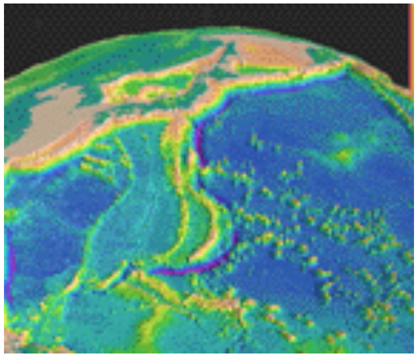

Plate Tectonics on a Plane

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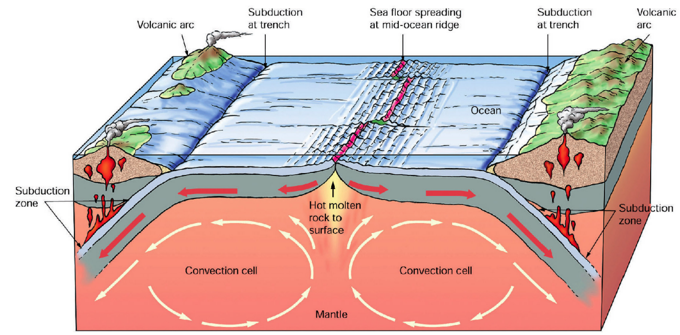


- Observations related to plate tectonics
  - Ocean and continent topography, hypsometry, and crustal thickness.
  - Global seismicity, Benioff zones, and focal mechanisms
  - Global volcanic activity
  - Geoid Height and gravity anomaly
  - Marine magnetic anomalies

- **Plate tectonic theory – types of plate boundaries**

- Plate motions on a plane and triple junction closure

- Plate motions on a sphere – next lecture

SEISMOLOGY AND NEW GLOBAL TECTONICS 5857

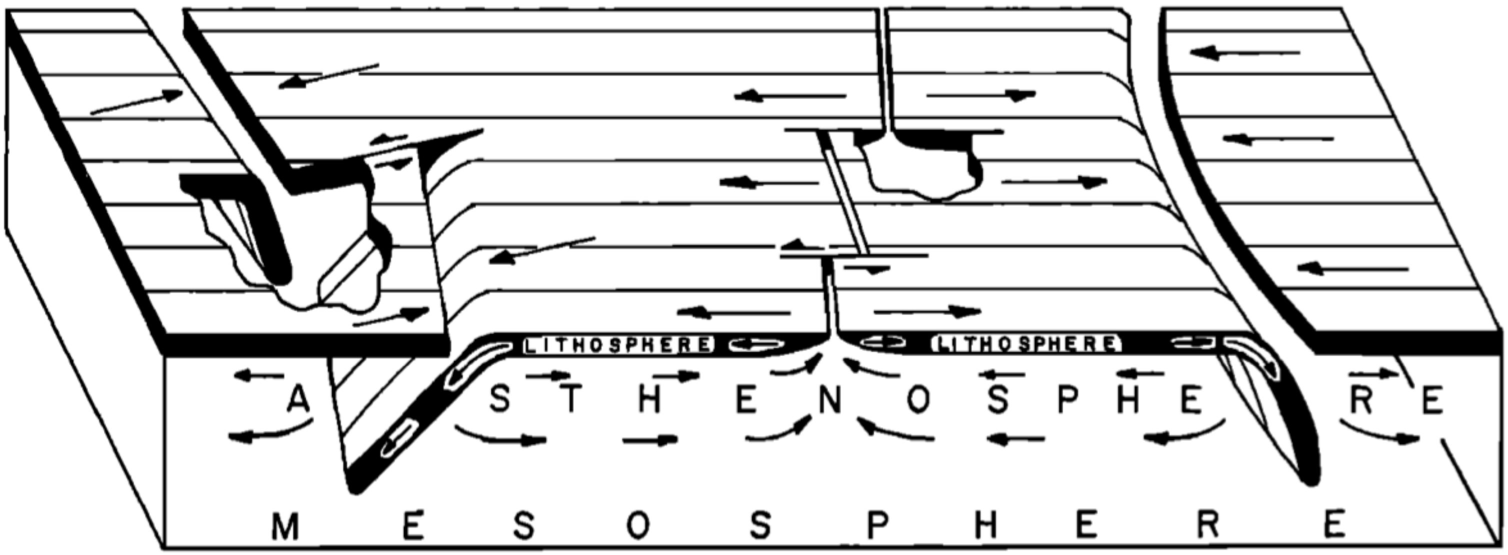


Fig. 1. Block diagram illustrating schematically the configurations and roles of the lithosphere, asthenosphere, and mesosphere in a version of the new global tectonics in which the lithosphere, a layer of strength, plays a key role. Arrows on lithosphere indicate relative movements of adjoining blocks. Arrows in asthenosphere represent possible compensating flow in response to downward movement of segments of lithosphere. One arc-to-arc transform fault appears at left between oppositely facing zones of convergence (island arcs), two ridge-to-ridge transform faults along ocean ridge at center, simple arc structure at right.

