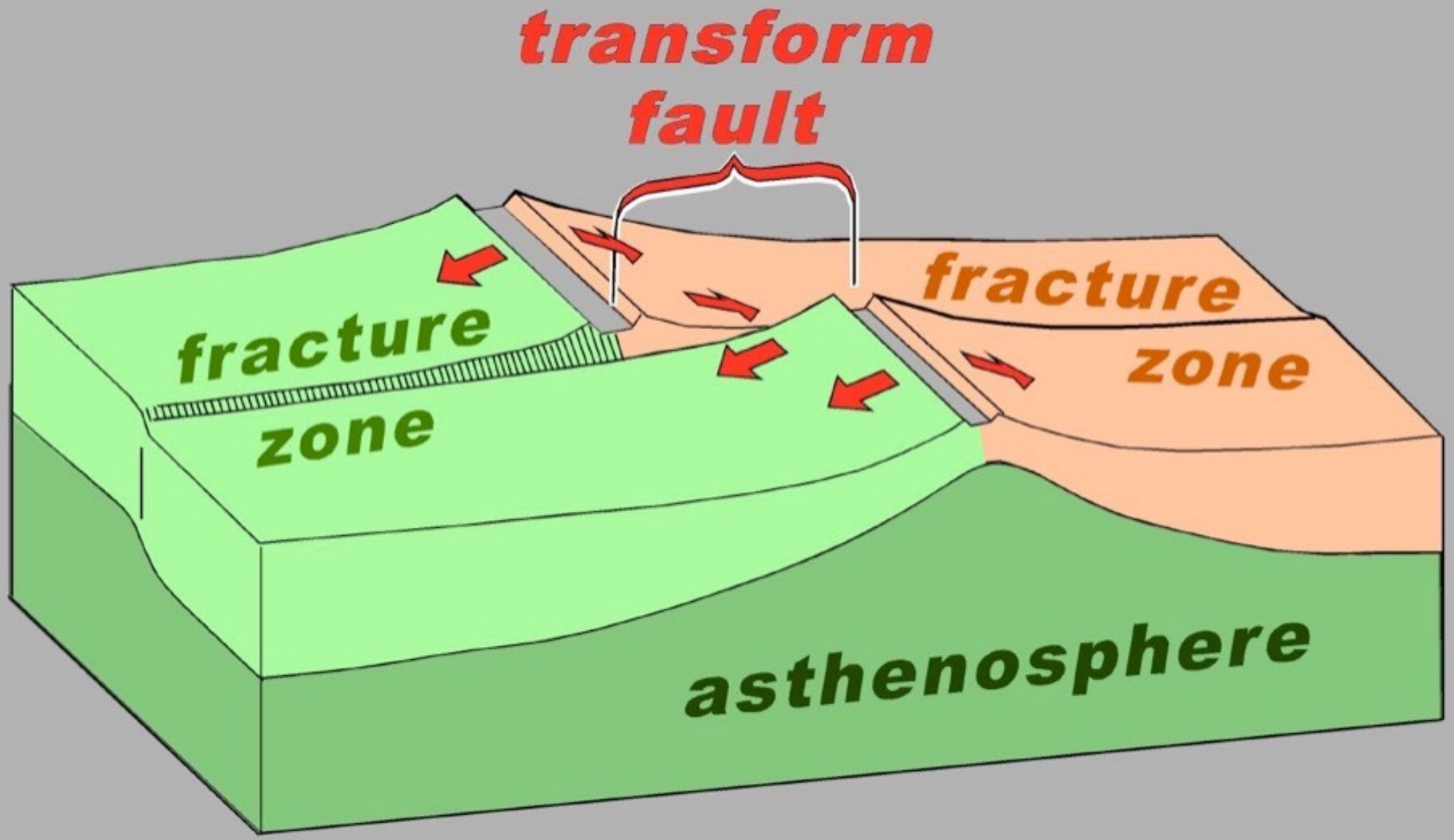
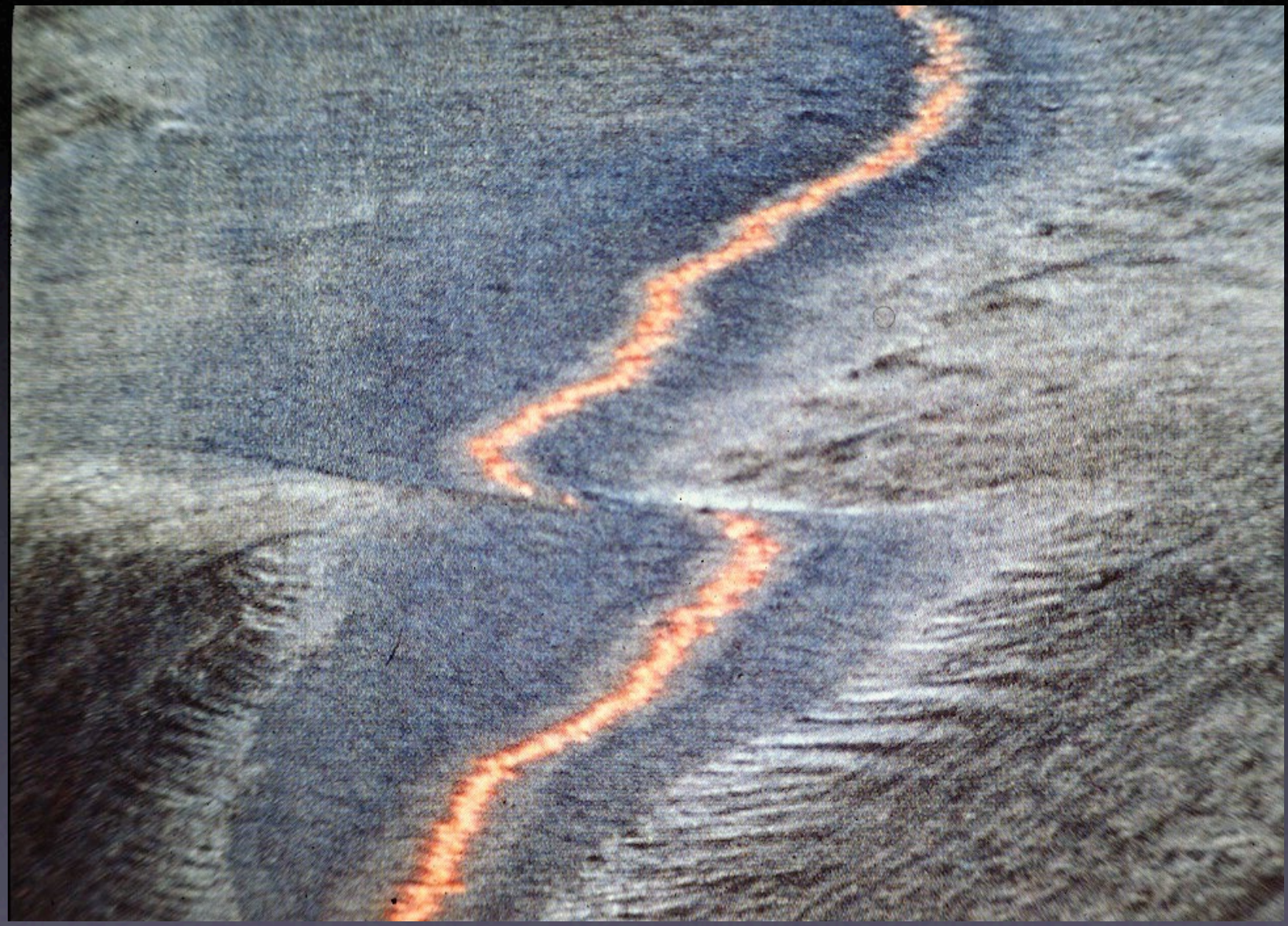
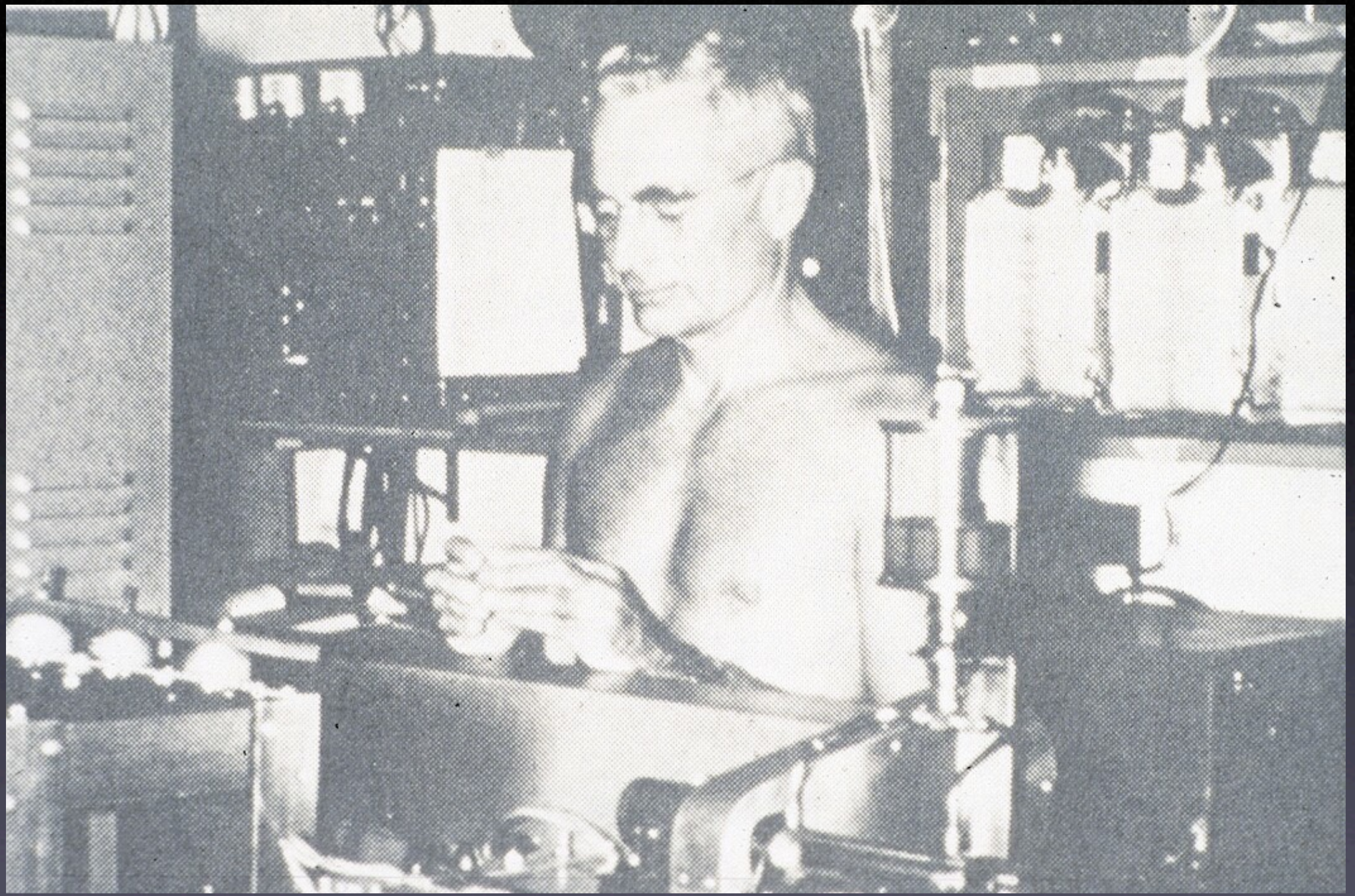
Progress in modeling the long-wavelength shape of oceanic fracture zones

Vince Cronin, revised April 2021

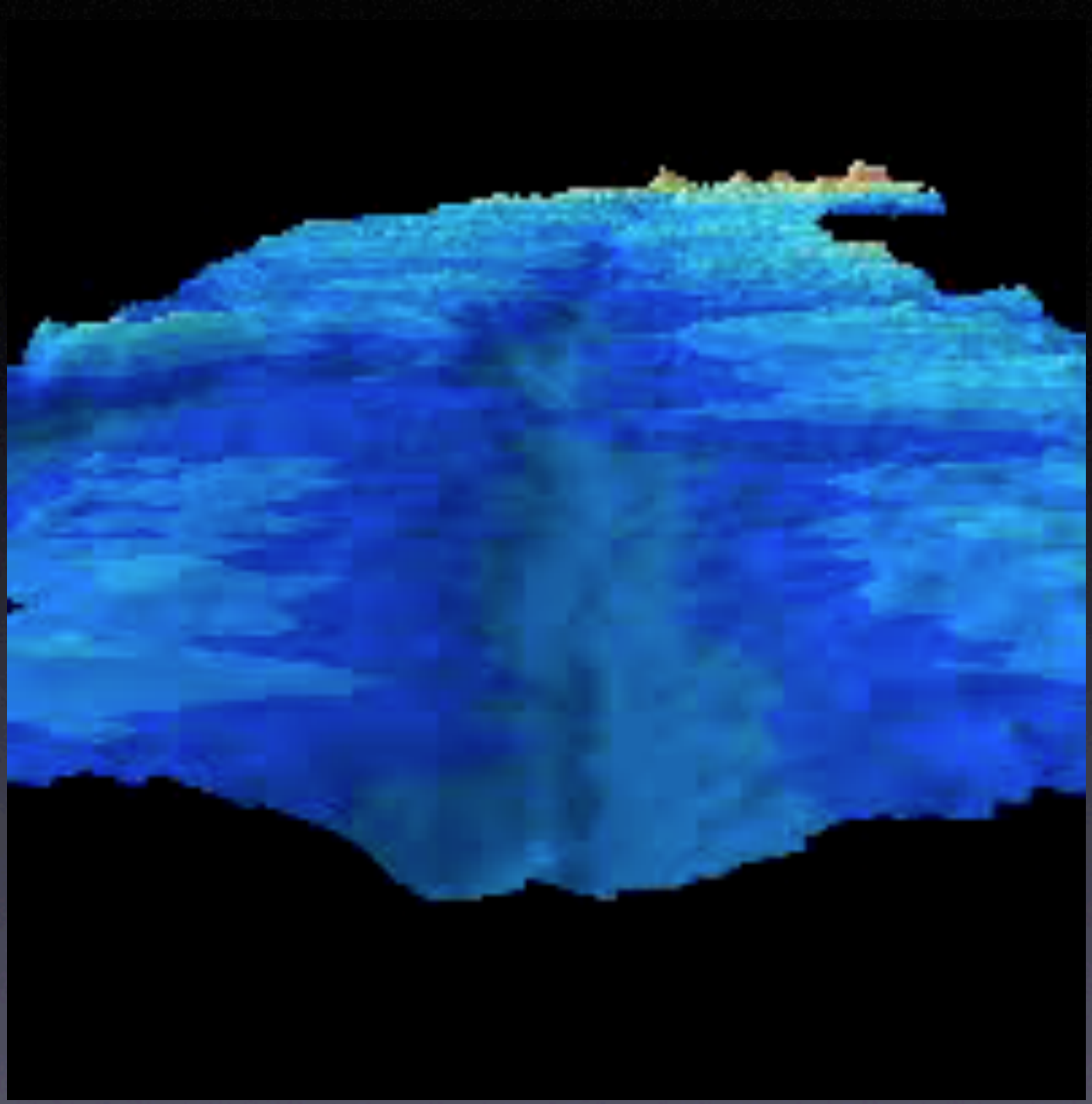
What is an oceanic fracture zone?


transform
fault
fracture
zone
fracture
zone
asthenosphere





Victor Vacquier, discoverer of oceanic fracture zones and transform faults



Pitman fracture zone

Lamont-Doherty
Geological Observatory

Progress toward a better model, and implications for the data content of oceanic fracture zones

The instantaneous velocity of one plate relative to another plate is now well known from multiple independent sources.

Instantaneous motion of individual plates can be computed relative to a frame of reference external to the plates.

