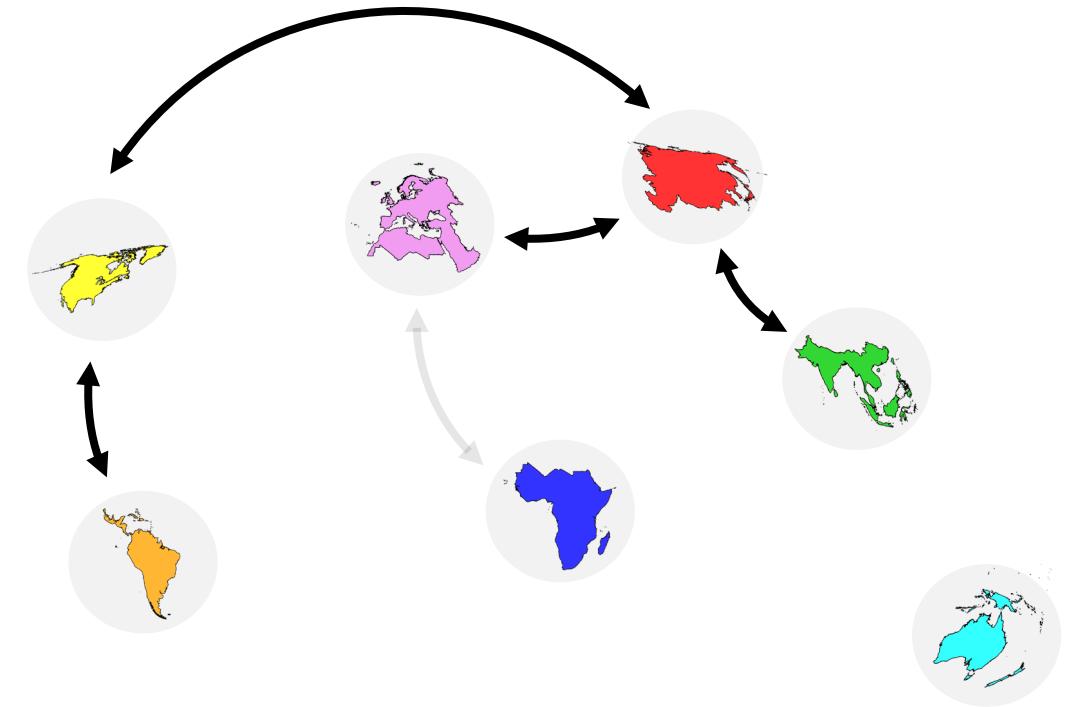
Biogeographic methods



Source: PALEOMAP Project by C. Scotese

Eocene to Oligocene

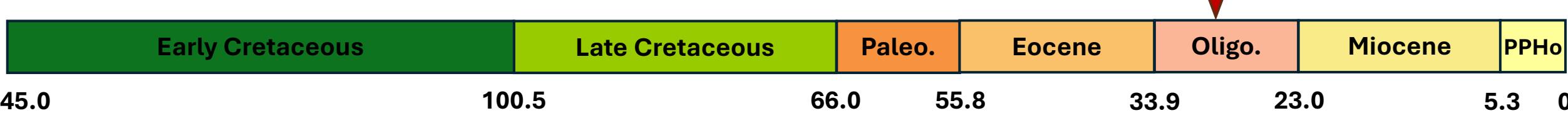
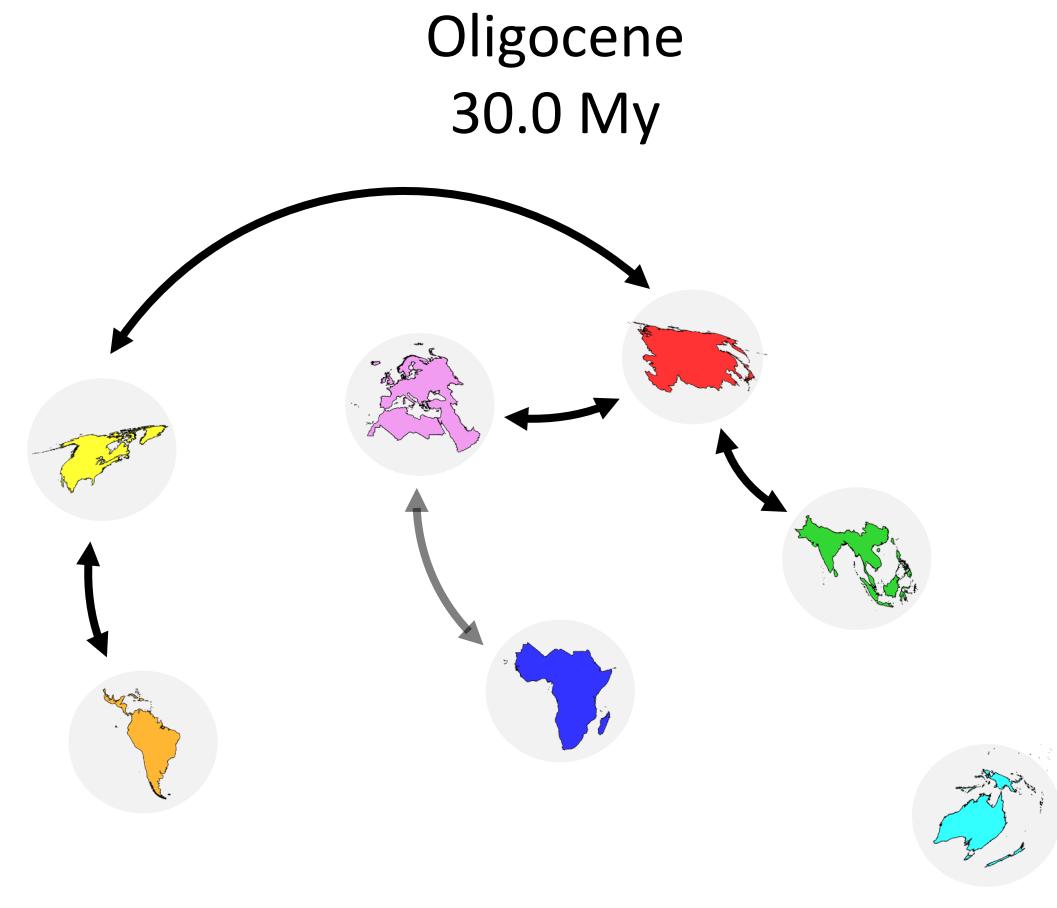
33.9 My



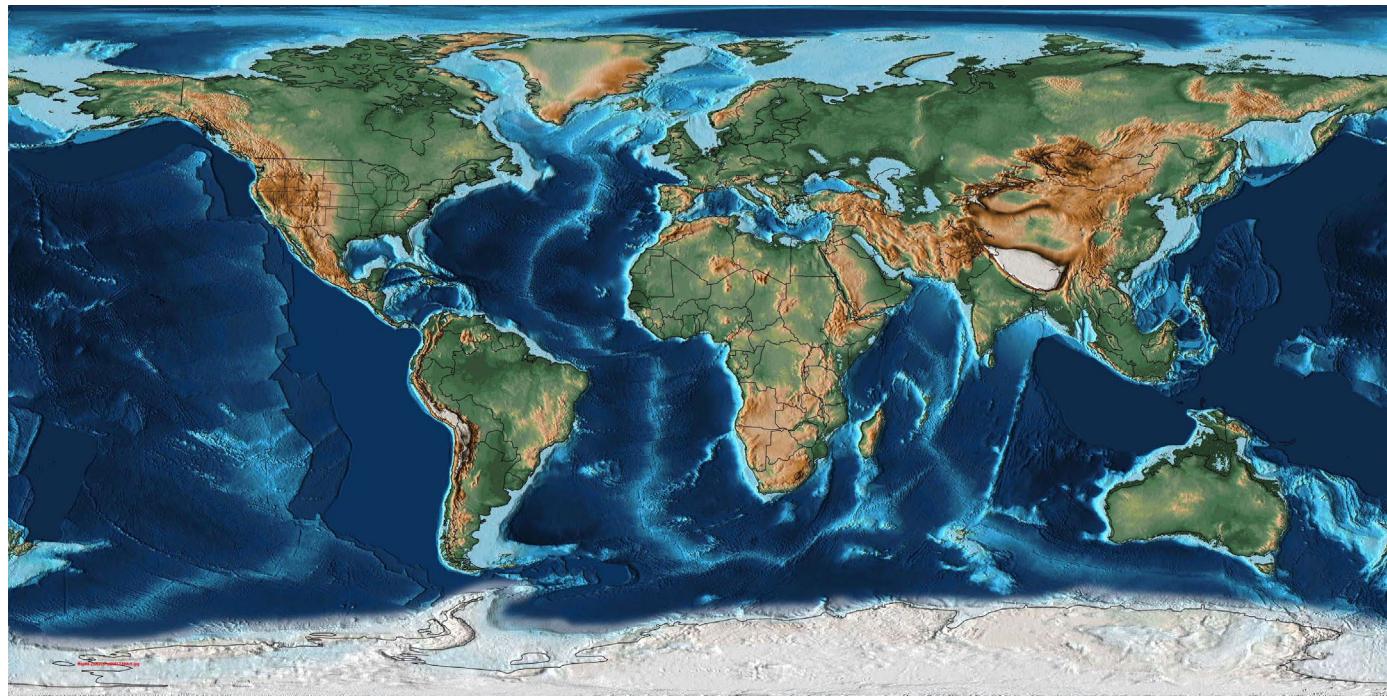
Biogeographic methods



Source: PALEOMAP Project by C. Scotese



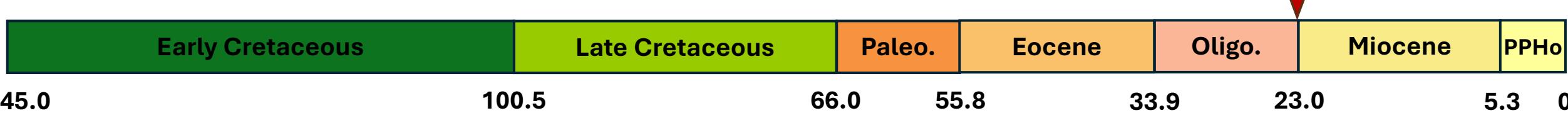
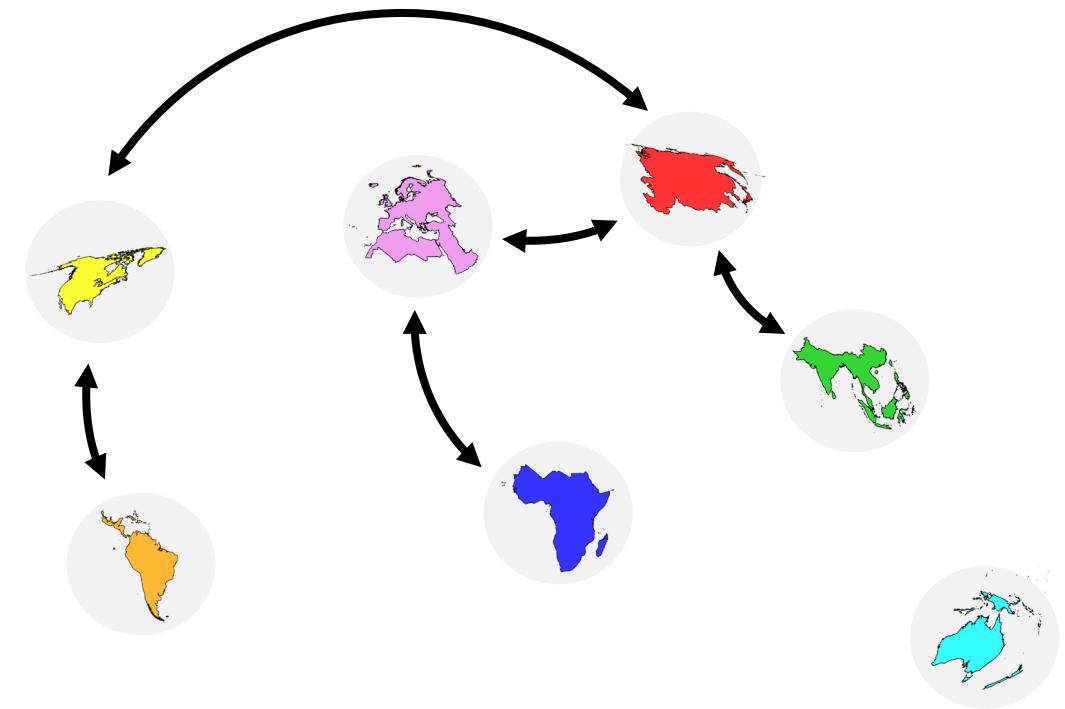
Biogeographic methods



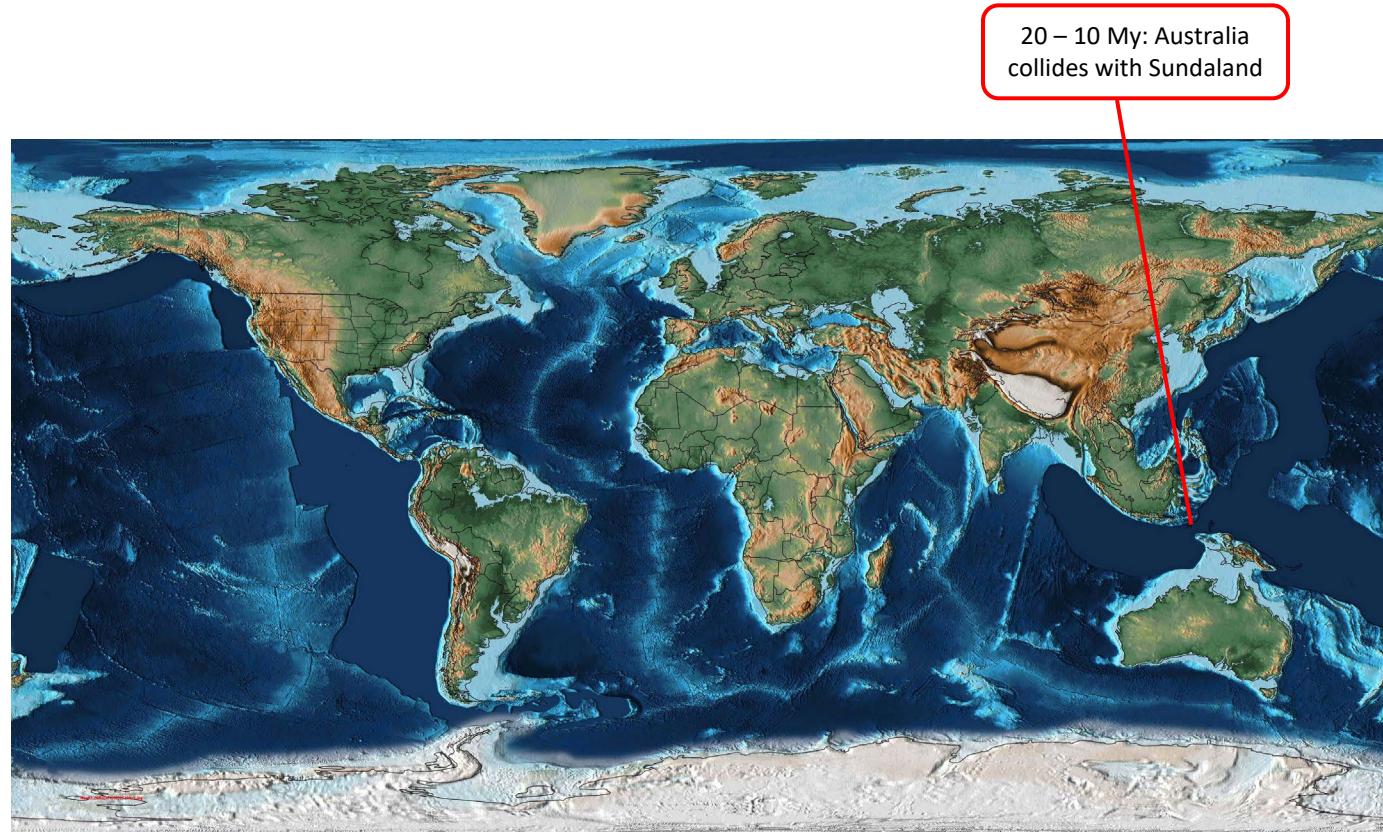
Source: PALEOMAP Project by C. Scotese

Oligocene to Miocene

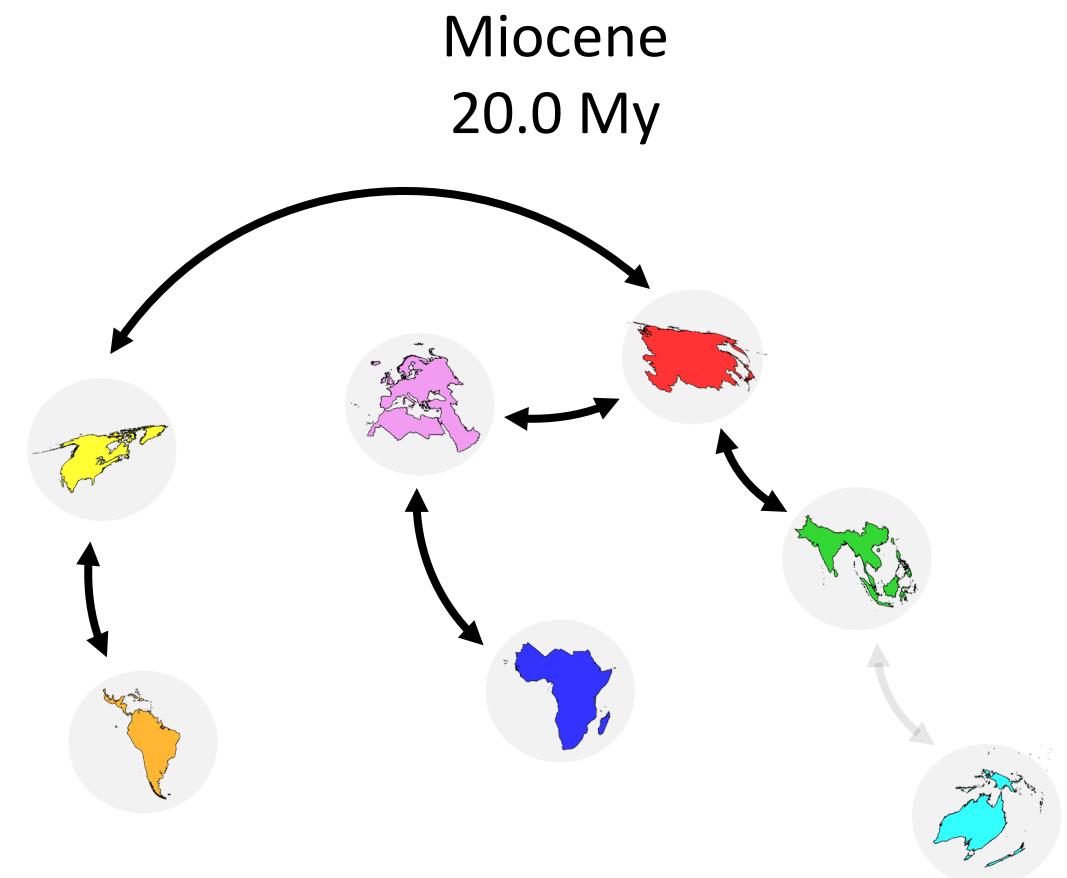
23.0 My



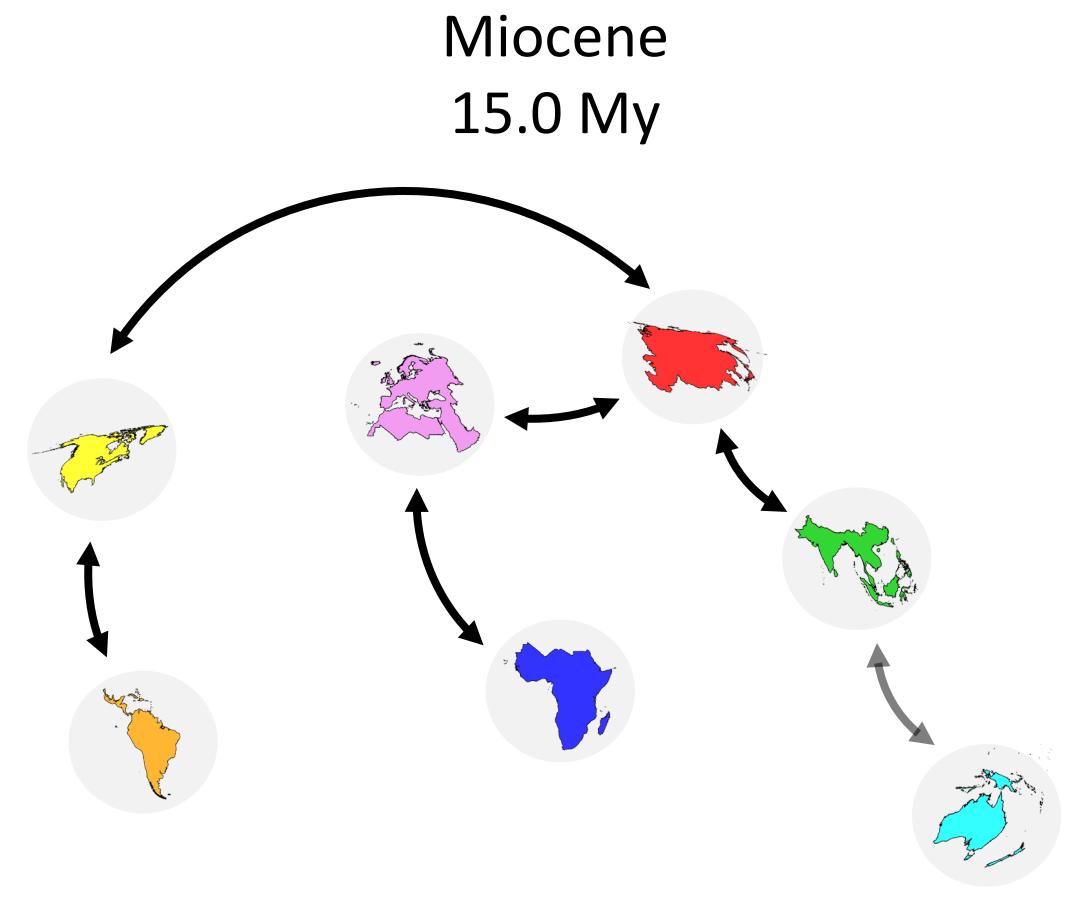
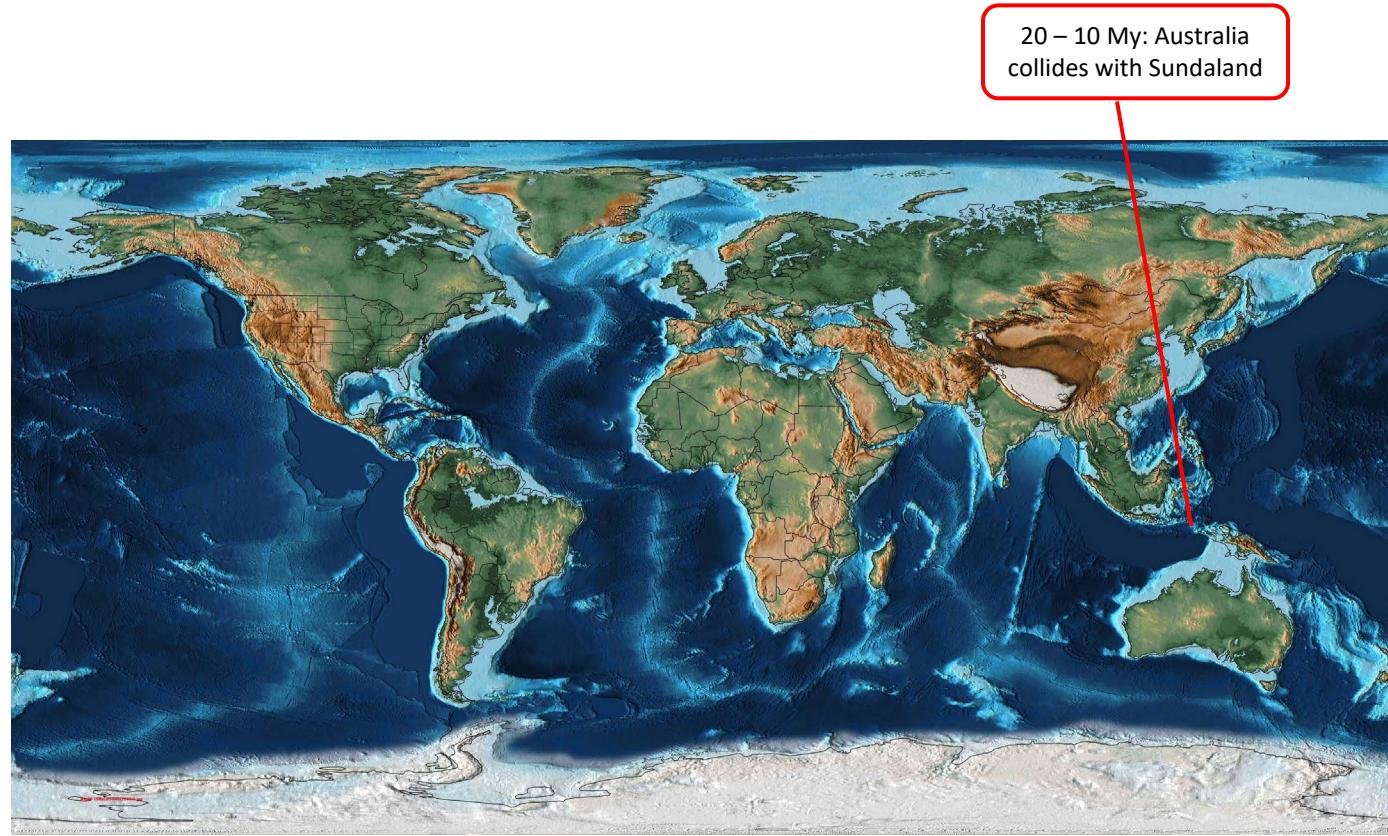
Biogeographic methods