[Isacks, Oliver, Sykes, JGR, 1966]

The theory of plate tectonics states that the lithosphere (strong layer) is divided into a small number of nearly rigid plates which are sliding over the asthensophere (weak layer). Most of the deformation occurs on plate boundaries.

How is the crust is different from the lithosphere?

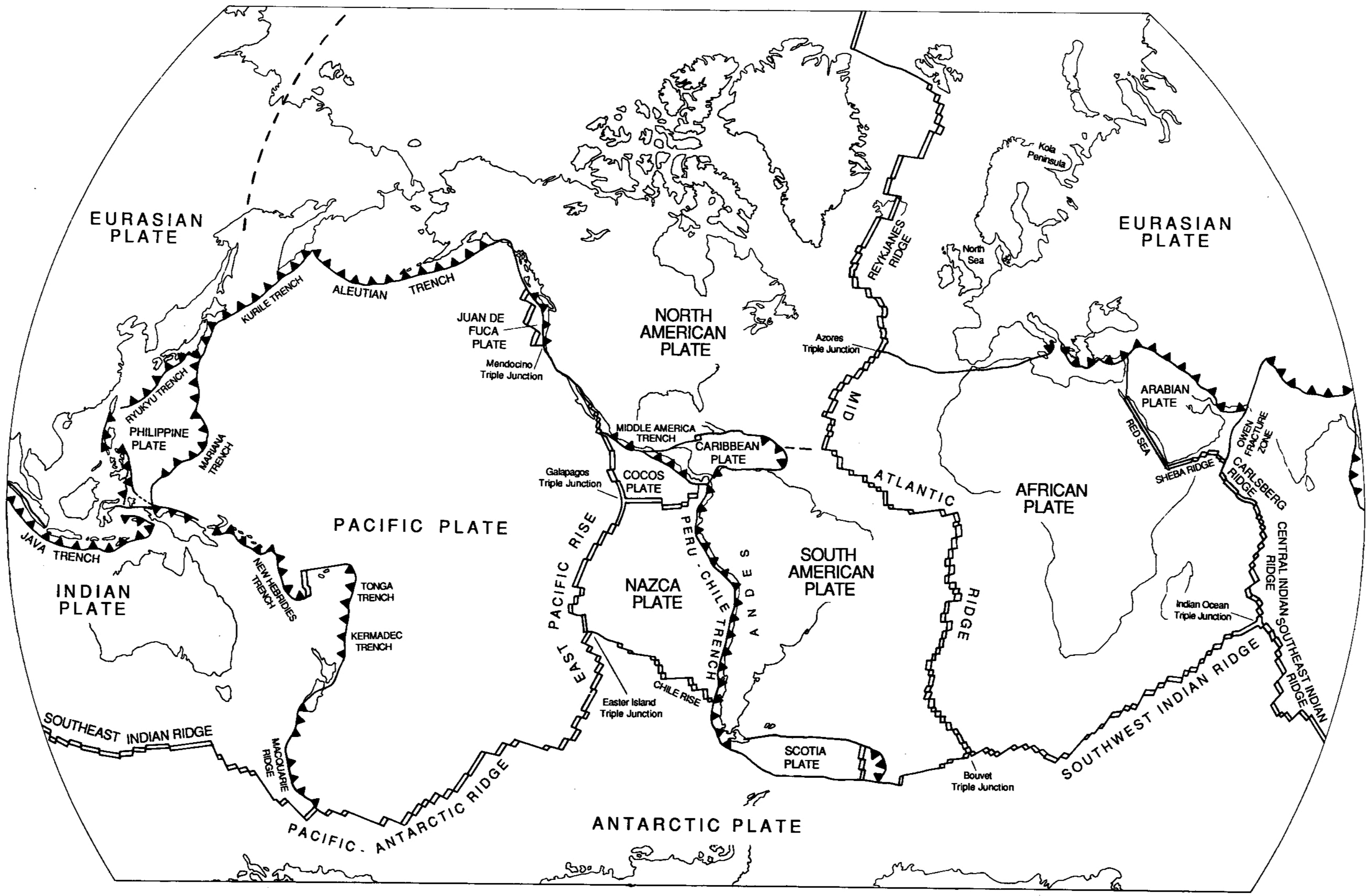


Figure 2.2. The major tectonic plates, midocean ridges, trenches and transform faults.

