SECULAR COOLING OF THE EARTH

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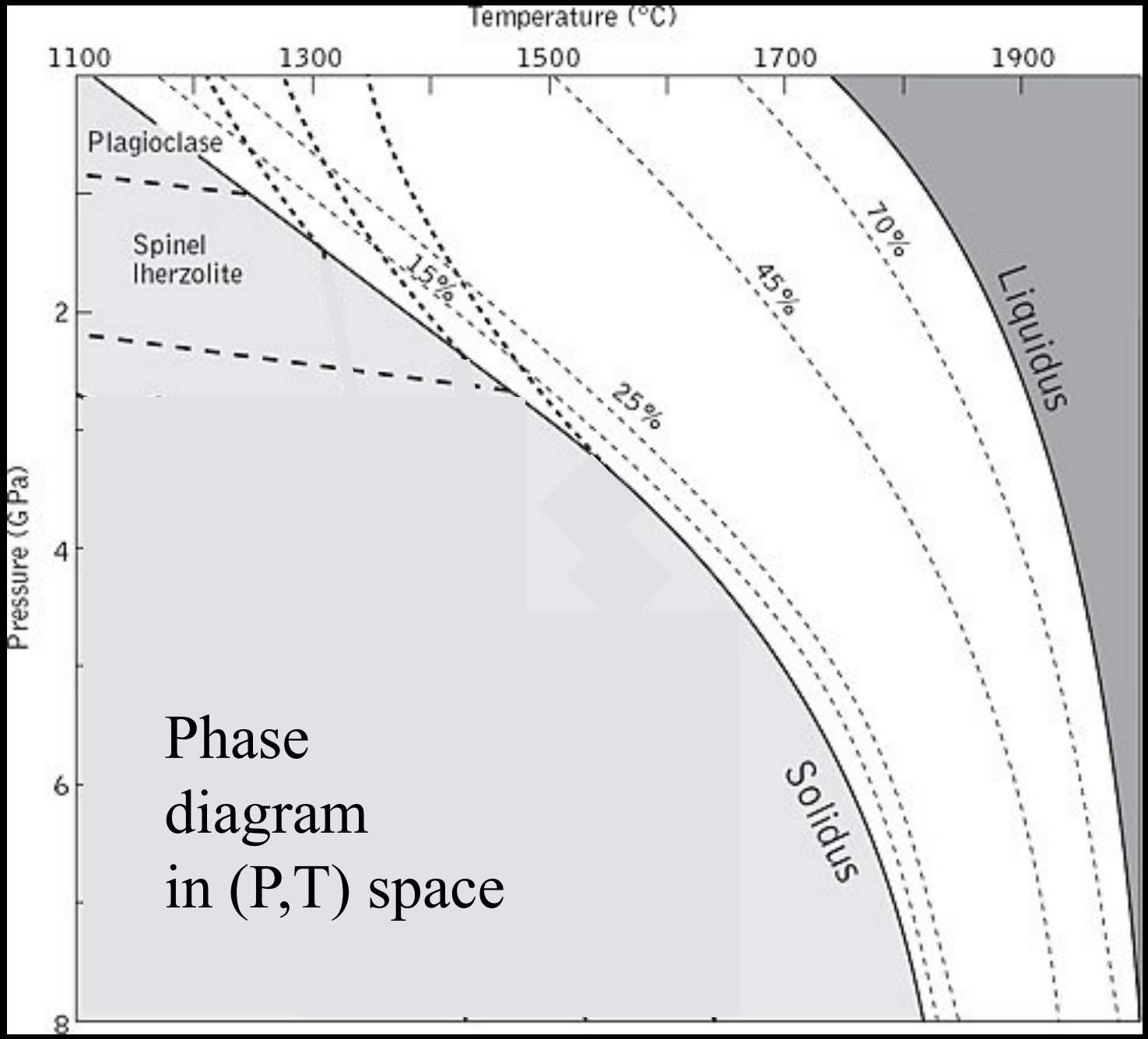
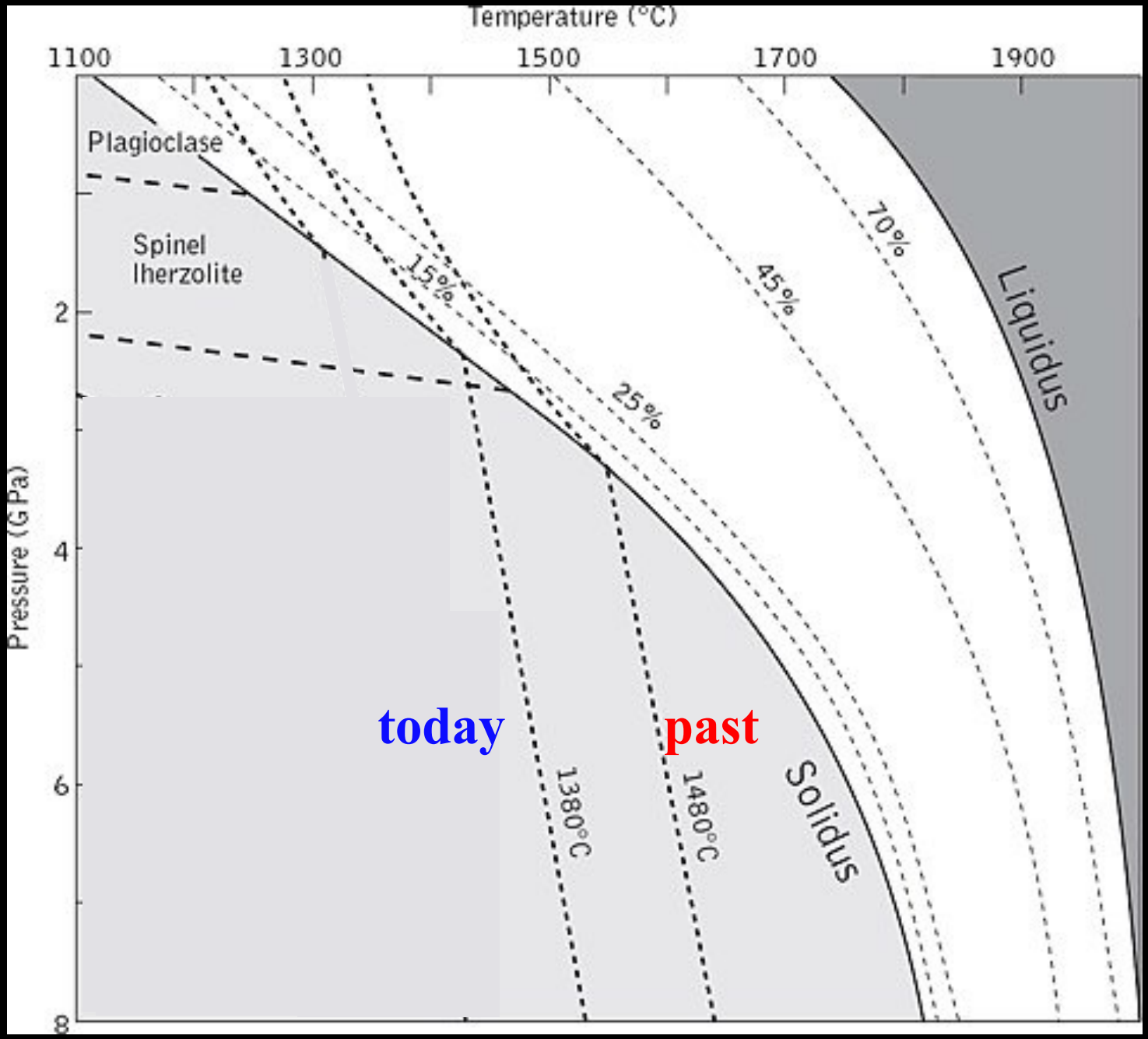
Tracking the mantle temperature : melting by decompression