Source: PALEOMAP Project by C. Scotese



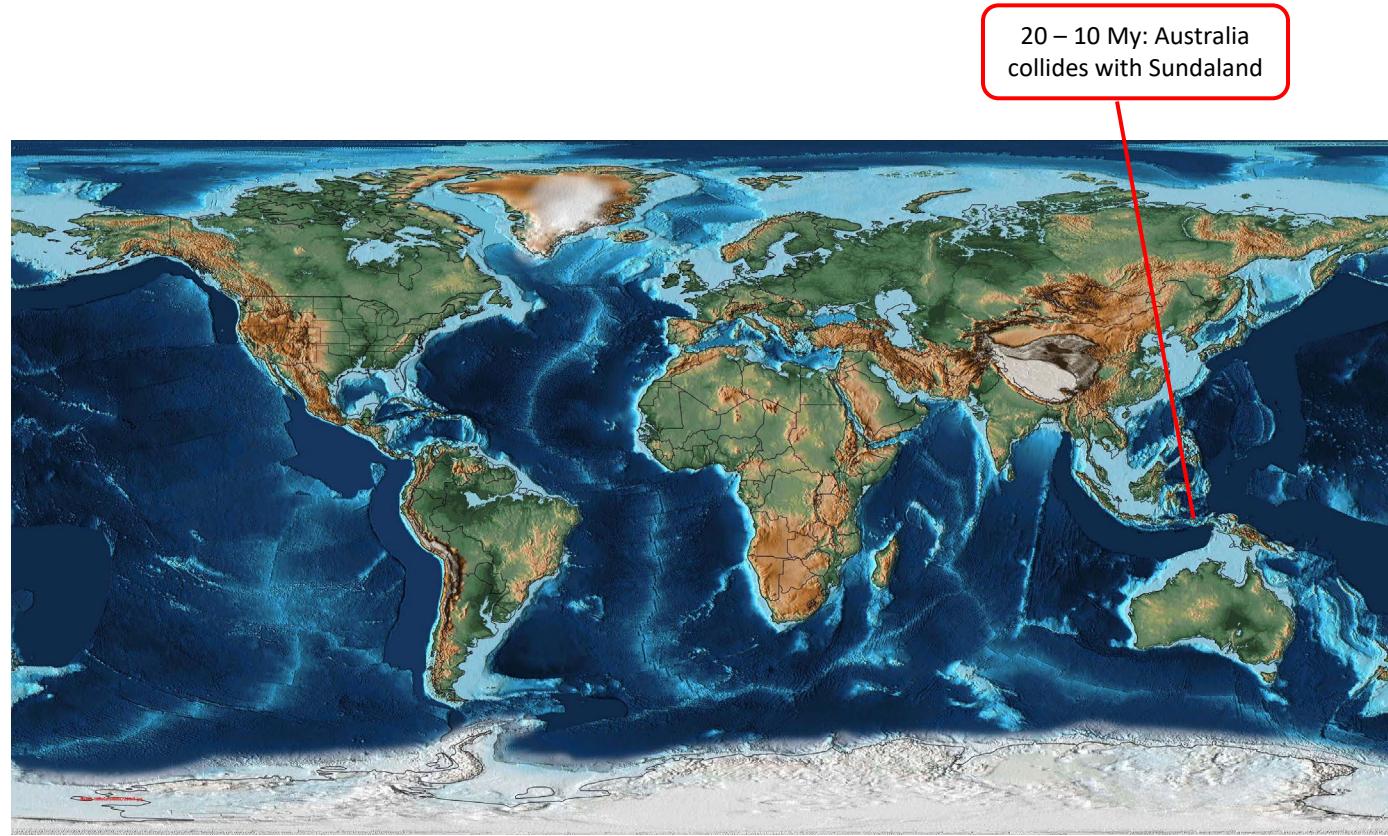
Biogeographic methods



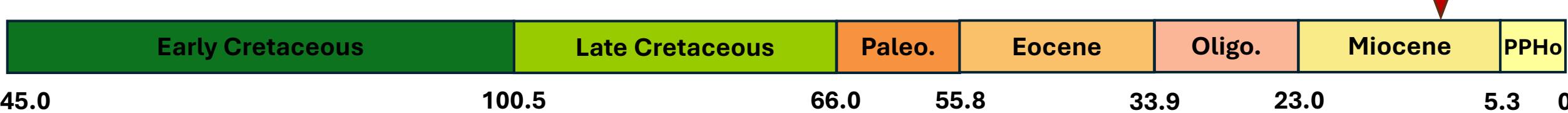
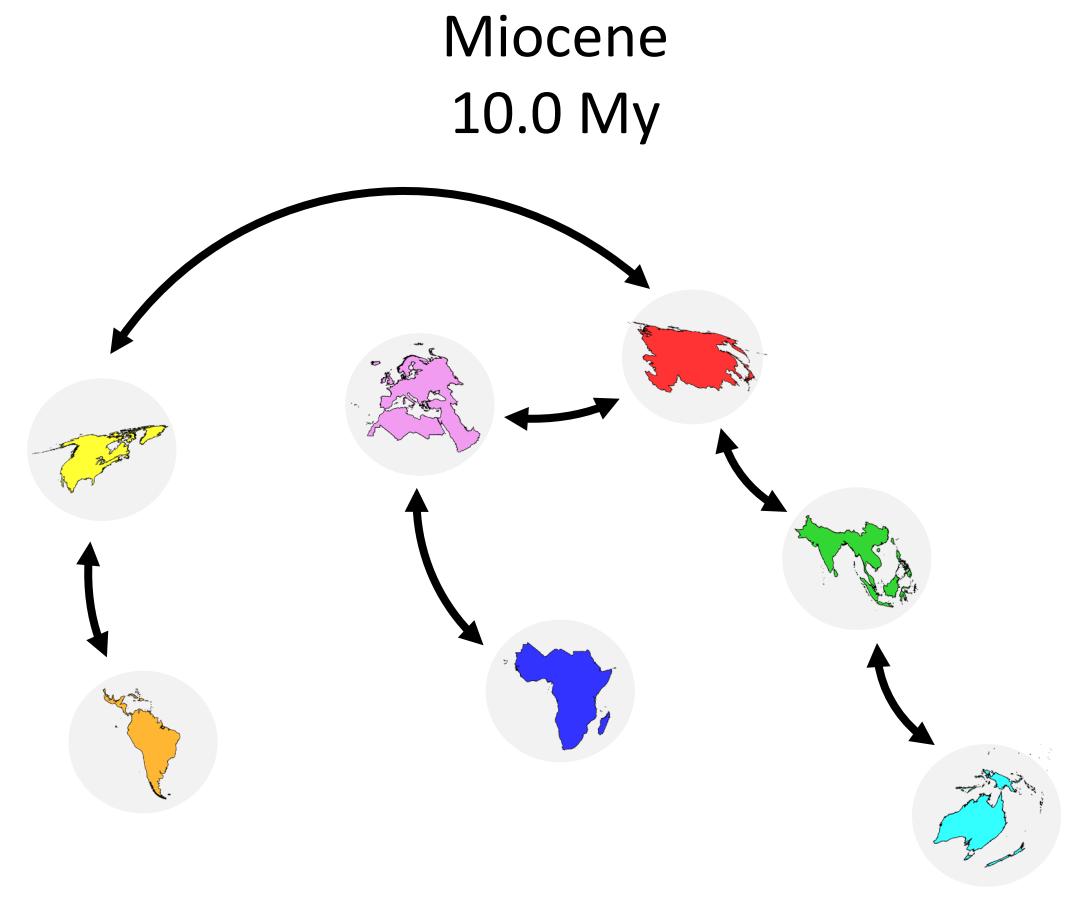
Source: PALEOMAP Project by C. Scotese



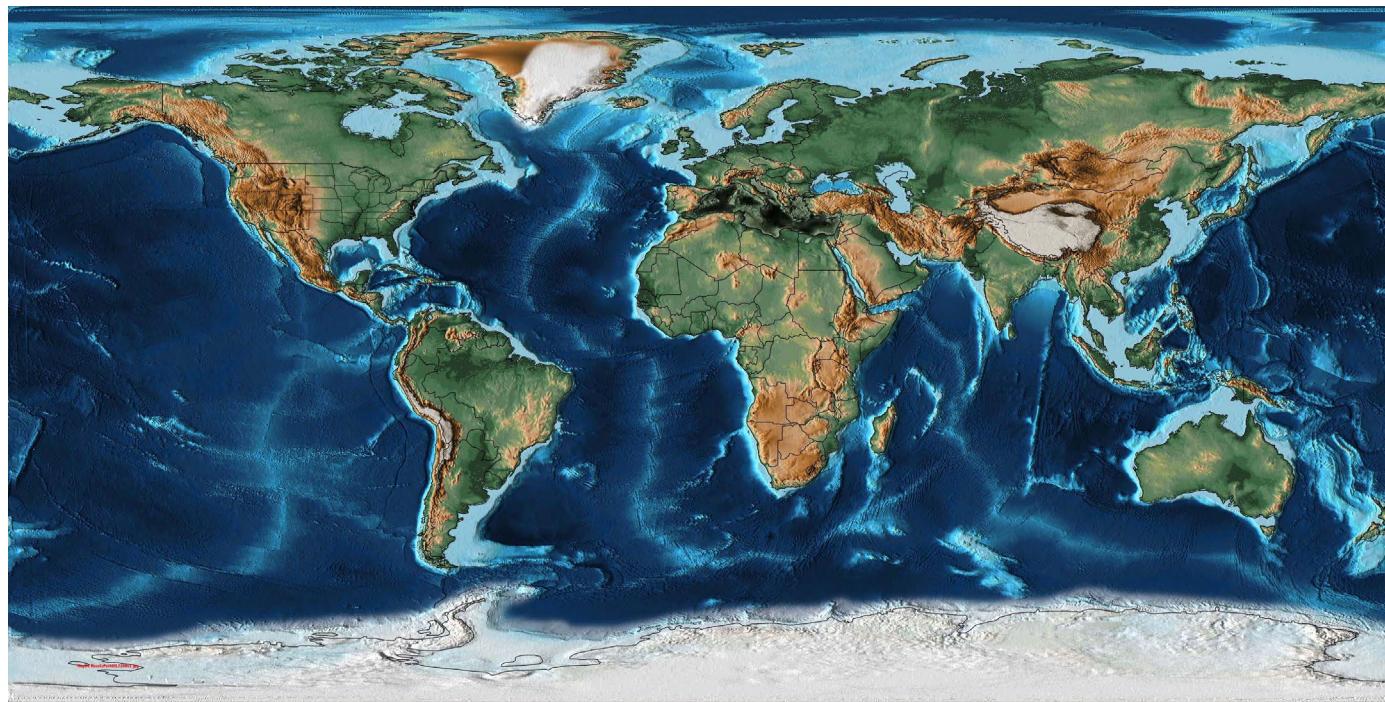
Biogeographic methods



Source: PALEOMAP Project by C. Scotese

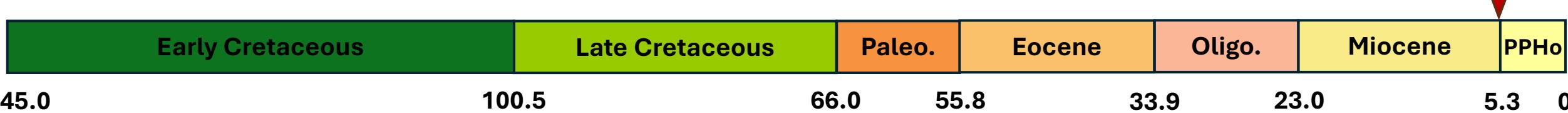
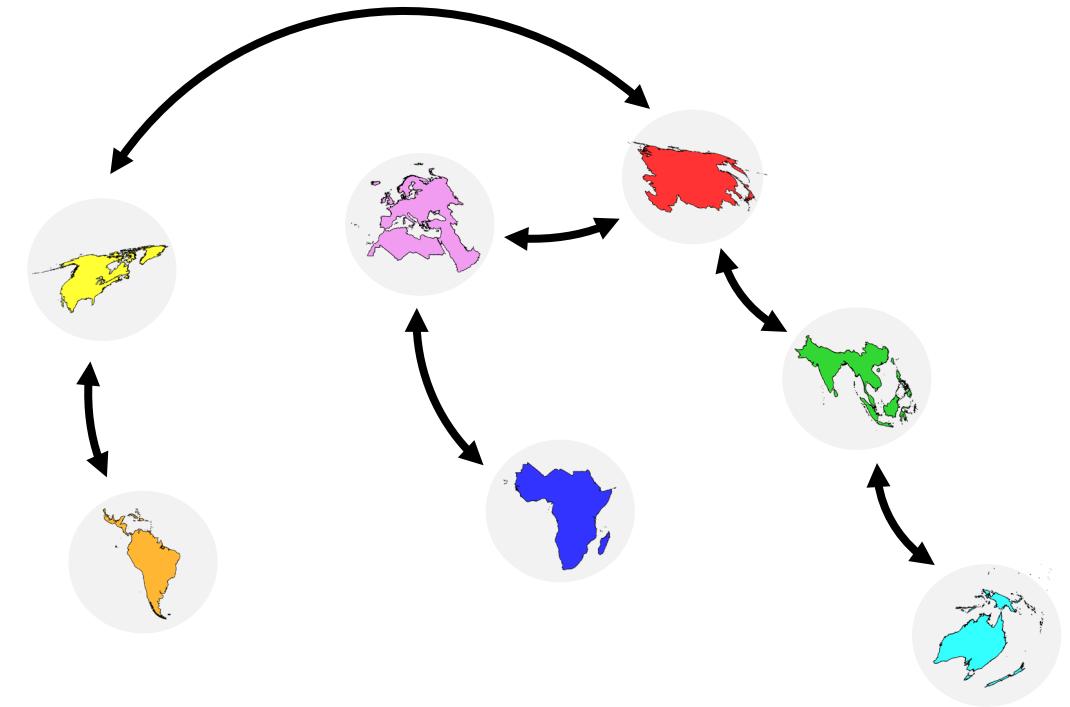


Biogeographic methods

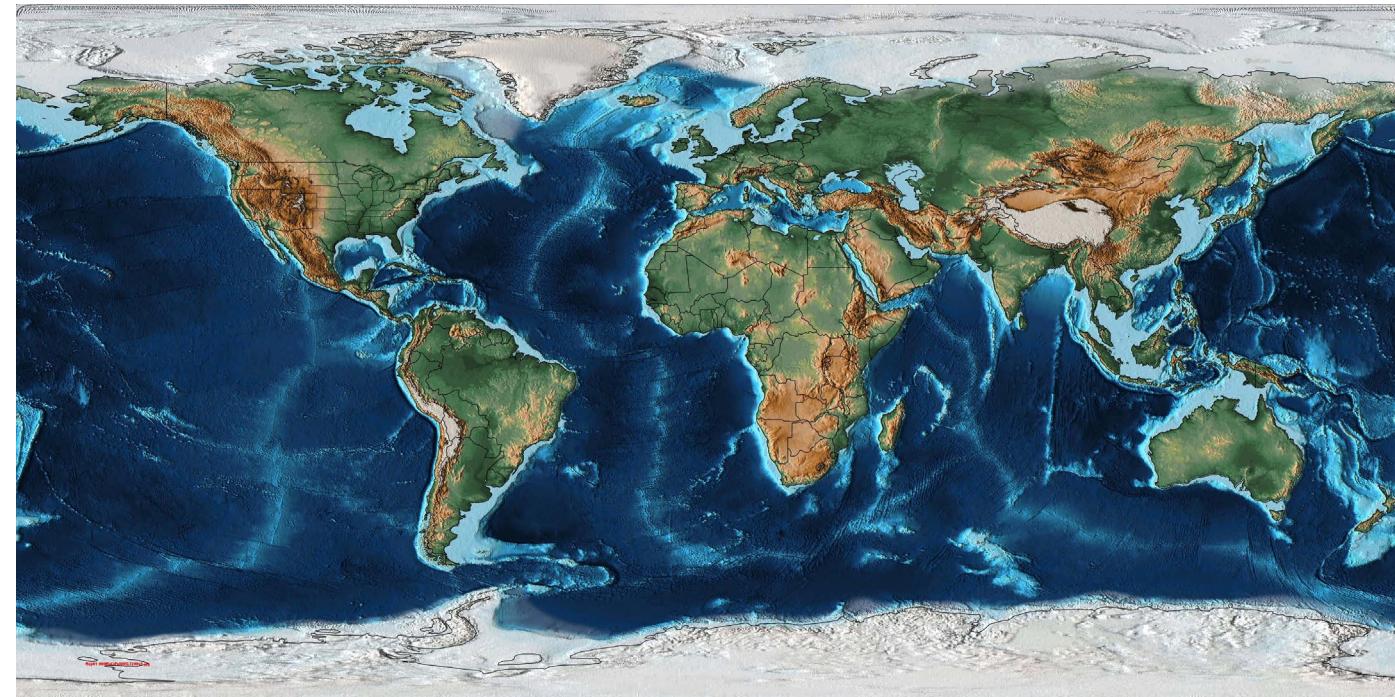


Source: PALEOMAP Project by C. Scotese

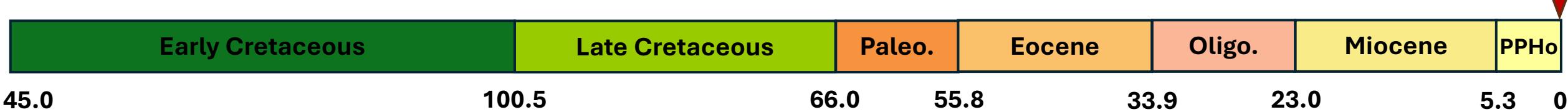
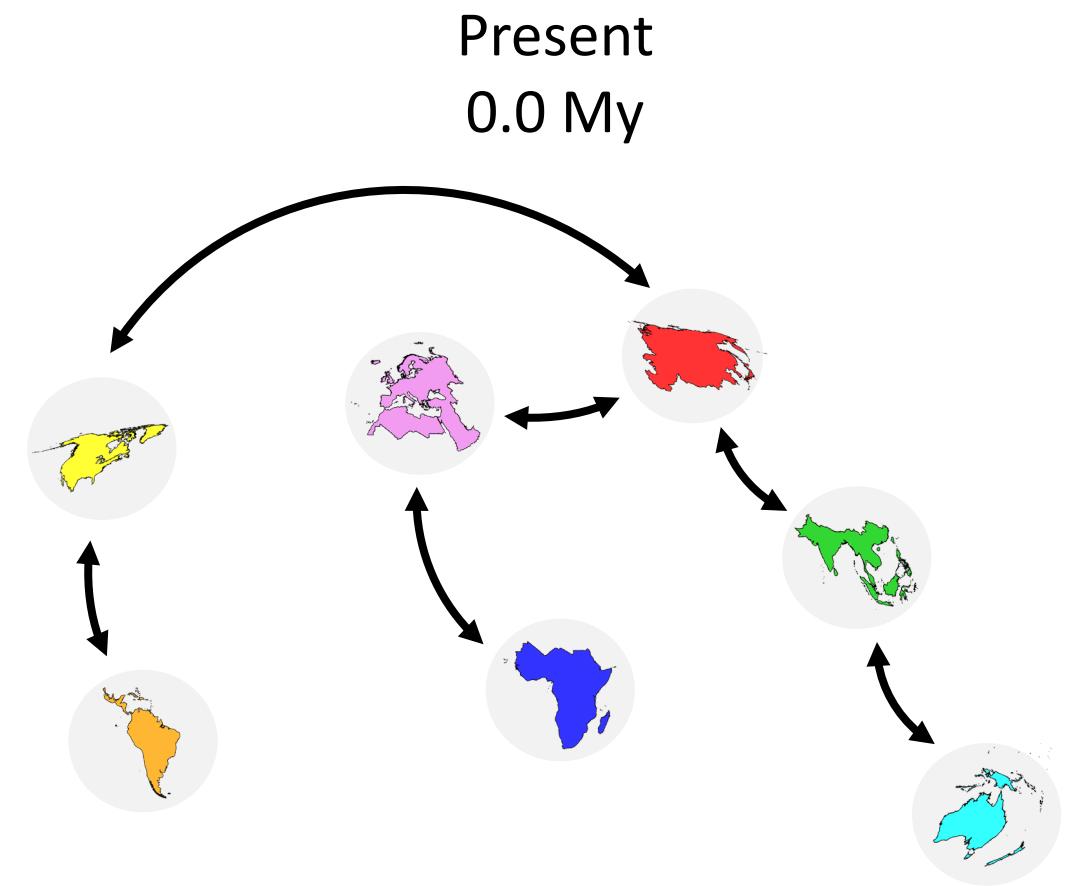
Miocene to Plio-Pleisto-Holocene
5.3 My



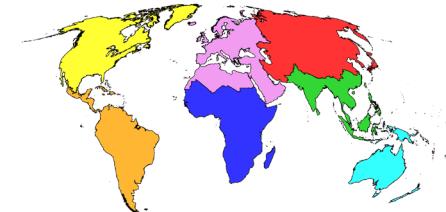
Biogeographic methods



Source: PALEOMAP Project by C. Scotese



Biogeographic methods



BioGeoBEARS framework:

- DIVALIKE, DEC, DIVALIKE + J, DEC + J
- Model selection based on AICc
- Best model = **Time-stratified DEC + J**