Study this map. There are 7 major plates and many minor plates. Memorize the names and style of the plate boundaries. Note the triple junctions. These are **good questions for a quiz.**

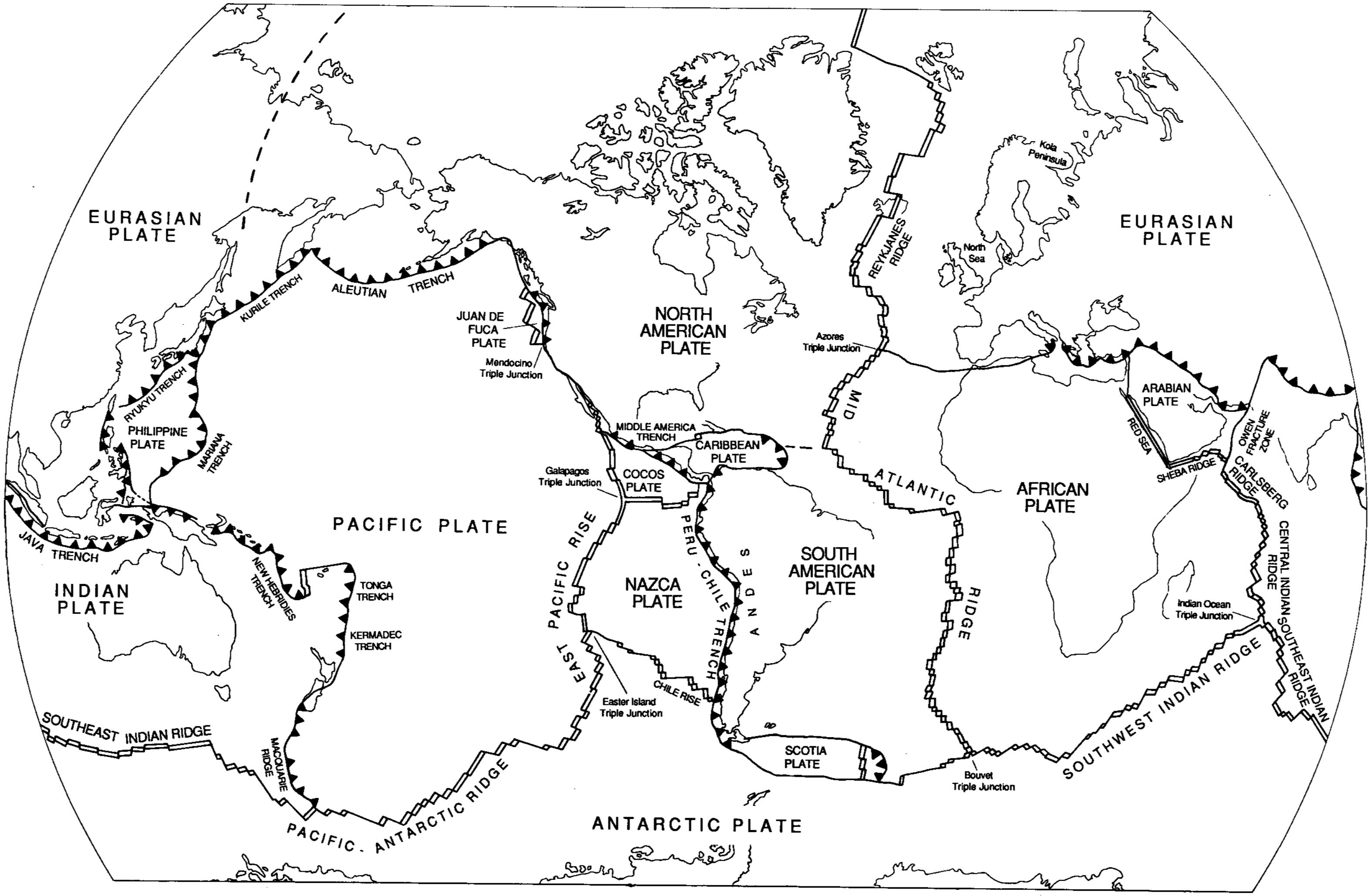


Figure 2.2. The major tectonic plates, midocean ridges, trenches and transform faults.

Assumptions:

1) Plate are only created at seafloor **spreading ridges**.
2) Plates are destroyed at **subduction zones**.
3) Plate slide past one another along **transform faults**.
4) The area of the Earth remains constant with time.
5) Plates can transmit stresses over global distances.

Spreading Ridge – constructive margin

Plates are created at the axis of a spreading ridge.

Plates are pulled apart by tectonic forces and hot mantle material flows up to fill the gap.

Melts are formed by pressure release at a depth of about 60 km. Melt accumulates into a small (magma) chamber.

A ~6 km crust forms despite variations in spreading rate.

The seismic layering of the crust has a sediment layer (1) above the basalt layer (2) consisting of extruded pillow basalts and sheeted dikes. These lie above a layer of gabbro (3).

Spreading rates vary from 10 mm/yr to 160 mm/yr.

The spreading ridge is usually perpendicular to the relative spreading vector between the plates. Of course the vector must be positive.

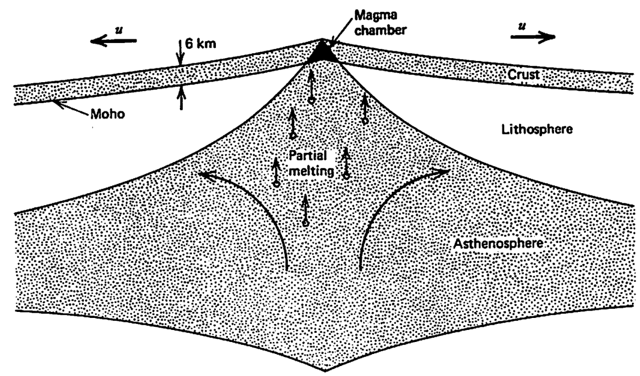


Figure 1-4 An accreting plate margin at an ocean ridge.