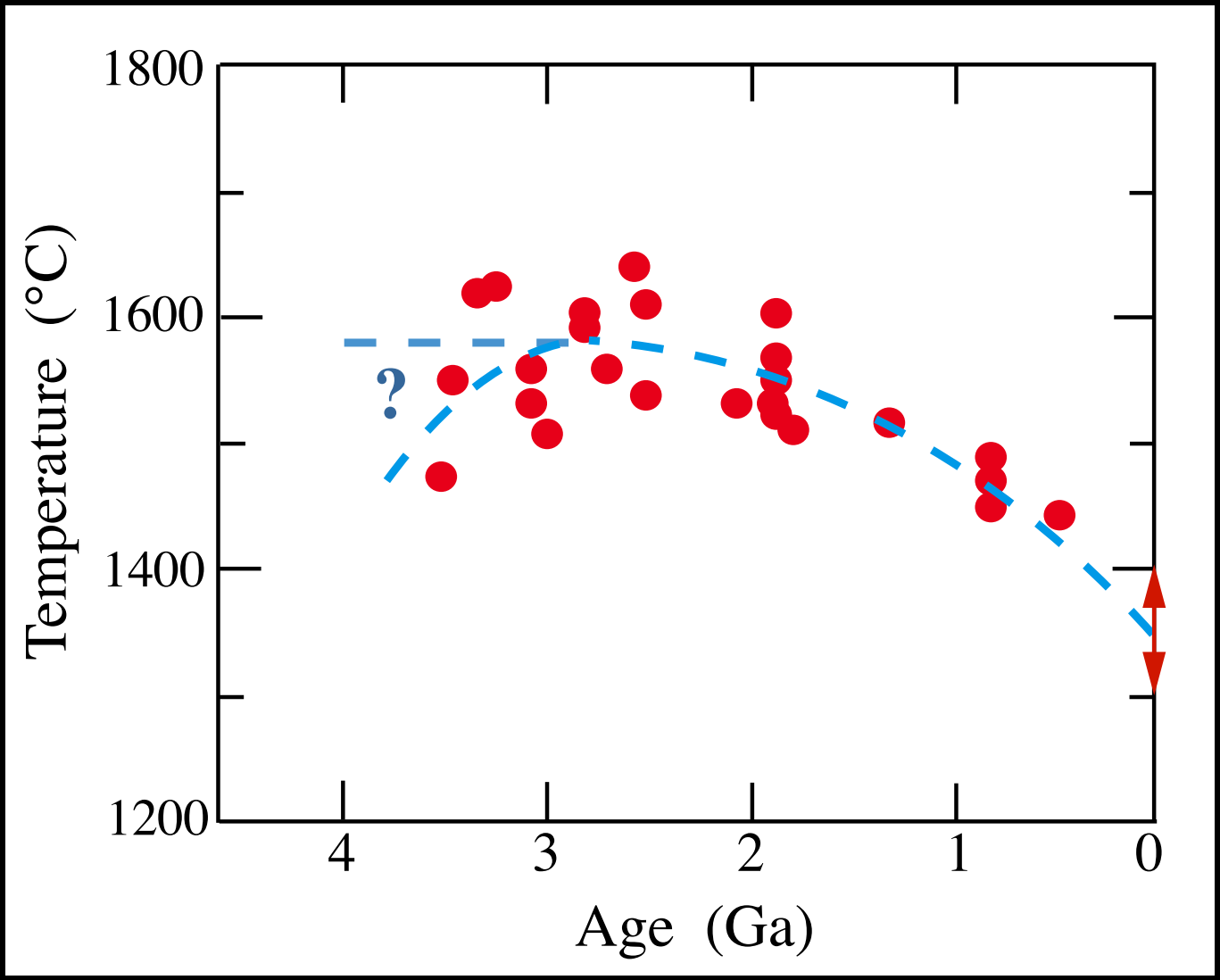



Temperature (°C)
1100
1300
1500
1700
1900
Plagioclase
Spinel
lherzolite
15%
25%
45%
70%
Liquidus
Solidus
1380°C
1480°C
today
past
Pressure (GPa)
2
4
6
8

At high temperature, Mg-rich basalt: komatiites

Barberton, South Africa

Mantle temperature vs. time



SECULAR COOLING EQUATION

$$M\,C_p\,\frac{dT}{dt} = -\int q_r\,dA + \int H\,dV + \int \psi\,dV$$

$$= \text{- surface heat loss}$$
$$\text{+ internal heat production}$$
$$\text{+ external energy tranfers (ex: tidal interaction)}$$

Note (1) : negligible contribution of contraction, zero contribution of dissipation

Note (2) : external energy transfers are negligible

$$M C_p \frac{dT}{dt} = -\int q_r \, dA + \int H \, dV$$

Core cooling (geodynamo) = 5 - 17 TW

Bulk Silicate Earth (BSE) radiogenic heat production
≈ 13 - 23 TW

Surface heat loss = 46 ± 3 TW

Secular cooling (mantle) ≈ 1 - 29 TW

Inferred from heat budget ≈ 7 - 200 K Gy^{-1}

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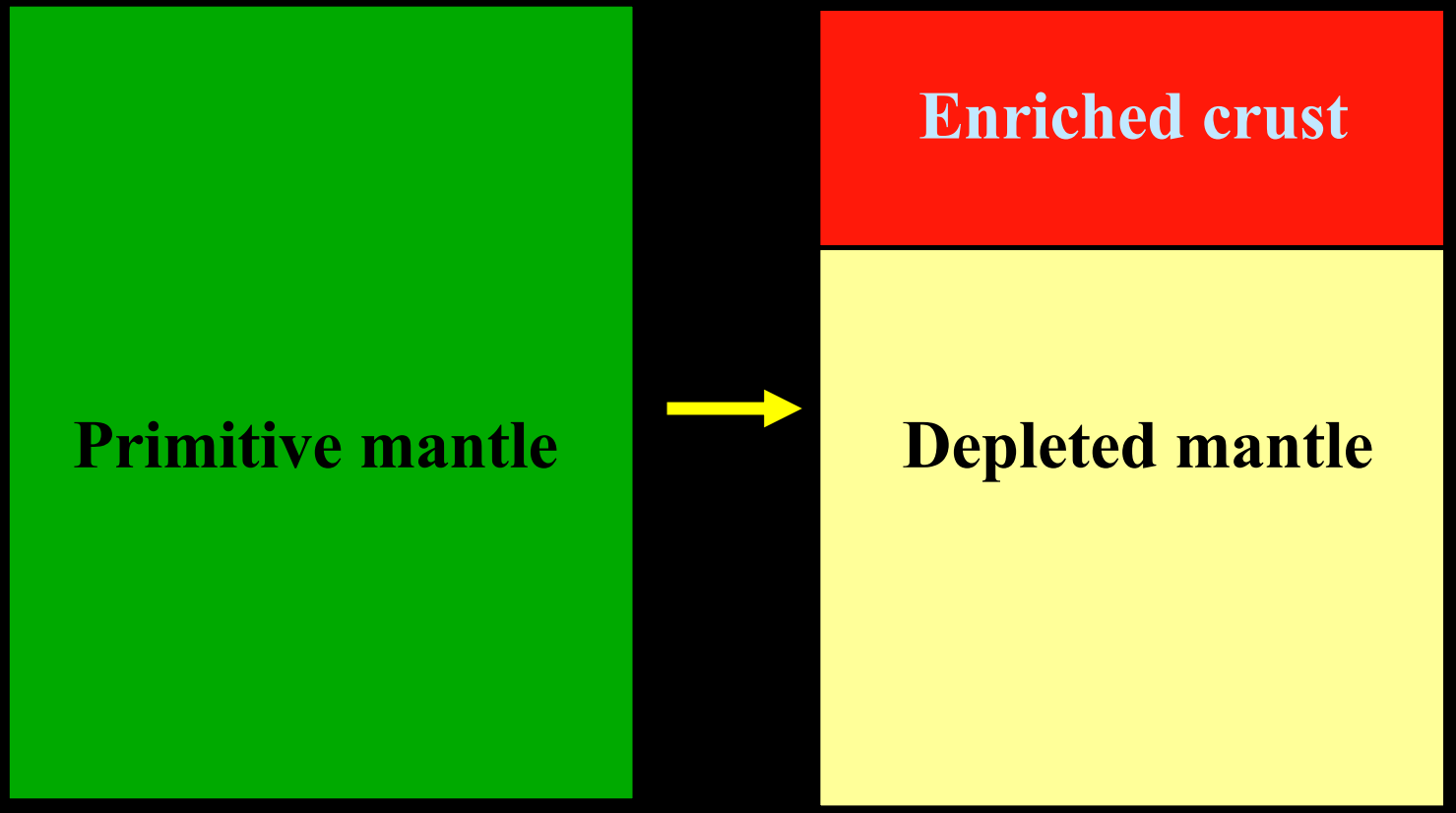
Surface heat loss = 46 ± 3 TW