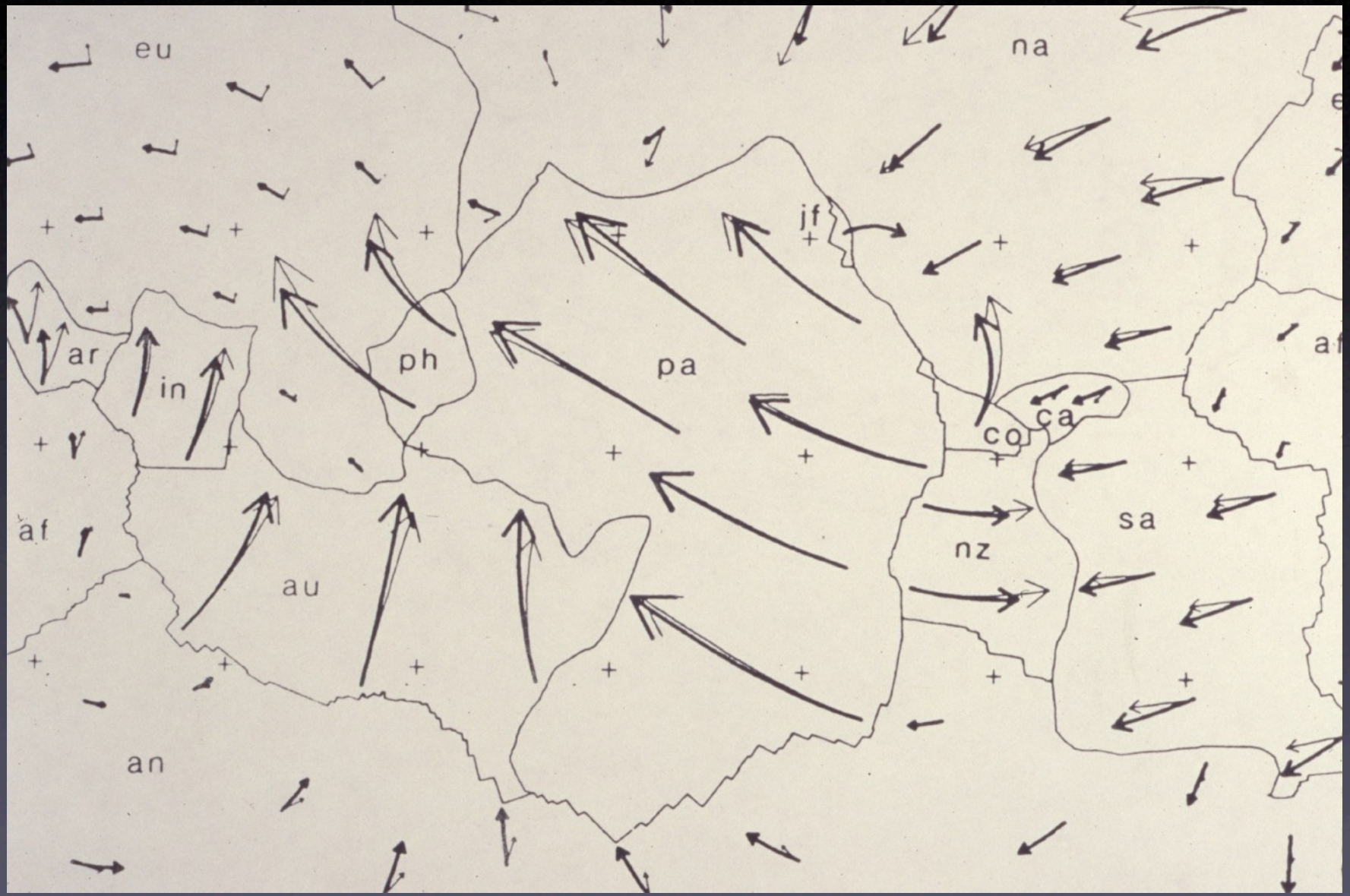


Plate motion relative to the Hawaiian hot spot, from Gripp and Gordon (1992)

$$ {}_{A}\omega_{B} = {}_{EX}\omega_{B} - {}_{EX}\omega_{A} $$

The angular velocity of plate B relative to plate A

$$ {}_{A}\omega_{B} = {}_{EX}\omega_{B} - {}_{EX}\omega_{A} $$

The angular velocity of plate B relative to plate A

is equal to

The angular velocity of plate B relative to an external frame of reference

$$ {}_{A}\omega_{B} = {}_{EX}\omega_{B} - {}_{EX}\omega_{A} $$

The angular velocity of plate B relative to plate A

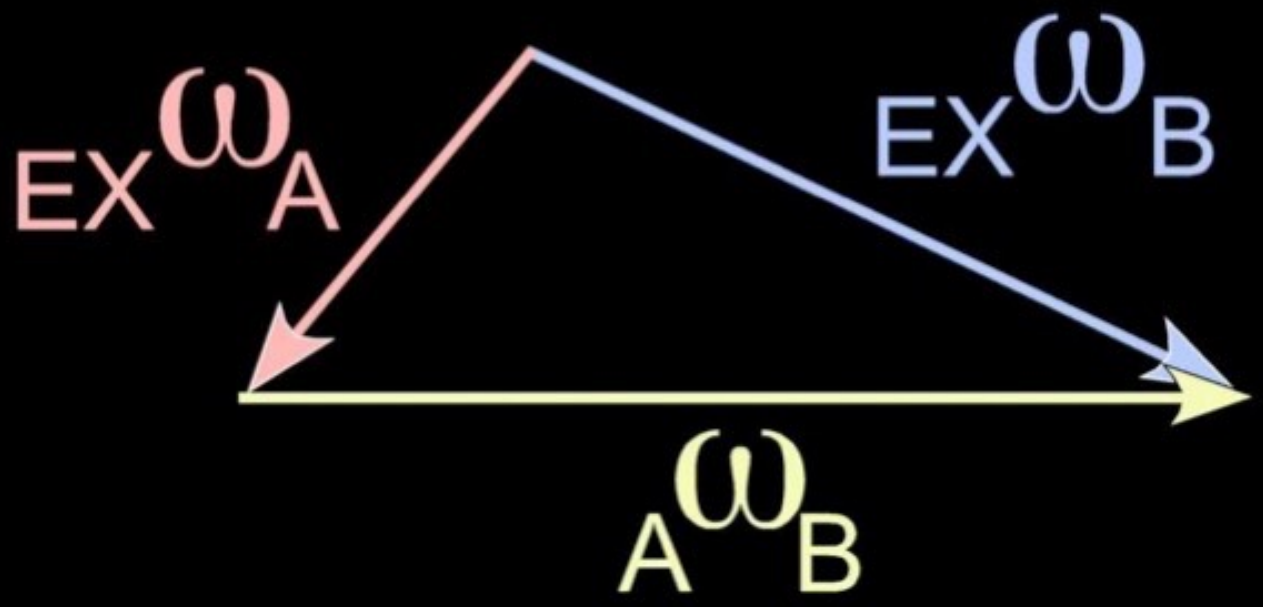
is equal to

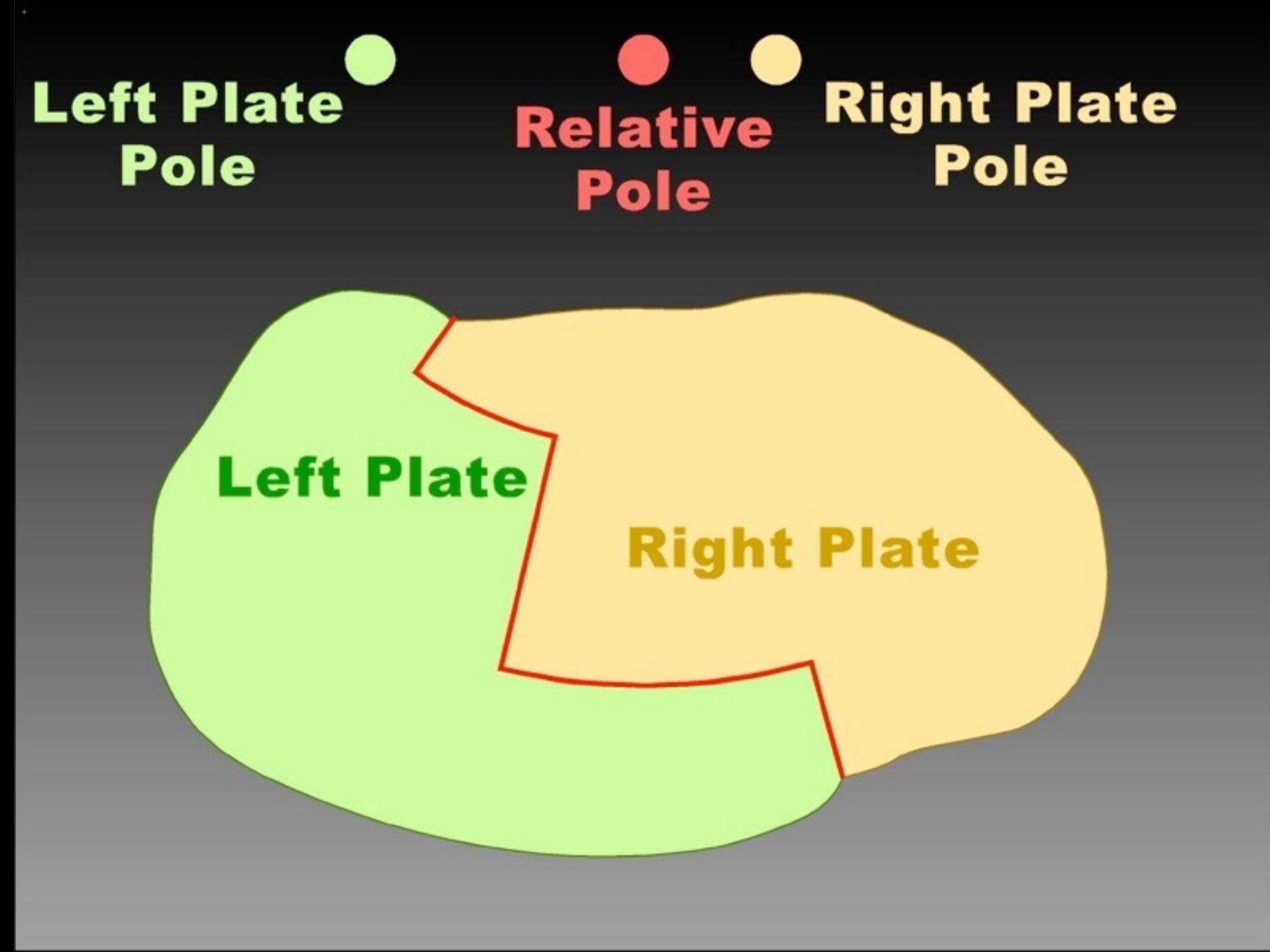
The angular velocity of plate B relative to an external frame of reference

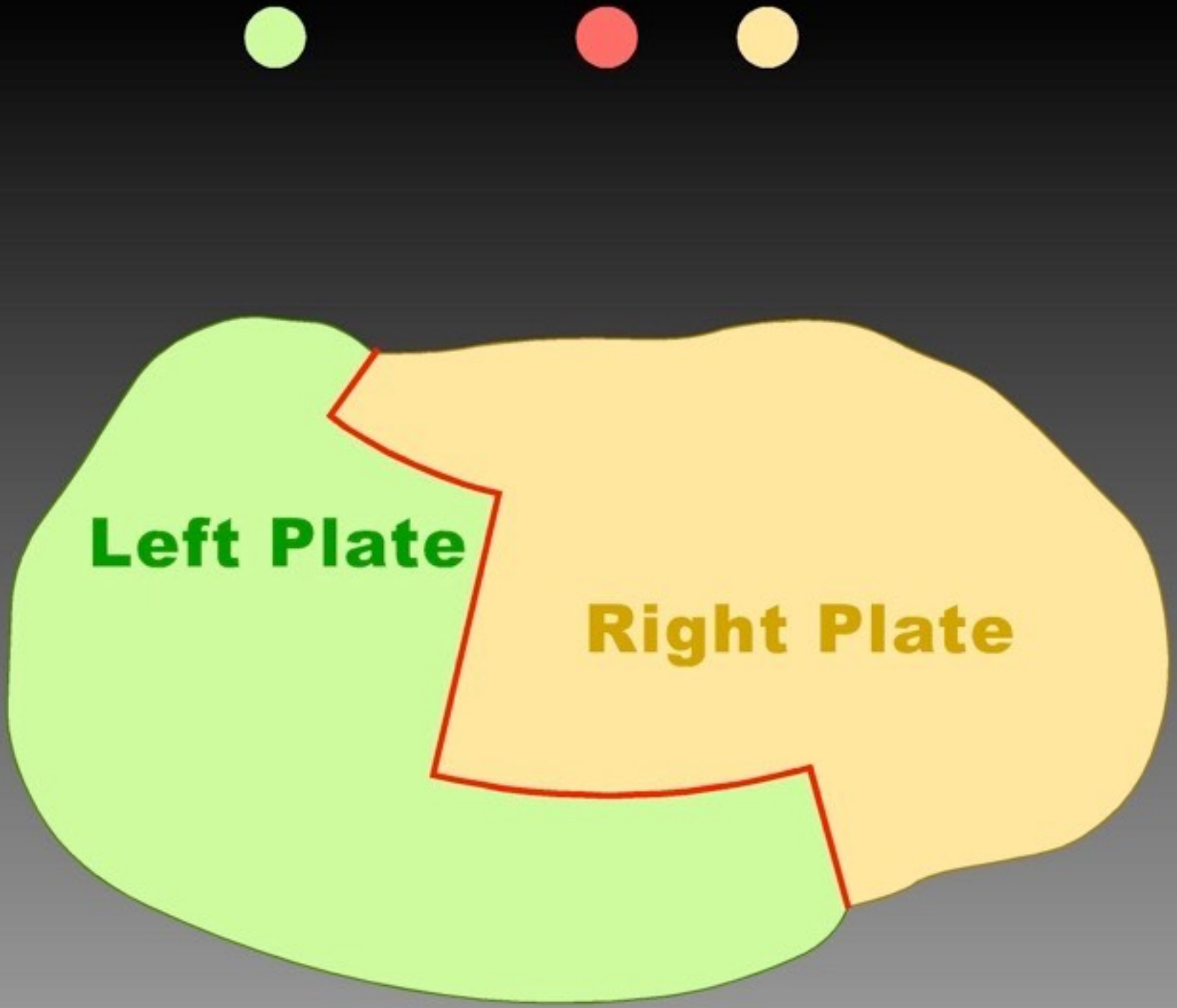
minus

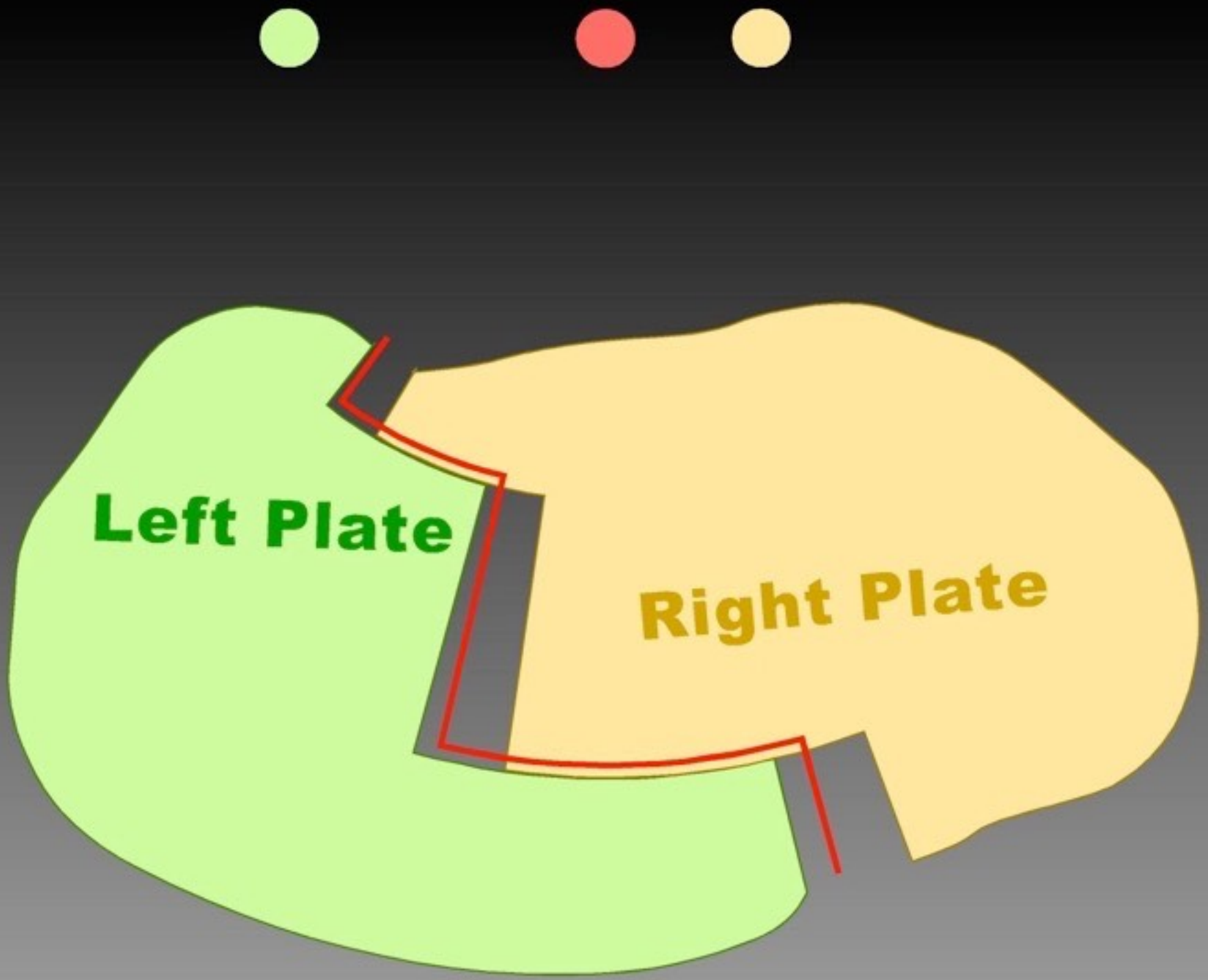
the angular velocity of plate A relative to that external reference frame.