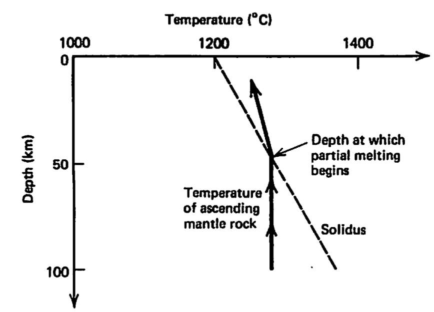


Figure 1-6 The process of pressure-release melting is illustrated. Melting occurs because the nearly isothermal ascending mantle rock encounters pressures low enough so that the associated solidus temperatures are below the rock temperatures.

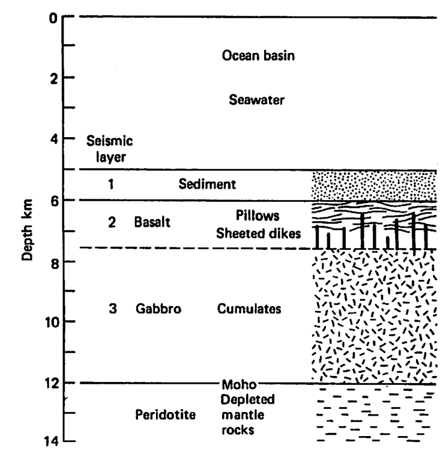


Figure 1-7 Typical structure of the oceanic crust, overlying ocean basin, and underlying depleted mantle rock.

Subduction Zone – destructive margin

Subduction is asymmetric. The denser oceanic plate subducts under the lighter continental or oceanic plate.

The negative buoyancy of the descending plate drives subduction and most plate tectonic activity.

It is common for the plate to fall vertically into the mantle so the trench retreats and back-arc spreading is needed to fill the void.

A volcanic arc occurs above the point where the oceanic crust reaches 150 km depth. Why?

The relative velocity vector across the trench is not usually perpendicular to the trench but of course must be negative.

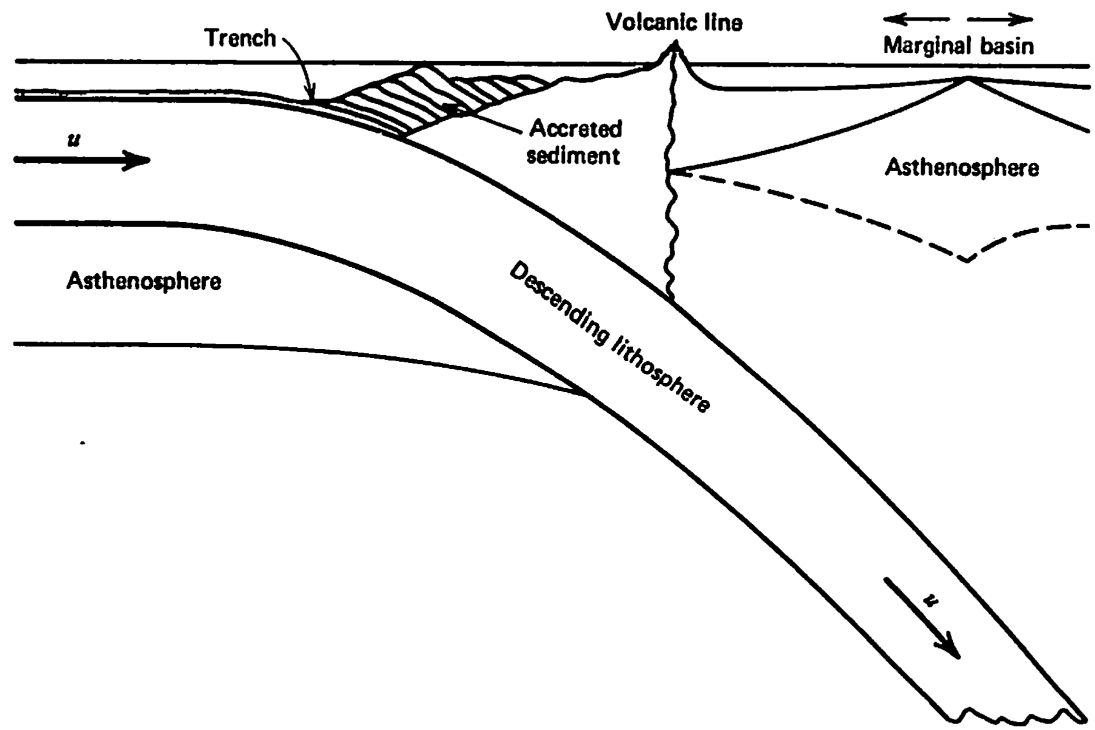


Figure 1-8 Subduction of oceanic lithosphere at an ocean trench.