Secular cooling (mantle) ≈ 1 - 29 TW
Inferred from heat budget ≈ **7 - 200 K Gy^{-1}**

Secular cooling (mantle) ≈ **25 - 75 K Gy^{-1}**
Deduced from lavas ≈ 4 - 12 TW

Formation of continental crust


Primitive mantle
Enriched crust
Depleted mantle

Is this significant ?

Bulk Silicate Earth

= **13 - 23 TW**

Continental Crust (+ lithos. mantle) (40% of total area)

= **6 - 8 TW**

Bulk Silicate Earth models

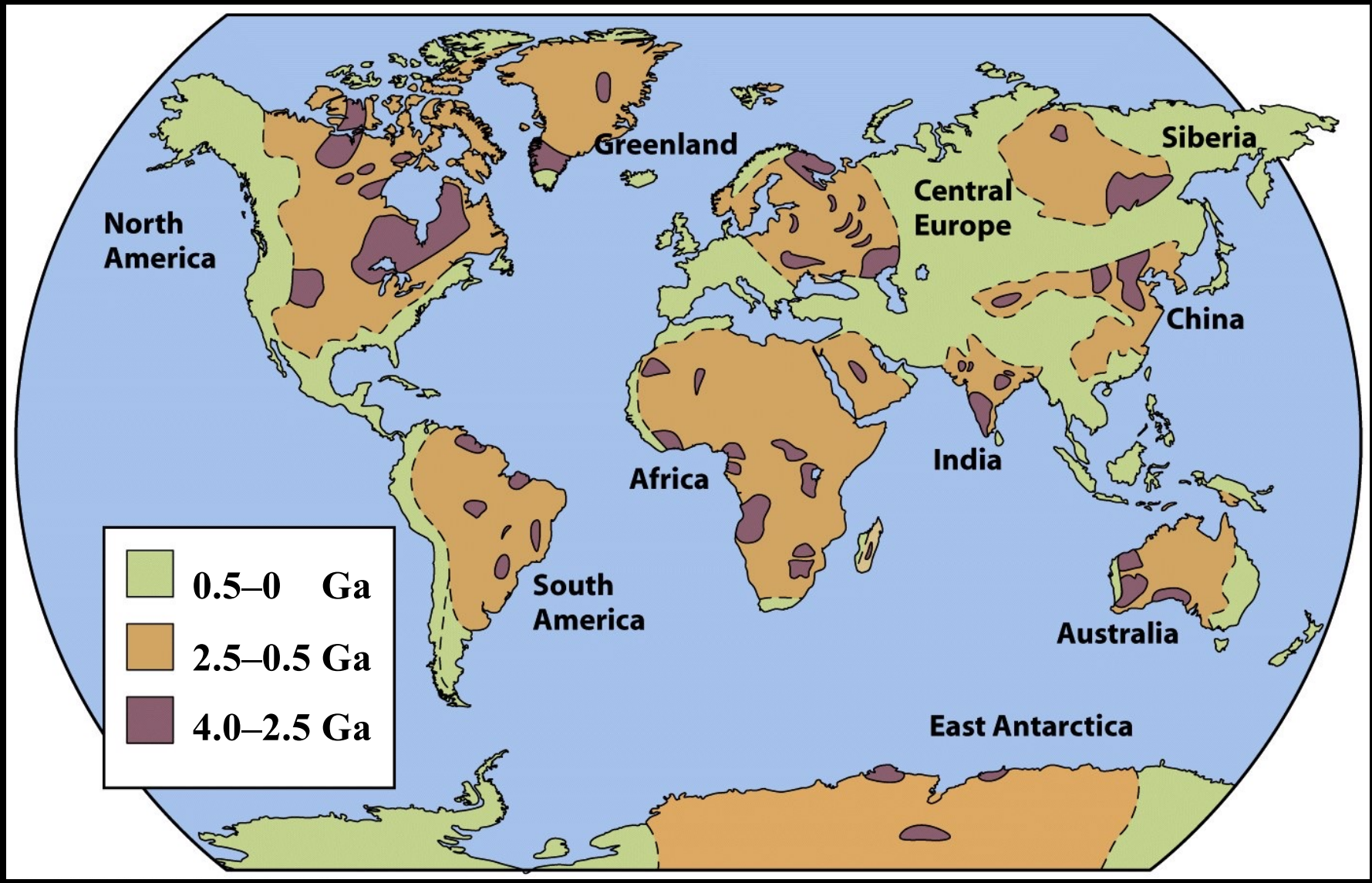
= **13 - 24 TW**

Continental Crust (+ lithos. mantle) (40% of total area)