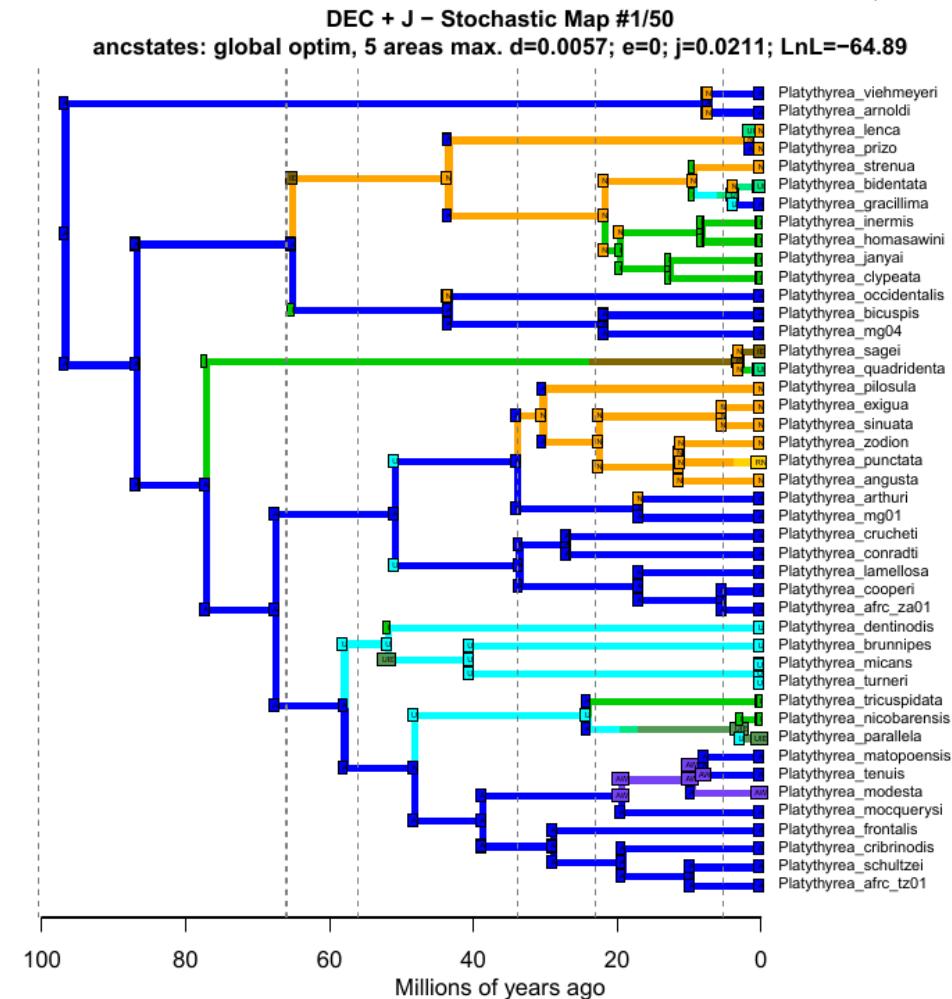
Model of continental connectivity

Ancestral Range Estimates (ARE):

- Marginal likelihoods of node ranges

Biogeographic Stochastic Mapping (BSM):

- Simulation of **biogeographic histories** compatible with ancestral ranges estimates
- Summary statistics across 1000 BSM



Origins of clades

Overall picture:

- Some important **regional radiations**
- Many **independent colonizations**

Origins of S&S clades:

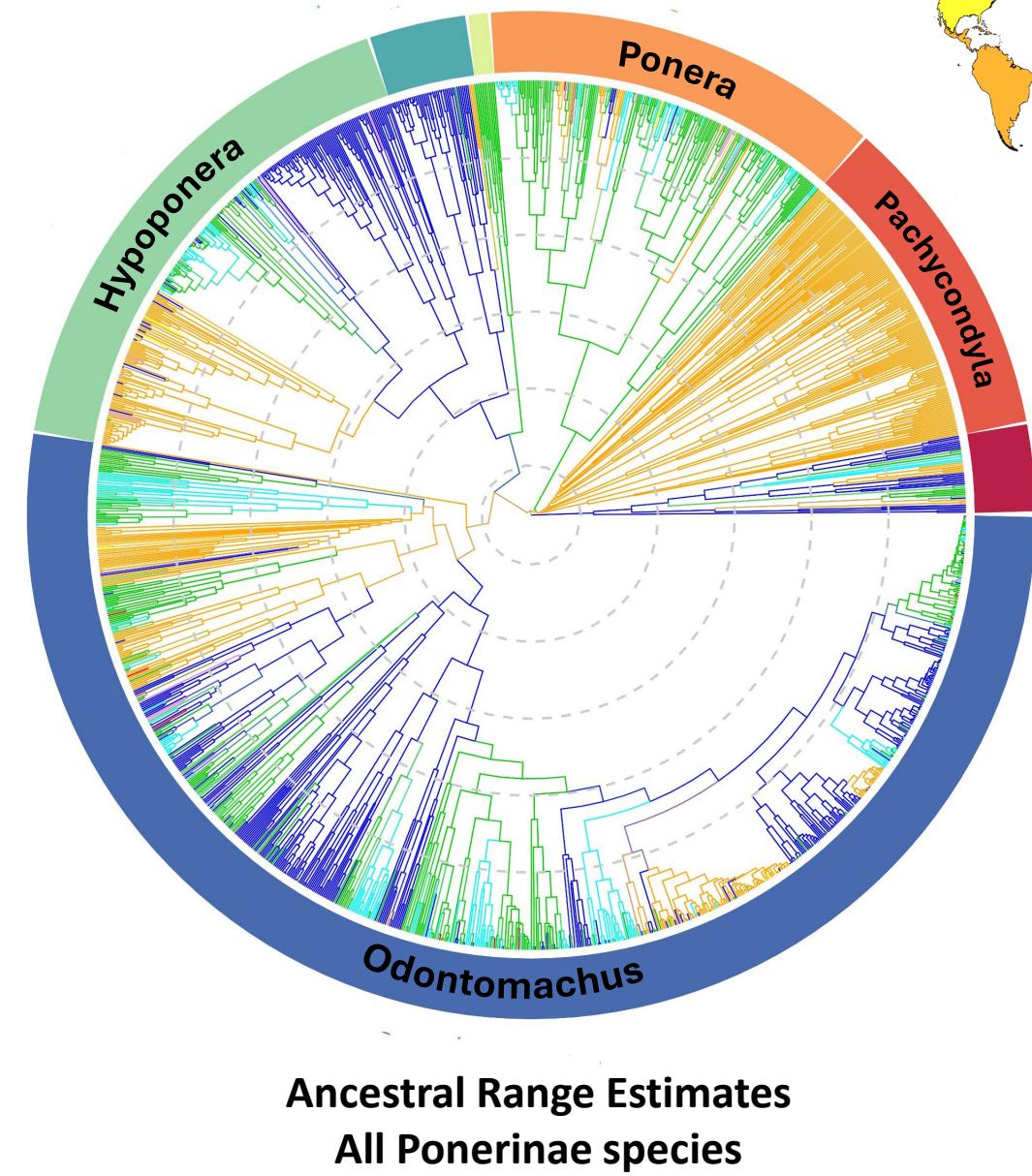
- **Afrotropics:** Platytherea, Plectroctena, Hypoponera
- **Neotropics:** Pachycondyla, Odontomachus
- **IndoMalaya:** Ponera, Harpegnathos

Origin of Ponerinae:

Afrotropics + Neotropics [+ Indo(Malaya)]

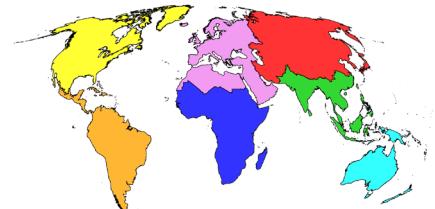
=

Gondwana



Ancestral Range Estimates
All Ponerinae species

Doré et al., *in prep.*



Origins of clades

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- Many **independent colonizations**

Origins of S&S clades:

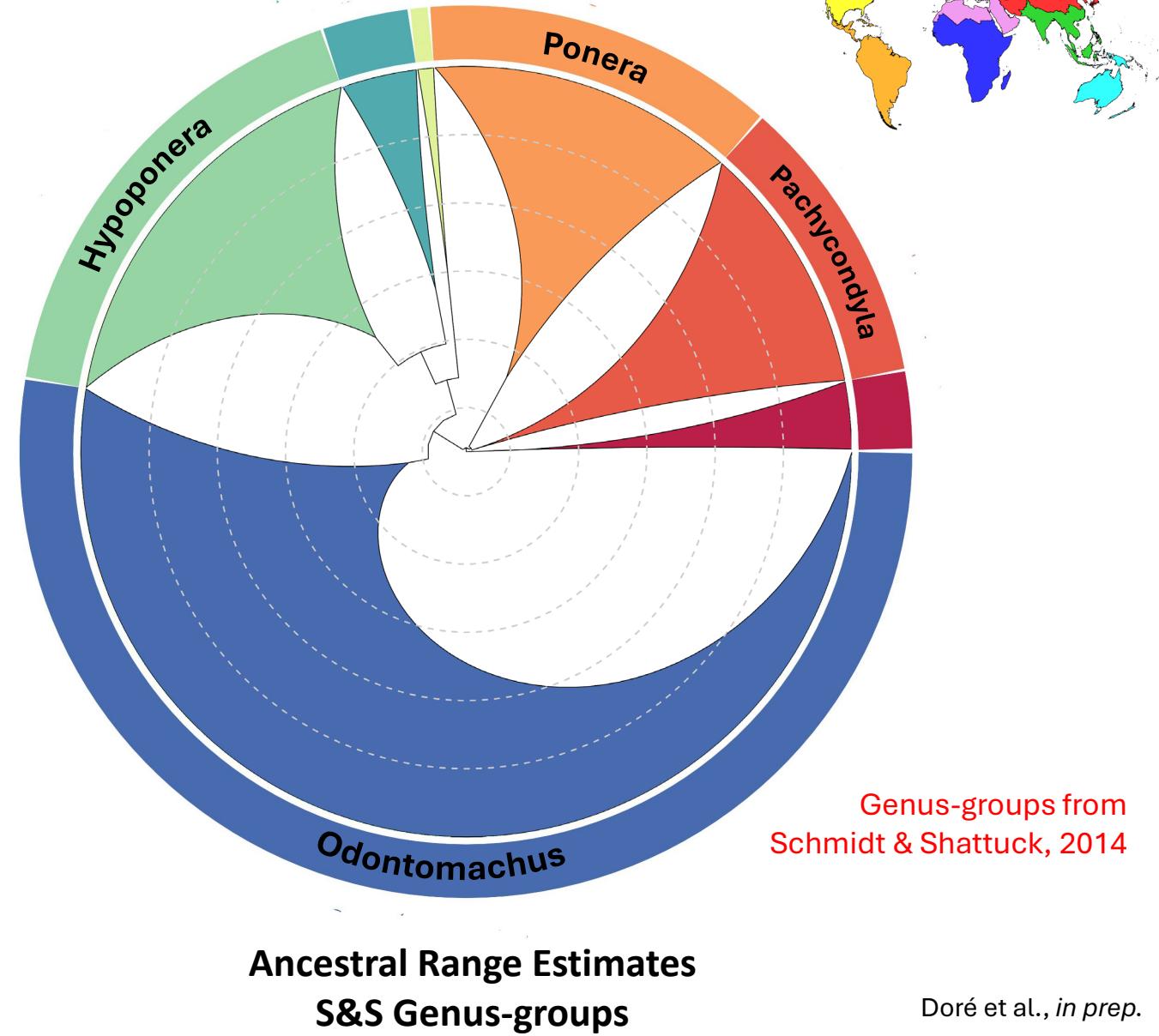
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Origin of Ponerinae:

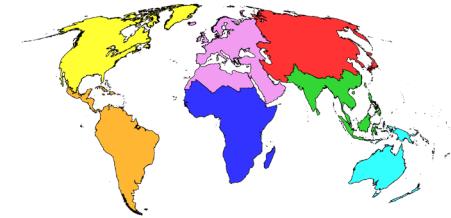
Afrotropics + Neotropics [+ Indo(Malaya)]

=

Gondwana



Origins of clades



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Origins of S&S clades:

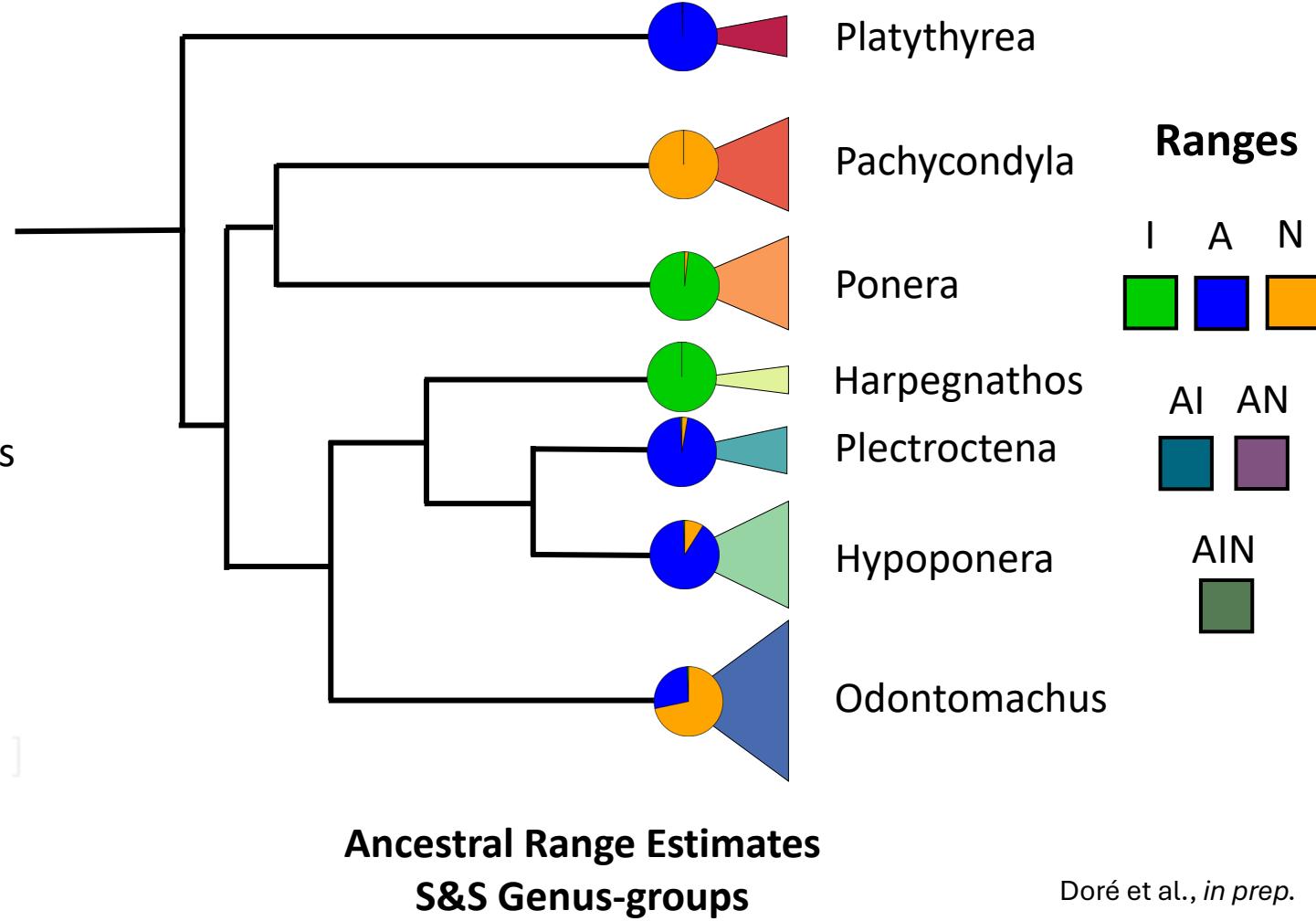
- **Afrotropics:** *Platythyrea*, *Plectroctena*, *Hypoponera*
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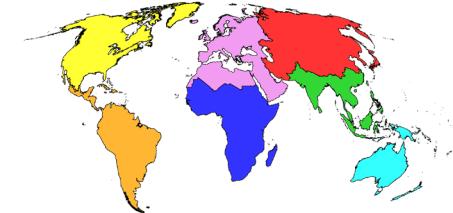
=

Gondwana



Doré et al., *in prep.*

Origins of clades



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- Many **independent colonizations**

Origins of S&S clades:

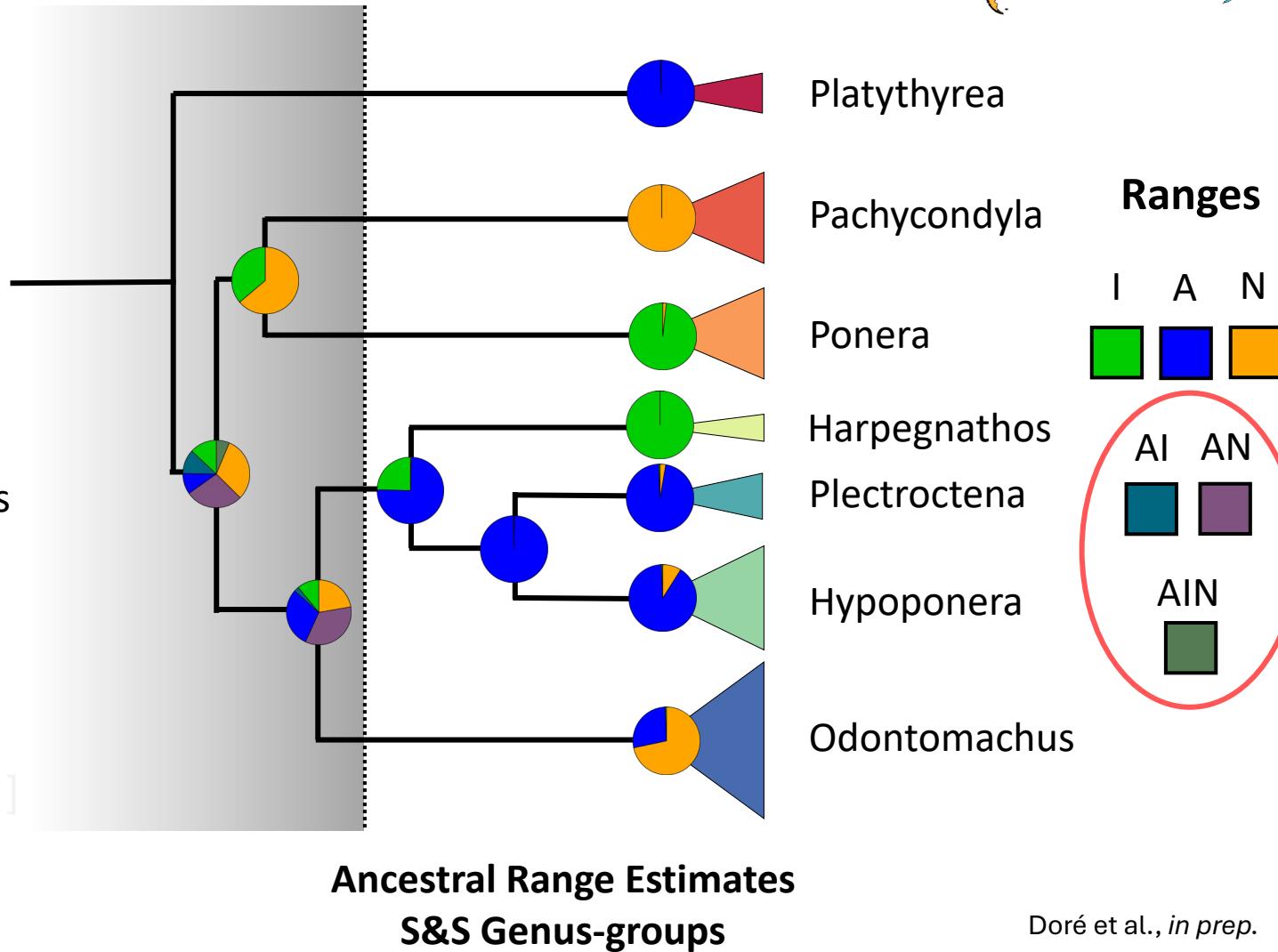
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Origin of Ponerinae:

Afrotropics + Neotropics [+ Indo(Malaya)]

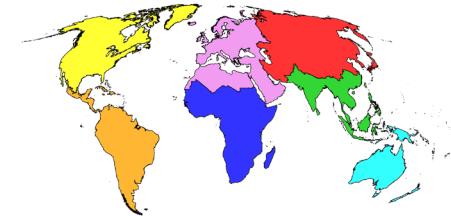
=
Gondwana

Gondwana split



Doré et al., *in prep.*

Origins of clades



Overall picture:

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- Many **independent colonizations**

Origins of S&S clades:

- **Afrotropics**: Platythyrea, Plectroctena, Hypoponera
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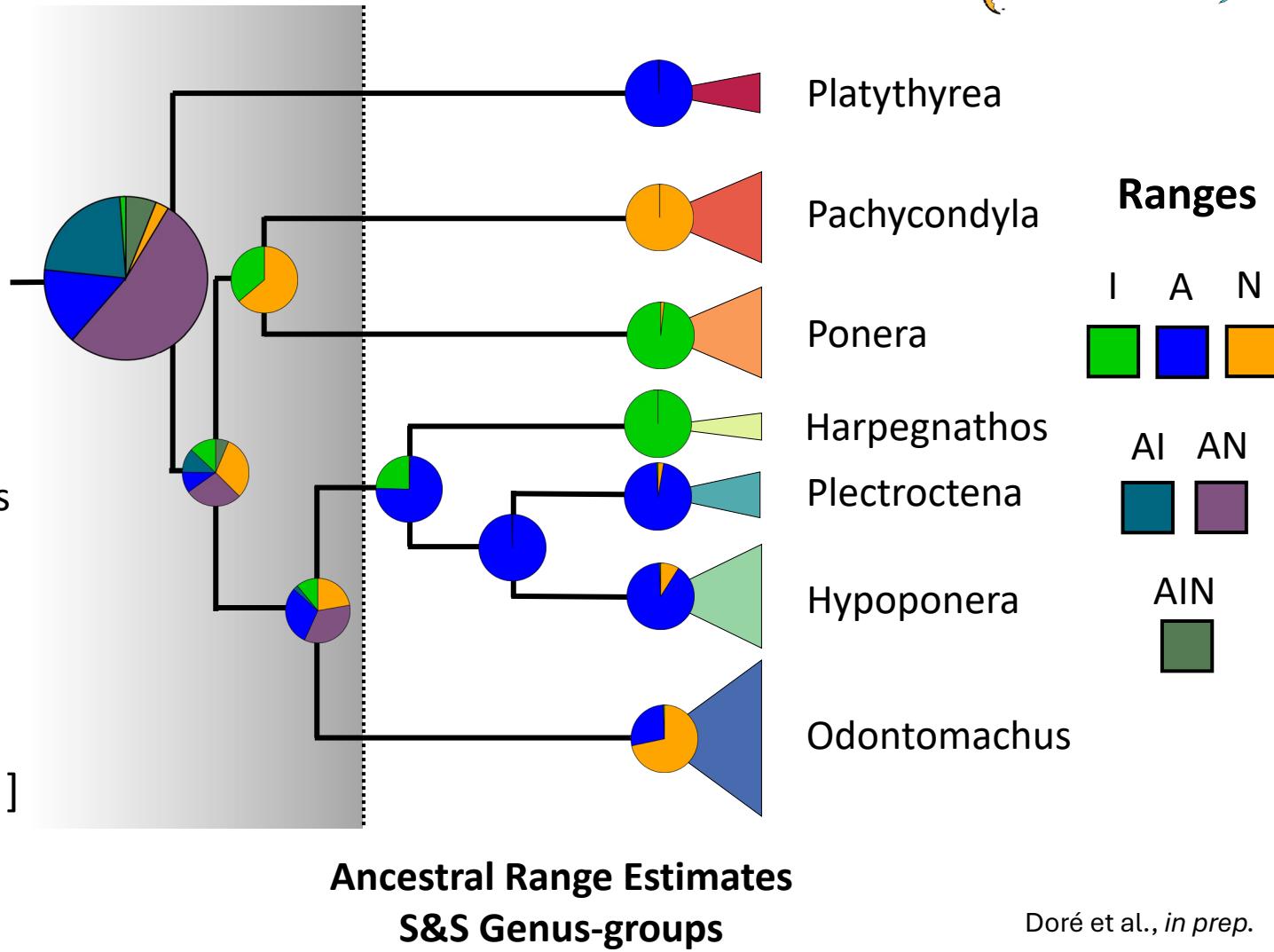
Origin of Ponerinae:

Afrotropics + Neotropics [+ Indo(Malaya)]

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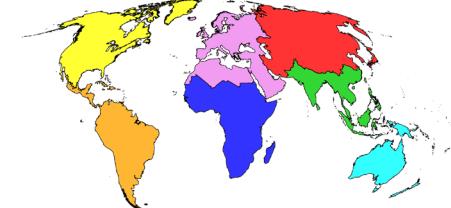
Gondwana

Gondwana split

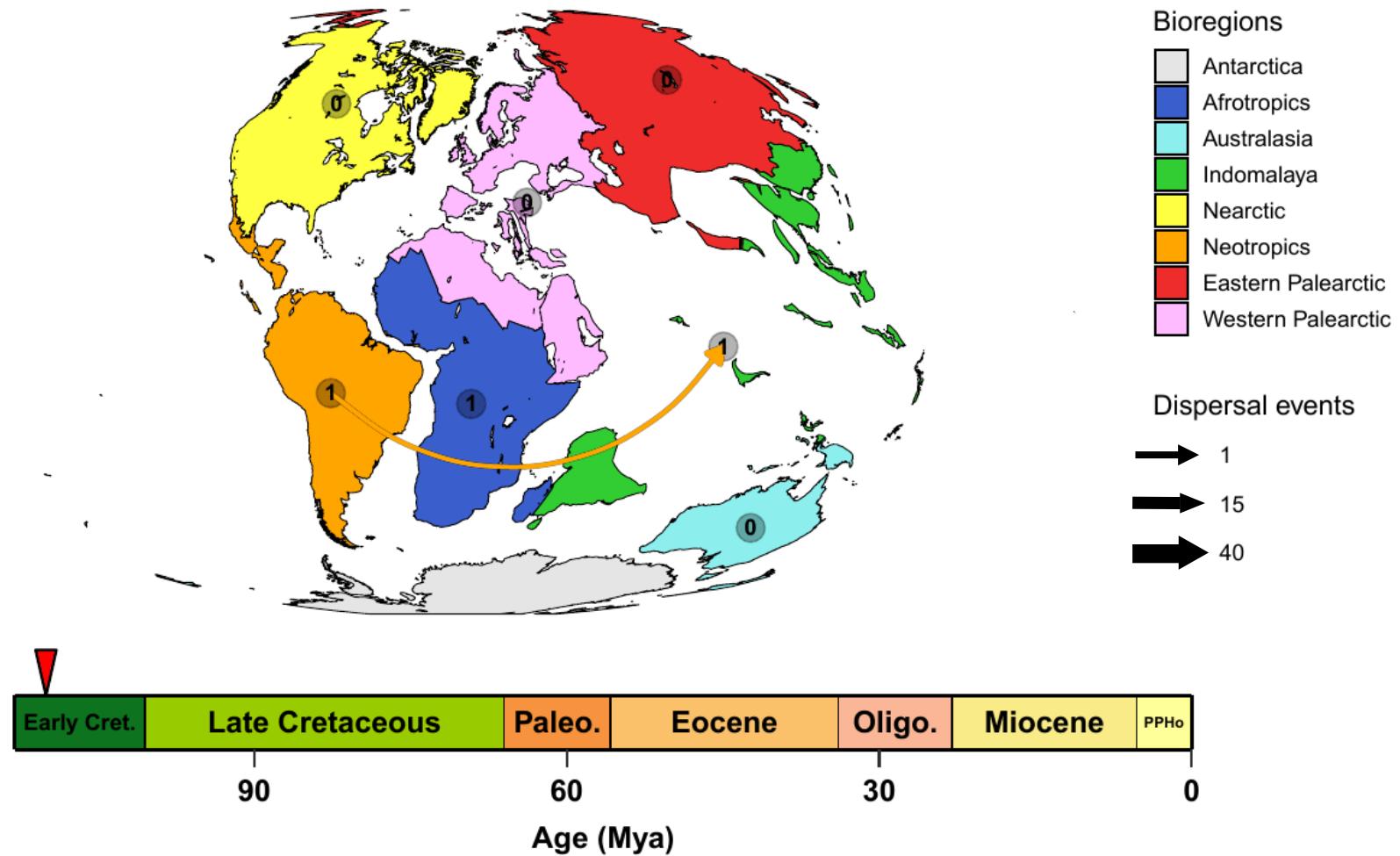


Doré et al., *in prep.*

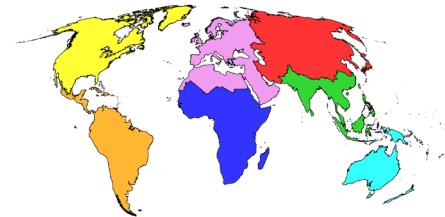
Dispersal events in time



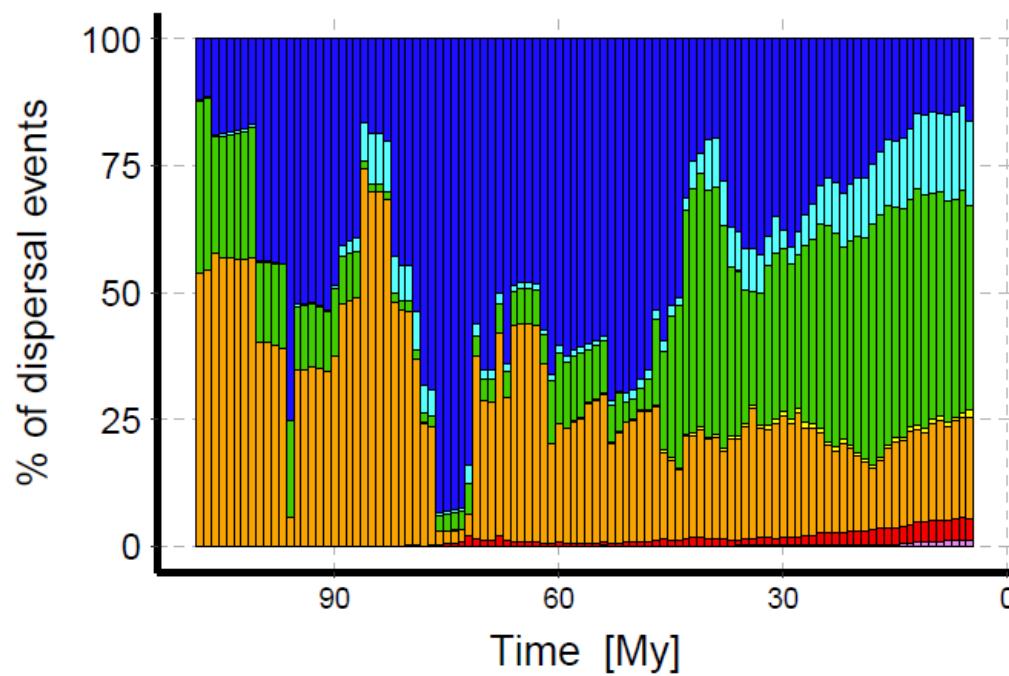
Time = 110 Mya



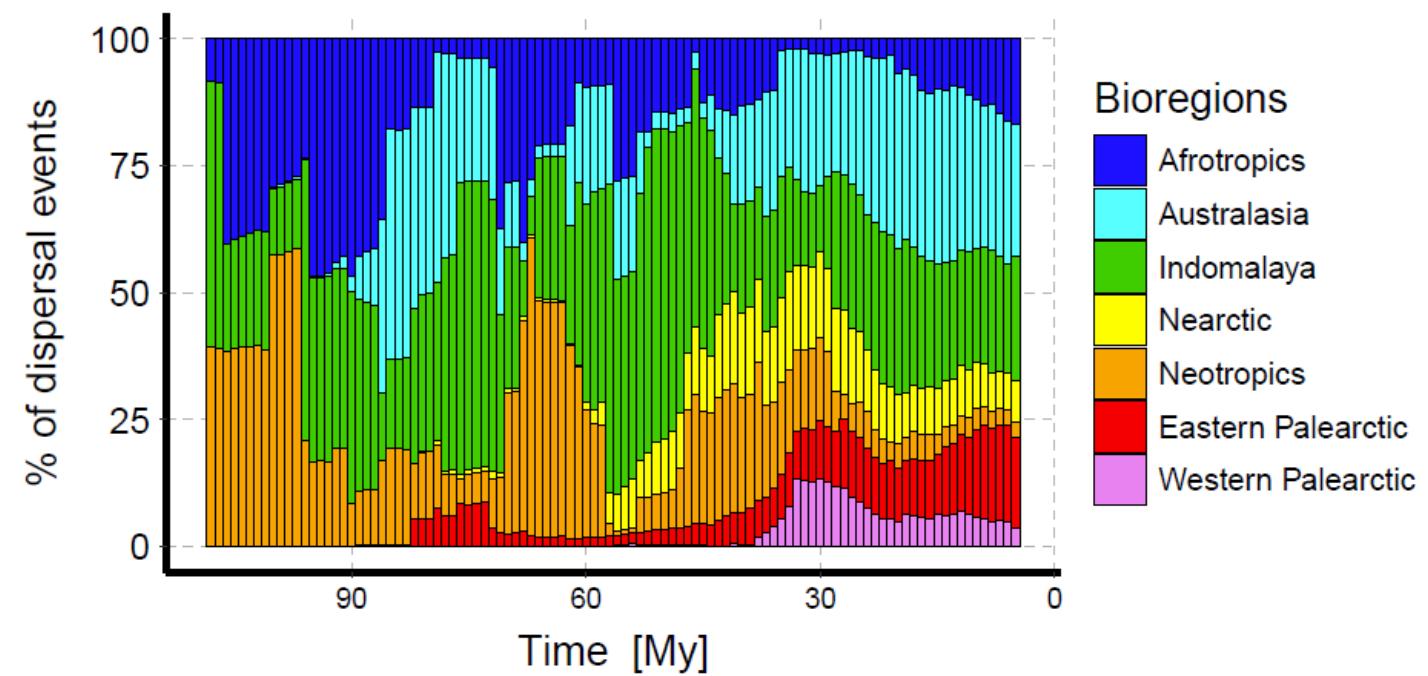
Dispersal events in time



Dispersal events
per Source bioregions

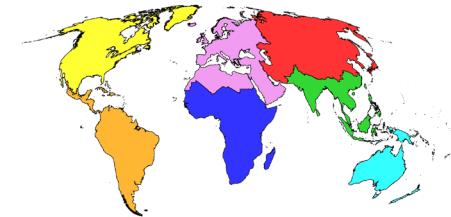


Dispersal events
per Destination bioregions

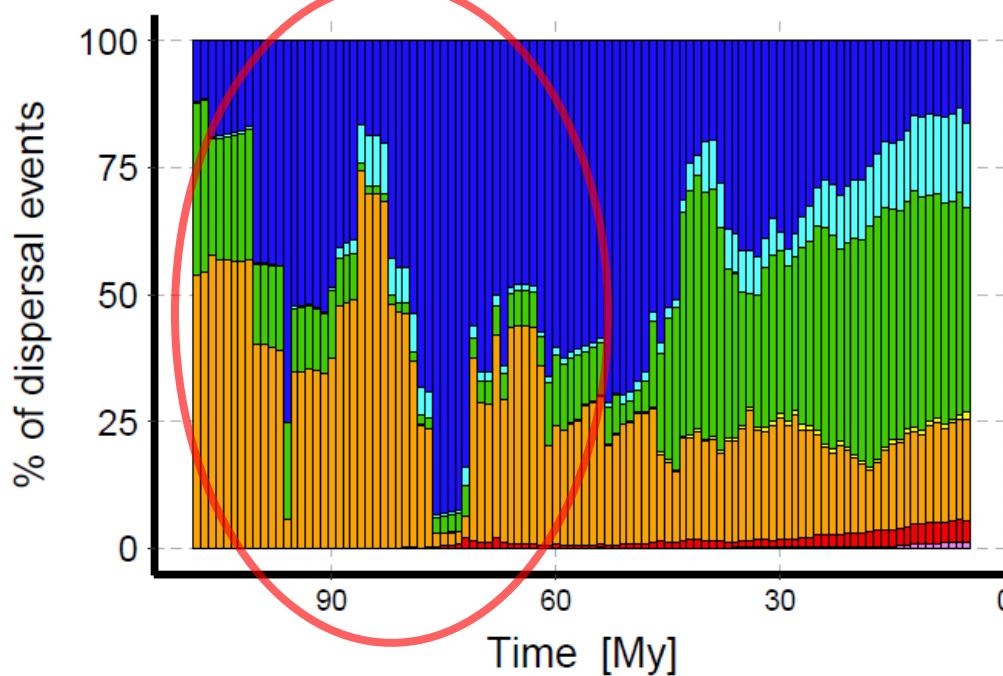


Doré et al., *in prep.*

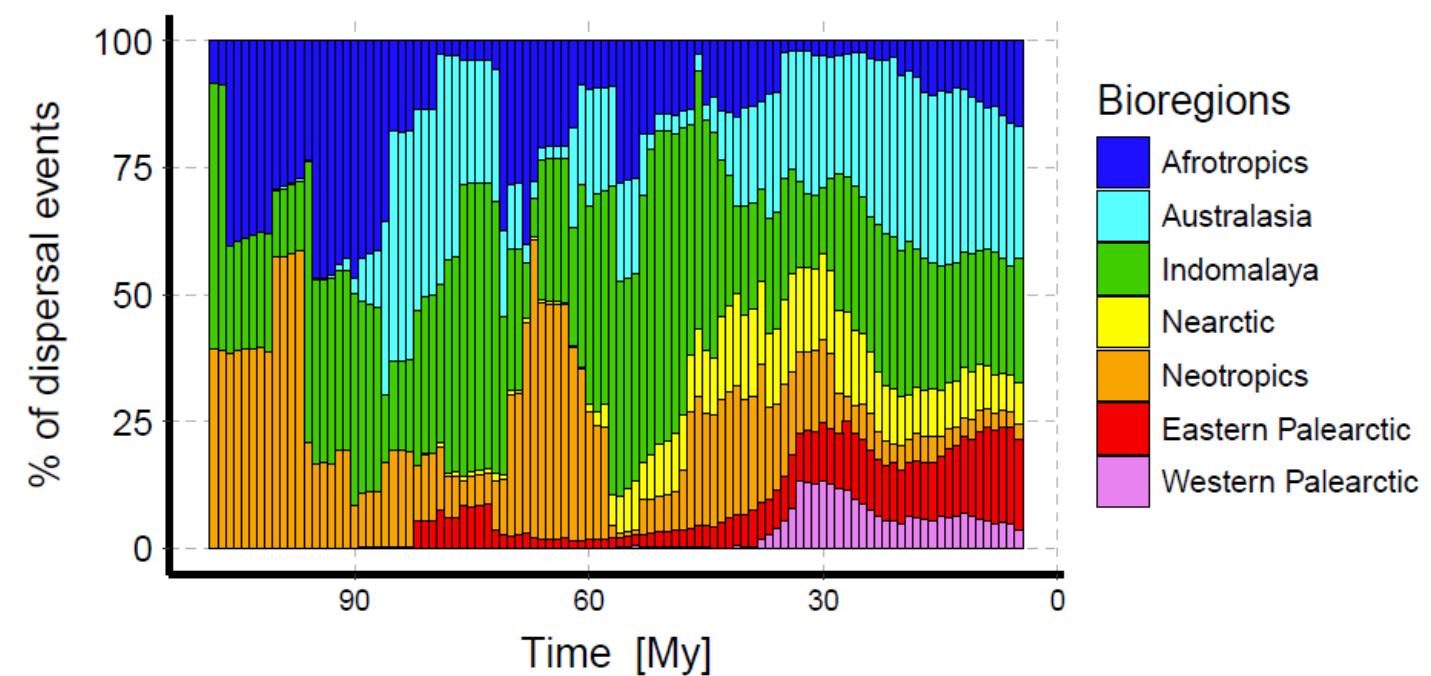
Dispersal events in time



Dispersal events
per Source bioregions

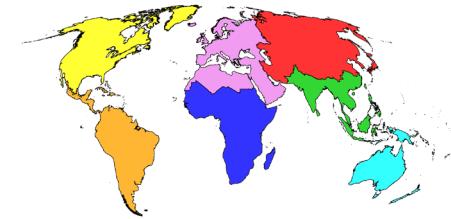


Dispersal events
per Destination bioregions

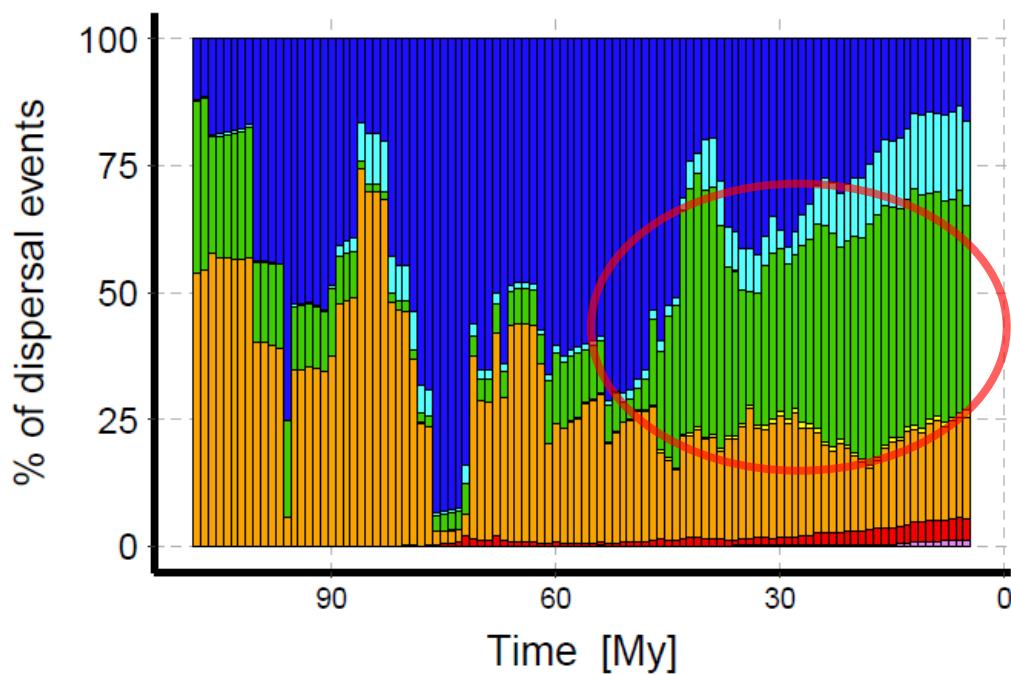


Doré et al., *in prep.*

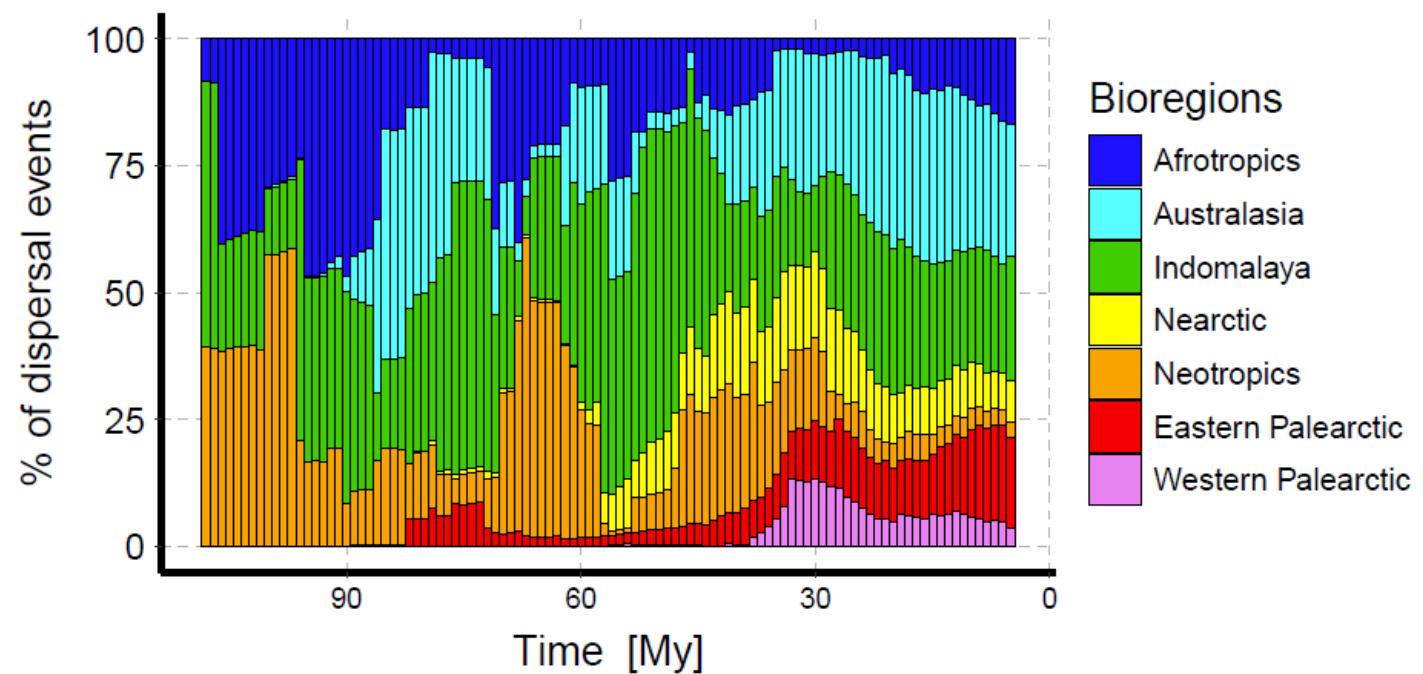