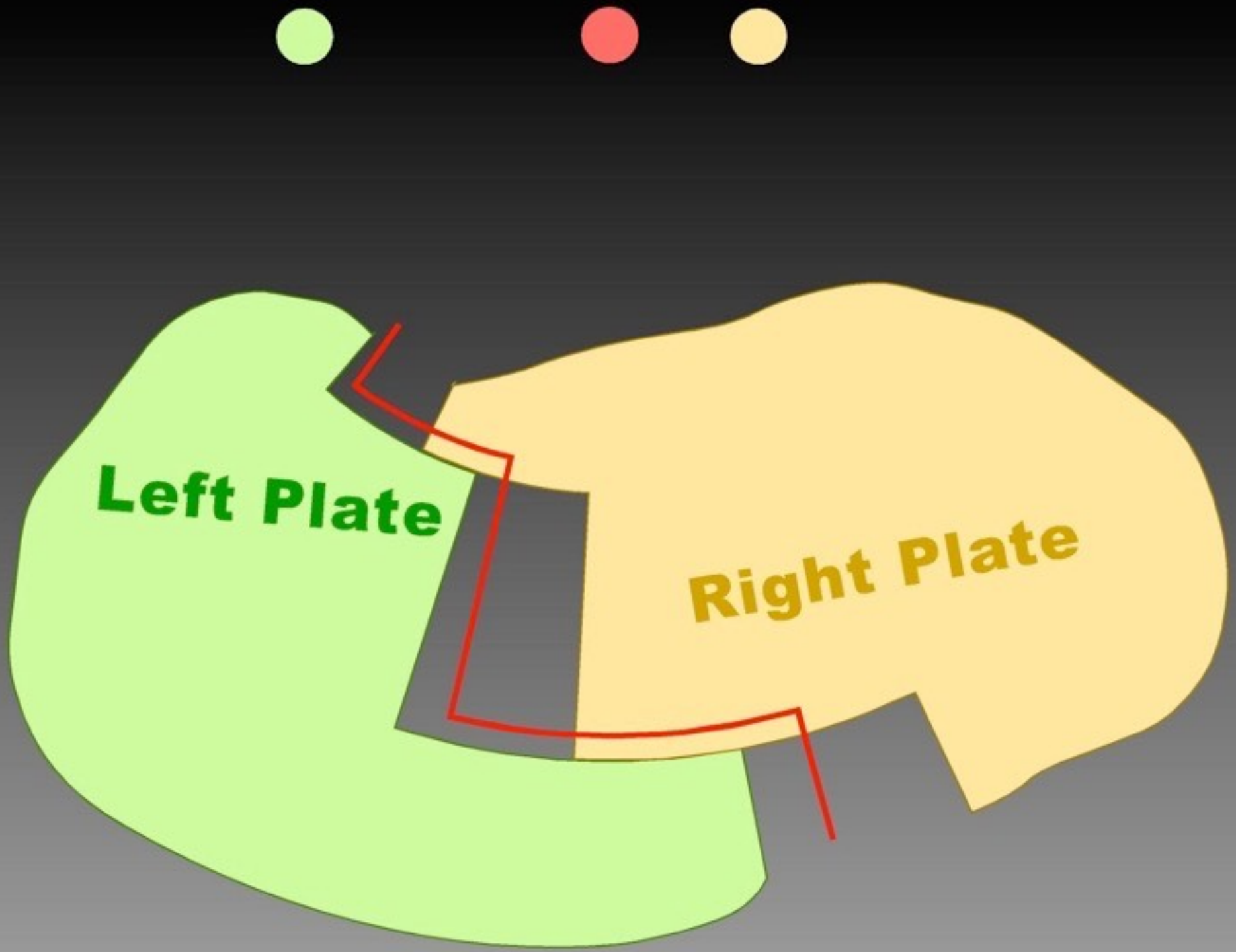
$$ {}_{A}\omega_{B} = {}_{EX}\omega_{B} - {}_{EX}\omega_{A} $$