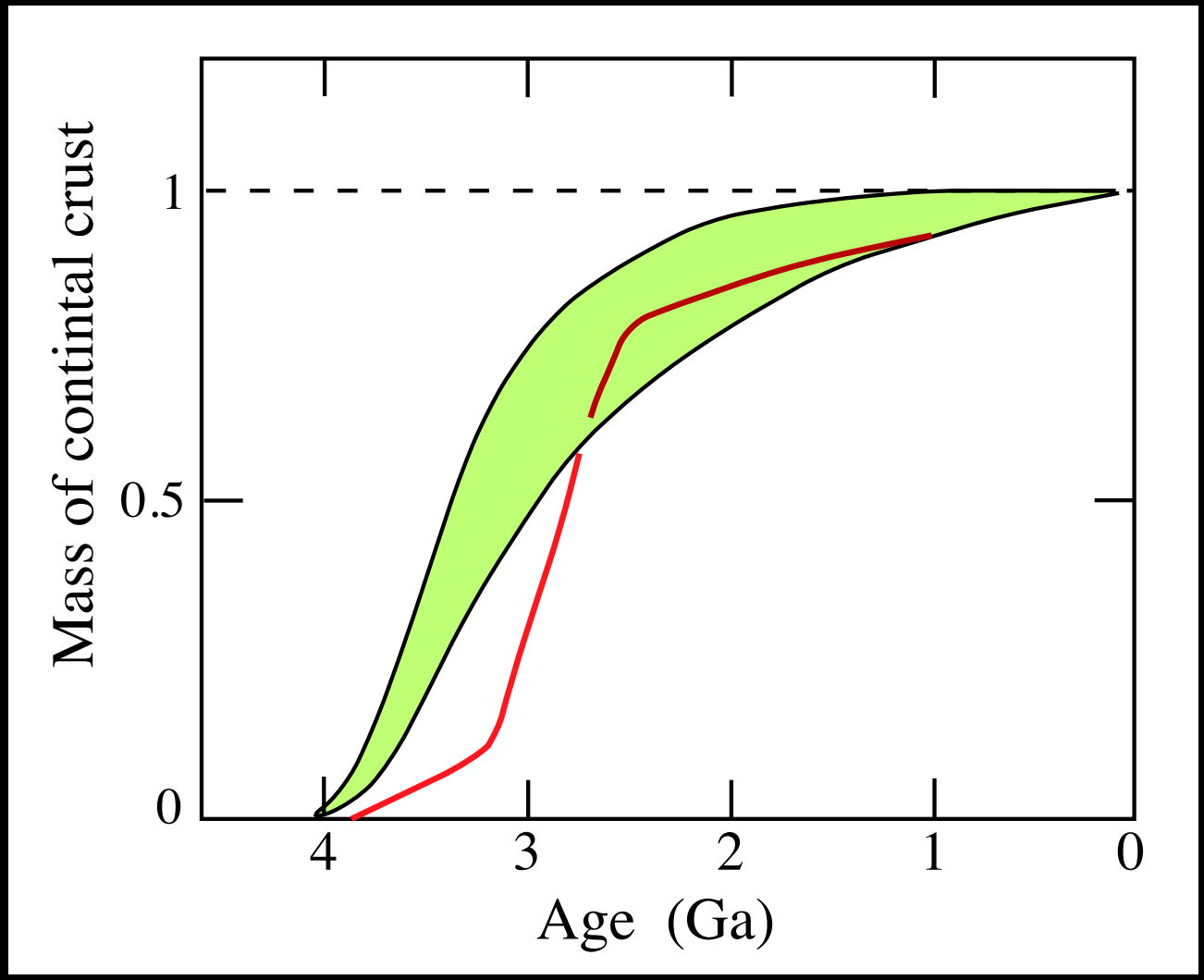
= **6 - 8 TW**

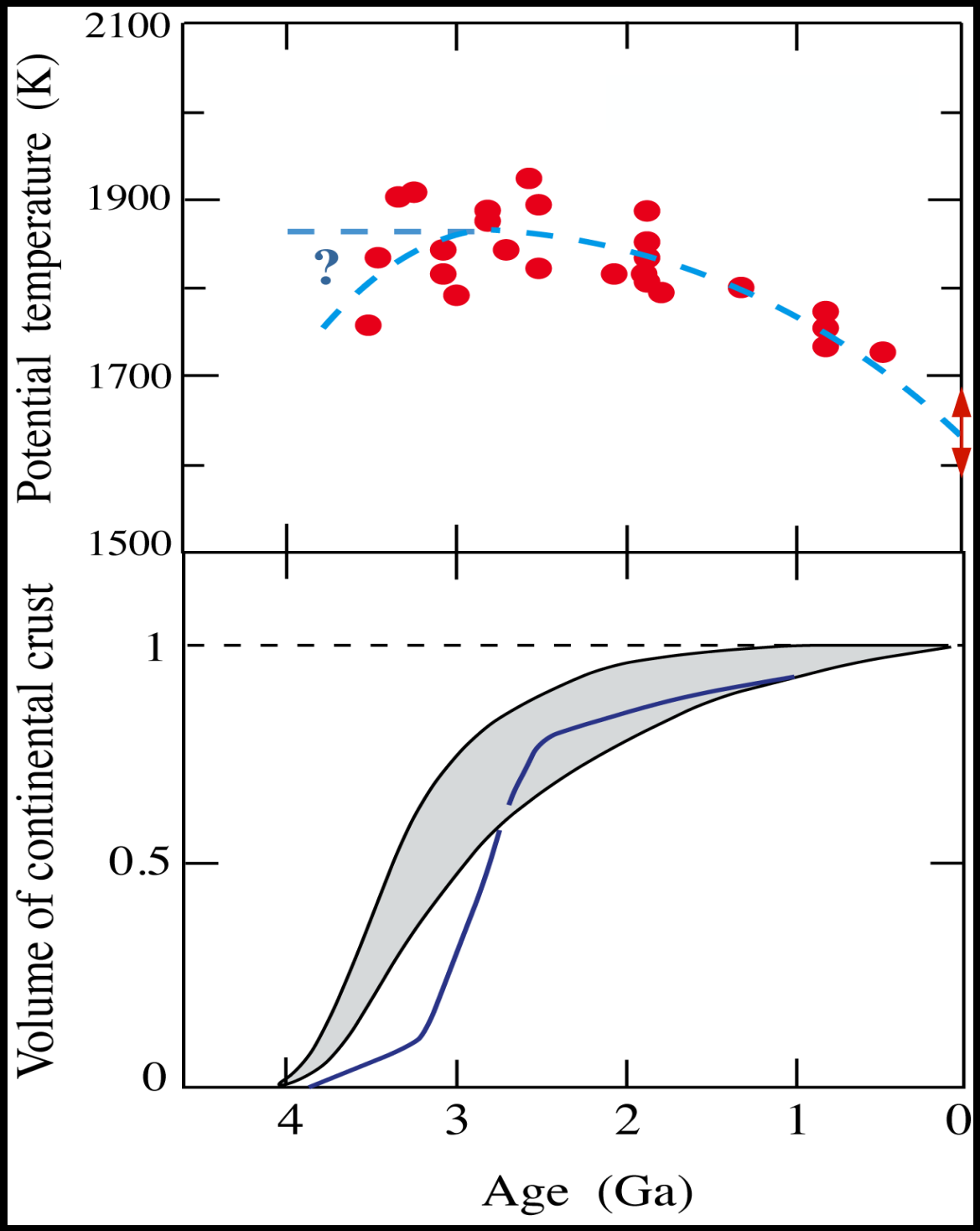
Continental Crust over whole Earth's surface