Dispersal events in time



Dispersal events
per Source bioregions

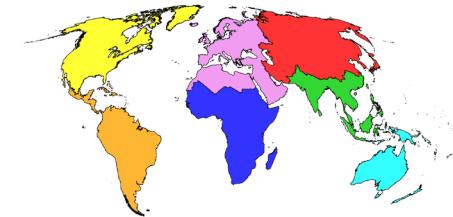


Dispersal events
per Destination bioregions

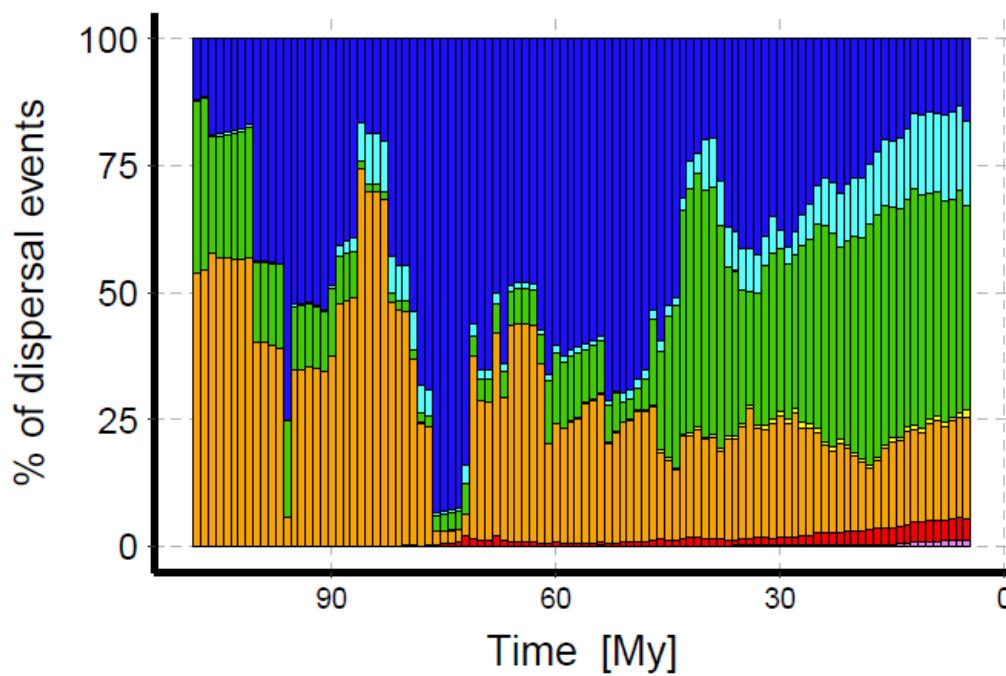


Doré et al., *in prep.*

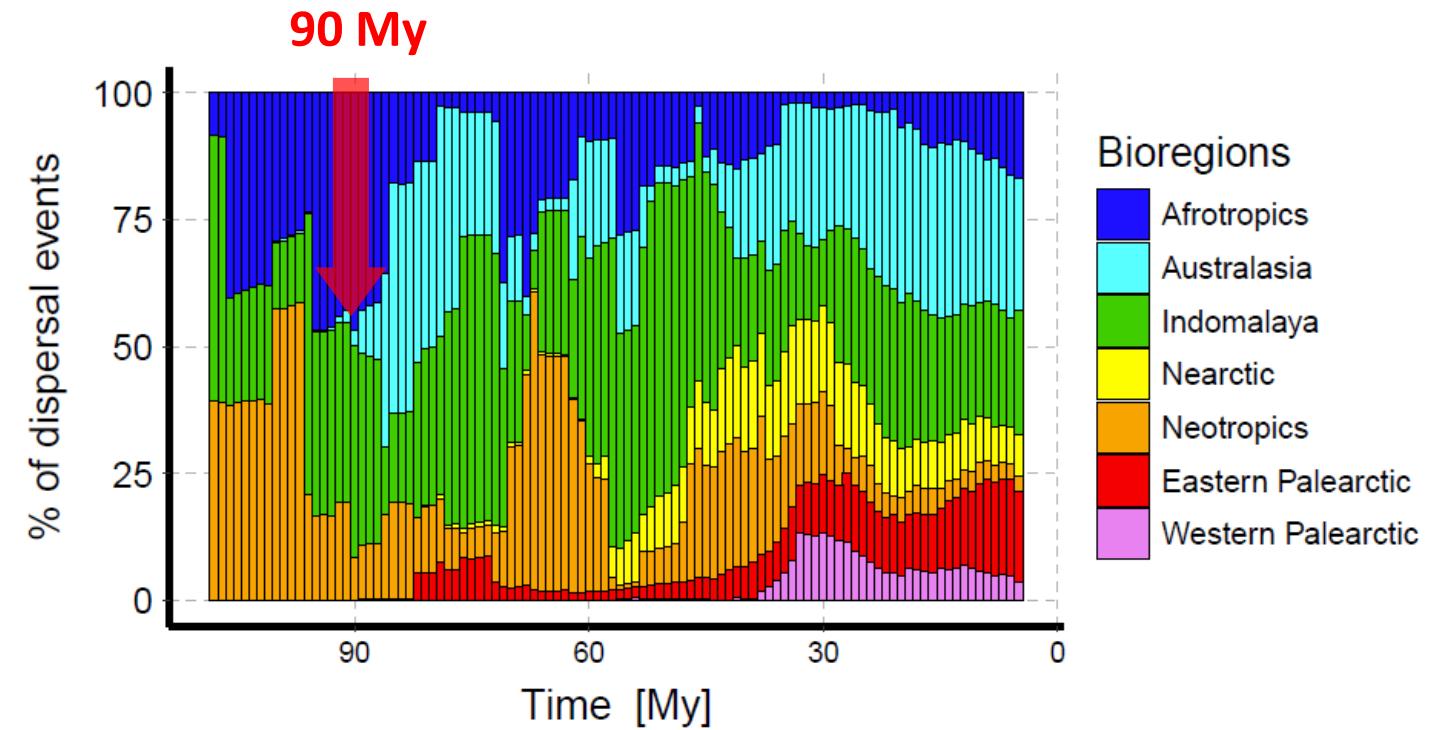
Dispersal events in time



Dispersal events
per Source bioregions

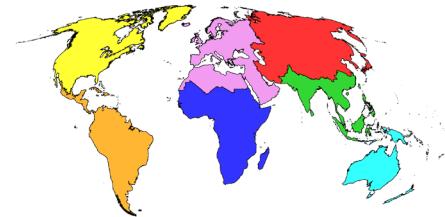


Dispersal events
per Destination bioregions

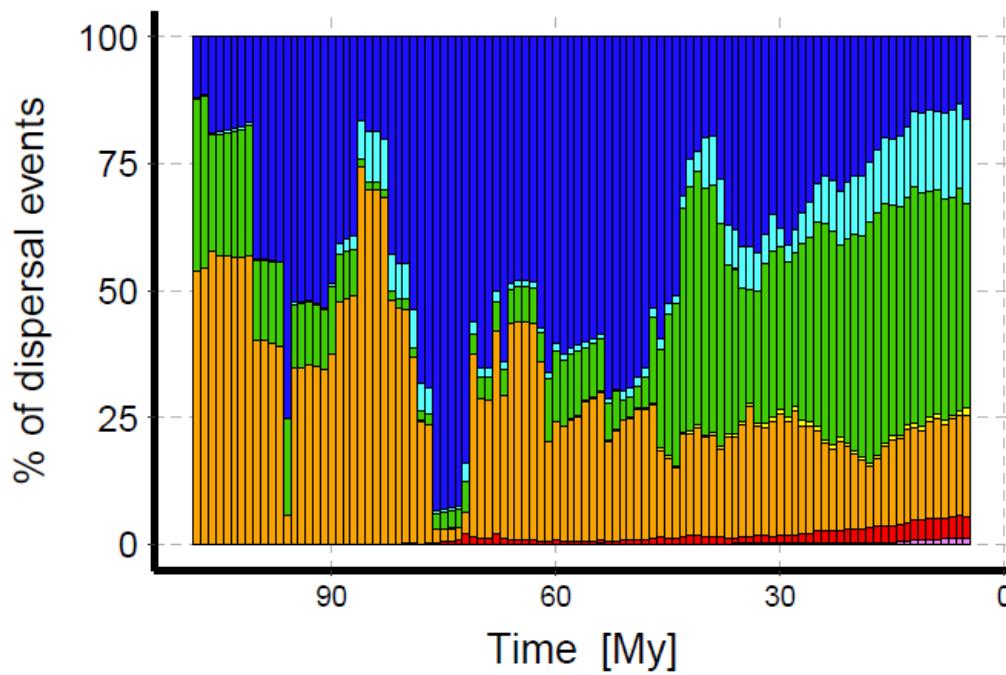


Doré et al., *in prep.*

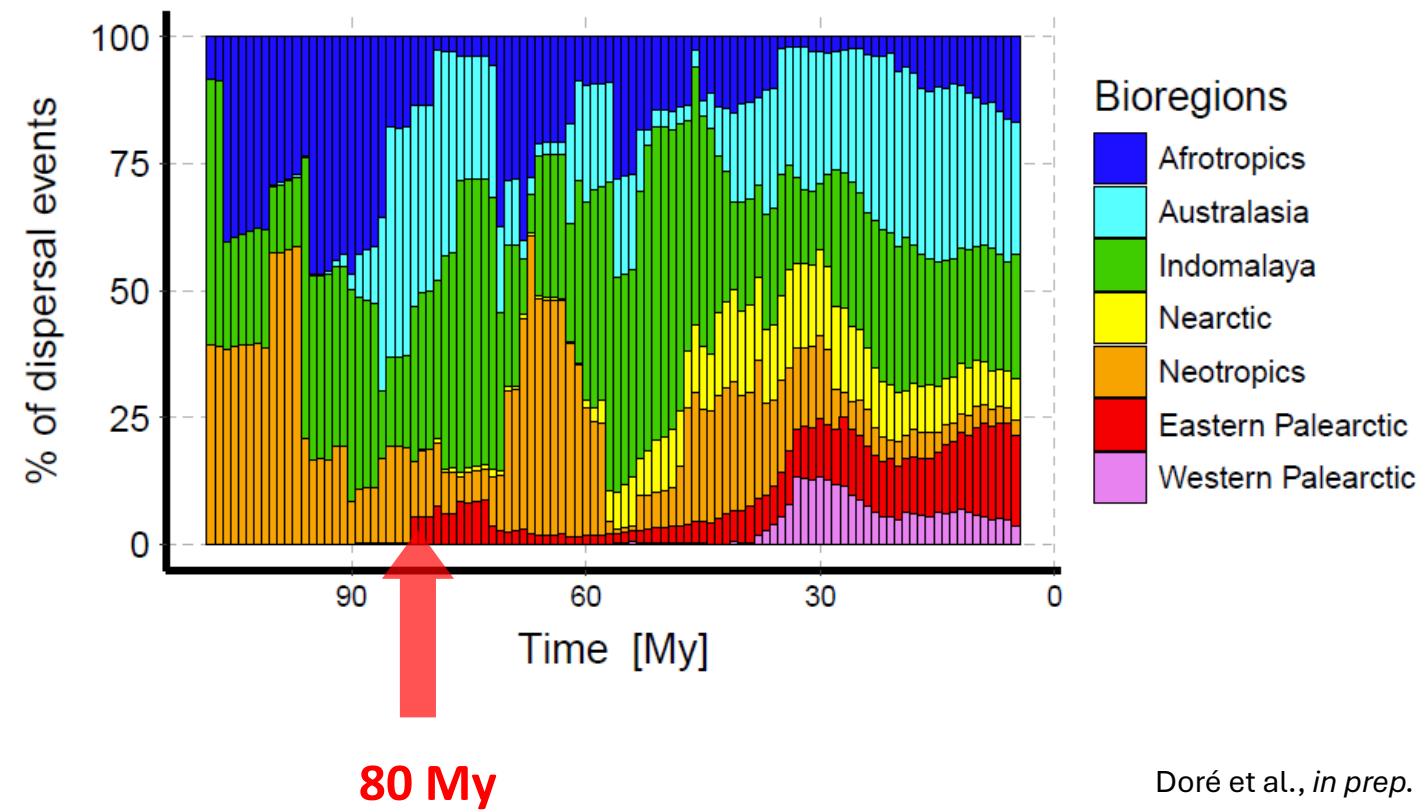
Dispersal events in time



Dispersal events
per Source bioregions

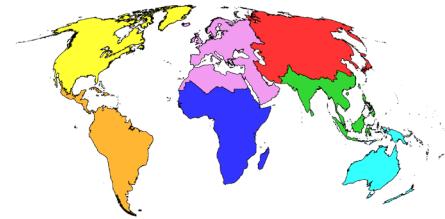


Dispersal events
per Destination bioregions

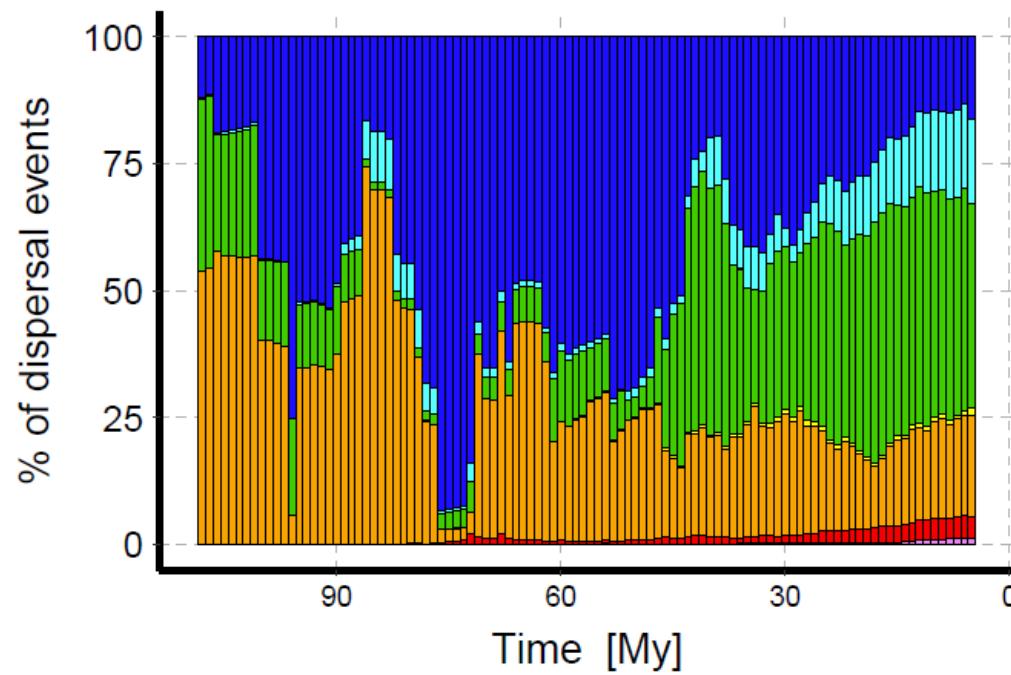


Doré et al., *in prep.*

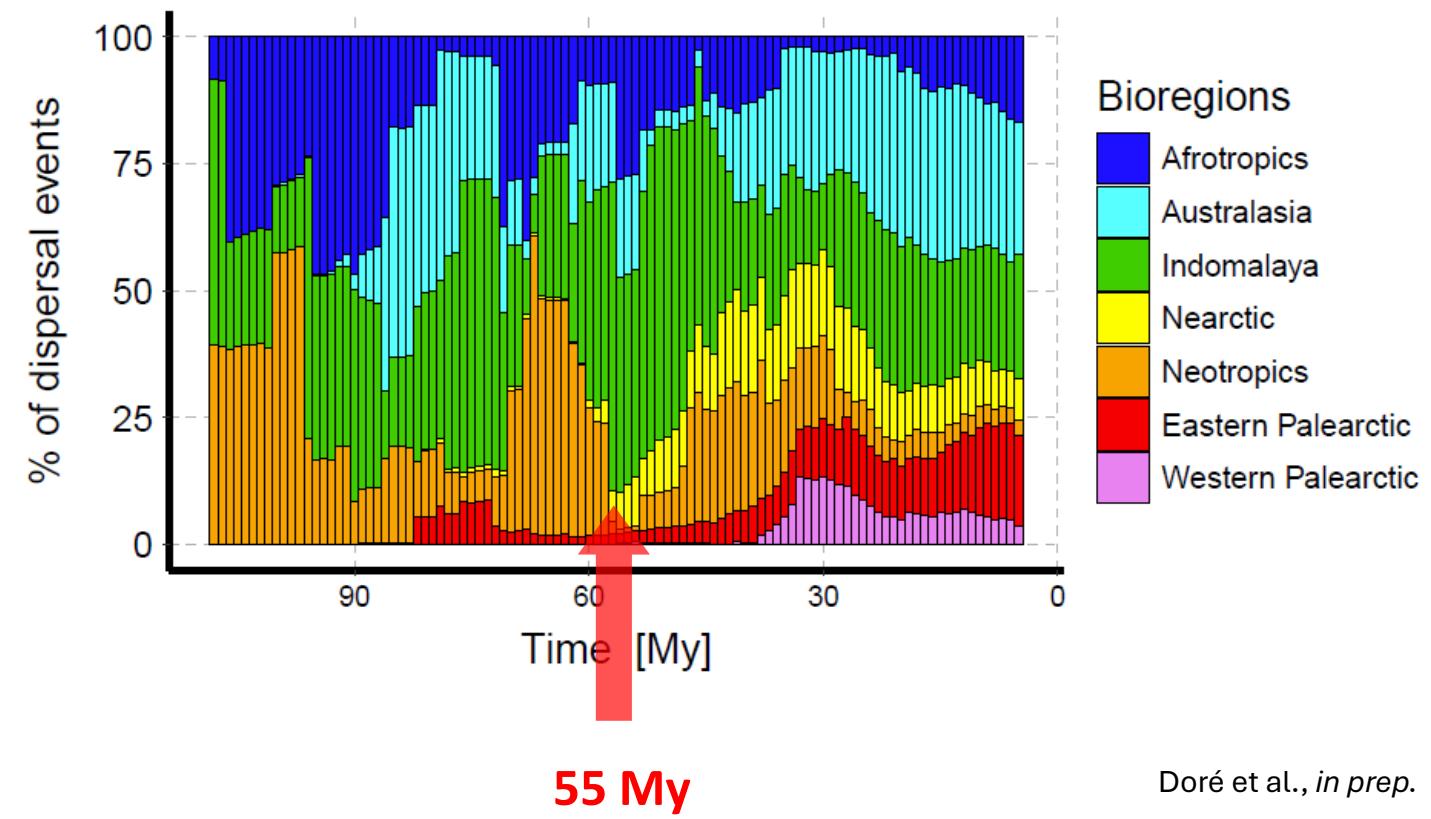
Dispersal events in time



Dispersal events
per Source bioregions

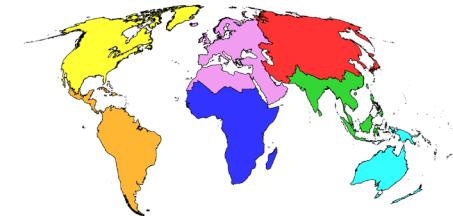


Dispersal events
per Destination bioregions