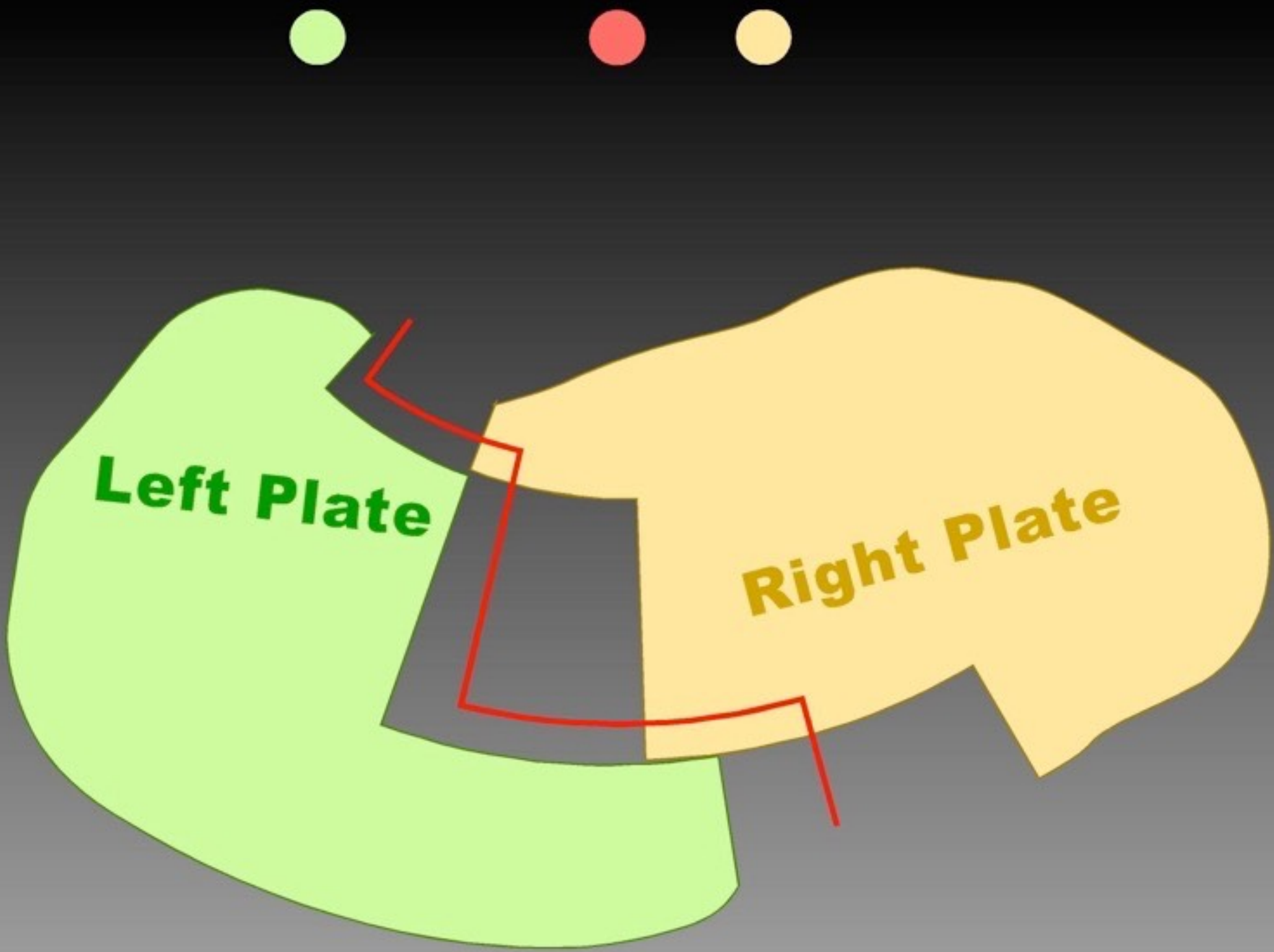


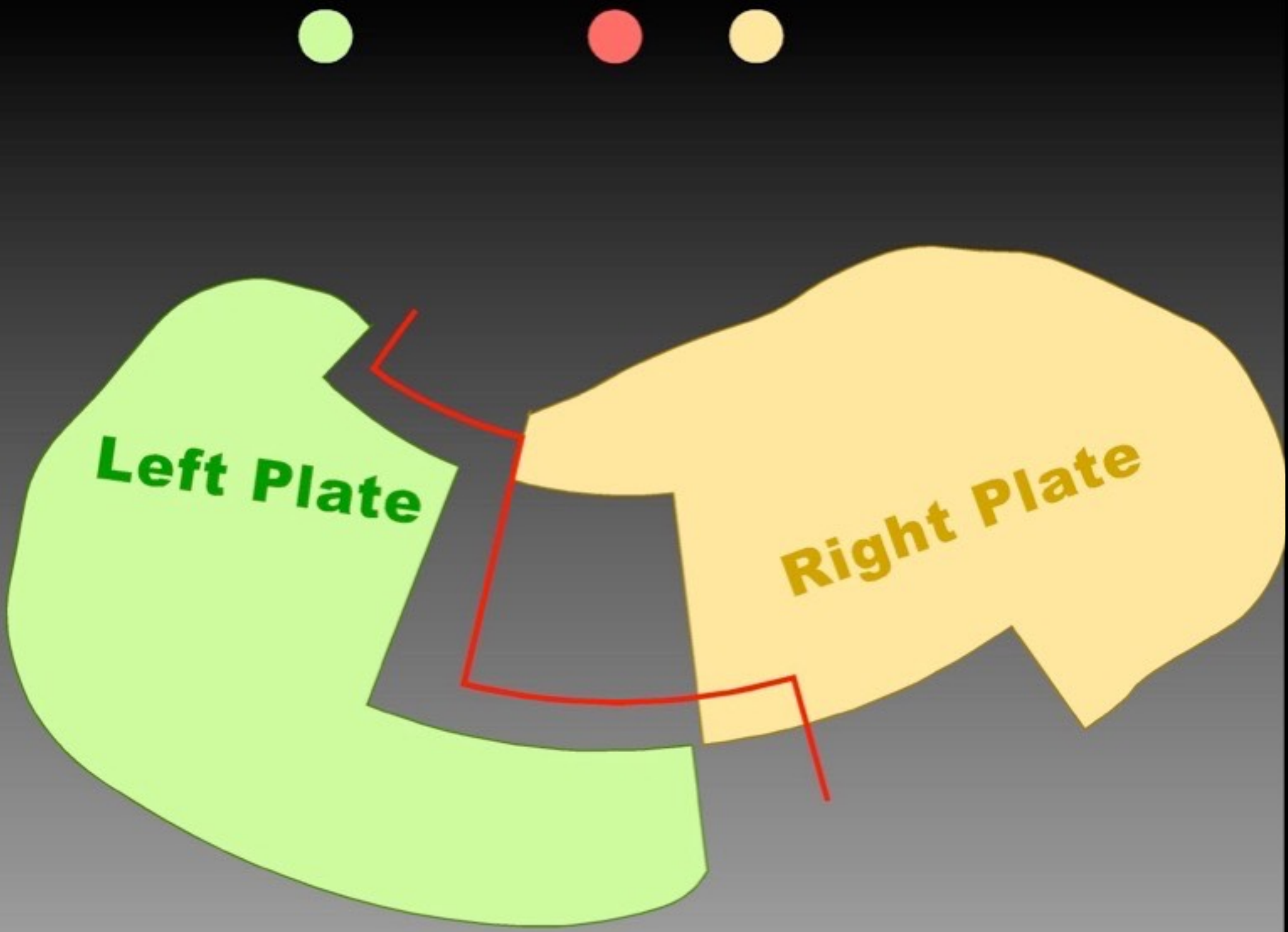

Left Plate Pole
Relative Pole
Right Plate Pole
Left Plate
Right Plate

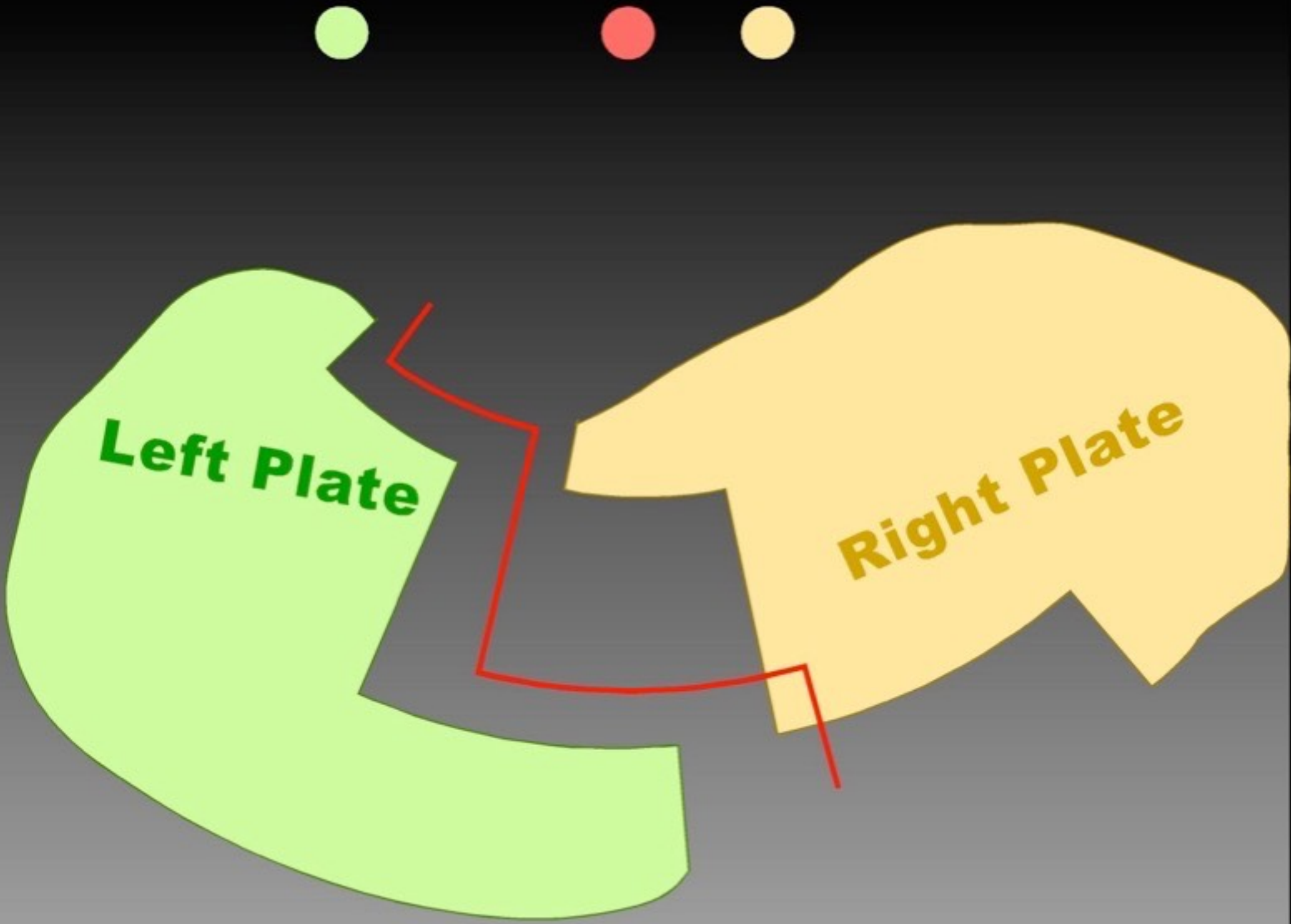

Left Plate
Right Plate

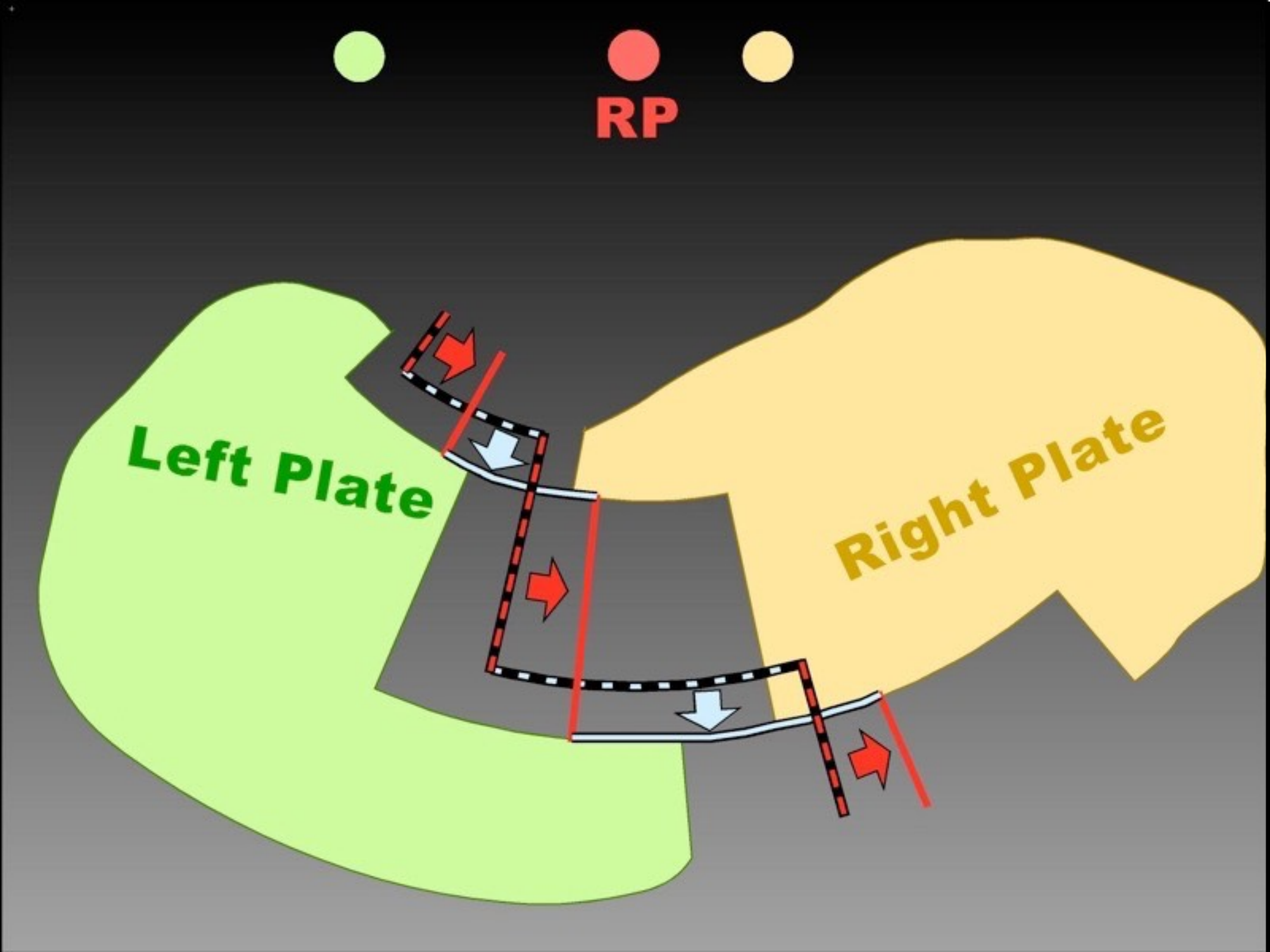

Left Plate
Right Plate


Left Plate
Right Plate


Left Plate
Right Plate

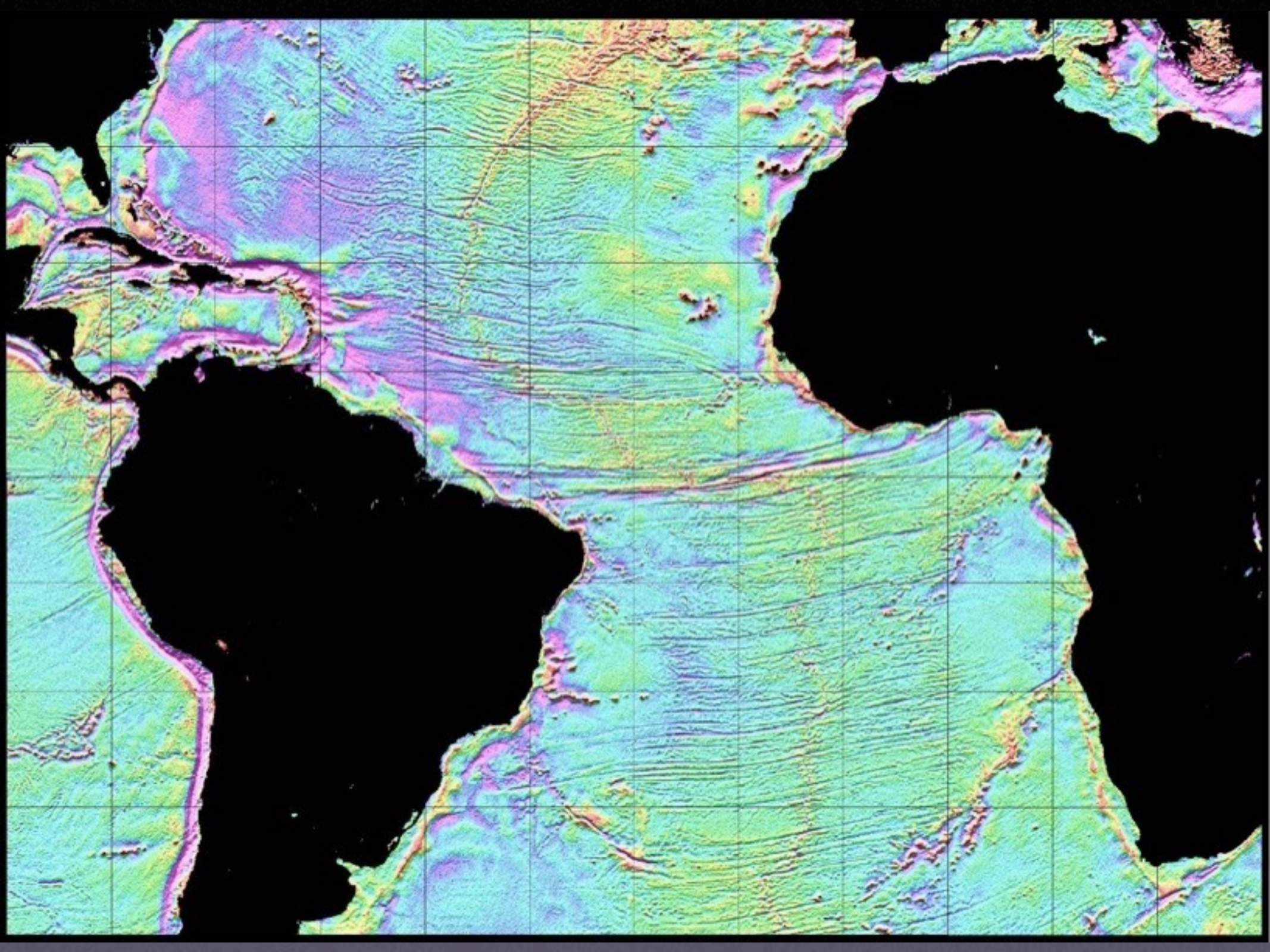

Left Plate
Right Plate

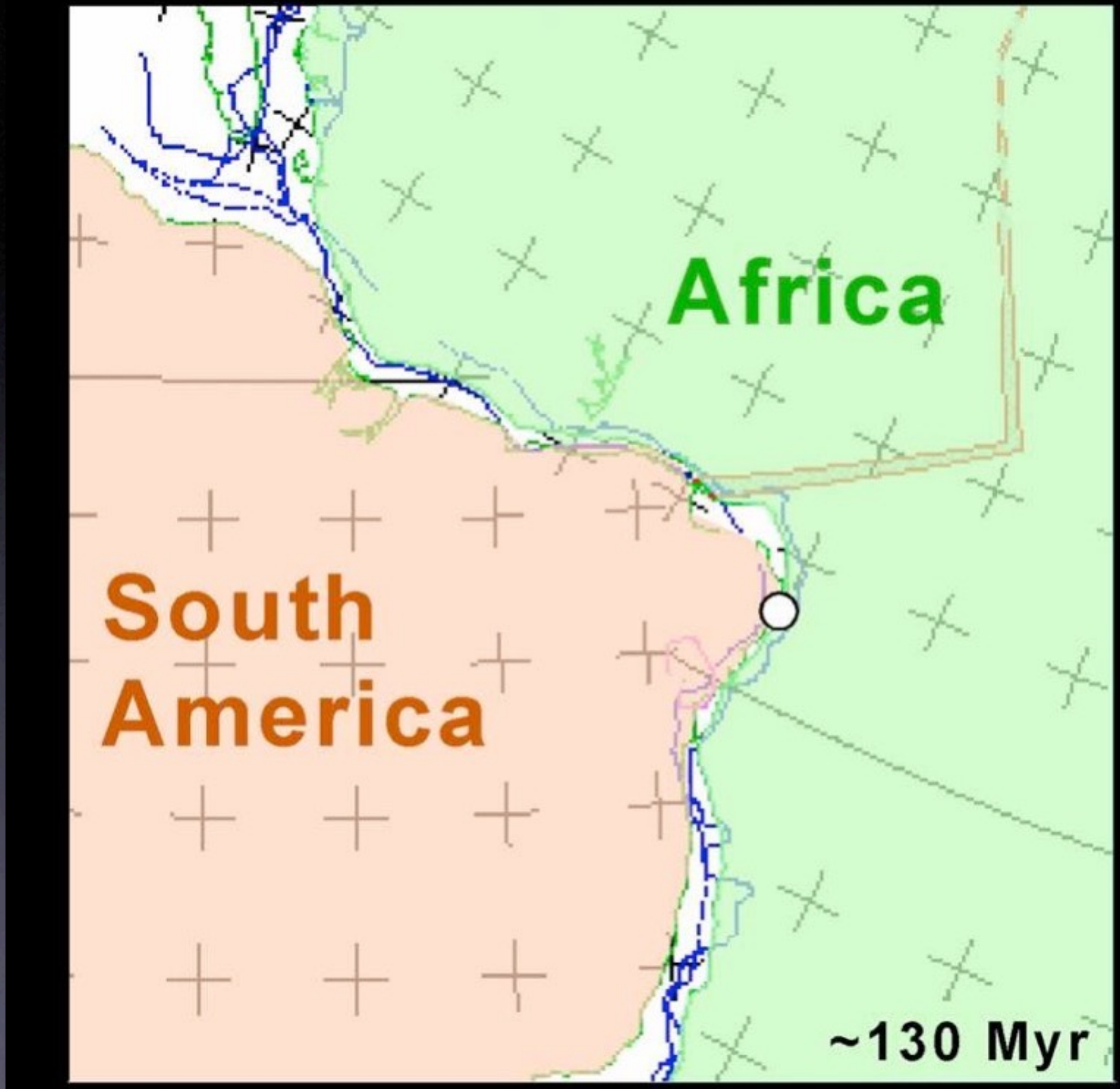

Left Plate
Right Plate

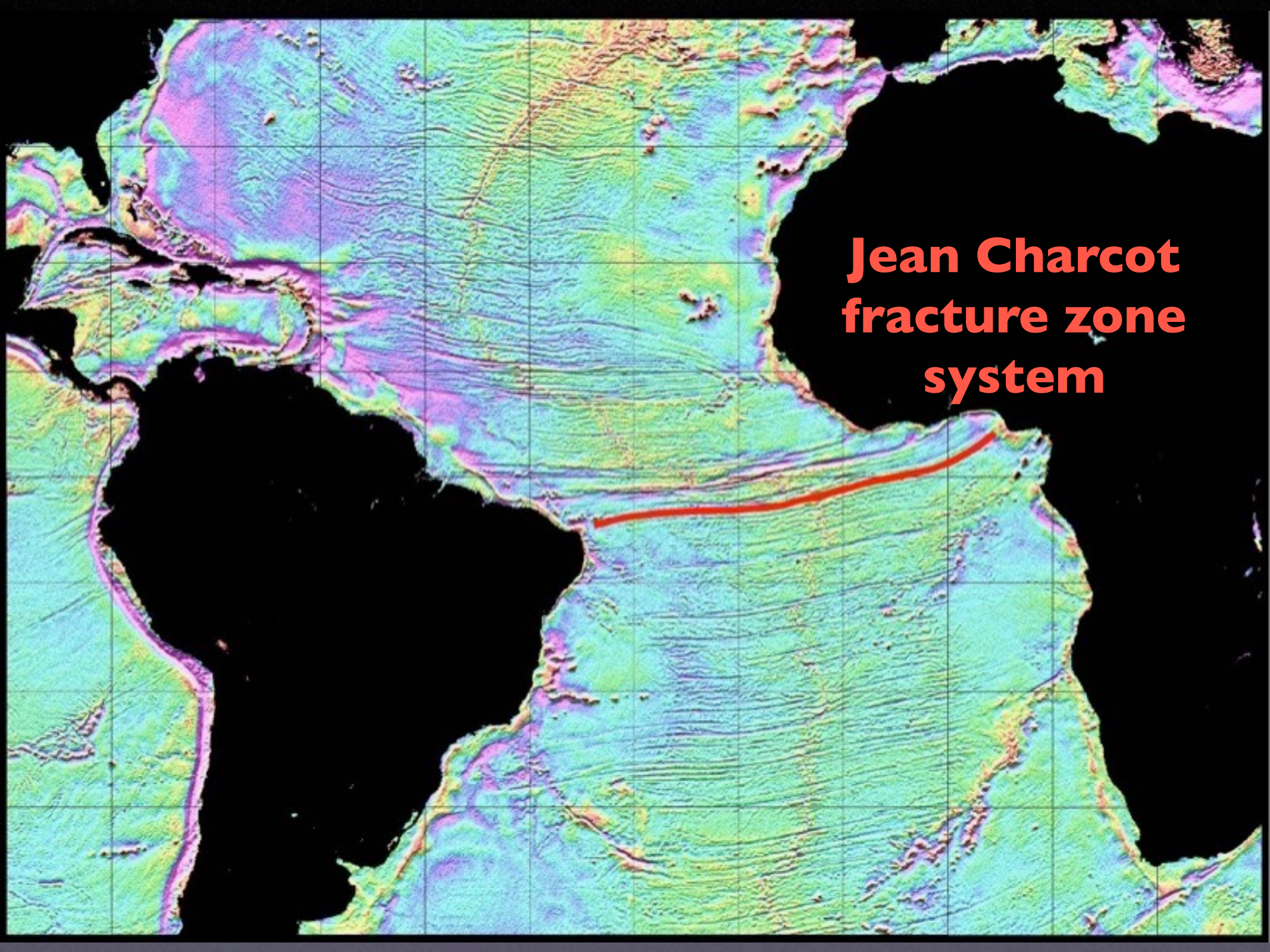

RP
Left Plate
Right Plate

Basis idea, new model:

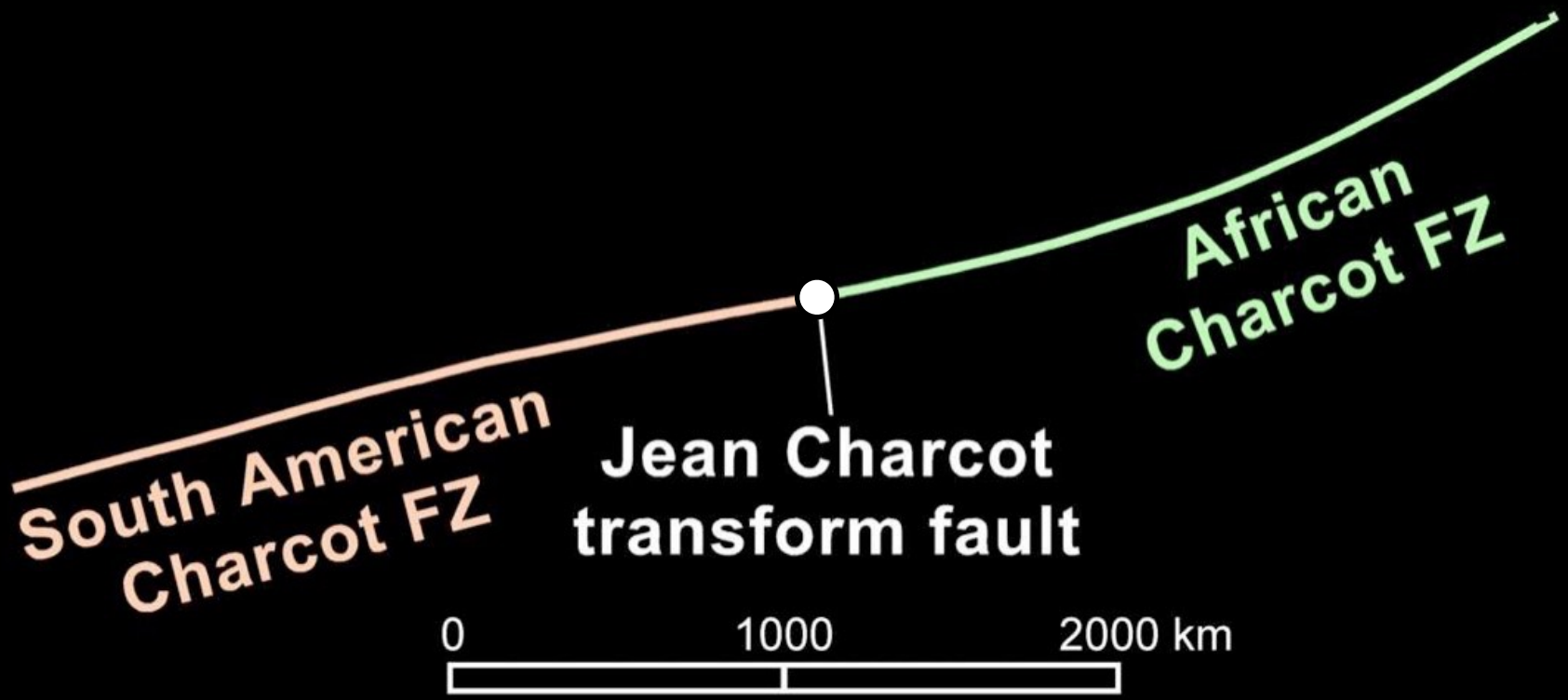
An oceanic fracture zone on a given plate has the shape of the flow line (finite trajectory) of the end of the corresponding transform fault relative to that plate.