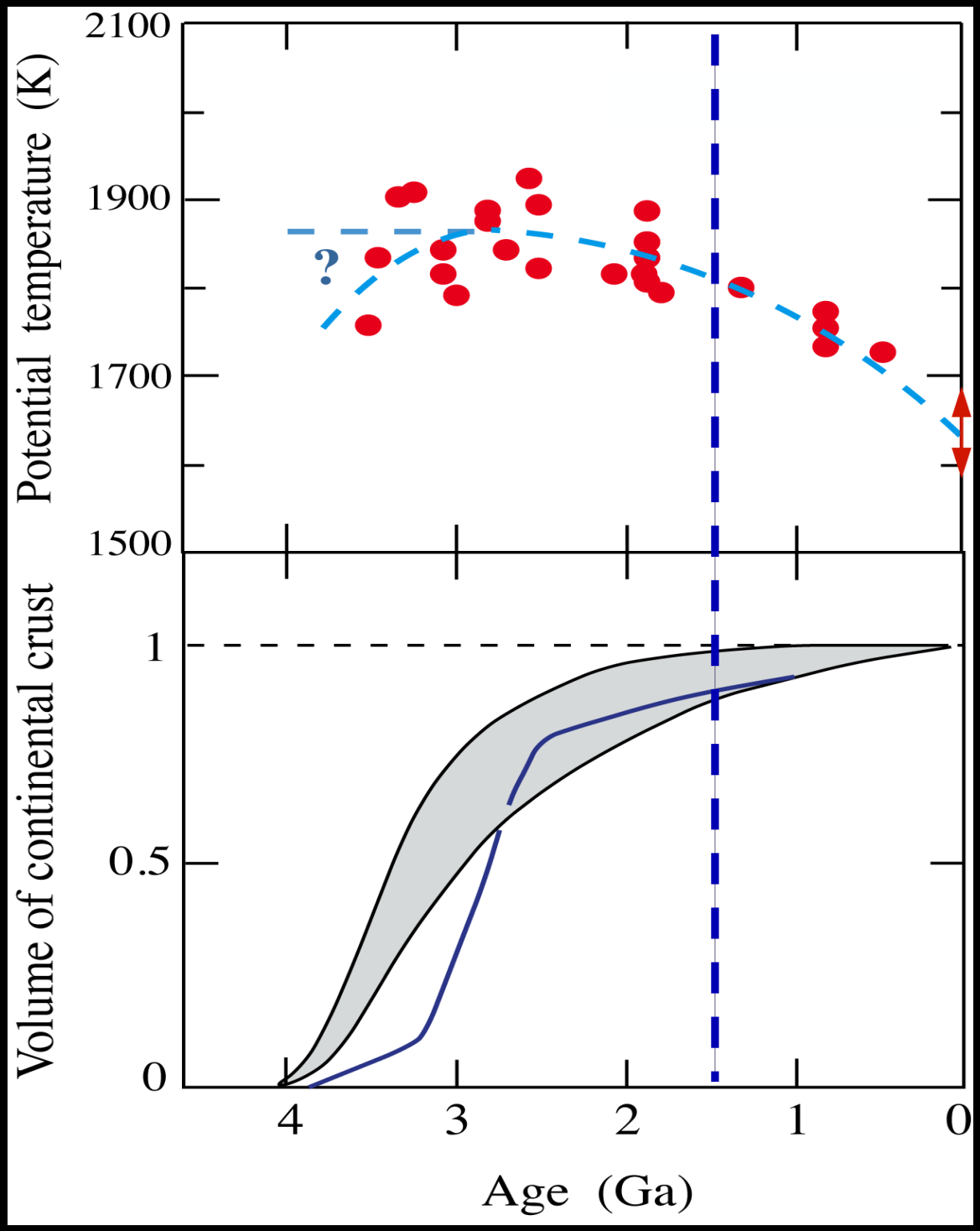
= **15 - 20 TW**


Greenland
Siberia
Central
Europe
North
America
China
India
Africa
South
America
Australia
East Antarctica
0.5–0 Ga
2.5–0.5 Ga
4.0–2.5 Ga

Growth of continents



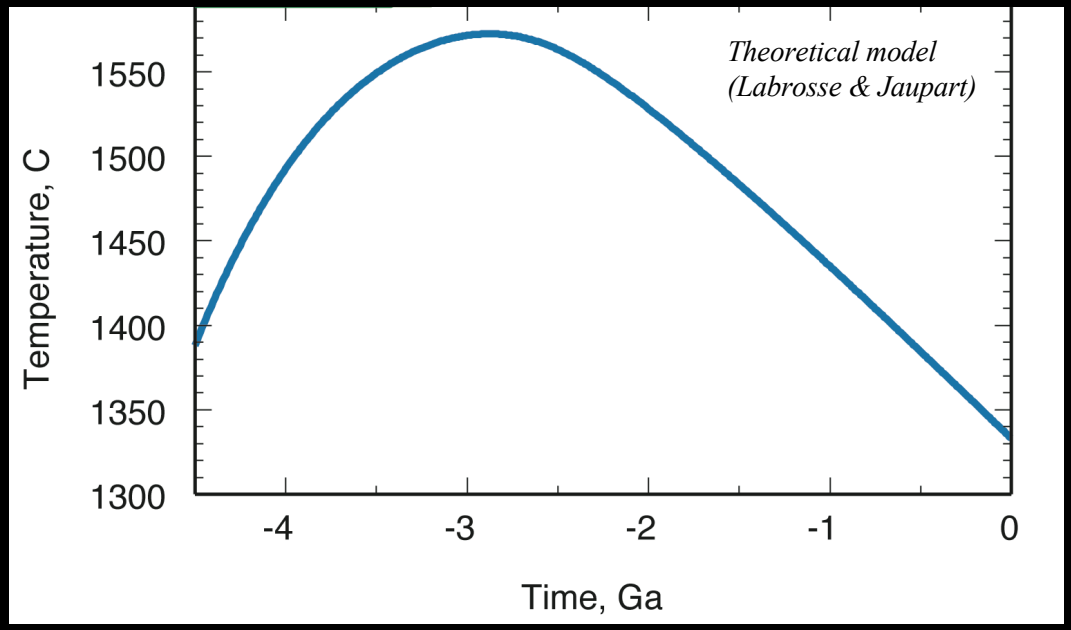

2100
1900
1700
1500
Potential temperature (K)
?
1
0.5
0
Volume of continental crust
4
3
2
1
0
Age (Ga)

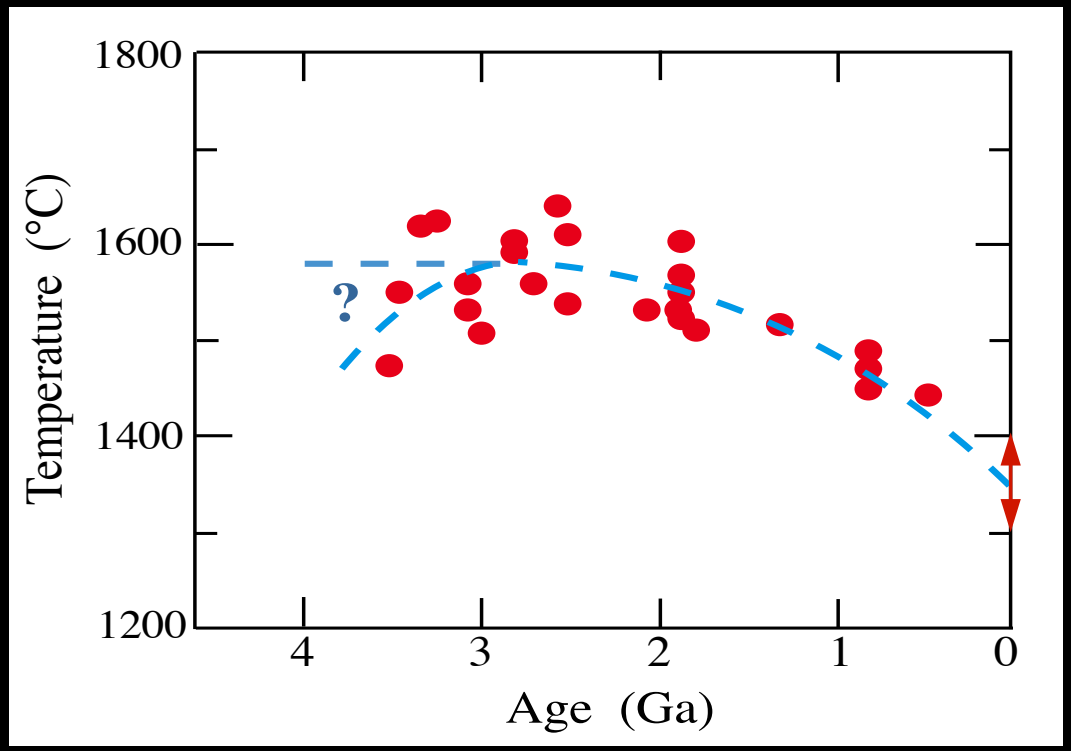

2100
1900
1700
1500
Potential temperature (K)
?
1
0.5
0
Volume of continental crust
4
3
2
1
0
Age (Ga)