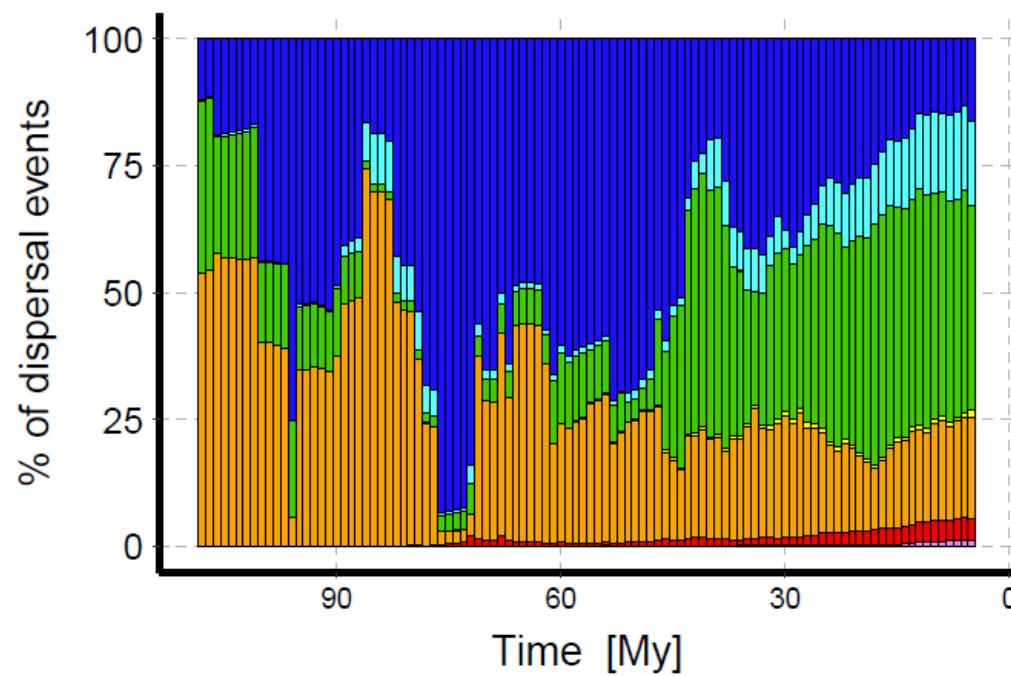


Doré et al., *in prep.*

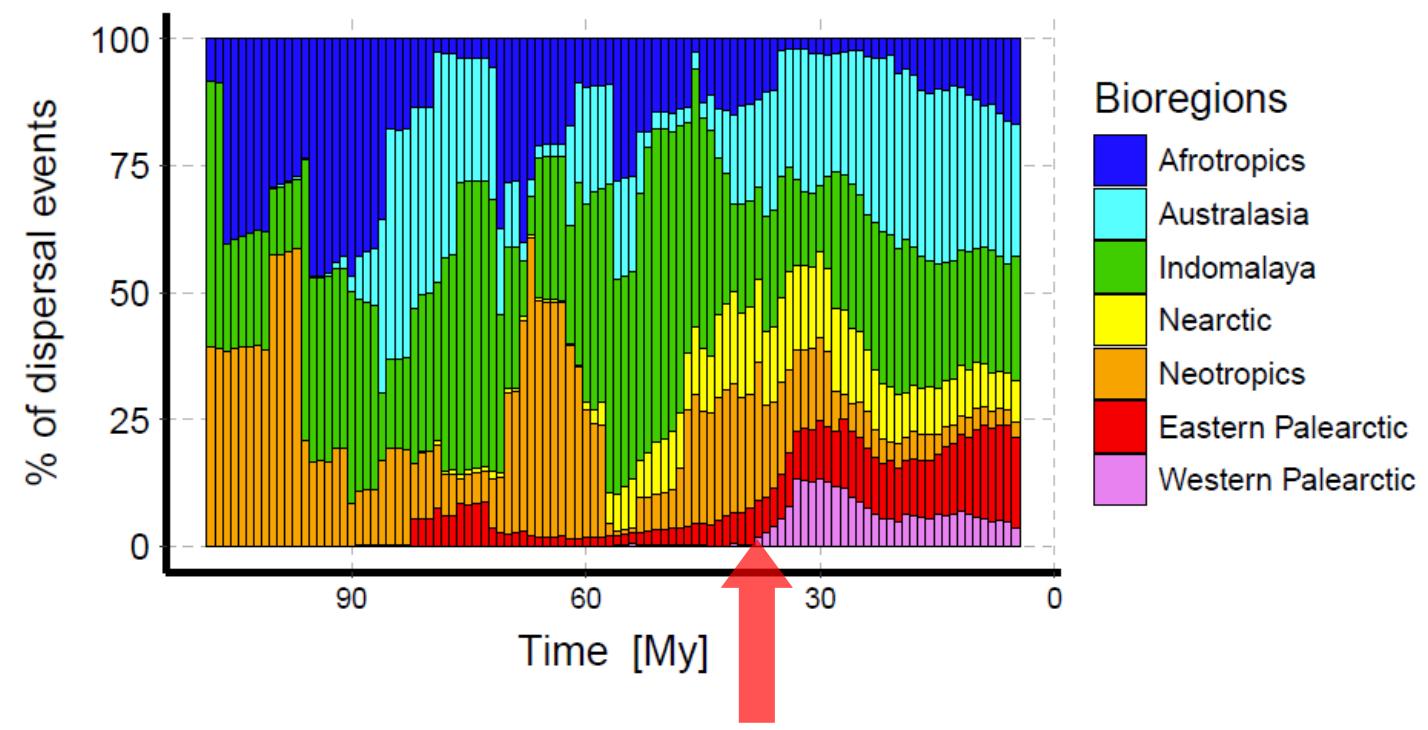
Dispersal events in time



Dispersal events
per Source bioregions



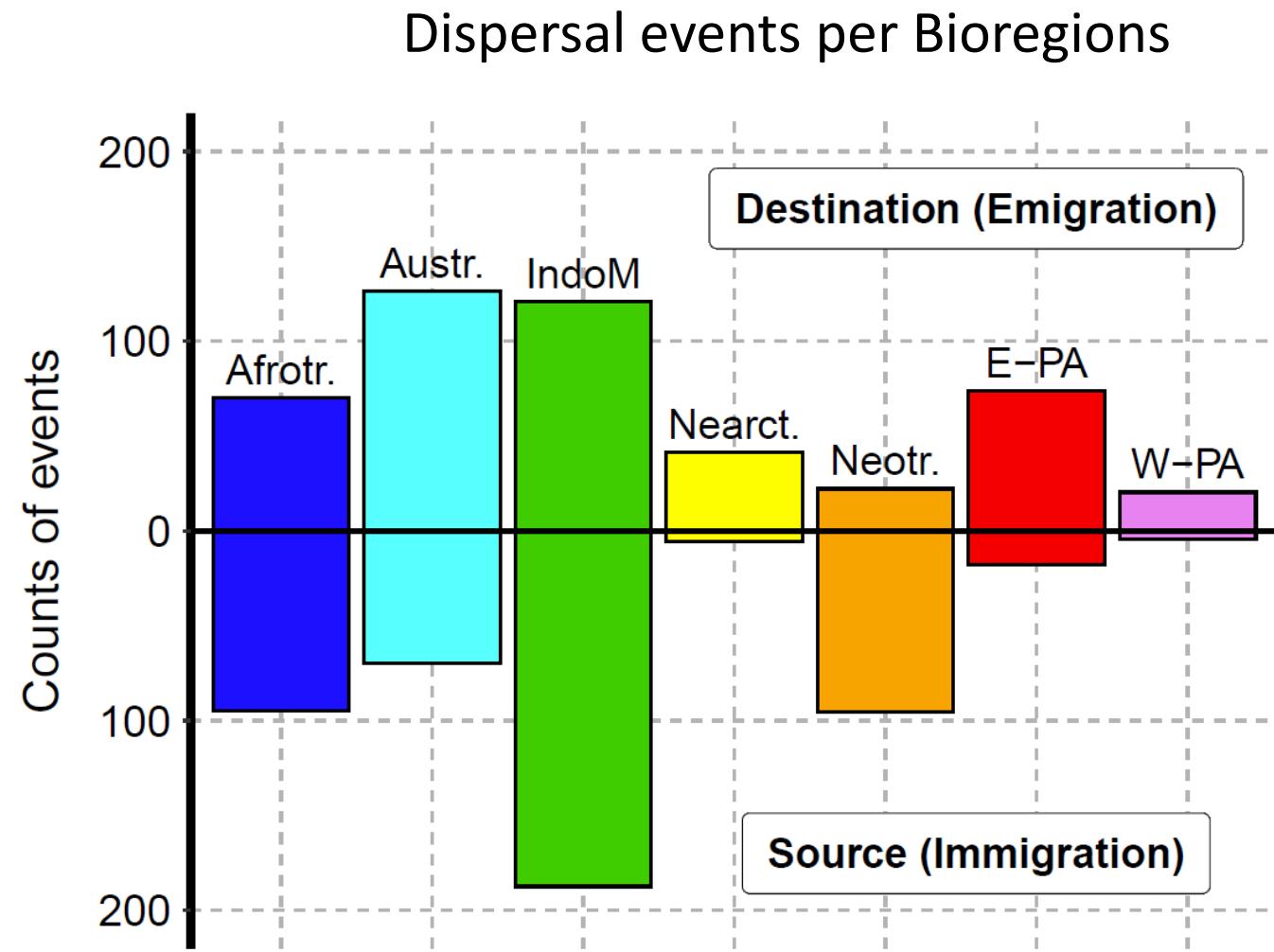
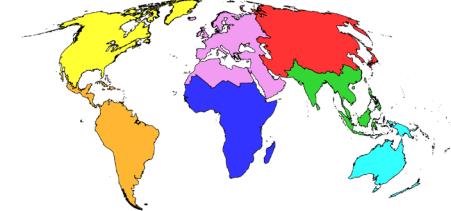
Dispersal events
per Destination bioregions



35 My

Doré et al., *in prep.*

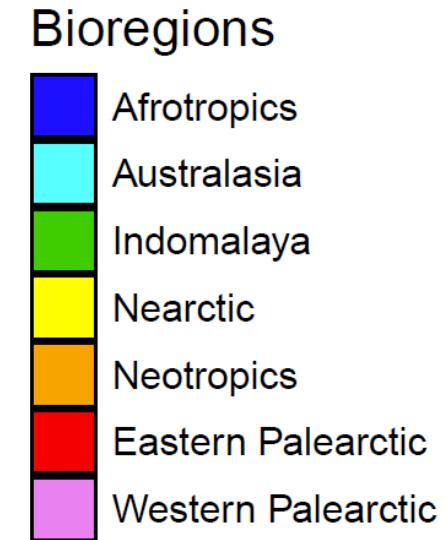
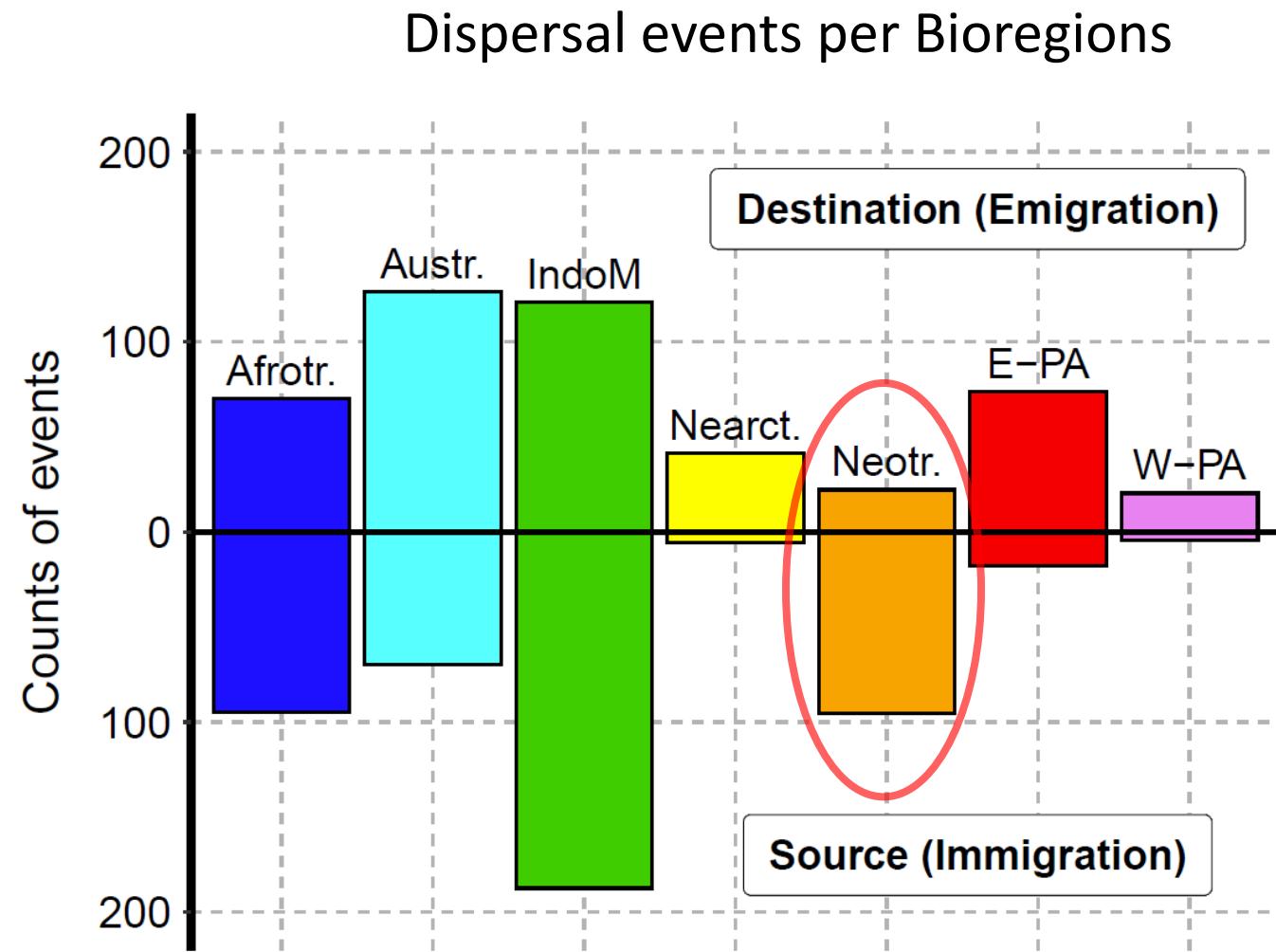
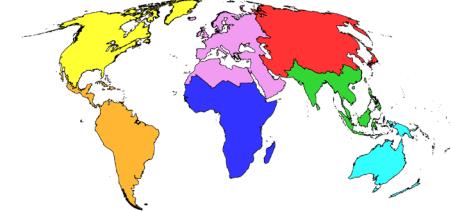
Macroevolutionary sources & sinks



Bioregions
Afrotropics
Australasia
Indomalaya
Nearctic
Neotropics
Eastern Palearctic
Western Palearctic

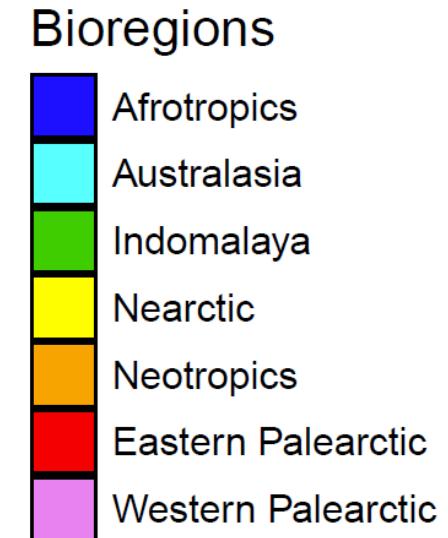
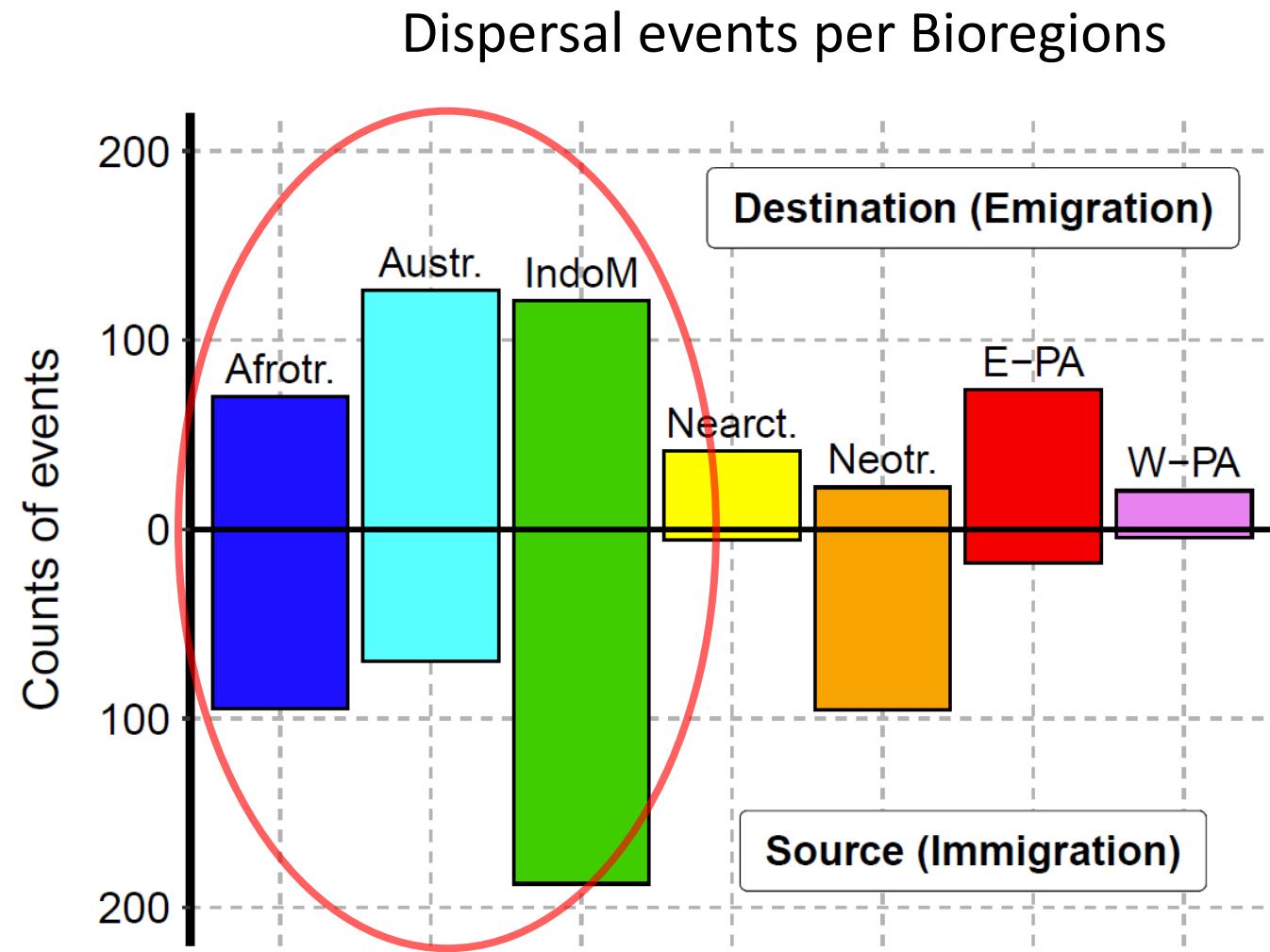
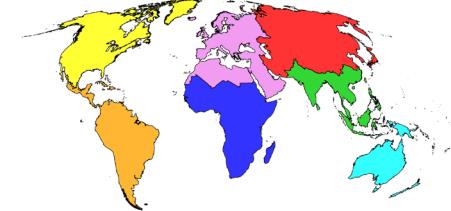
Doré et al., *in prep.*

Macroevolutionary sources & sinks



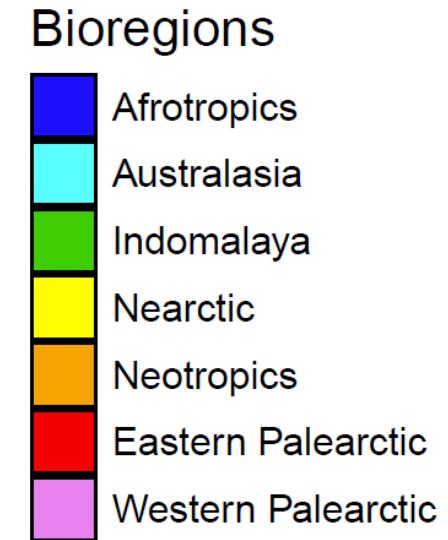
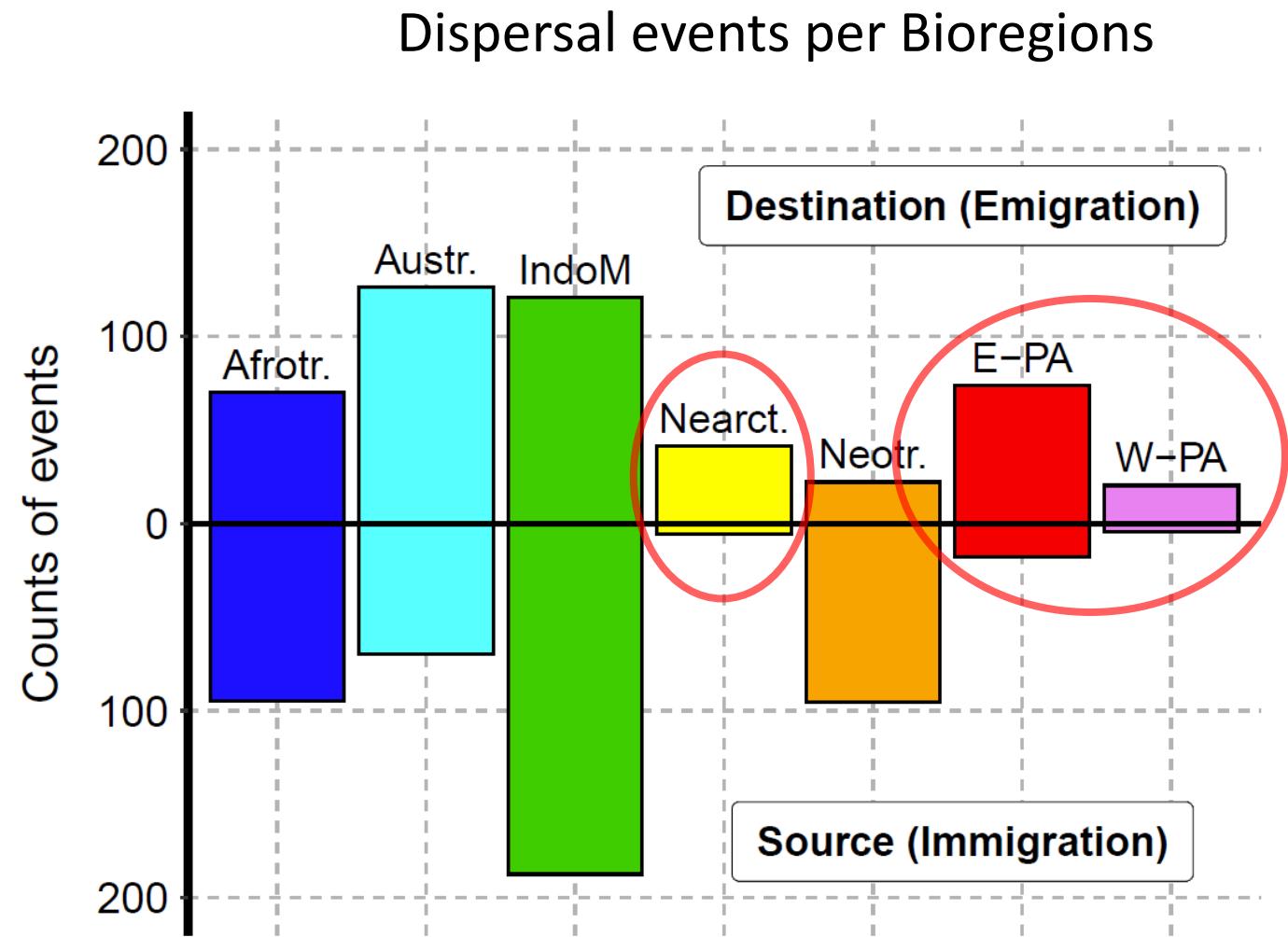
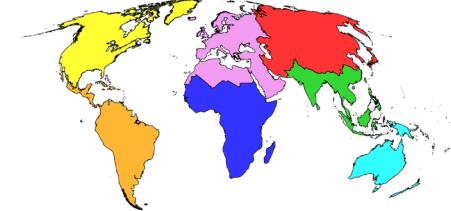
Doré et al., *in prep.*