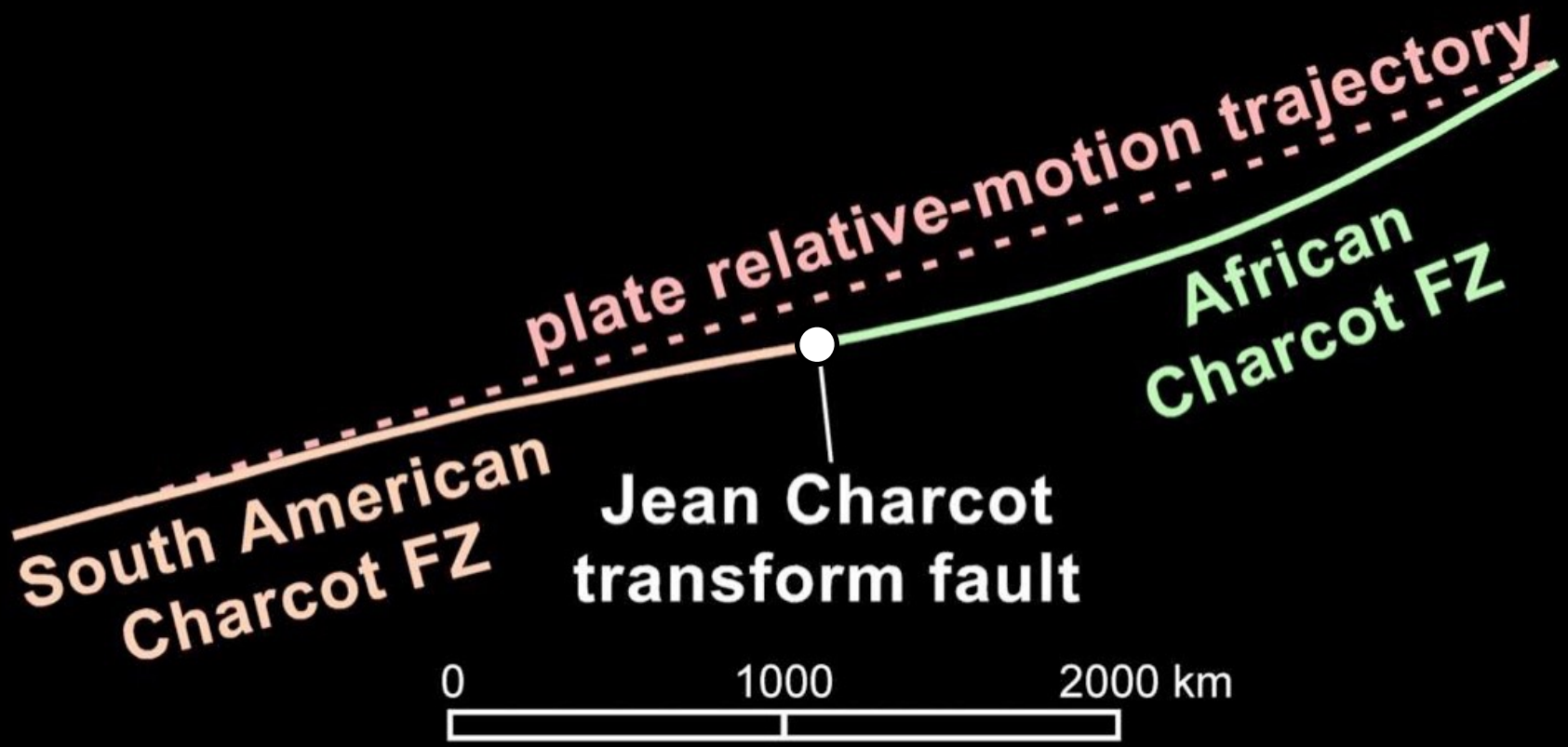

Africa
South America
~130 Myr

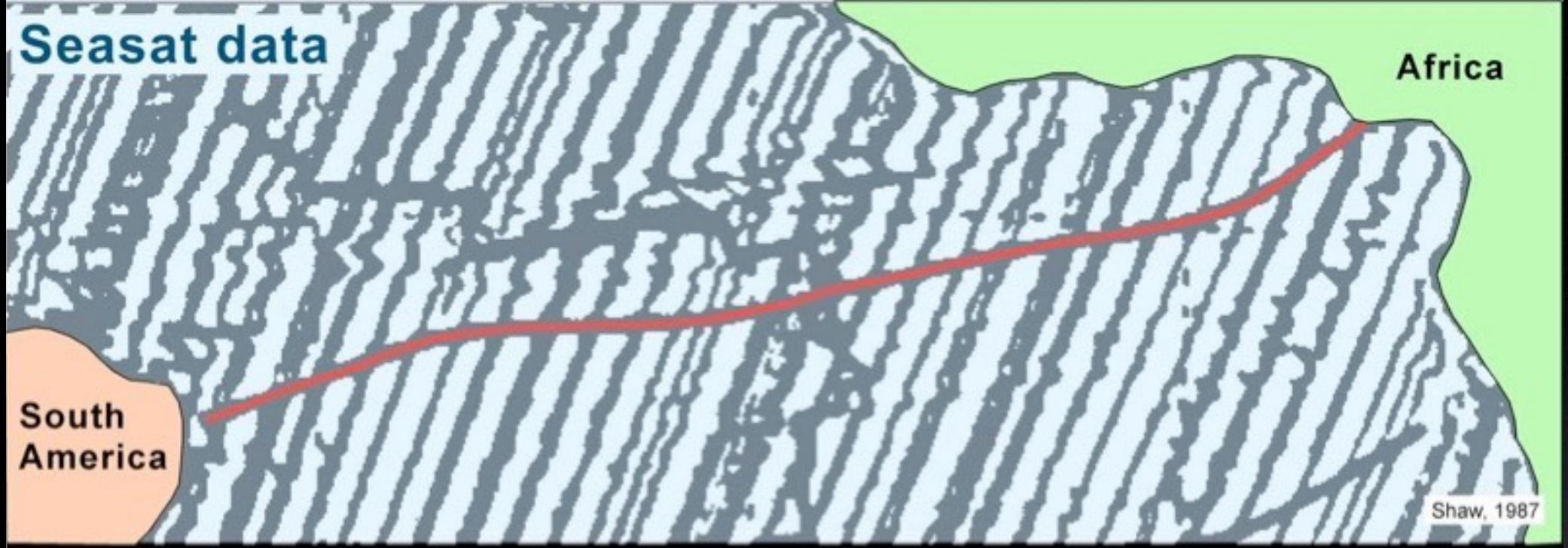

Jean Charcot
fracture zone
system

numerical model results

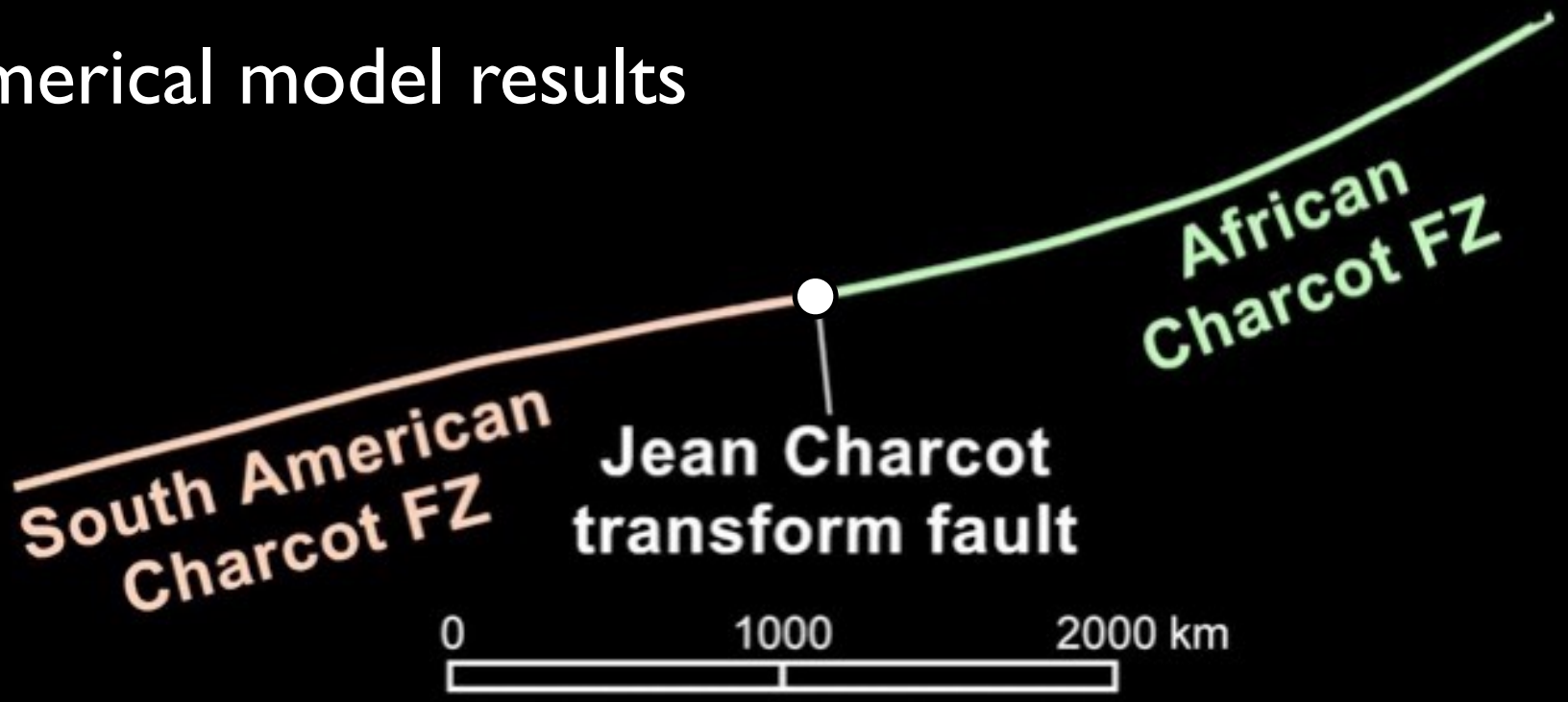


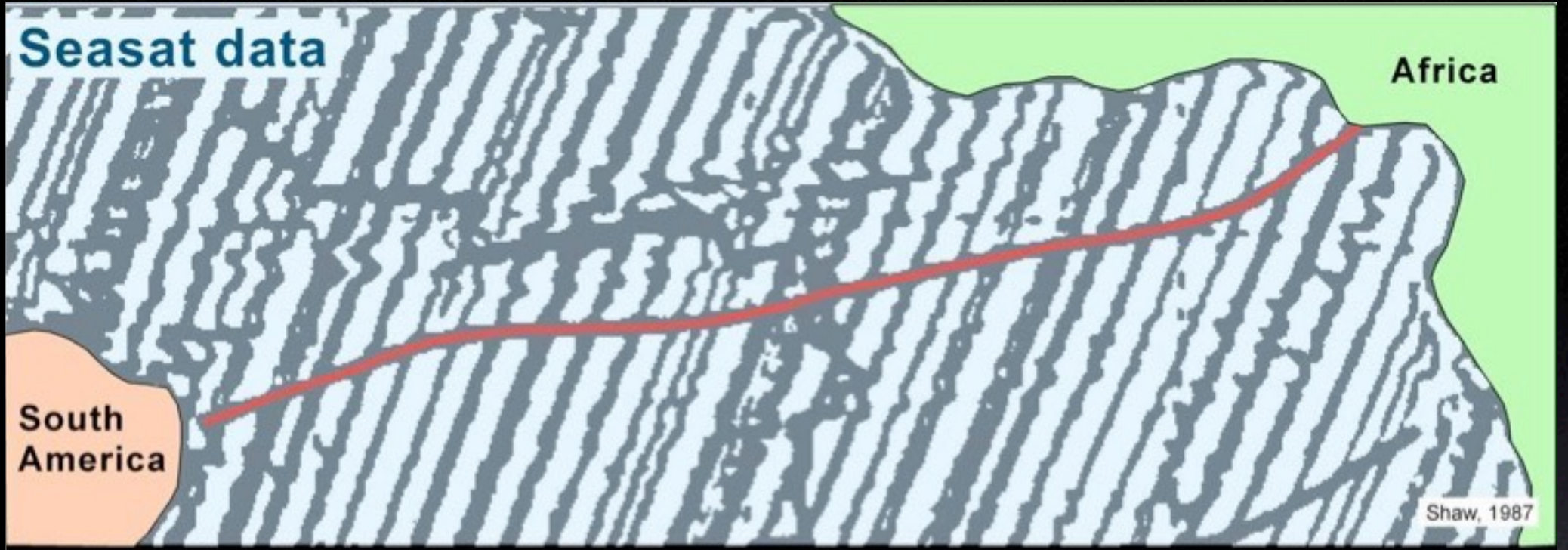
numerical model results



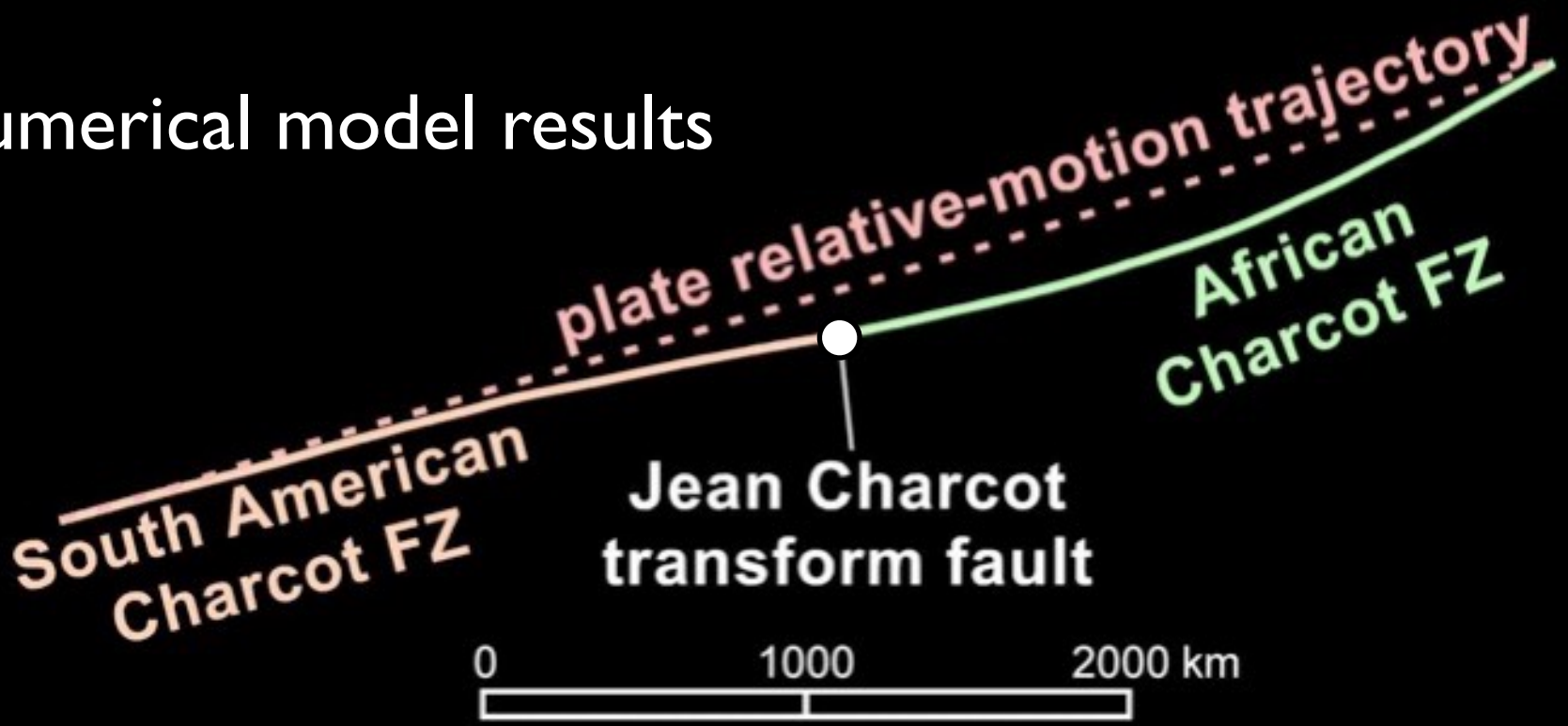


numerical model results



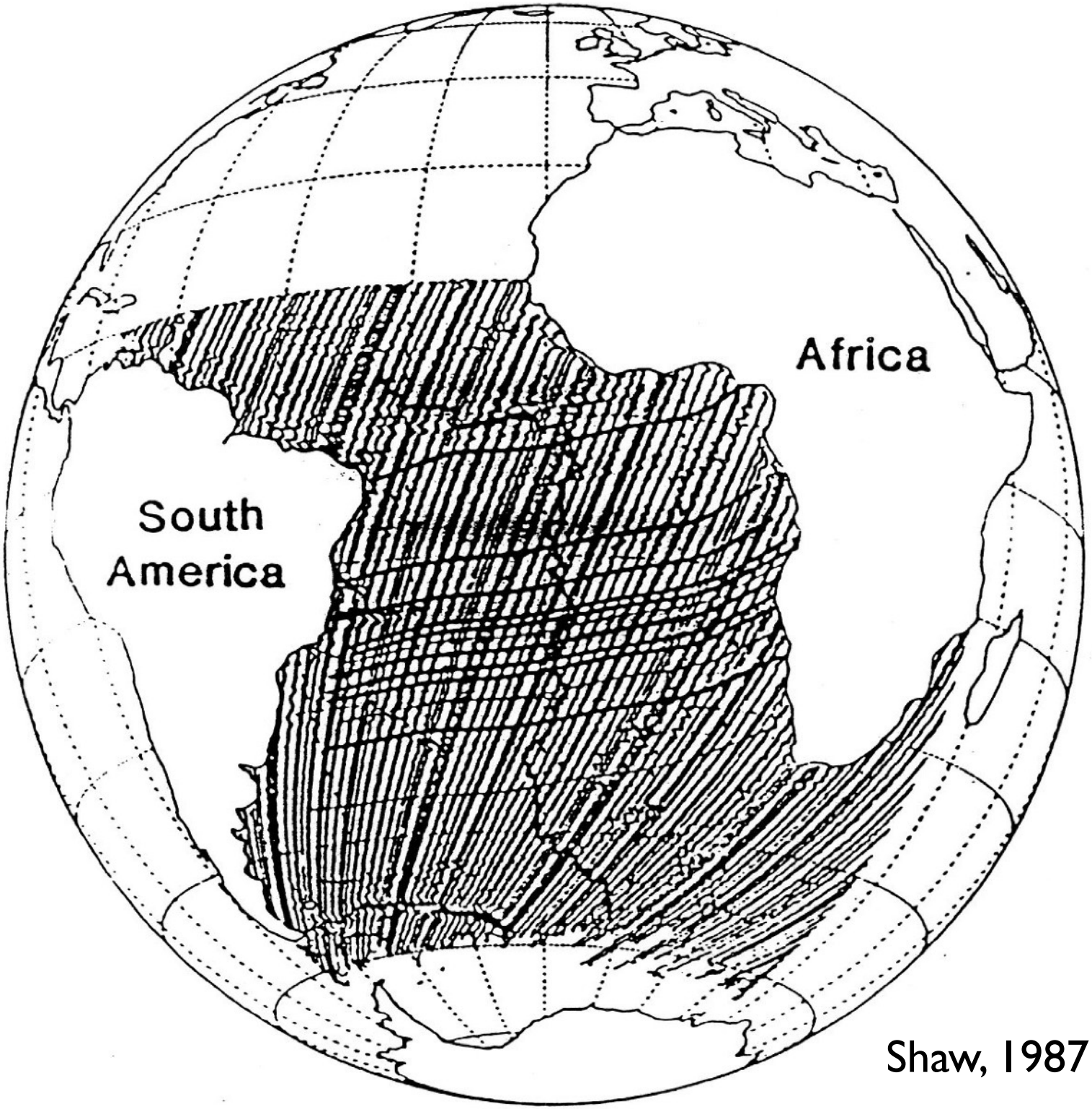


numerical model results

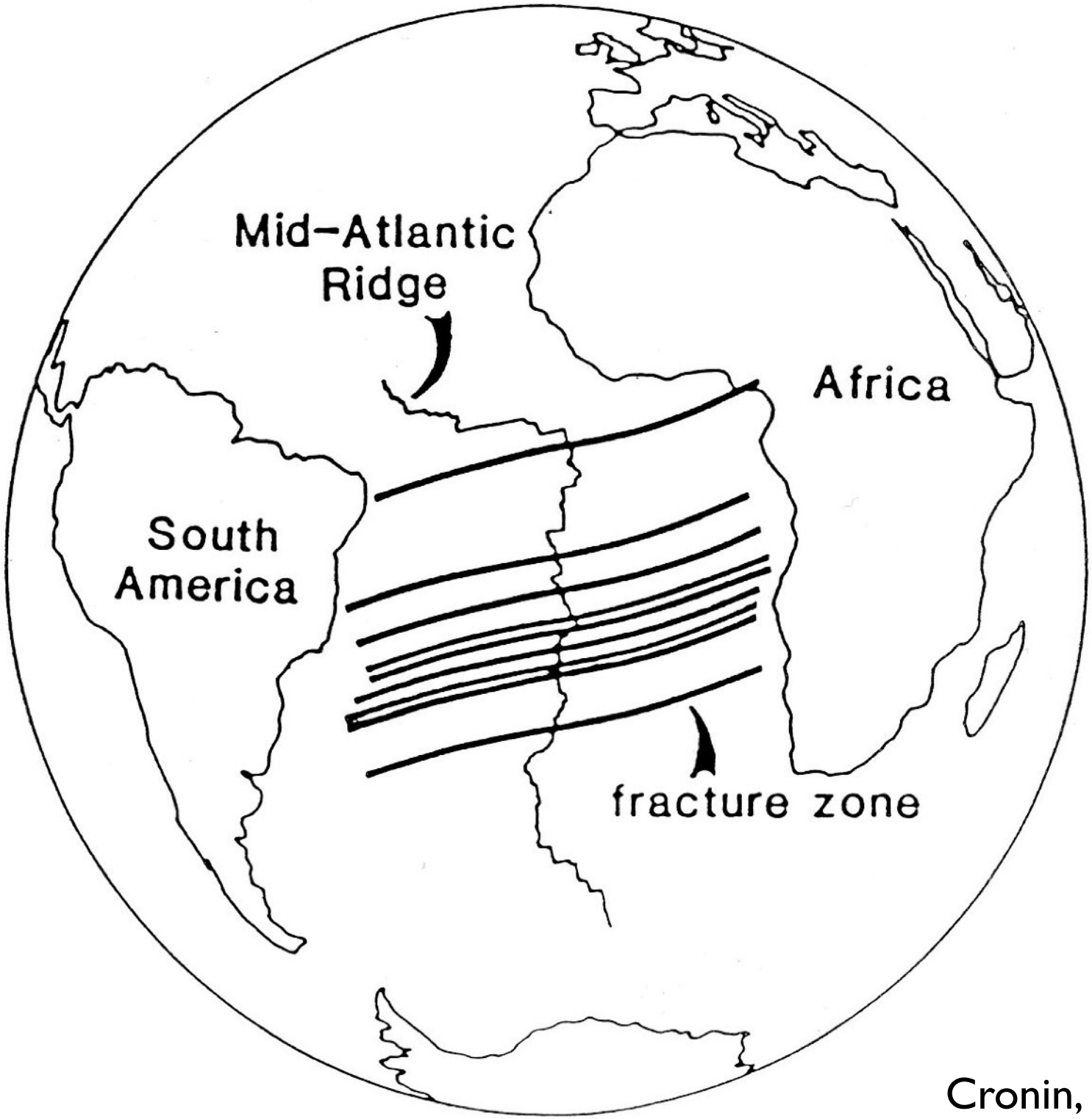


Ergo...

- An oceanic fracture zone on a given plate is the flow line of the end of a transform fault relative to that plate. It is not generally the flow line of any point on the adjacent plate.
- Oceanic fracture zones are not generally circular, as indicated by observation.

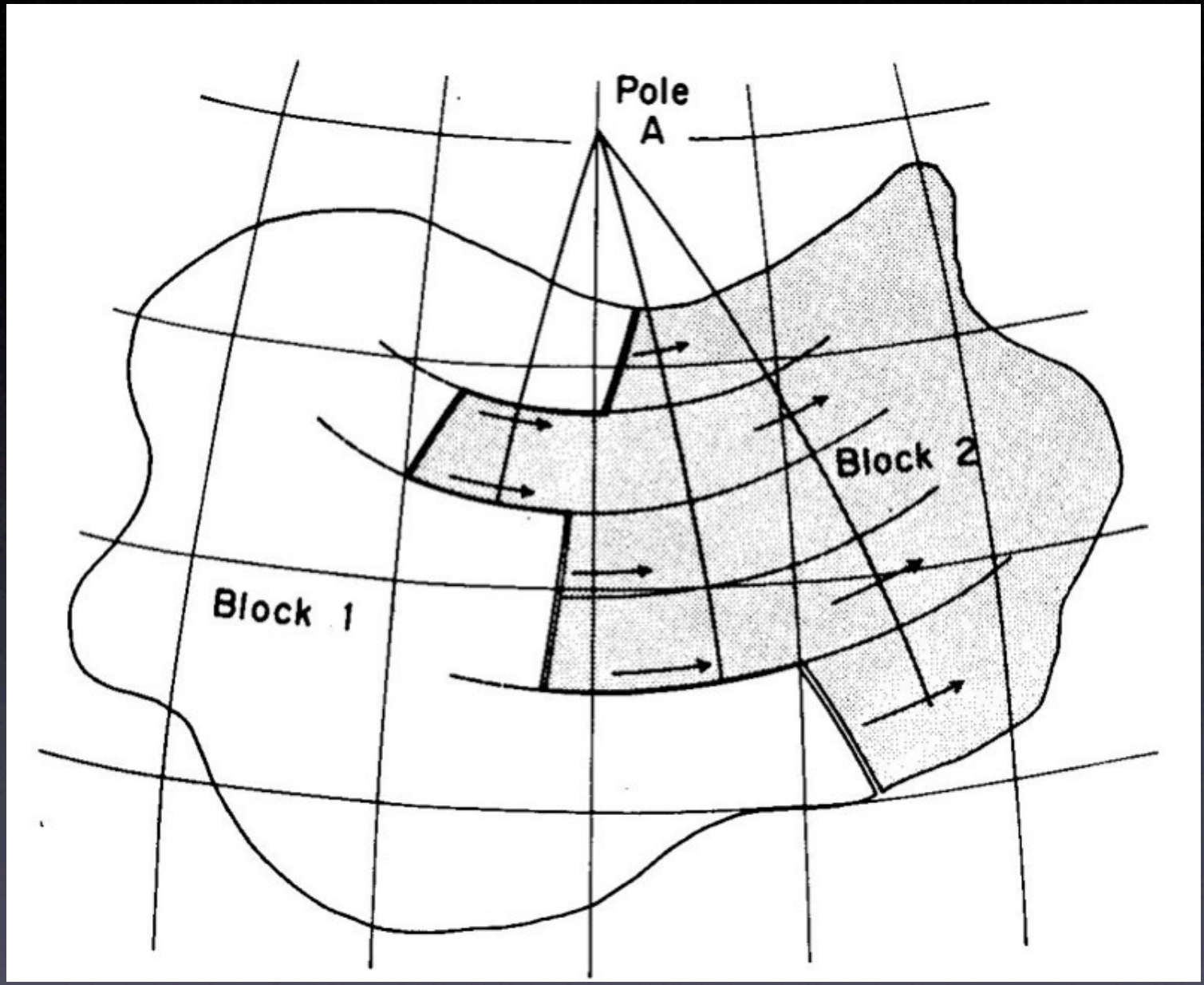


Shaw, 1987



Cronin, 1988

What is the standard model for the shape of oceanic fracture zones?