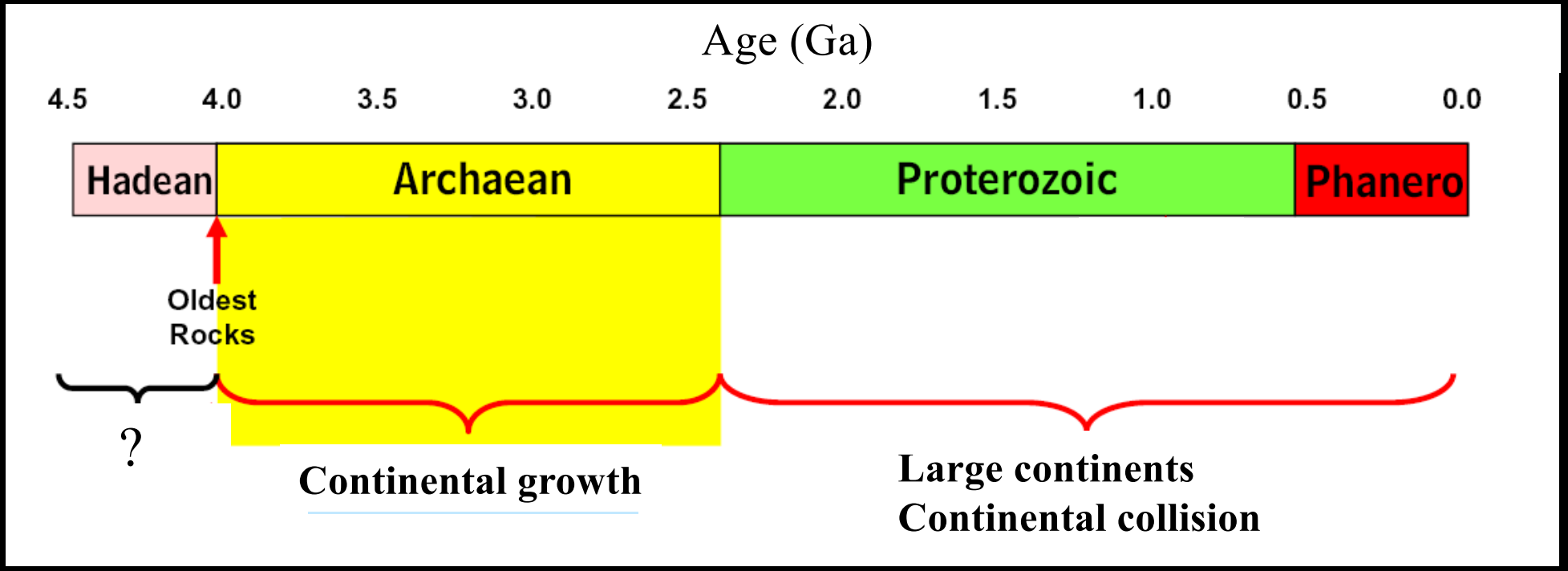
Continental growth:
two competing effects

(1) Mantle depletion (decreasing heat production).
Acts to decrease mantle temperature.

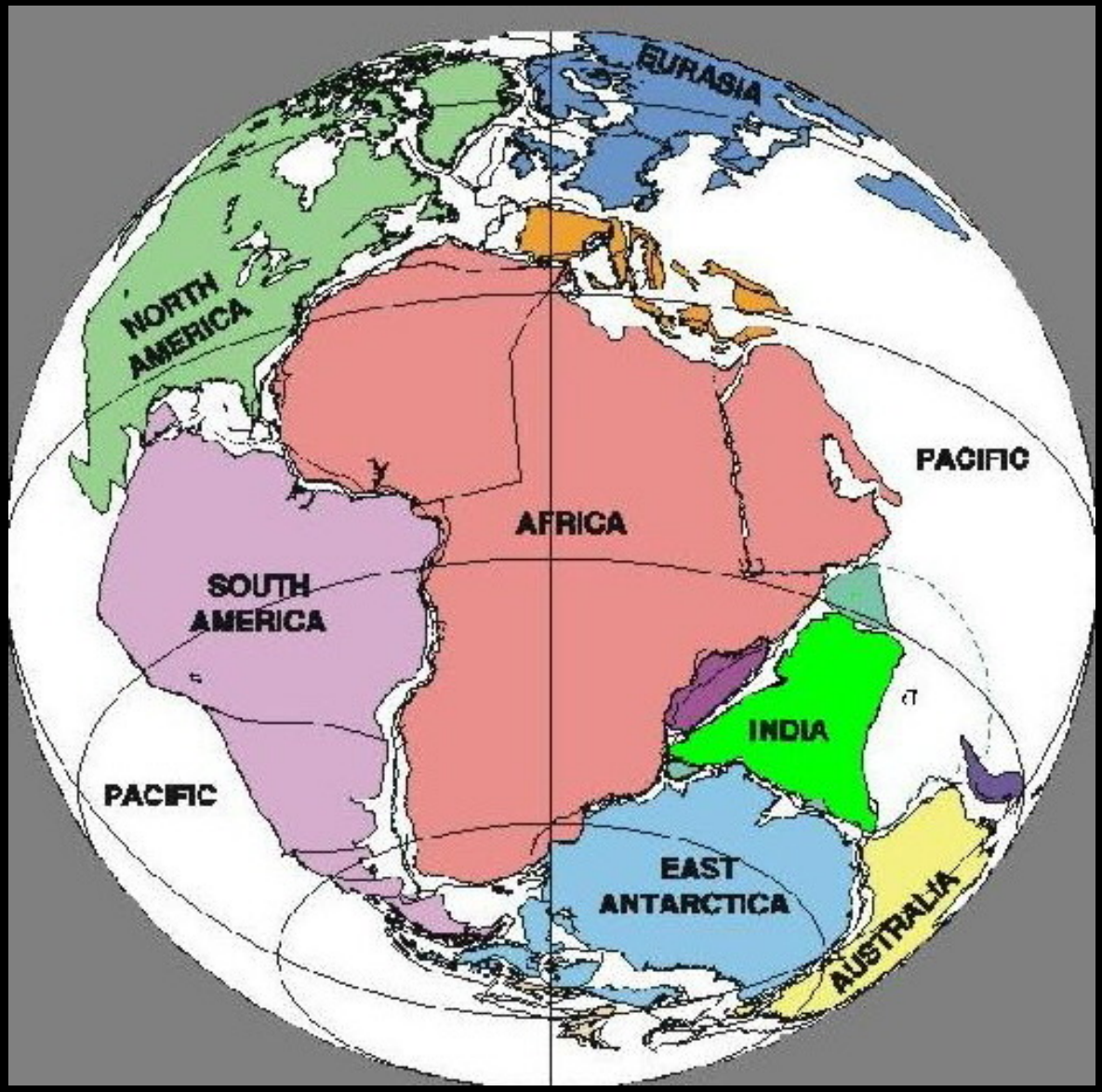
(2) Mantle isolation (decreasing oceanic area).
Acts to increase temperature.