Macroevolutionary sources & sinks



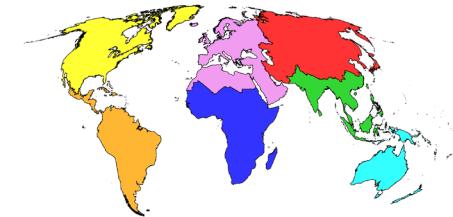
Doré et al., *in prep.*

Macroevolutionary sources & sinks

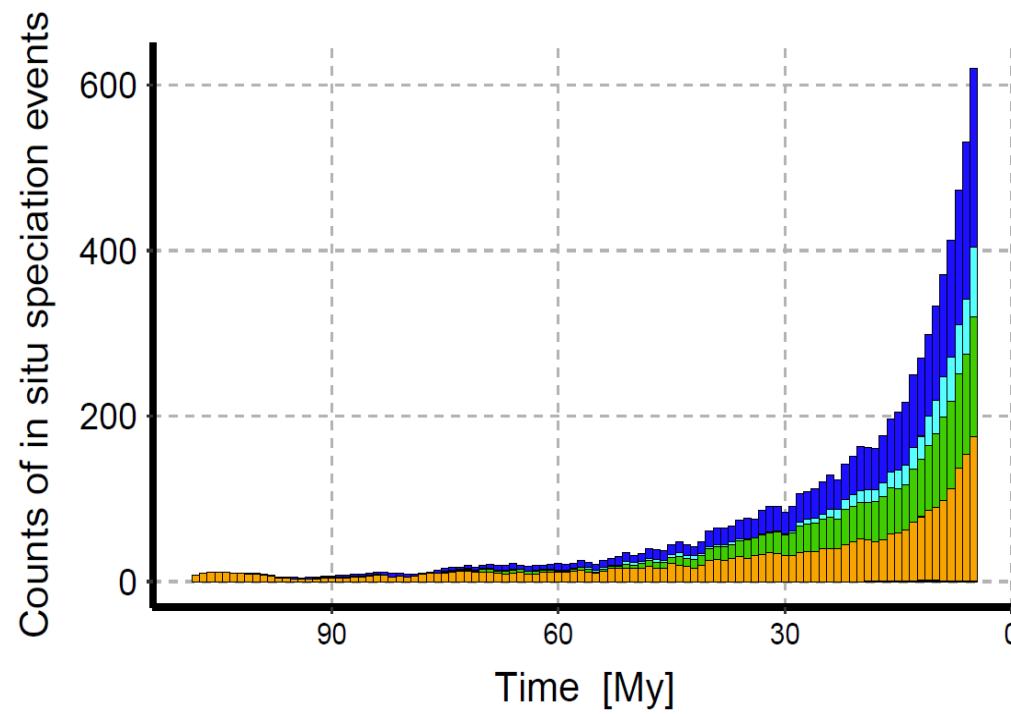


Doré et al., *in prep.*

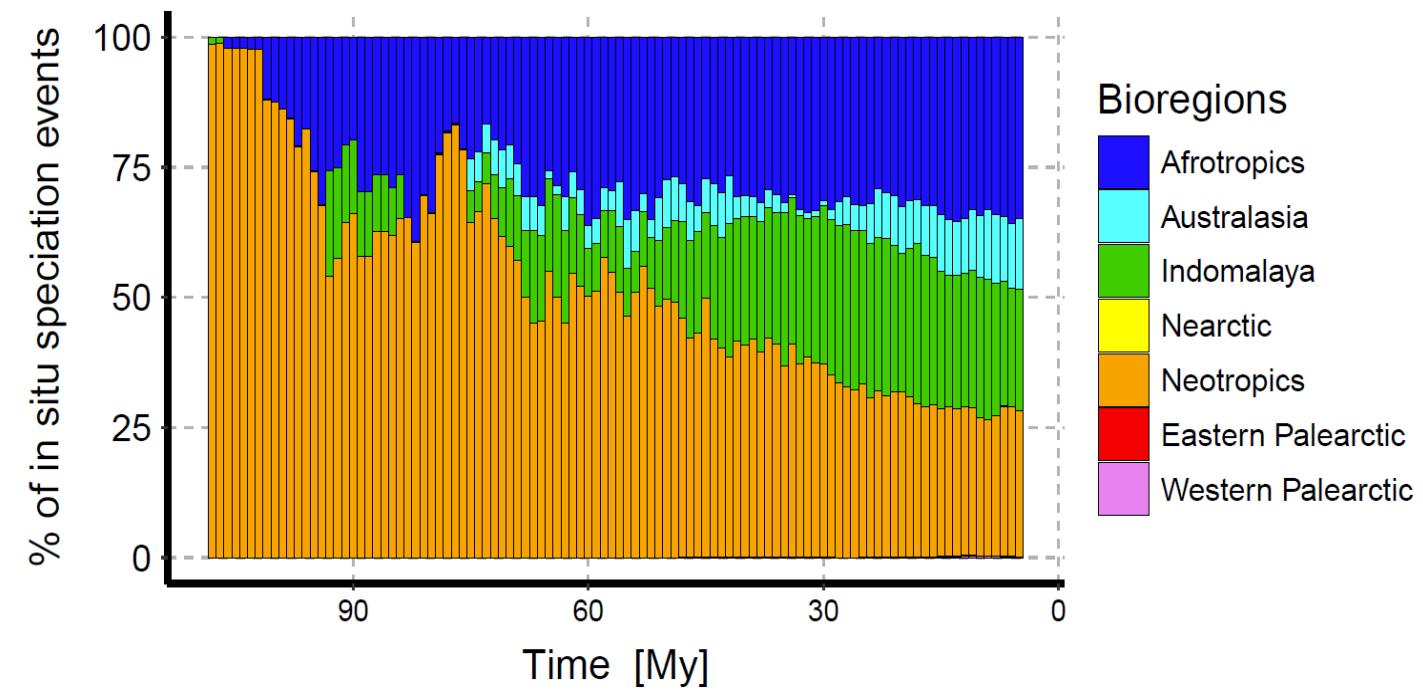
In situ diversification in time



Counts
in situ speciation events
per Bioregions

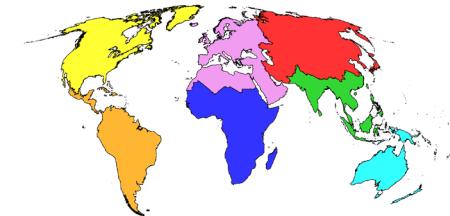


Percentages
in situ speciation events
per Bioregions

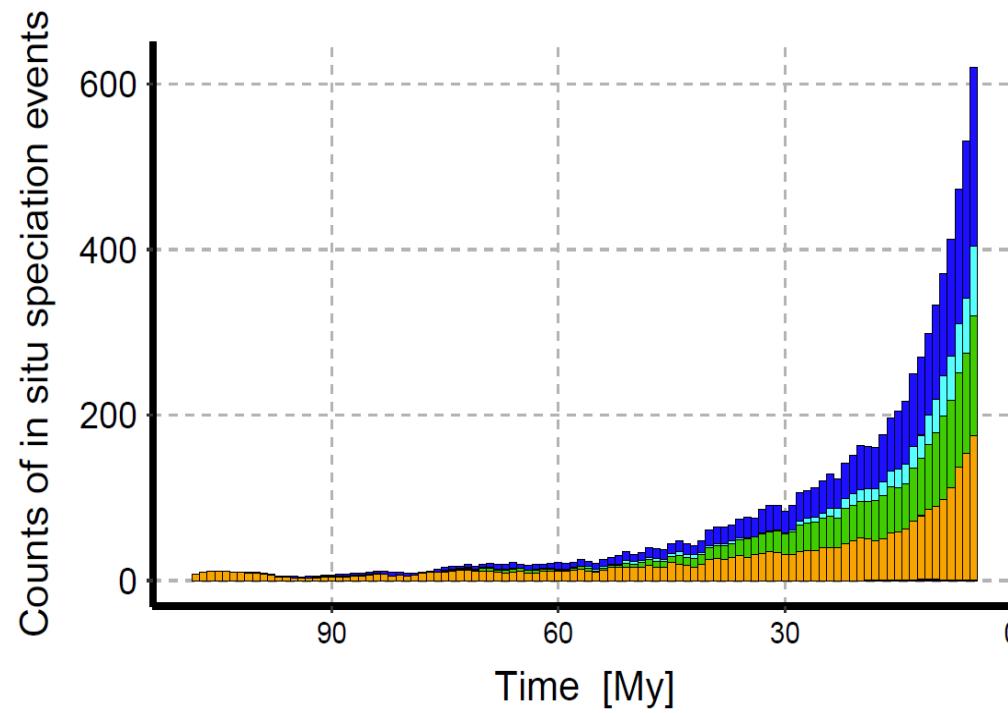


Doré et al., *in prep.*

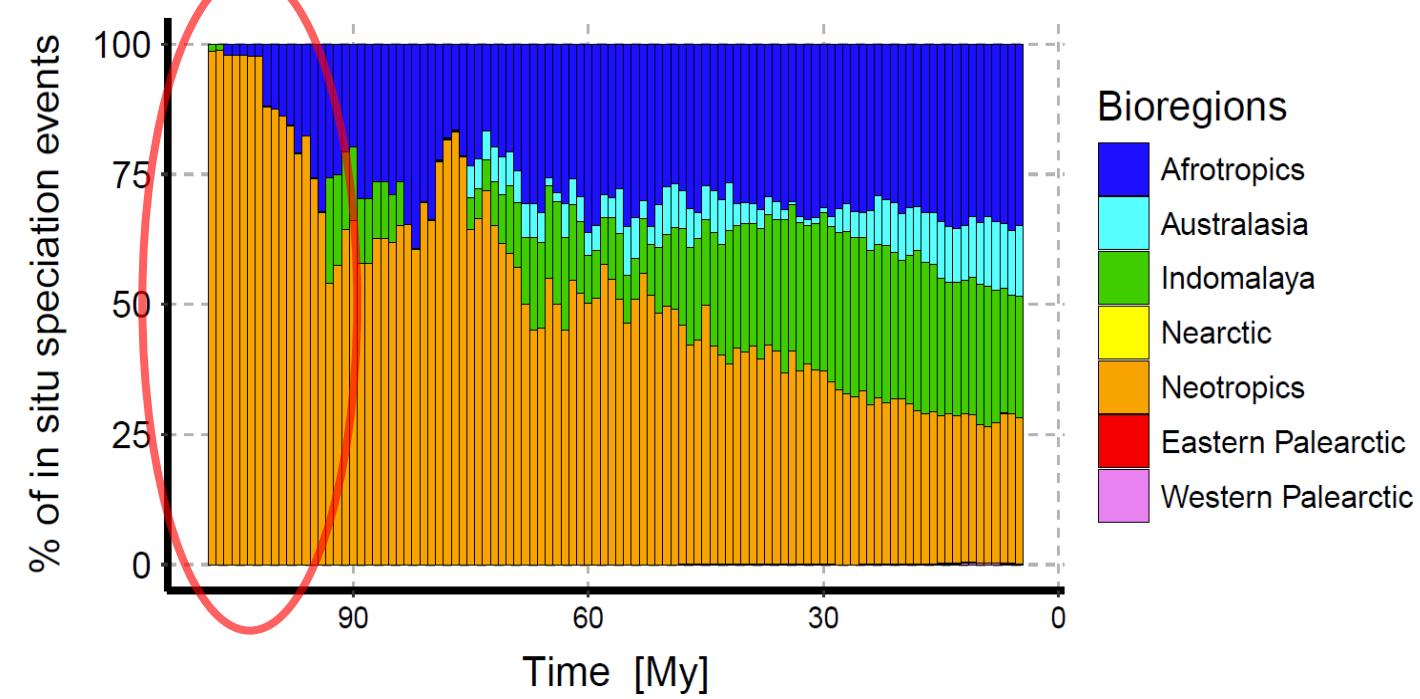
In situ diversification in time



Counts
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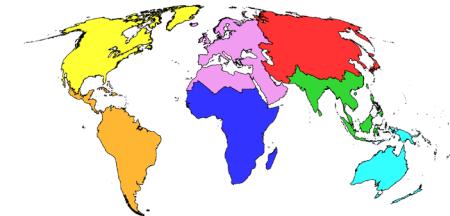


Percentages
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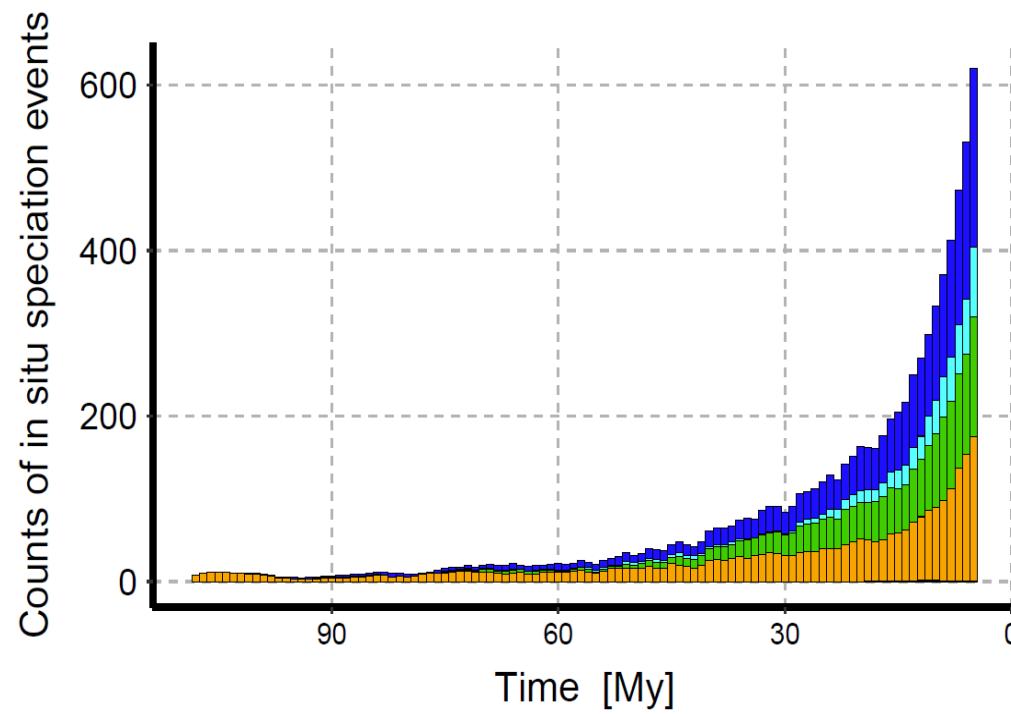


Doré et al., *in prep.*

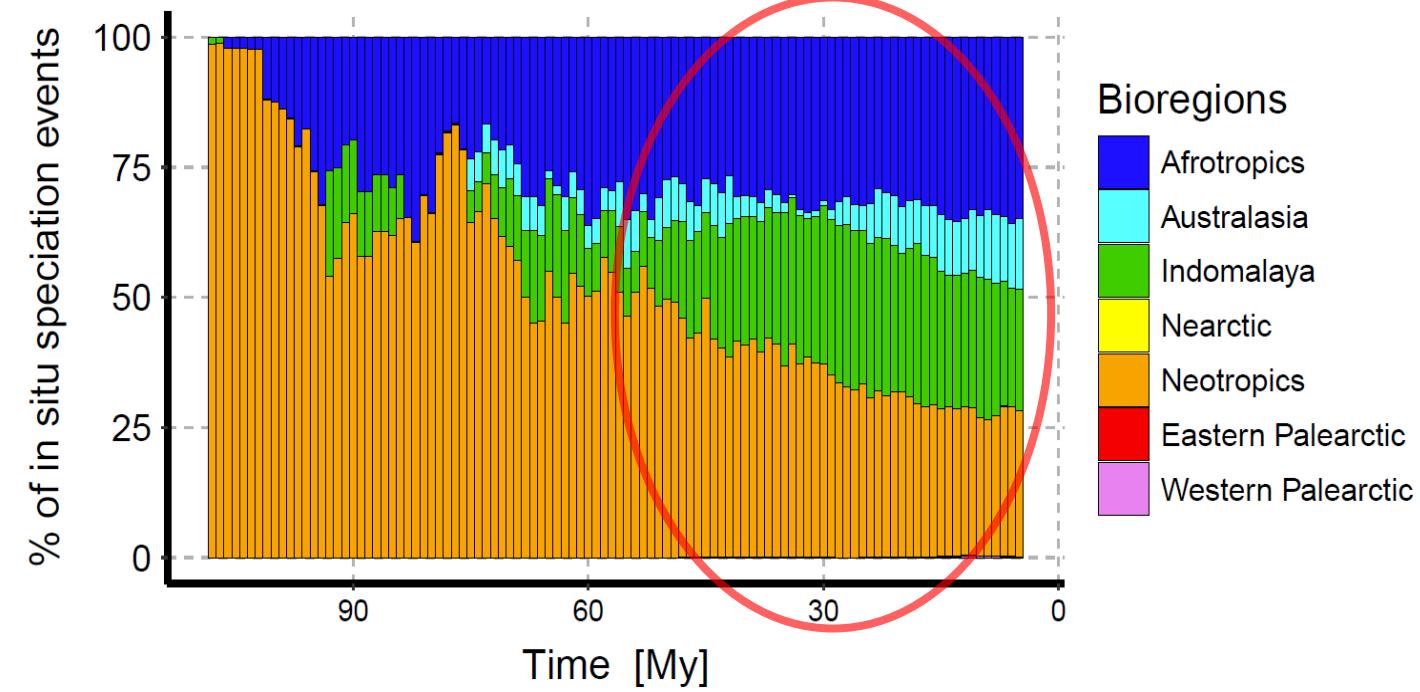
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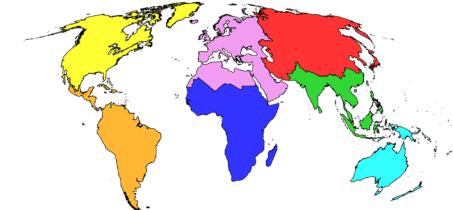


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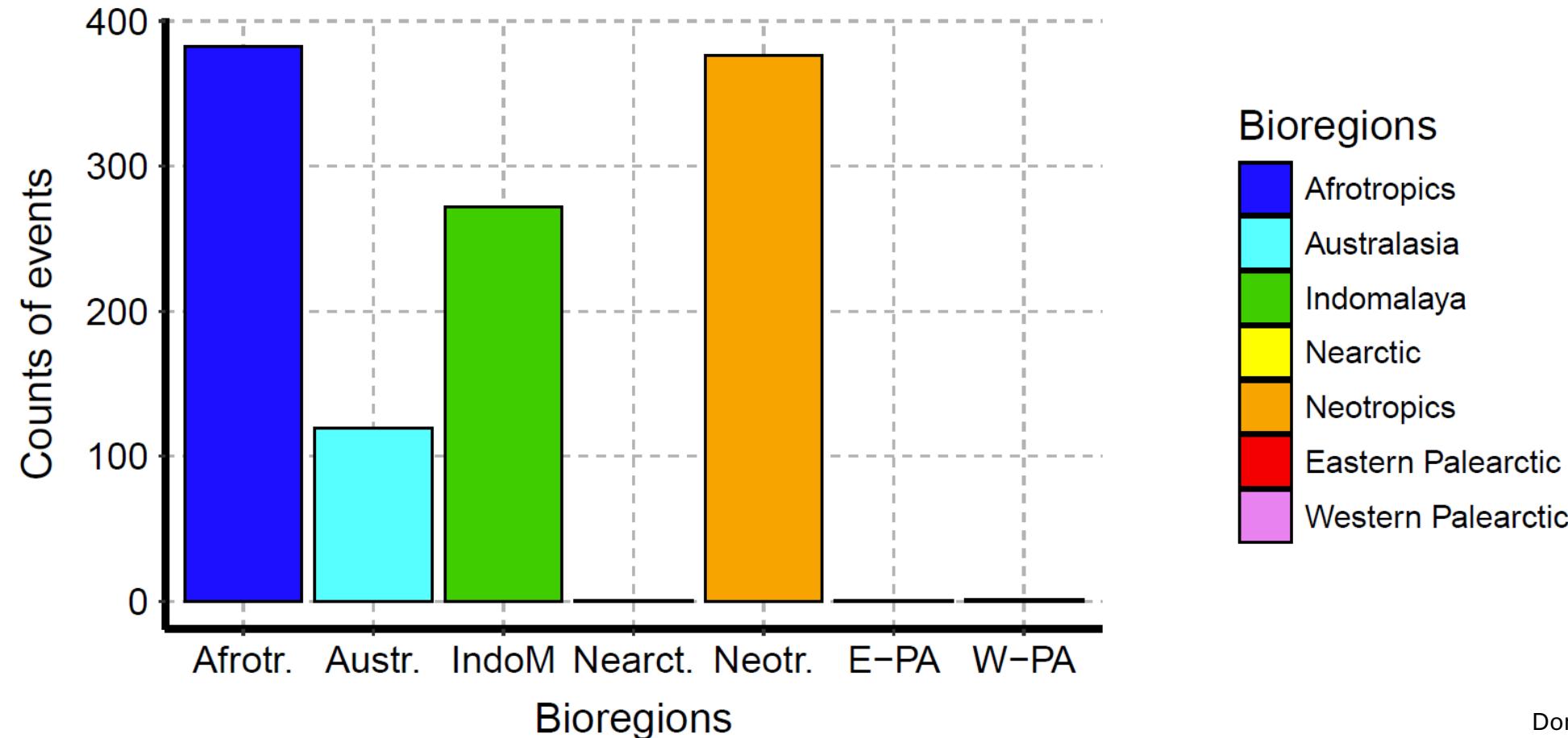


Doré et al., *in prep.*

Overall *in situ* diversification

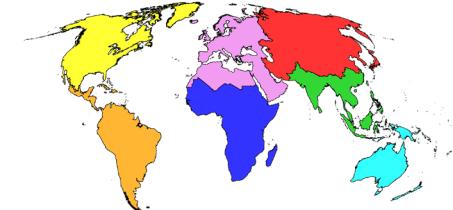


Counts of *in situ* speciation events
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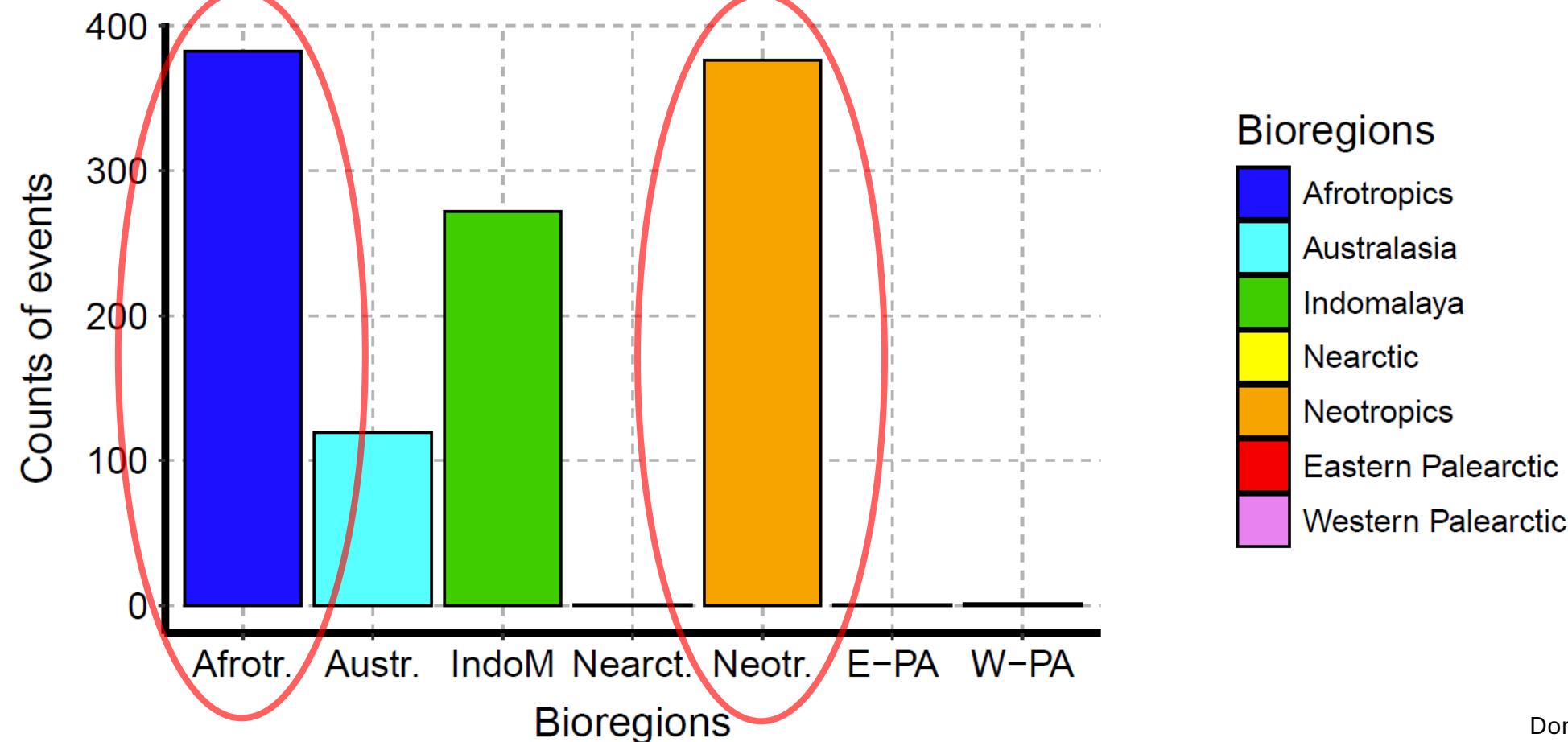


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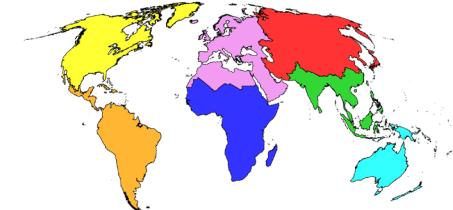
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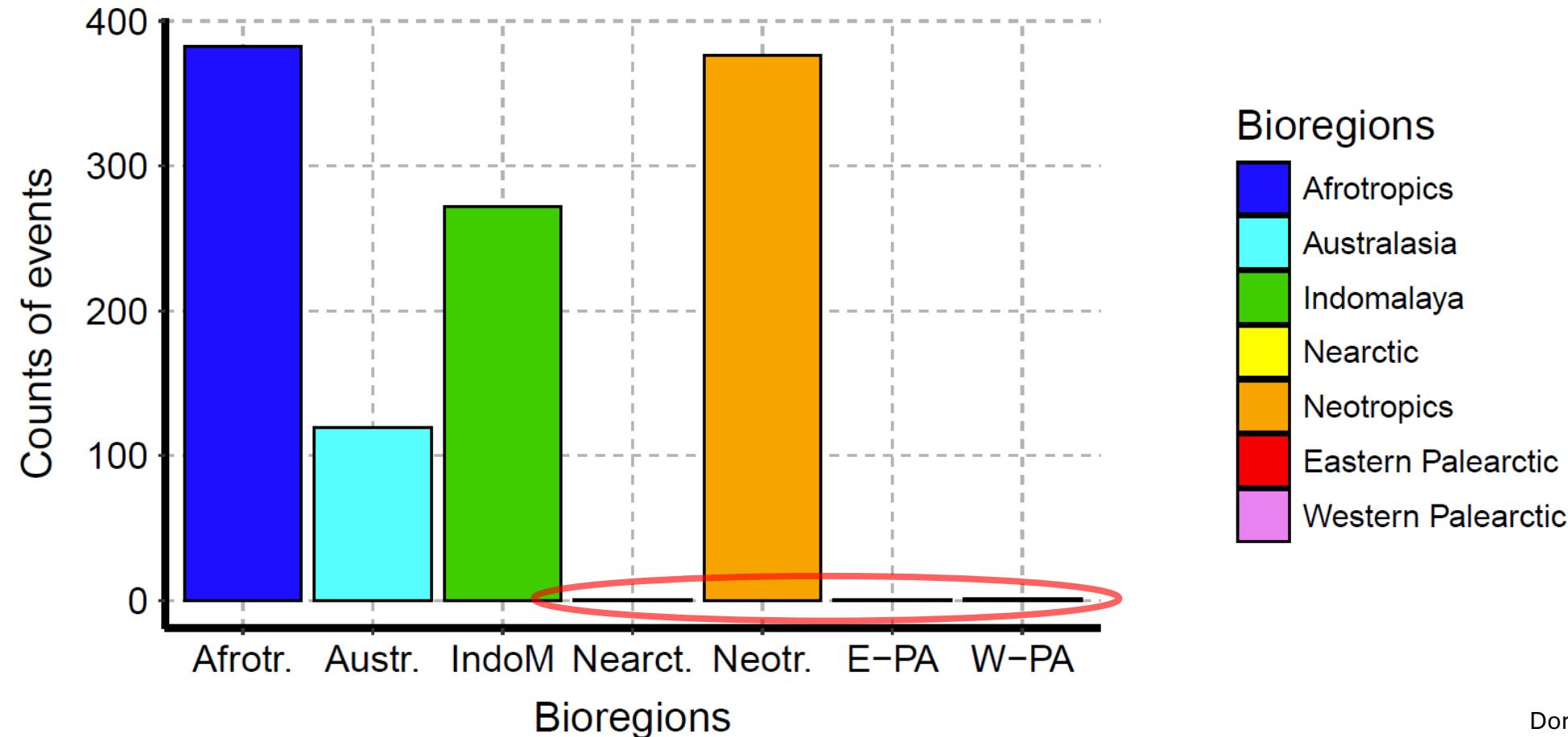
Counts of *in situ* speciation events
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Doré et al., *in prep.*