Transform Fault – conservative margin

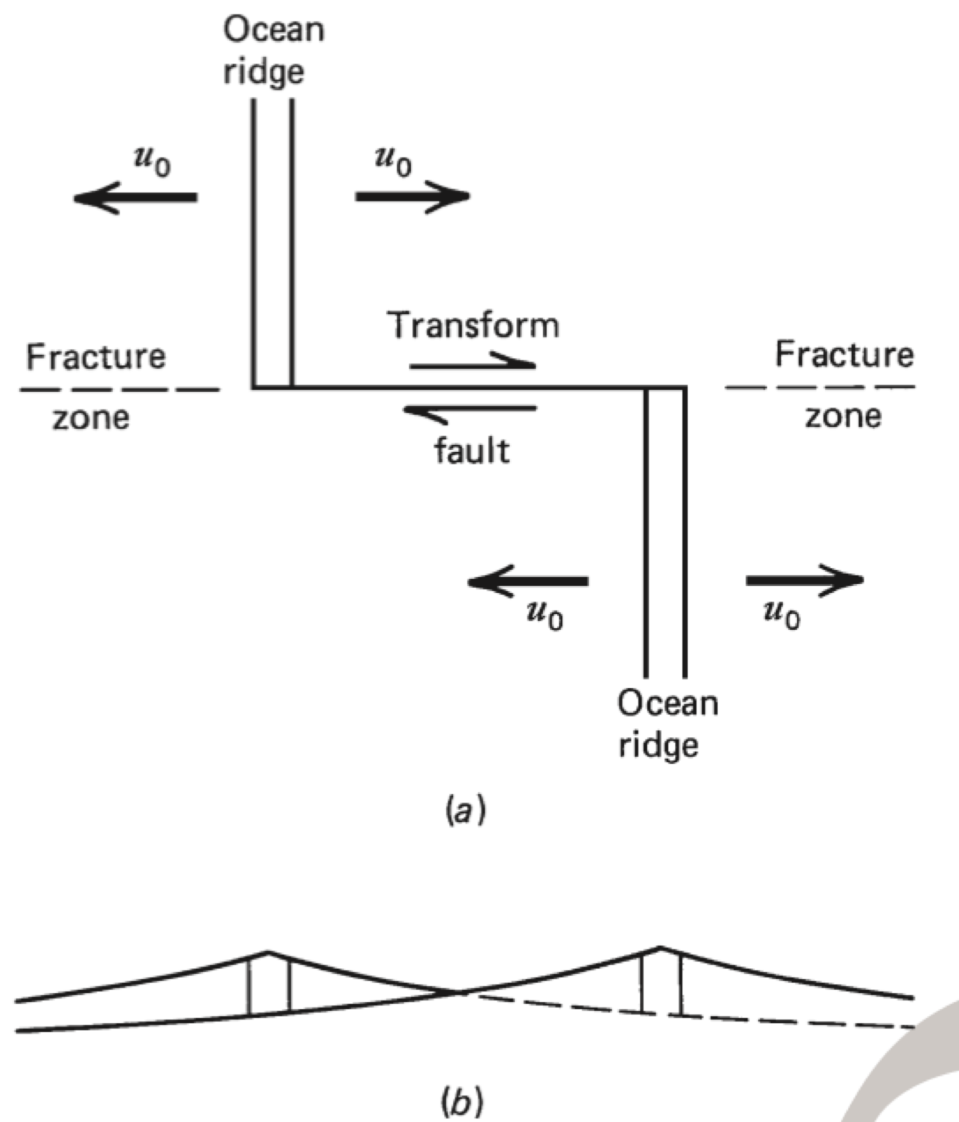
Transform faults are conservative boundaries where plates are neither created nor destroyed.