Theoretical model
(Labrosse & Jaupart)
Temperature, C
1550
1500
1450
1400
1350
1300
-4
-3
-2
-1
0
Time, Ga


Temperature (°C)
1800
1600
1400
1200
?
4
3
2
1
0
Age (Ga)


Age (Ga)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Hadean
Archaean
Proterozoic
Phanero
Oldest Rocks
?
Continental growth
Large continents
Continental collision

Amalgamation and dispersal of supercontinents



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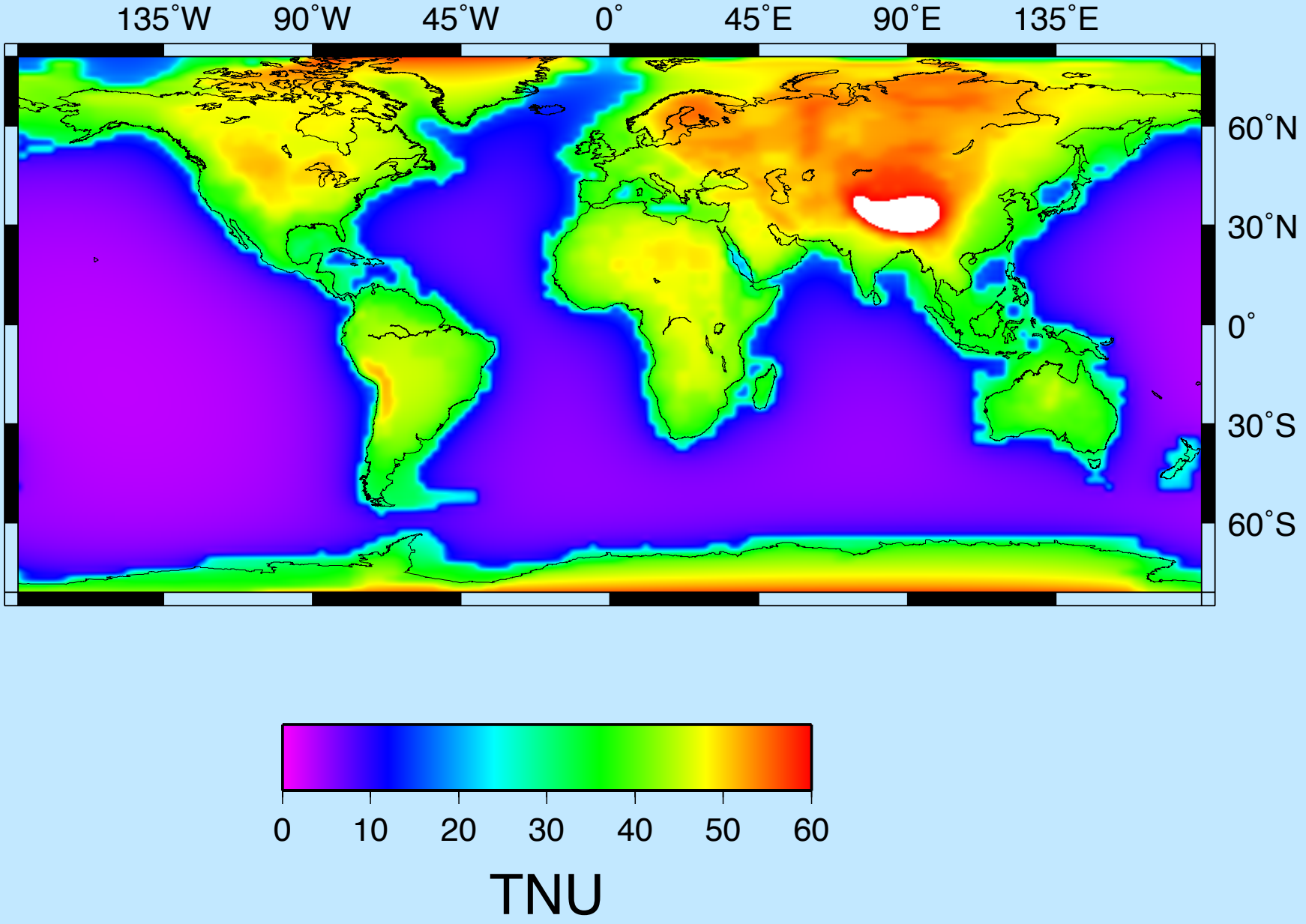
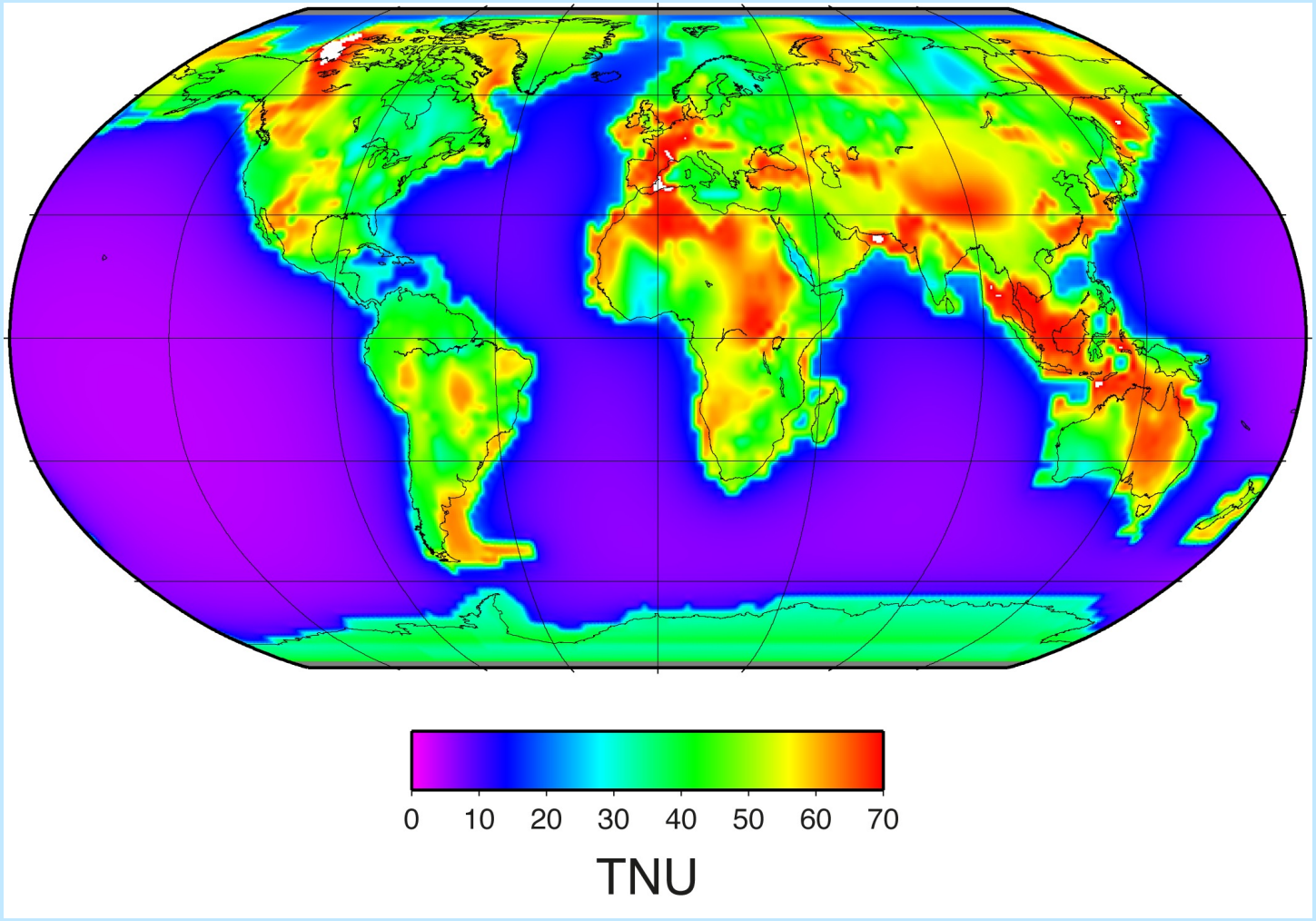
Geoneutrino flux (from crustal model)