Jason Morgan's view of the kinematic origin of oceanic fracture zones (Morgan, 1968)

Typical Textbook Statements

- Oceanic fracture zones are the flow line of one plate as observed from another plate
- Oceanic fracture zones are circular, unless something has happened to change the direction of relative motion of the adjacent plates

What are the indicators that the standard model is not entirely accurate?

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- Observational data indicate that fracture zones are not circular.

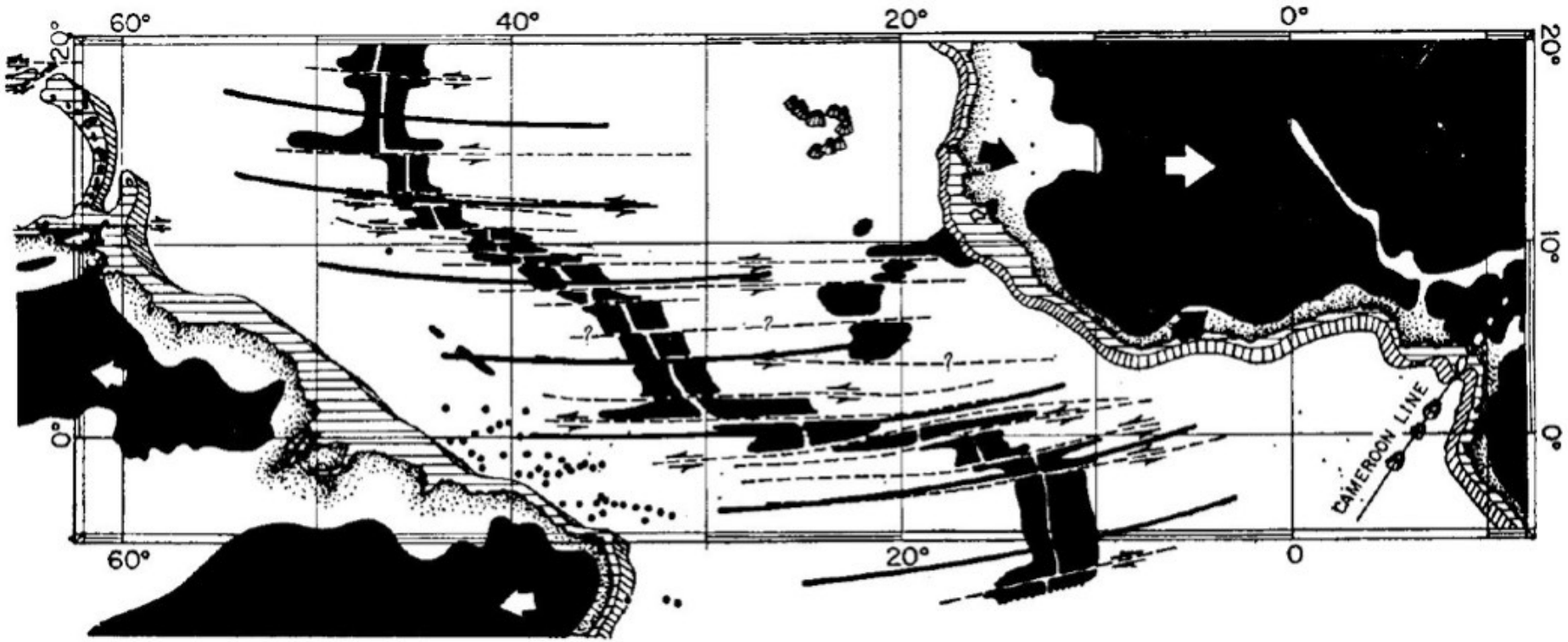


Fig. 7. The strike of the transform faults in the equatorial Atlantic are compared with circles concentric about a pole at 62°N, 36°W. These circles indicate the present motion of Africa relative to South America. (Figure is adapted from *Heezen and Tharp* [1965].)