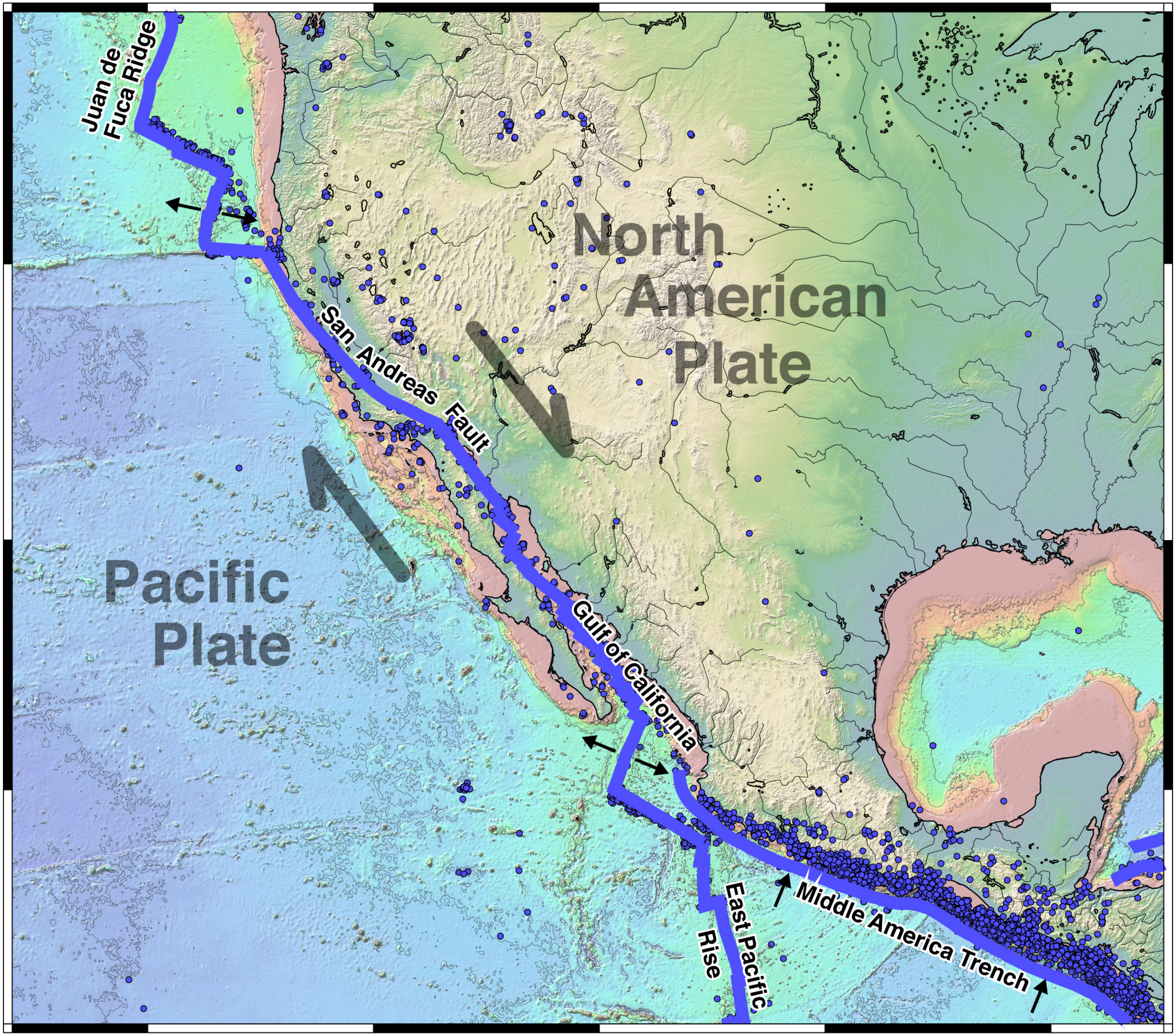
The sense of offset across a transform fault is either right lateral or left lateral.

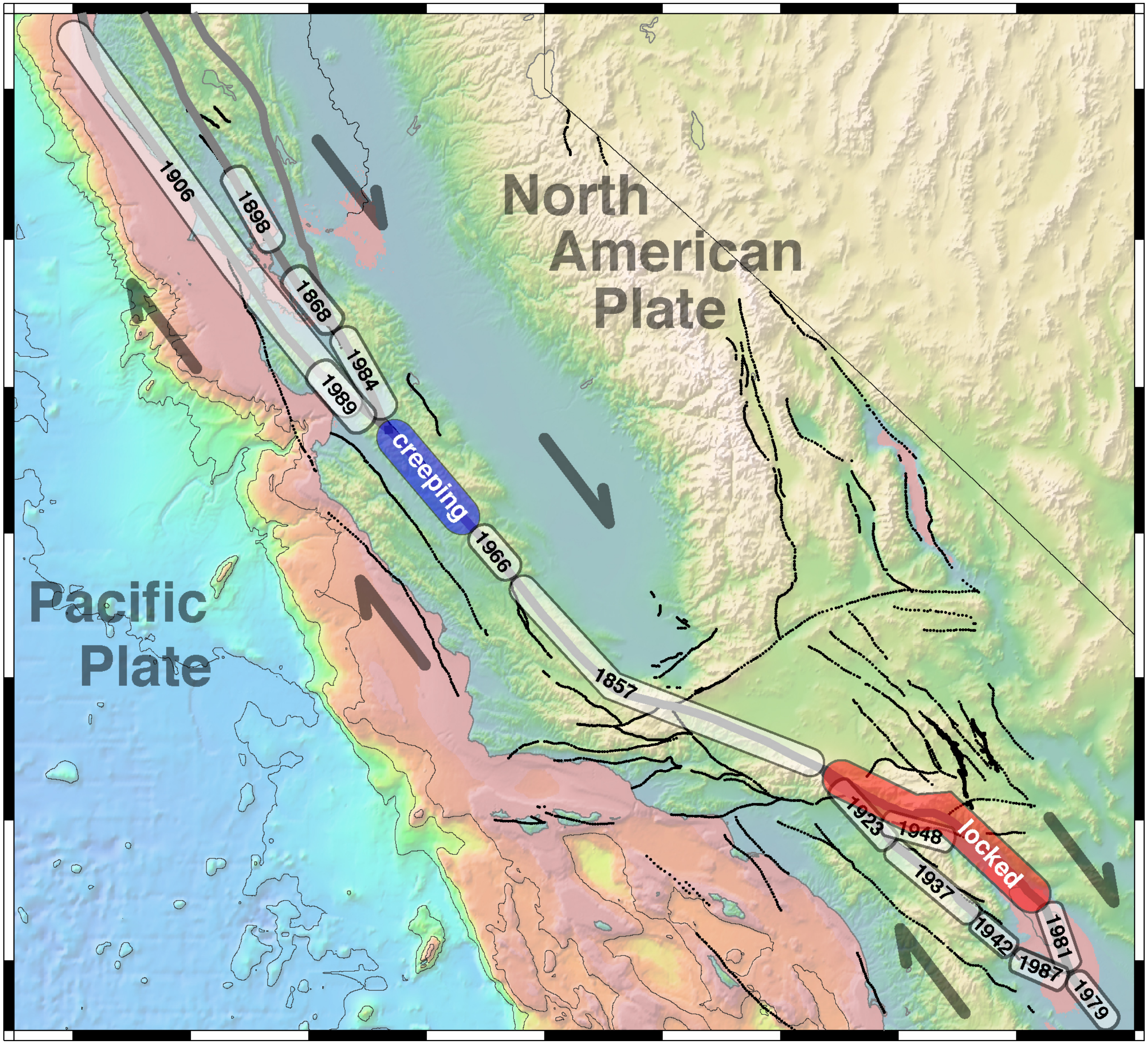
A Fracture zone is the inactive trace of the transform fault.