Conclusions

Origin in **Gondwana** ≈ 110-120 My

Timing of first colonizations:

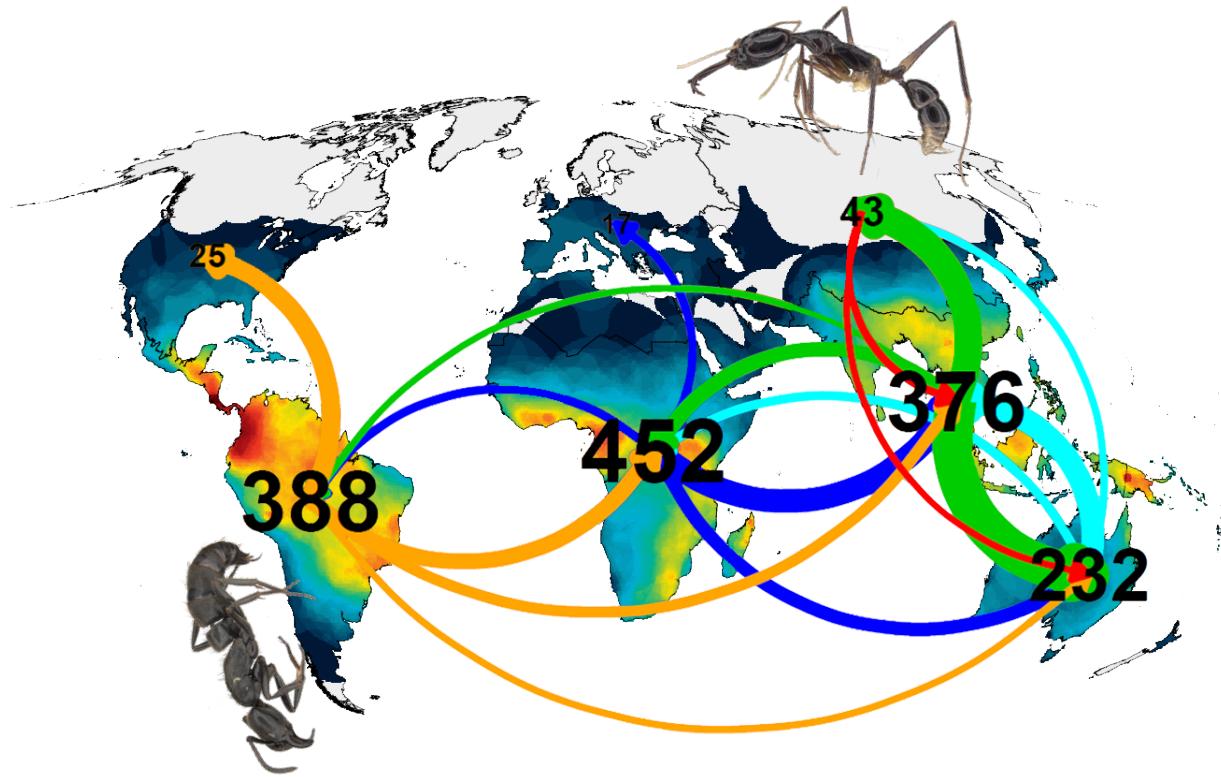
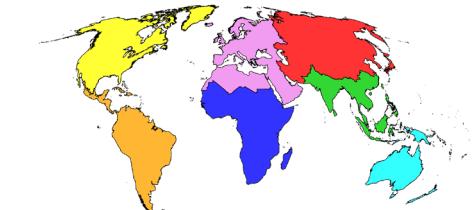
- Australasia from Neotropics = 90 My
- Eastern Palearctic from (Indo)Malaya = 80 My
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Dispersal dynamics:

- Early sources: Neotropics + Afrotropics
- Overall/Recent source: IndoMalaya

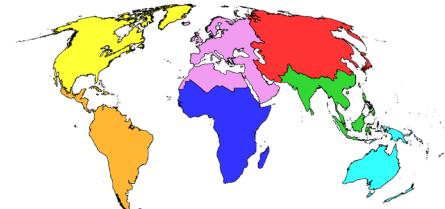
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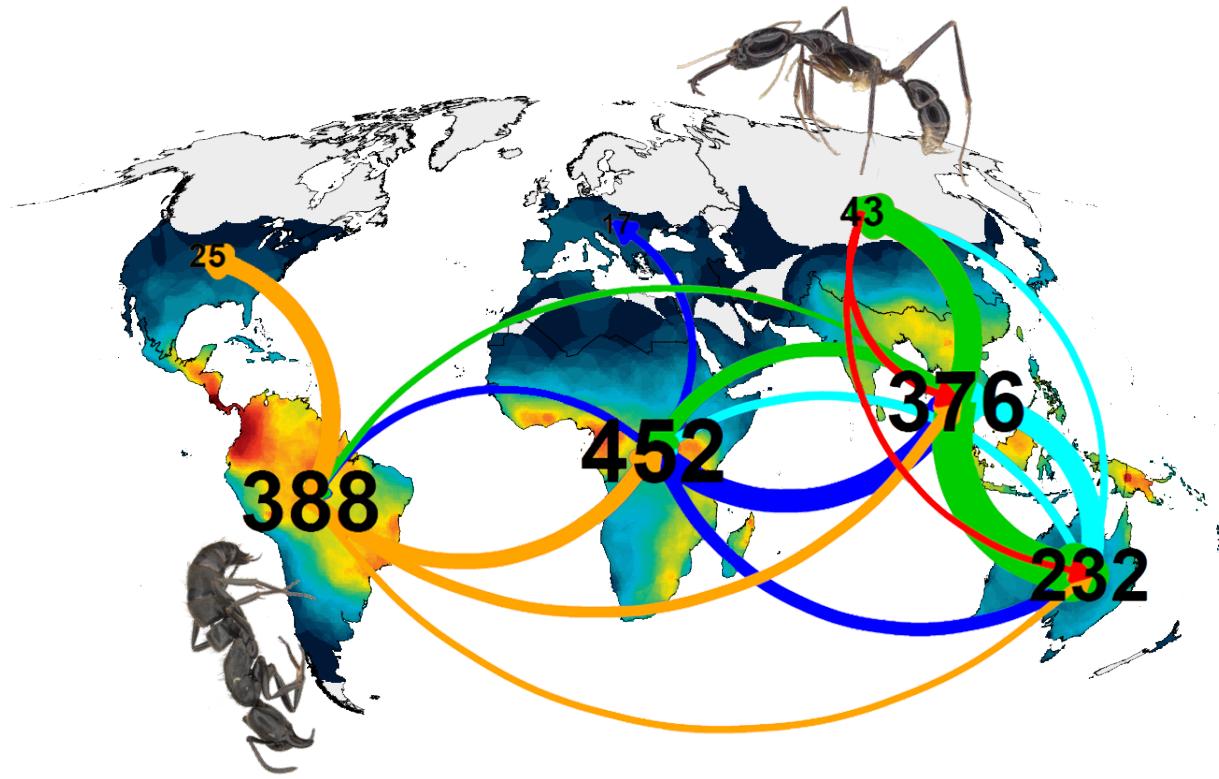
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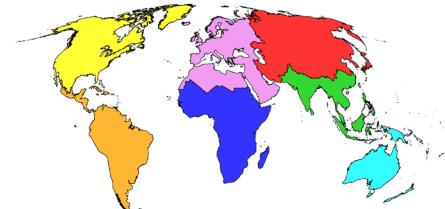
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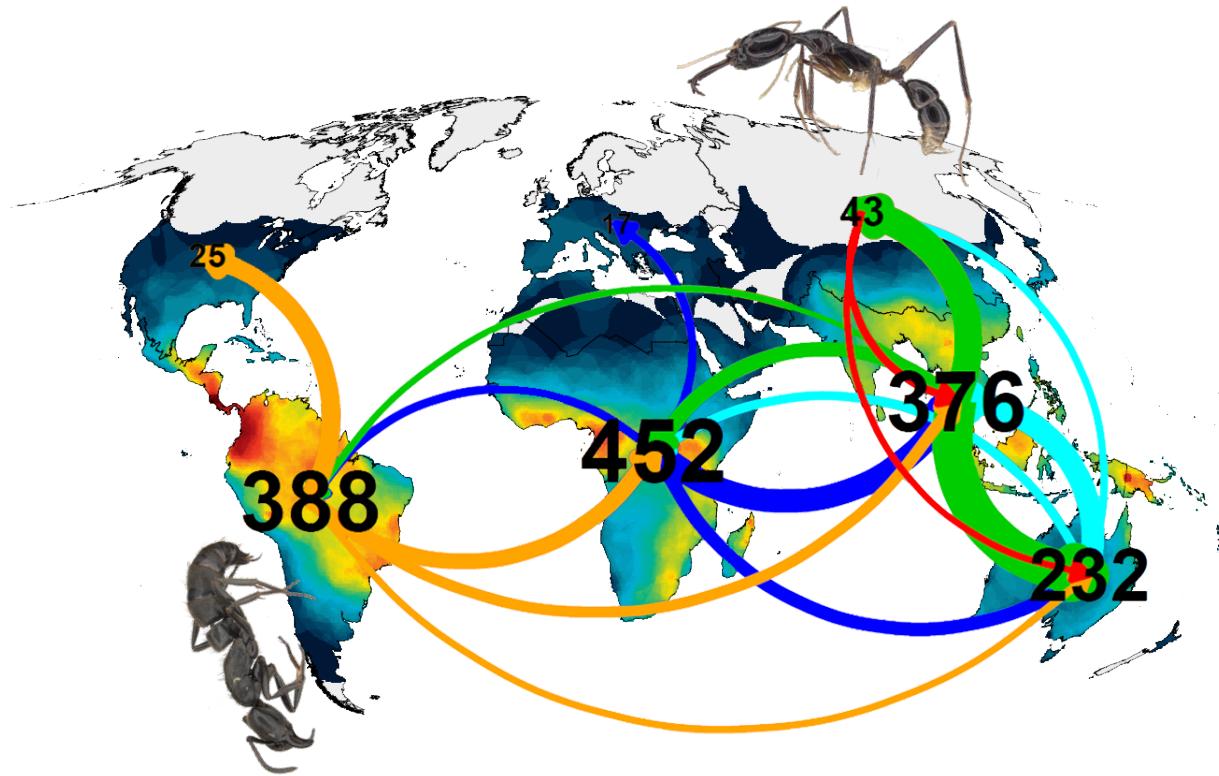
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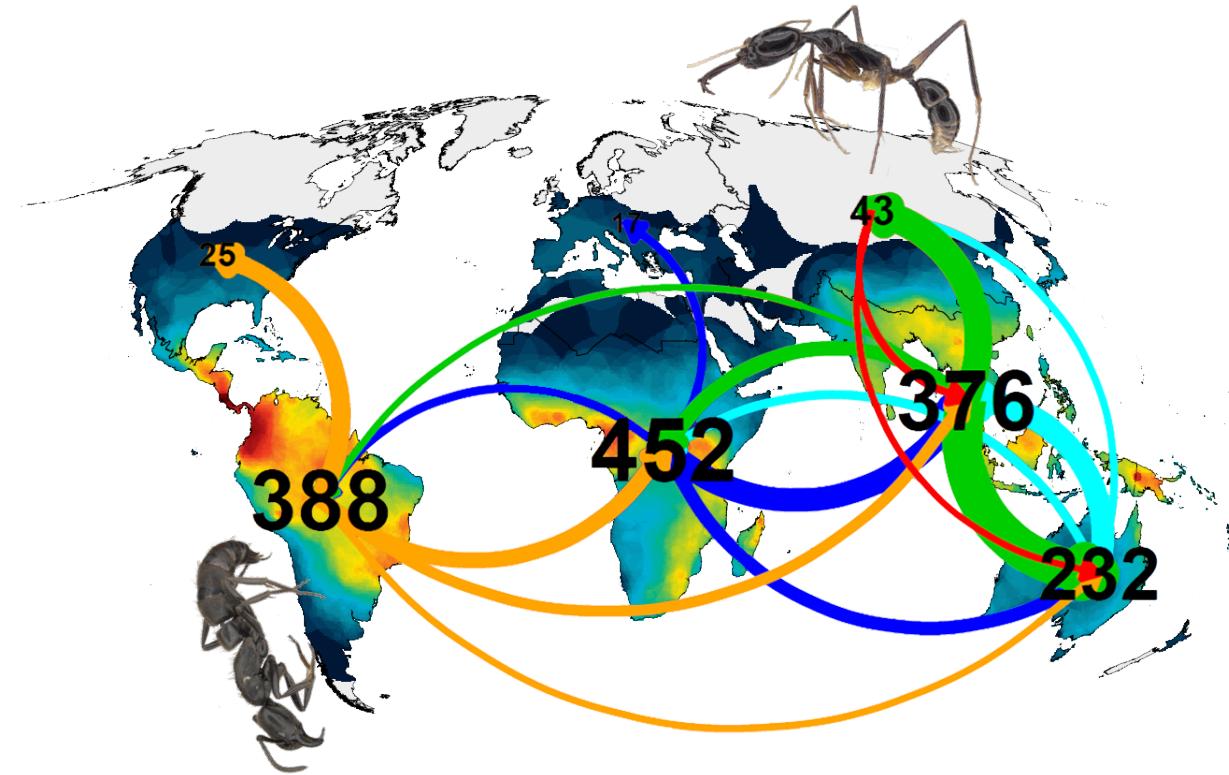
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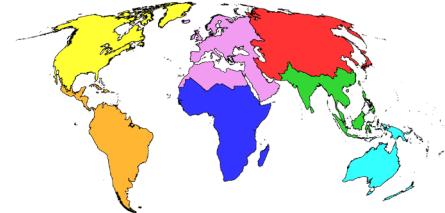
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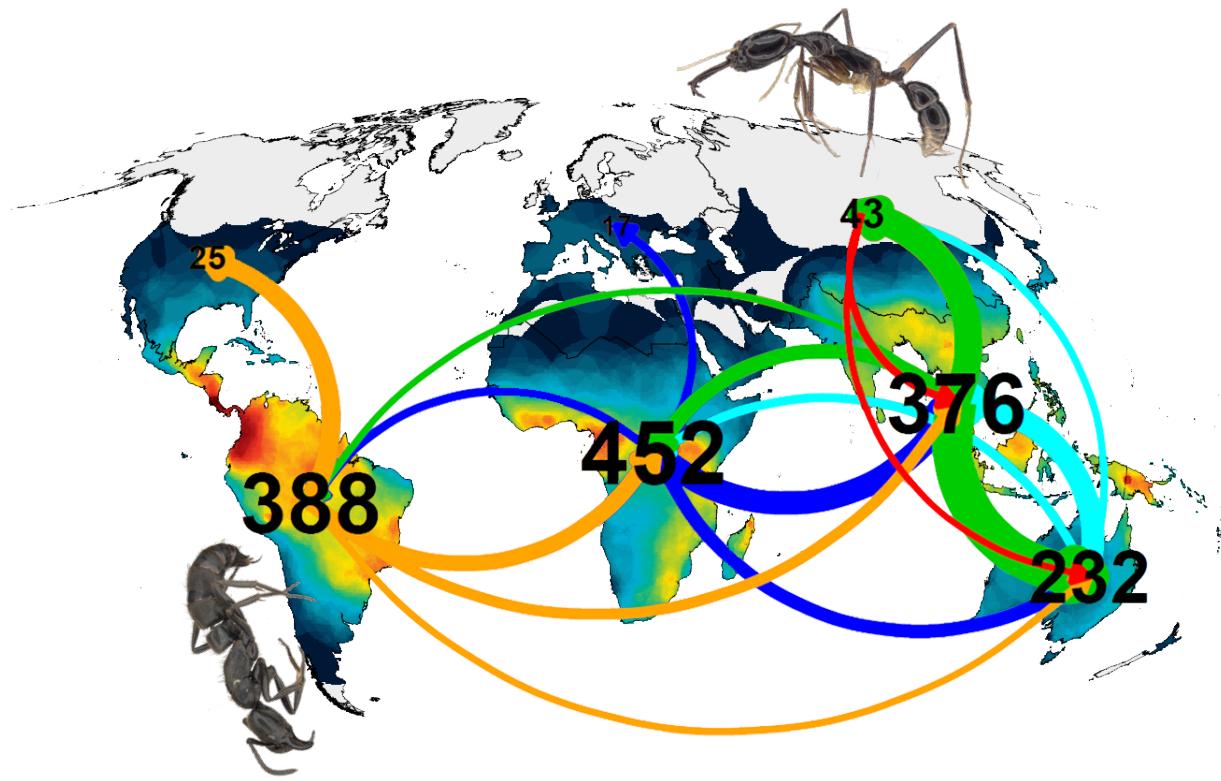


Macroevolutionary sources/sinks:

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- Sinks = Holarctic = **Palearctic + Nearctic**
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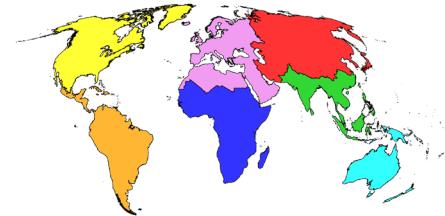
Mechanisms?

- Tropical niche conservatism
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Doré et al., *in prep.*

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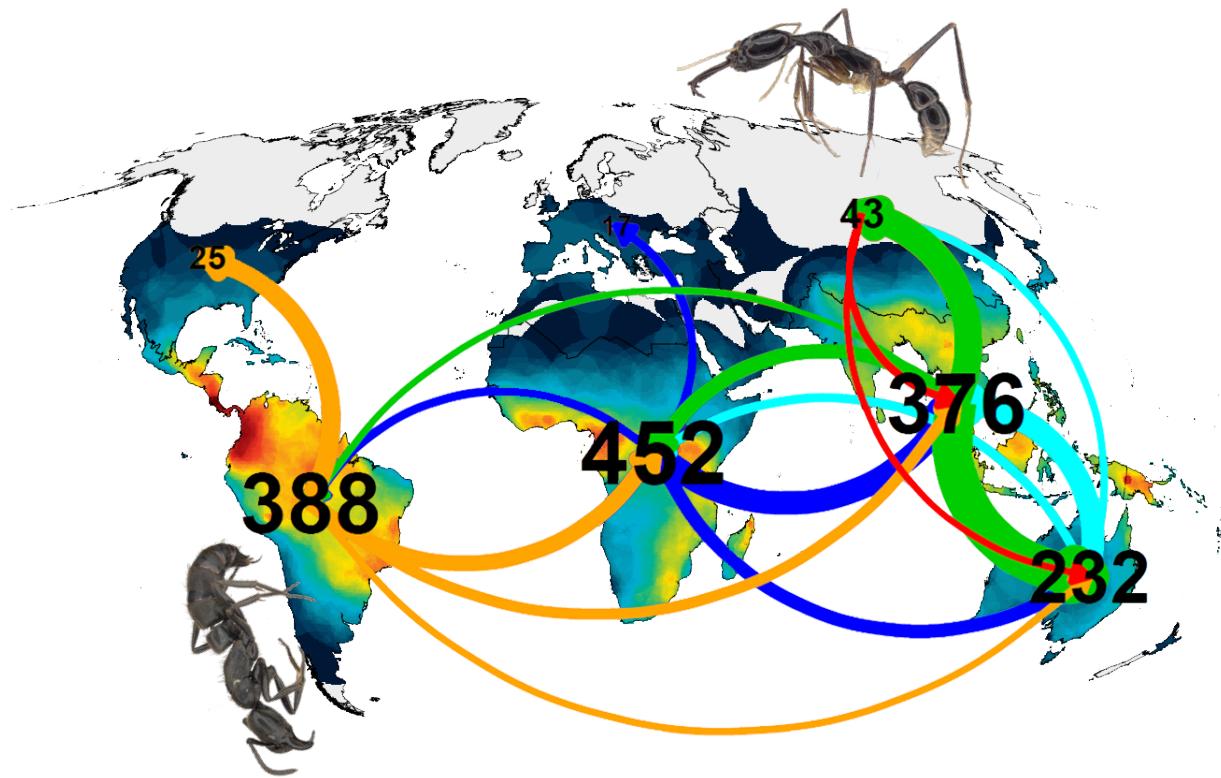


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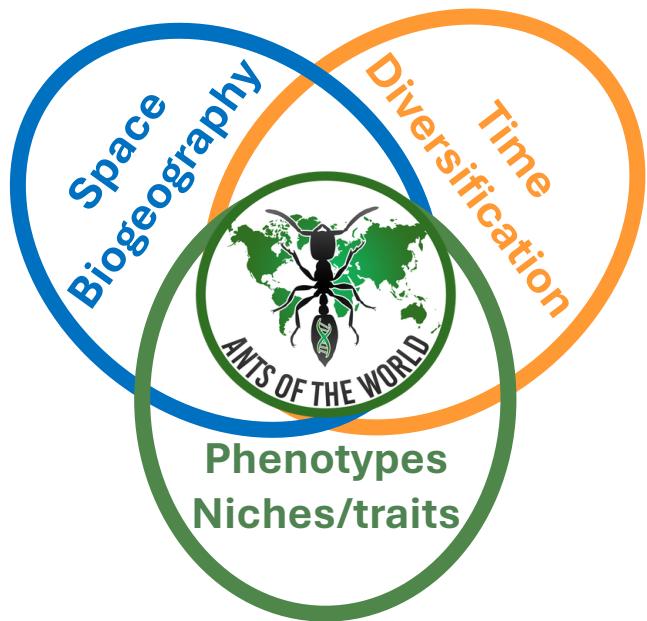
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Doré et al., *in prep.*

Perspectives



Climatic niche evolution:

- Is evolution repeating itself? Compare the **filling of the niche** across bioregions

Morphology & Diversification:

- Do **key morphological innovations** trigger diversification uplifts?



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DEB-1932467, DEB-1932062, DEB-2019431

Bonnie Blaimer



Marek Borowiec



Gabi Camacho



Jack Longino



Michael Branstetter



Brian Fisher



Phil Ward





SCAN ME

Questions?



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<https://doi.org/10.1371/journal.pone.0231866>

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