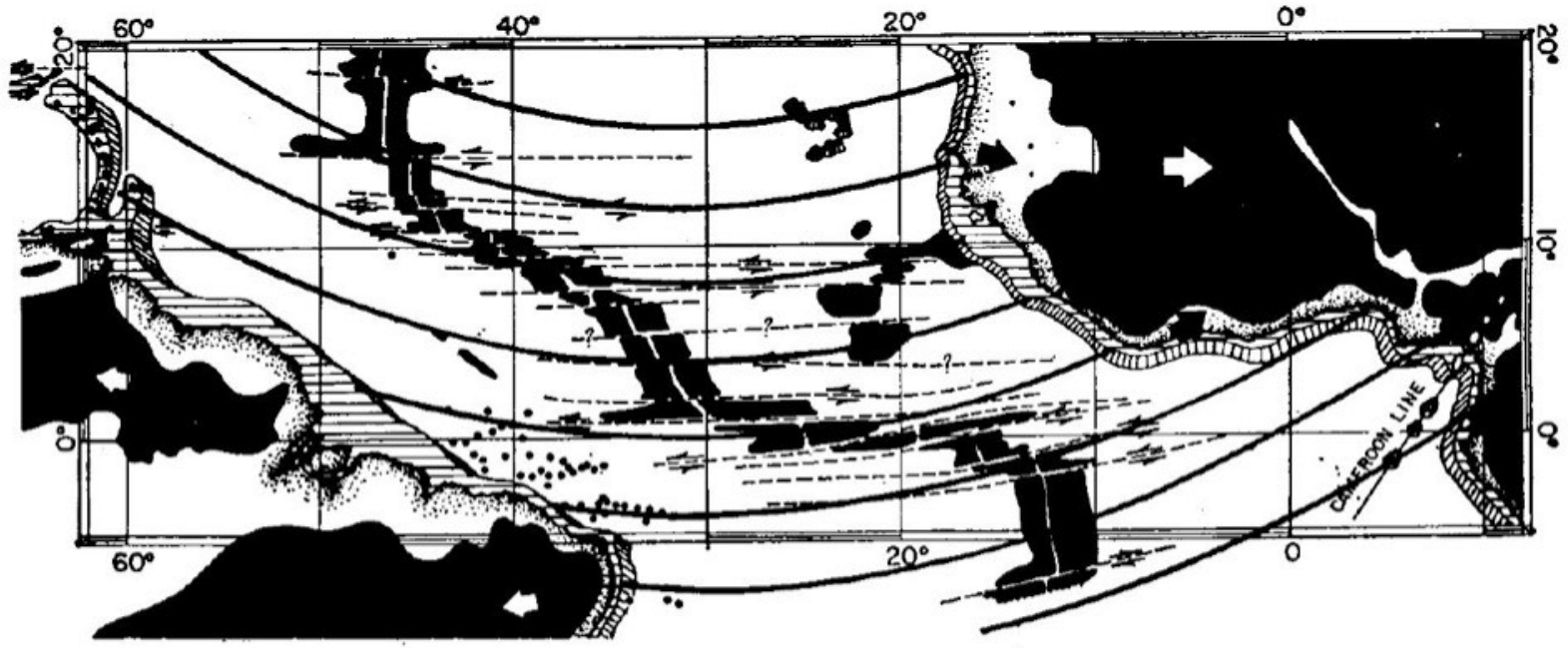
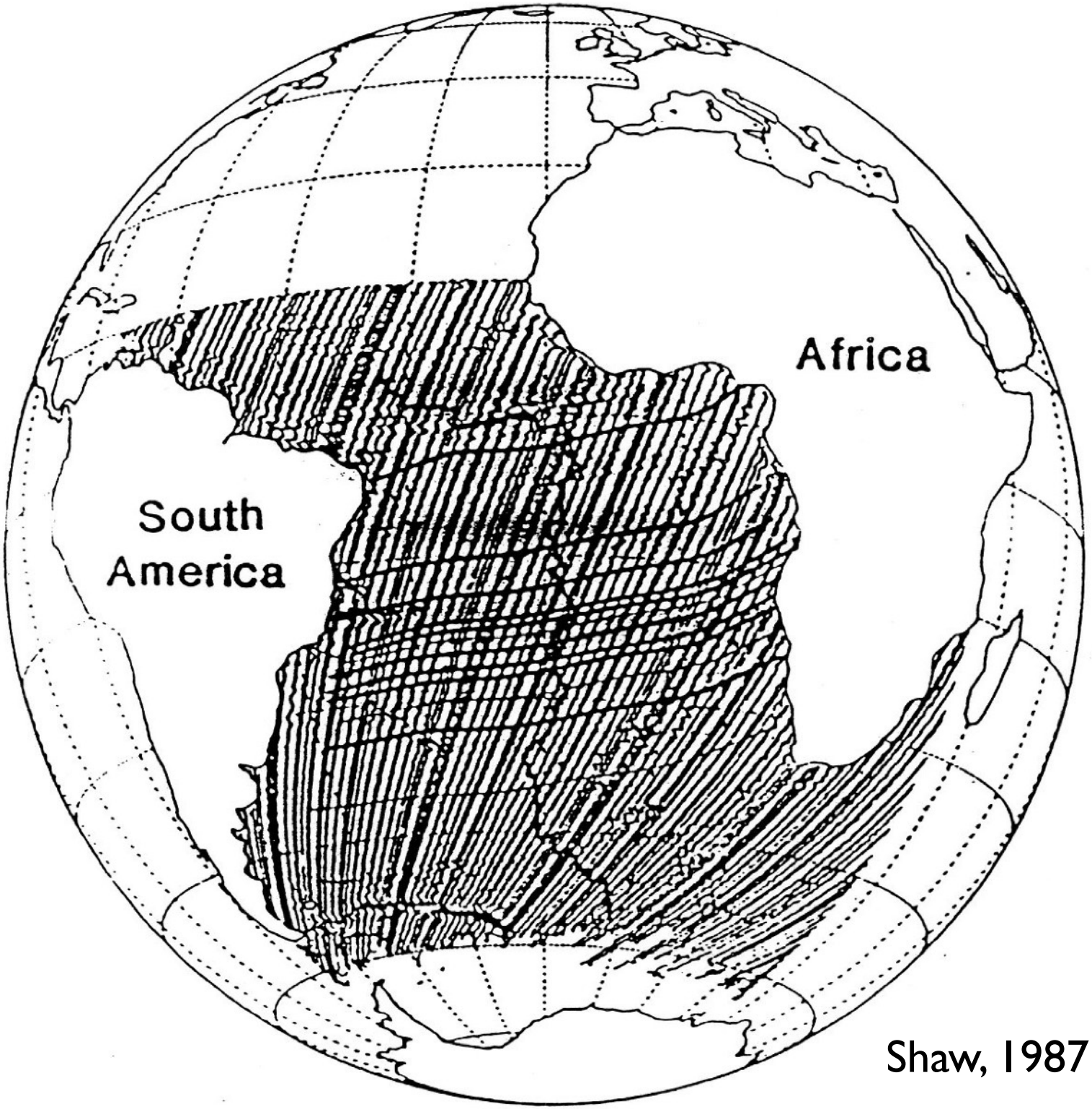
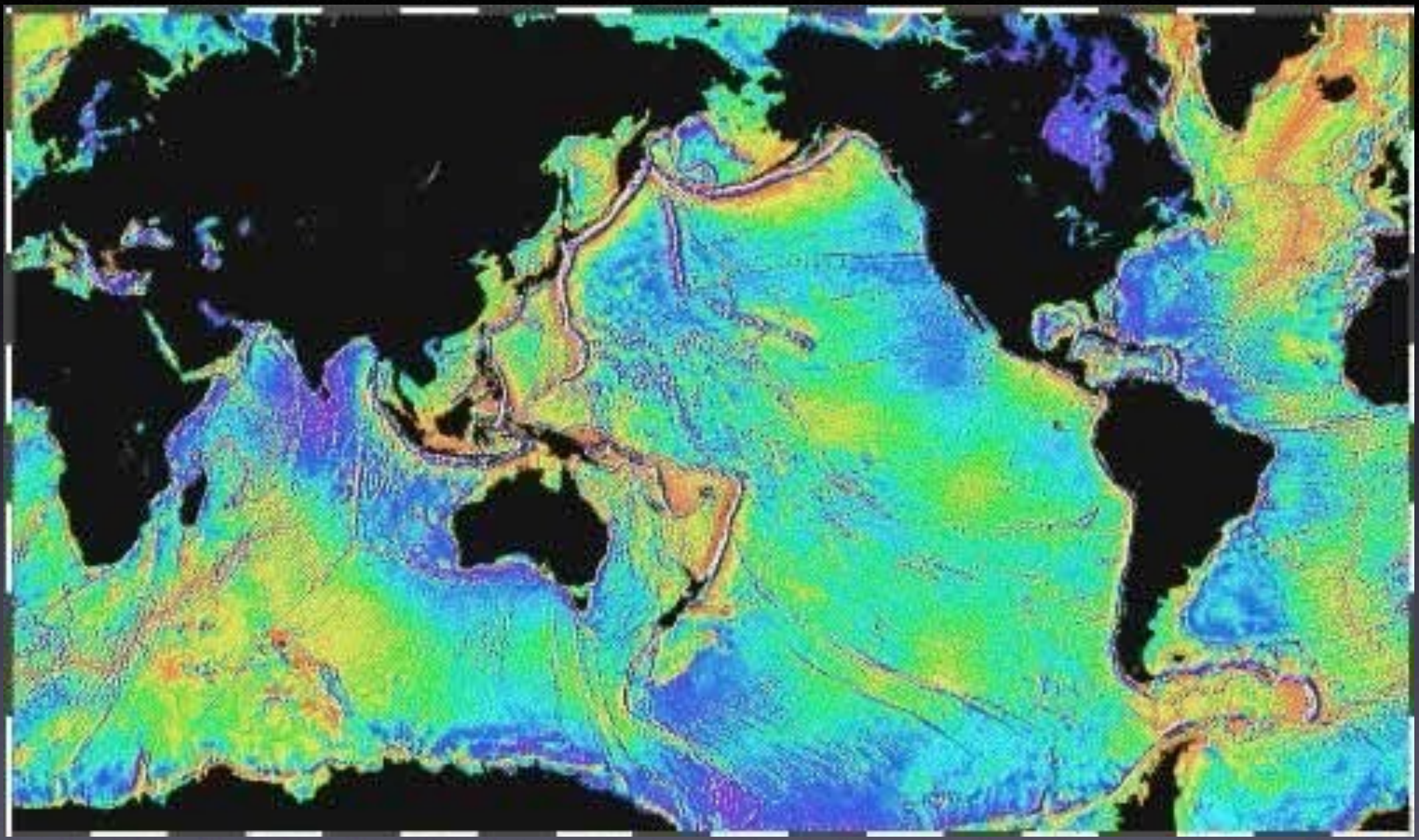
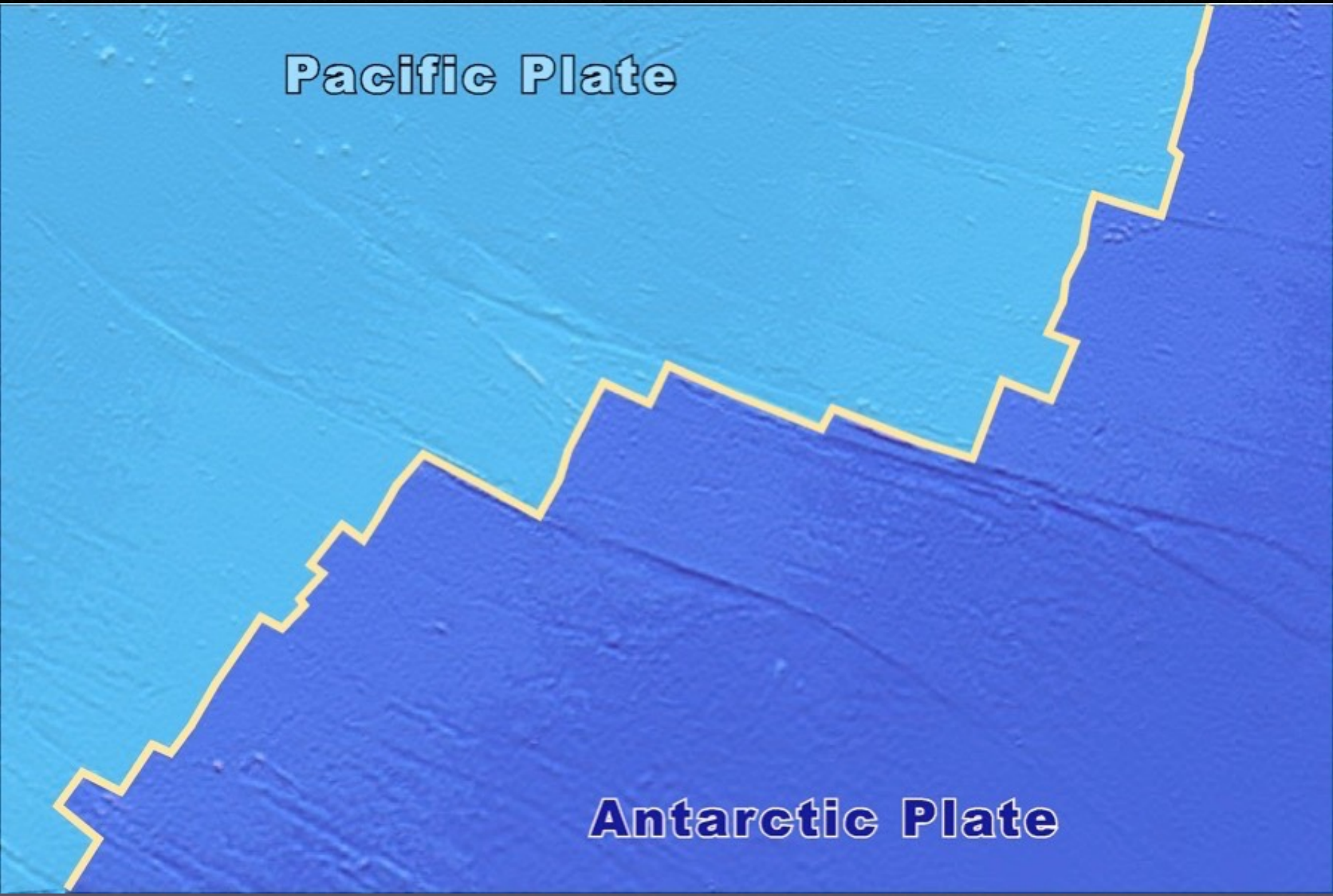


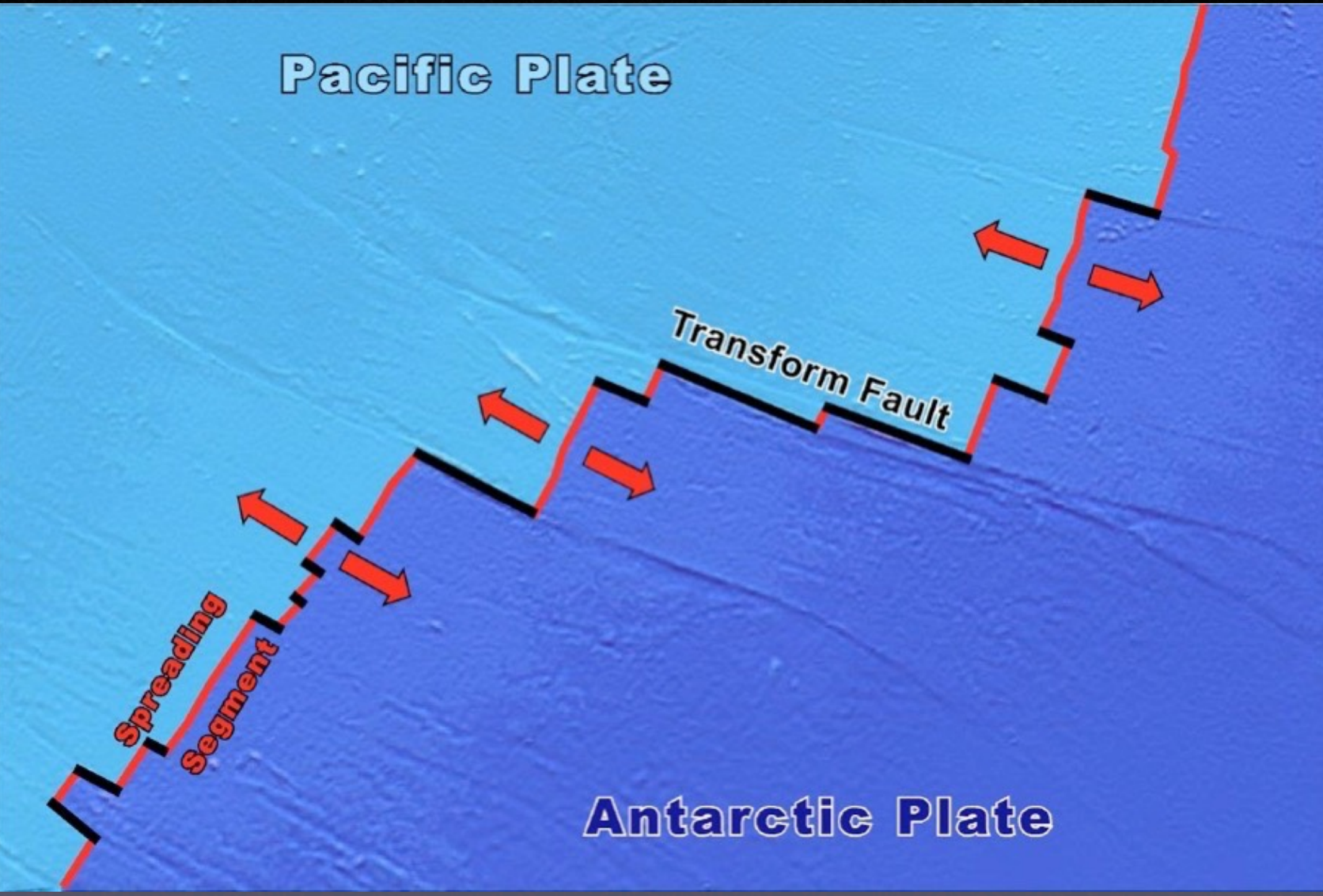
Fig. 10. The strike of the faults in the equatorial Atlantic are compared with circles concentric about a pole at 44.0°N, 30.6°W, the pole about which South America must be rotated to make its coastline (500-fm isobath) coincide with the coastline of Africa [*Bullard et al.*, 1965]. These circles indicate the average motion since drifting began. (Figure is adapted from *Heezen and Tharp* [1965].)