The relative motion vector across a transform fault is always parallel to the spreading direction. (Next lecture we'll see that transform faults lie along a small circle about the pole of rotation between the two plates.)

What is the most important TF for people living in California?




Juan de Fuca Ridge
North American Plate
San Andreas Fault
Pacific Plate
Gulf of California
East Pacific Rise
Middle America Trench


North American Plate
Pacific Plate
1906
1898
1868
1984
1989
creeping
1966
1857
1923
1948
locked
1937
1942
1981
1987
1979

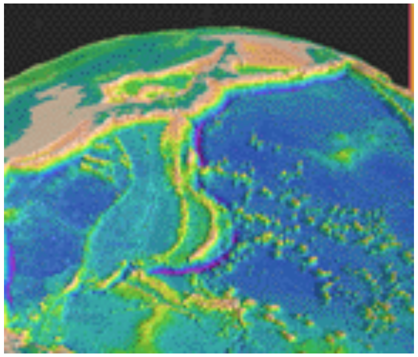


Plate Tectonics on a Plane

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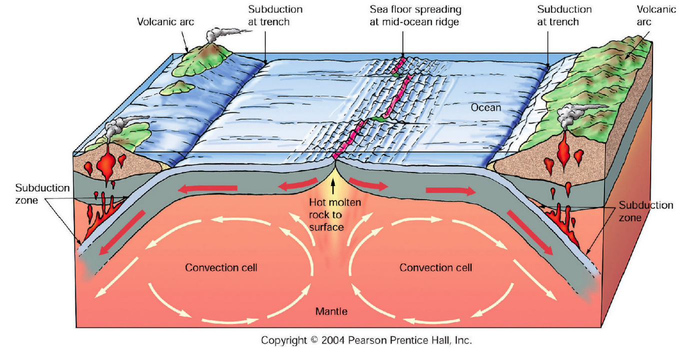

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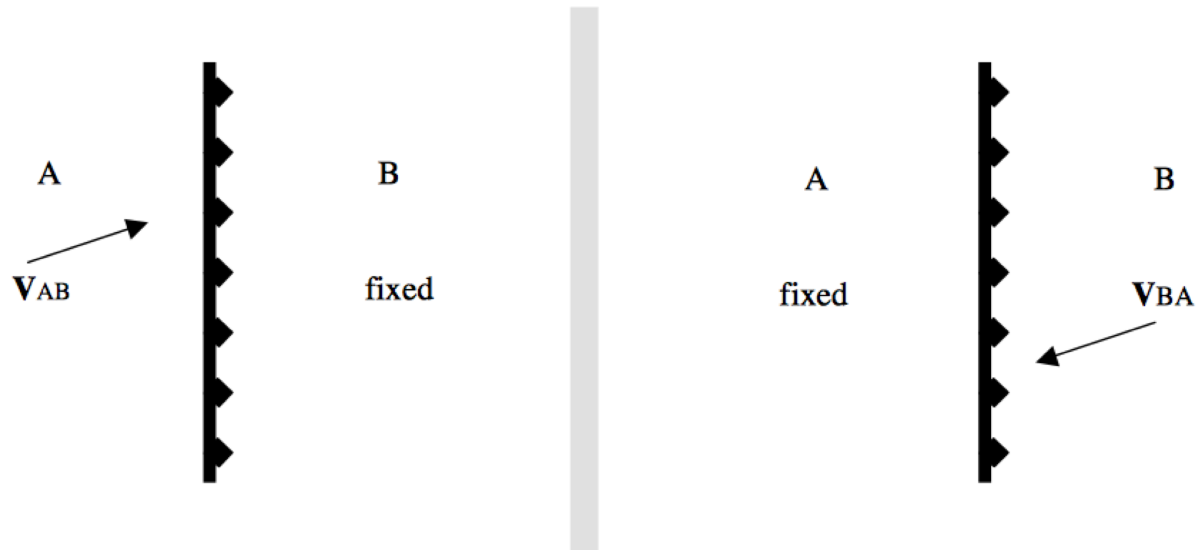
- Plate tectonic theory – types of plate boundaries