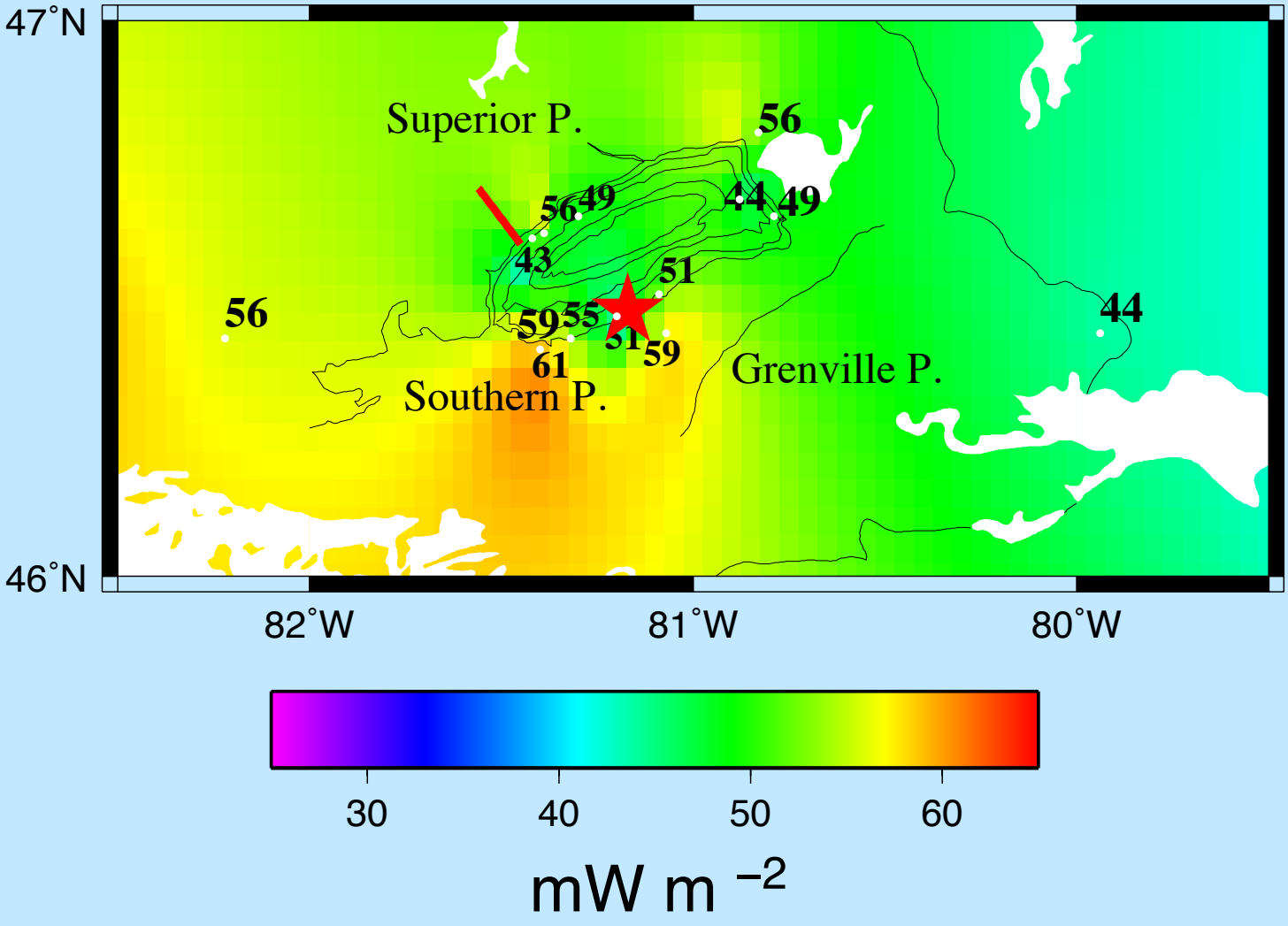
1 TNU = 1 geoneutrino event recorded over a year-long fully efficient exposure of 10^{32} free protons, which is approximately the number of free protons in a 1 kiloton liquid scintillation detector.

Geoneutrino flux (from heat flux data)

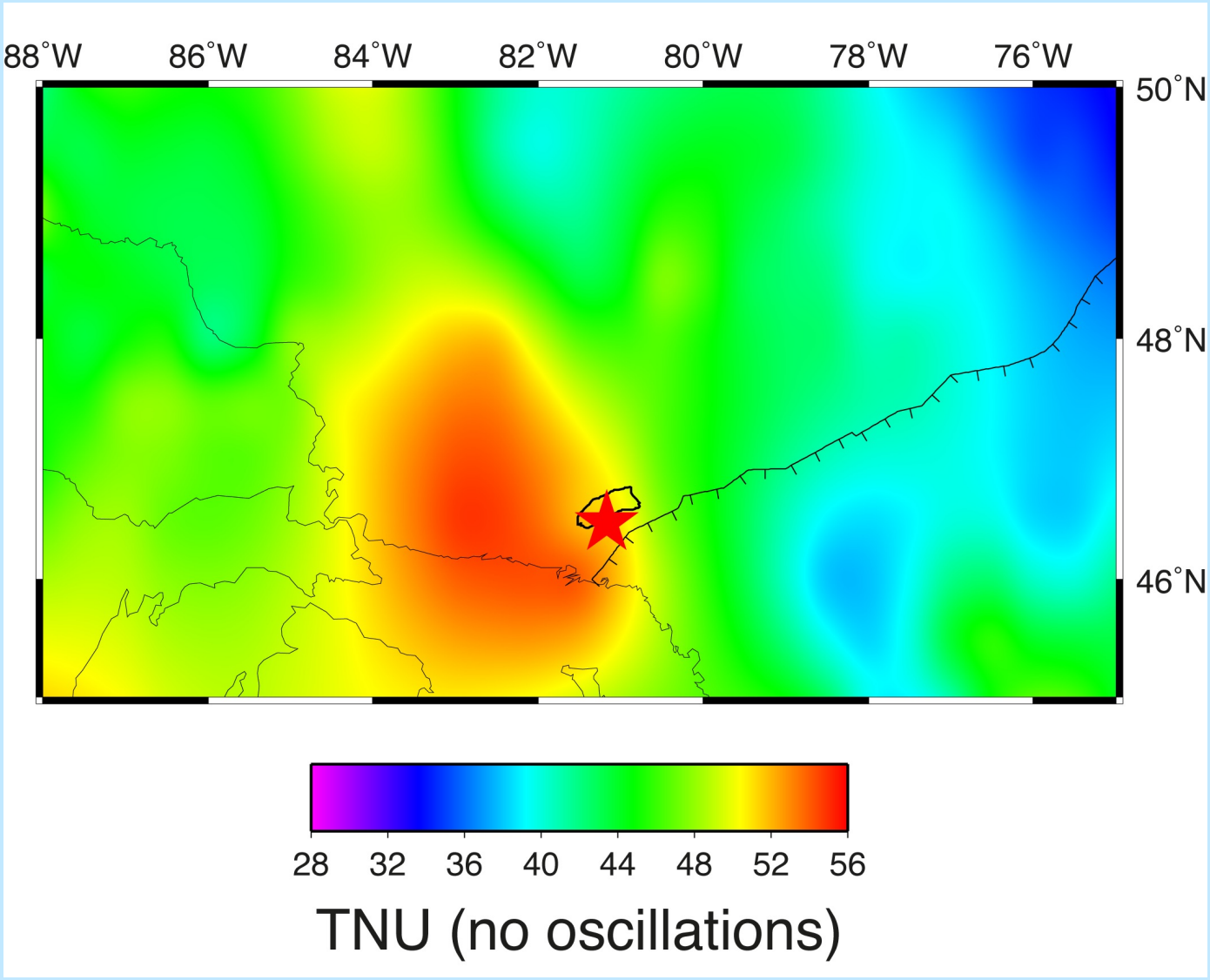


To be compared to:
depleted mantle contribution = 11 TNU

SNOLAB, Sudbury, Canada



Local crustal geoneutrino flux at SNO+ (Canada)



THE END

Even the Earth's magnetic field …