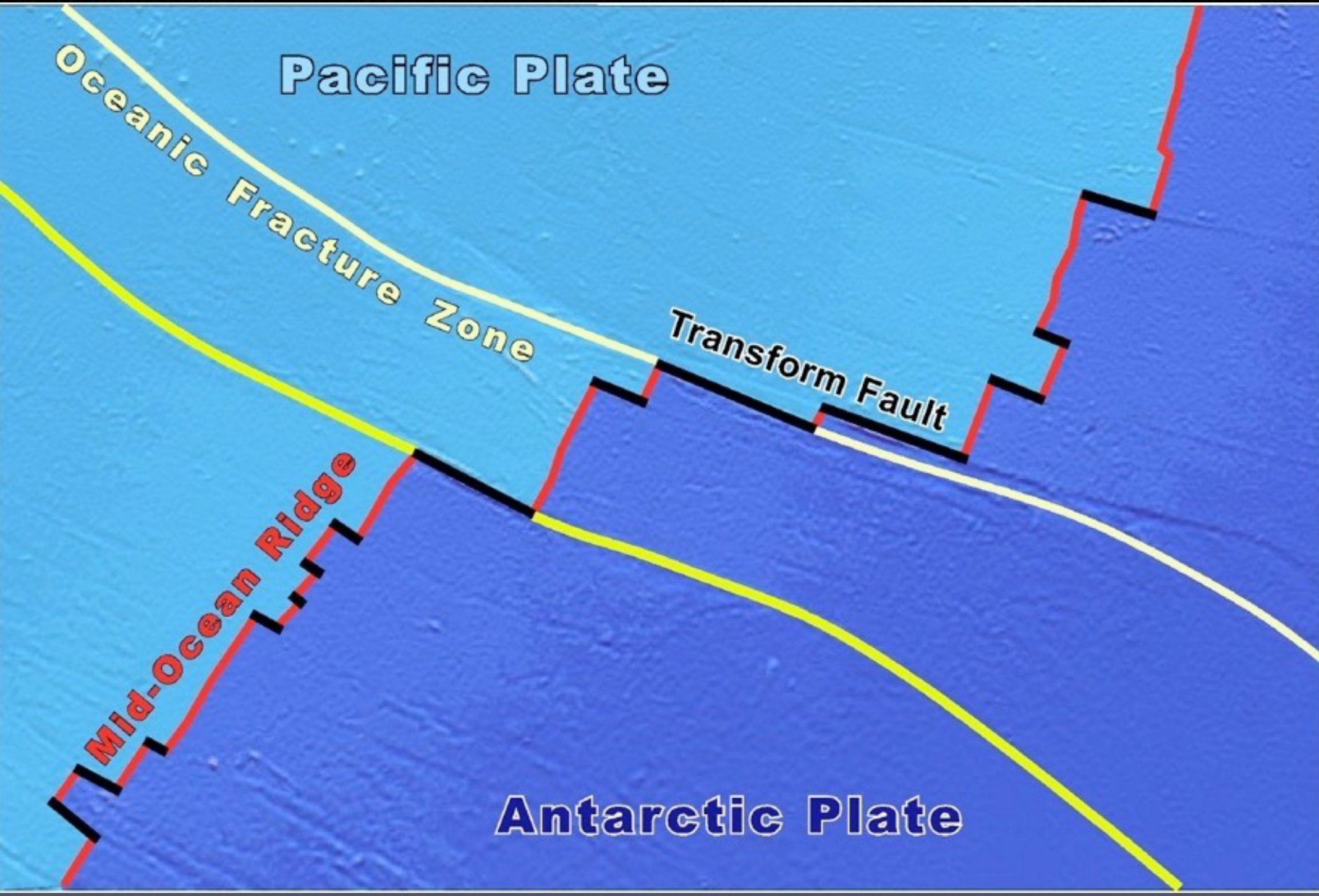


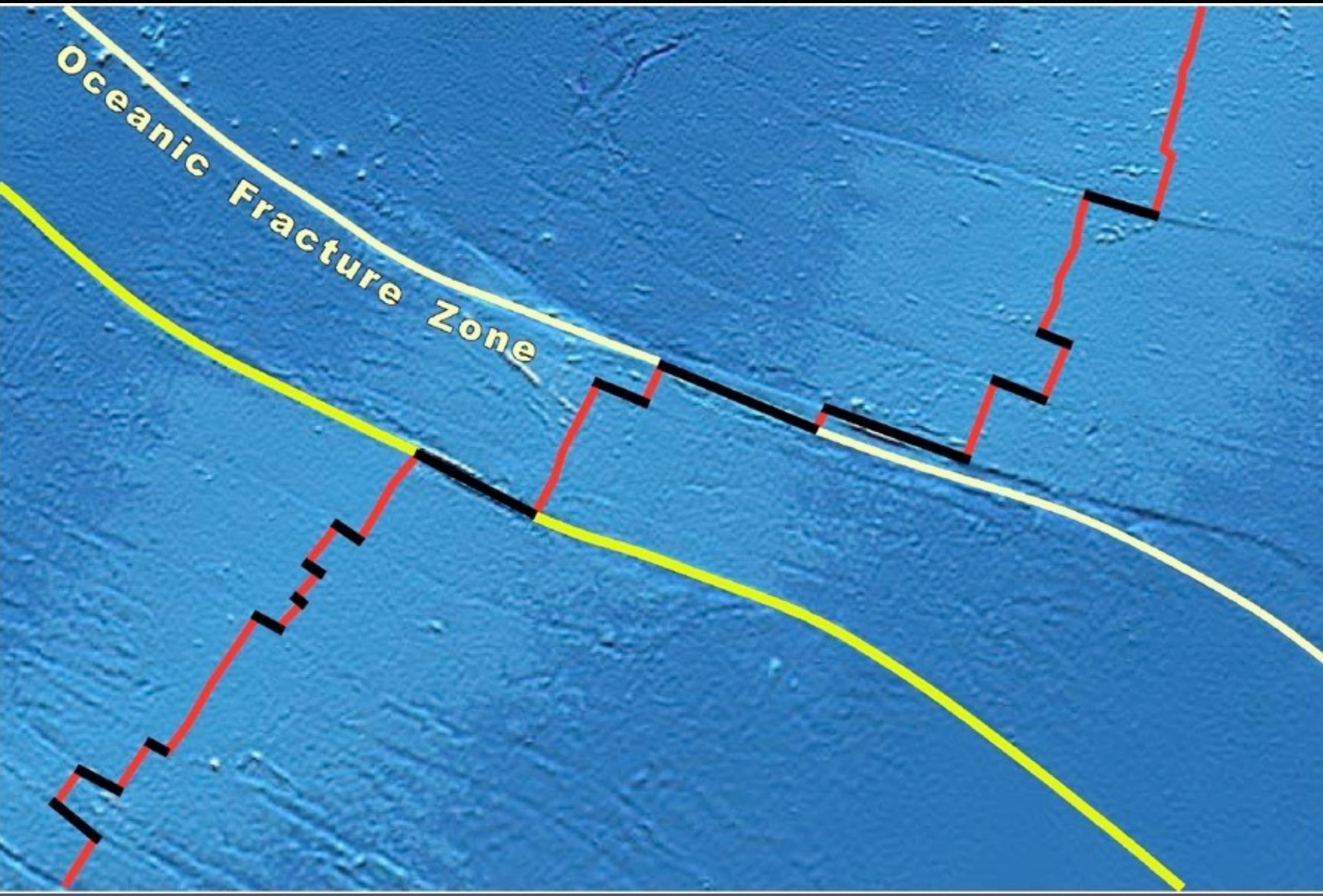
Shaw, 1987




Pacific Plate
Antarctic Plate


Pacific Plate
Transform Fault
Spreading Segment
Antarctic Plate


Pacific Plate
Oceanic Fracture Zone
Transform Fault
Mid-Ocean Ridge
Antarctic Plate


Oceanic Fracture Zone

What are the indicators that the standard model is not entirely accurate?

- Observational data indicate that fracture zones are not circular.
- Alan Cox's "three-plate problem"

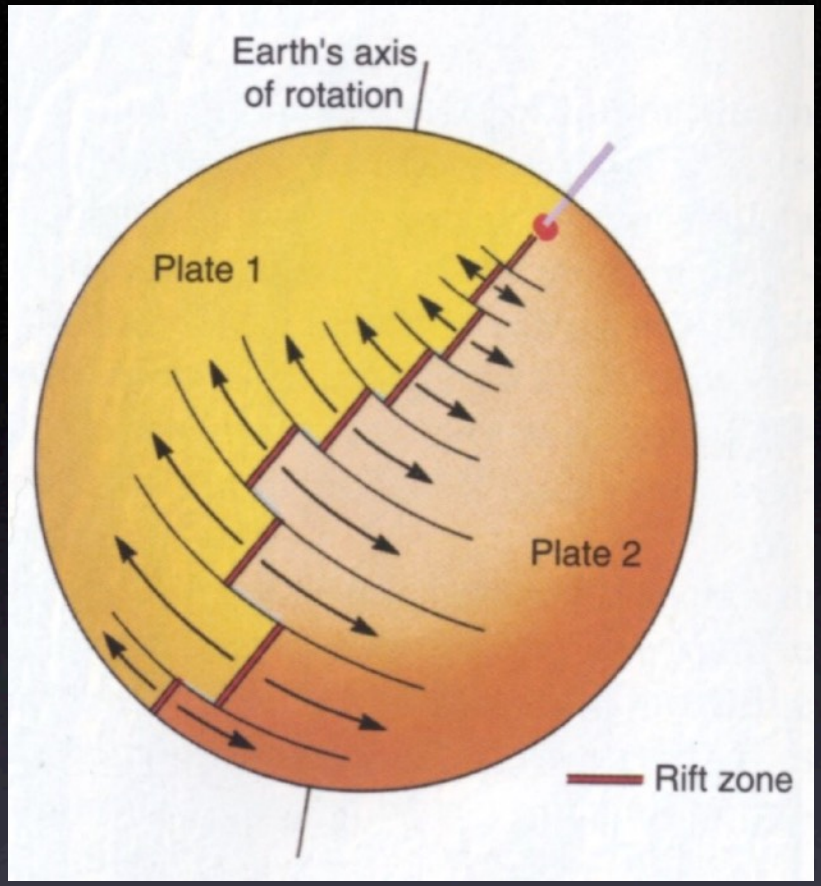
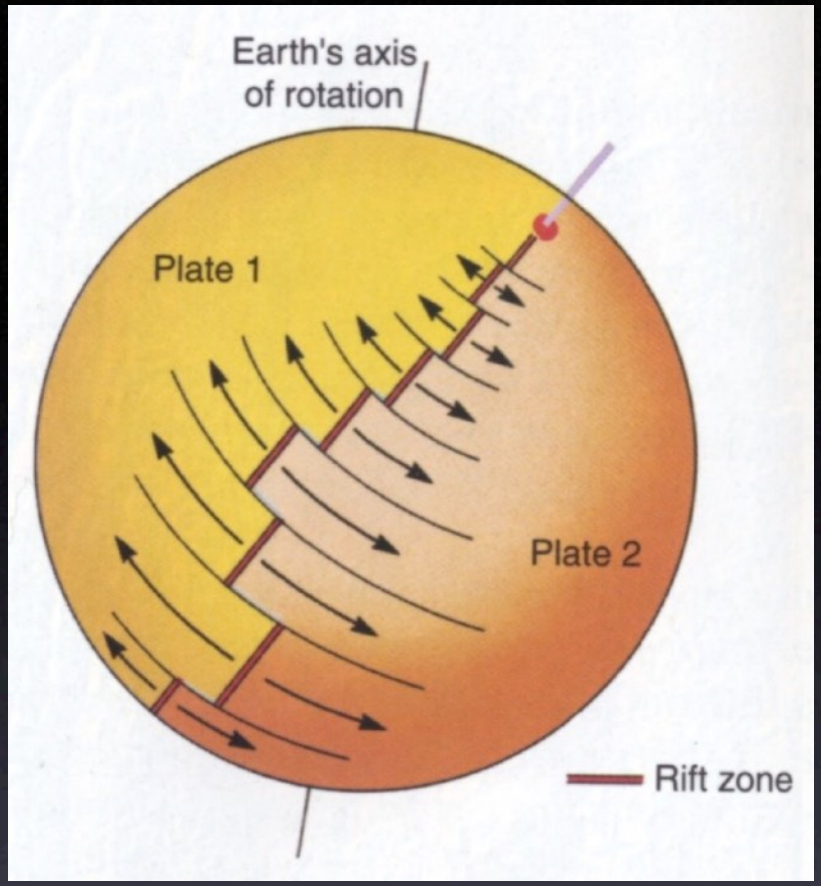


Illustration from a physical geology textbook, 2004

Although it is inadequate, the idea that fracture zones should normally be circular persists.



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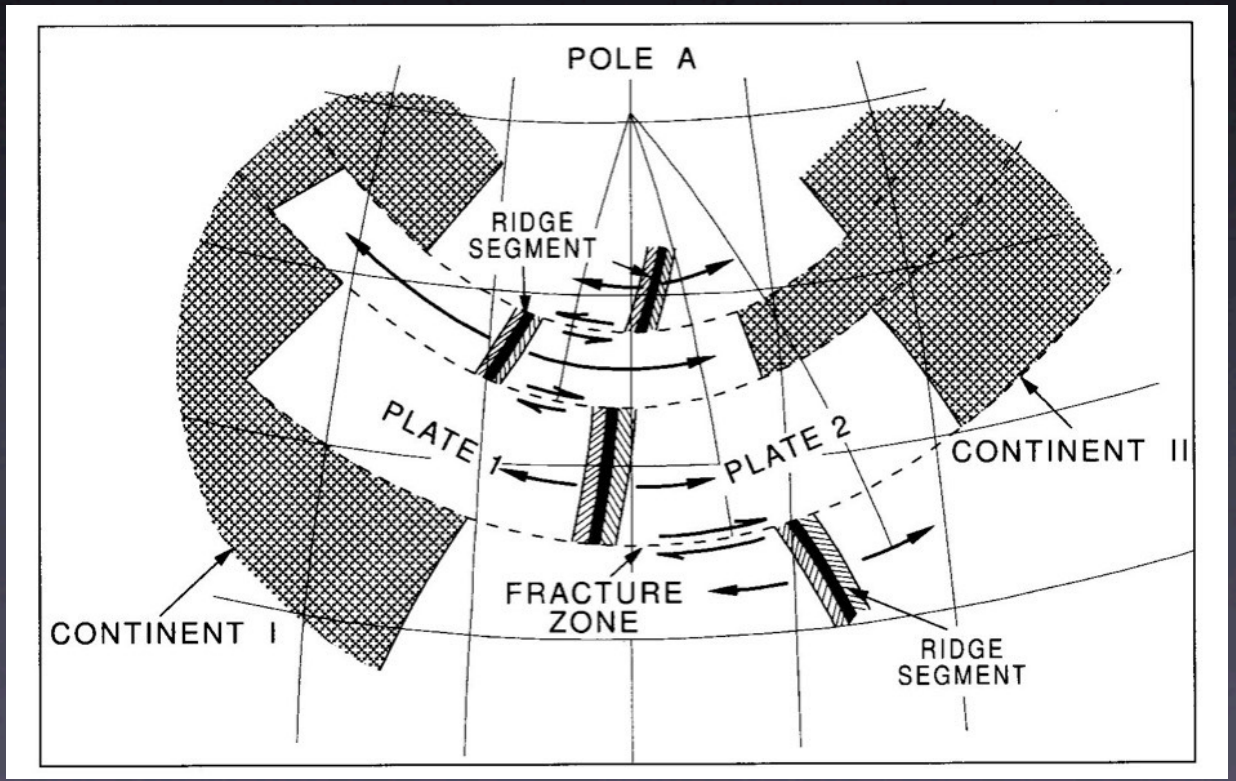

Illustration from a research monograph, 1999

Unfortunately, this is not the way it works.

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If it worked this way,

(1) transform faults would be zones of simple shear whose individual lengths should remain constant.

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(3) the shape of oceanic fracture zones would be circular and concentric.

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(3) the shape of oceanic fracture zones would be circular and concentric.

They aren't.