- **Plate motions on a plane and triple junction closure**

- Plate motions on a sphere – next lecture

Plate Motions on a Flat Earth

Plate tectonic theory describes the motions of rigid plates on a spherical earth. However, when considering the relative motions very close to the plate boundary, or at a triple junction, it is appropriate to use a flat earth approximation. We'll begin with the flat earth case and then move on to the spherical case. Consider 2 plates A and B, which have a subduction zone boundary between them such as the Nazca and South American plates. In this analysis all plate motions are relative so one can either consider plate B as fixed or plate A as fixed and draw the relative vector velocity between them as shown in the diagram below.



$\mathbf{V}_{AB}$ – velocity vector of plate A relative to plate B.

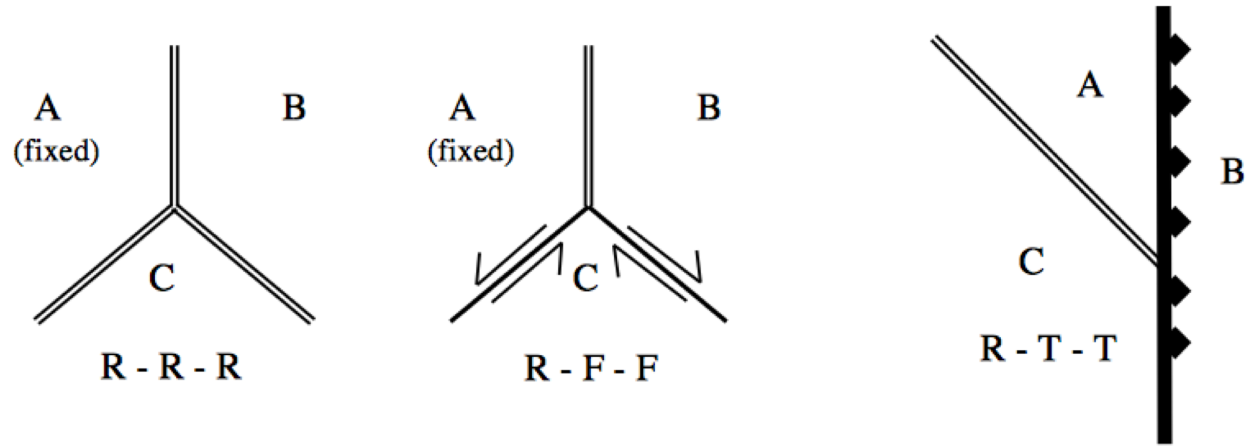
$\mathbf{V}_{BA}$ – velocity vector of plate B relative to plate A.

$$\mathbf{V}_{AB} = -\mathbf{V}_{BA}$$

$$\mathbf{V}_{AB} = V_x i + V_y j$$

Triple Junction

A triple junction is the intersection of three plate boundaries. The most common types of triple junctions are ridge-ridge-ridge (R-R-R), ridge-fault-fault (R-F-F), and ridge-trench-trench (R-T-T).



Each type of plate boundary has rules about relative velocities:

i) ridge - relative velocity must be divergent and is usually perpendicular to the ridge
ii) transform fault - relative velocity must be parallel to the fault
iii) trench - relative velocity must be convergent but no direction is preferred

All triple junctions must satisfy a velocity condition such that the vector sum around the plate circuit is zero.

$$\mathbf{V}_{BA} + \mathbf{V}_{CB} + \mathbf{V}_{AC} = 0 \tag{1}$$

In the real world we usually can map the geometry of the spreading ridges, transform faults and trenches but cannot always measure the relative velocities. The triple junction closure equation (1) can be used to solve for spreading velocities given the triple junction geometry, the rules, and at least one relative plate velocity.

Use Google Earth to explore plate tectonics

Gather the kmz files from the following ftp location for display in Google Earth.

http://topex.ucsd.edu/geodynamics/tectonics.kmz (linked on class web page)

plate_bounderies.kmz – Global plate boundaries divided into ridges, extinct ridges, trenches, and transform faults.

topography.kmz – Global bathymetry based on ship soundings and satellite gravity used as the base map for Google Earth.

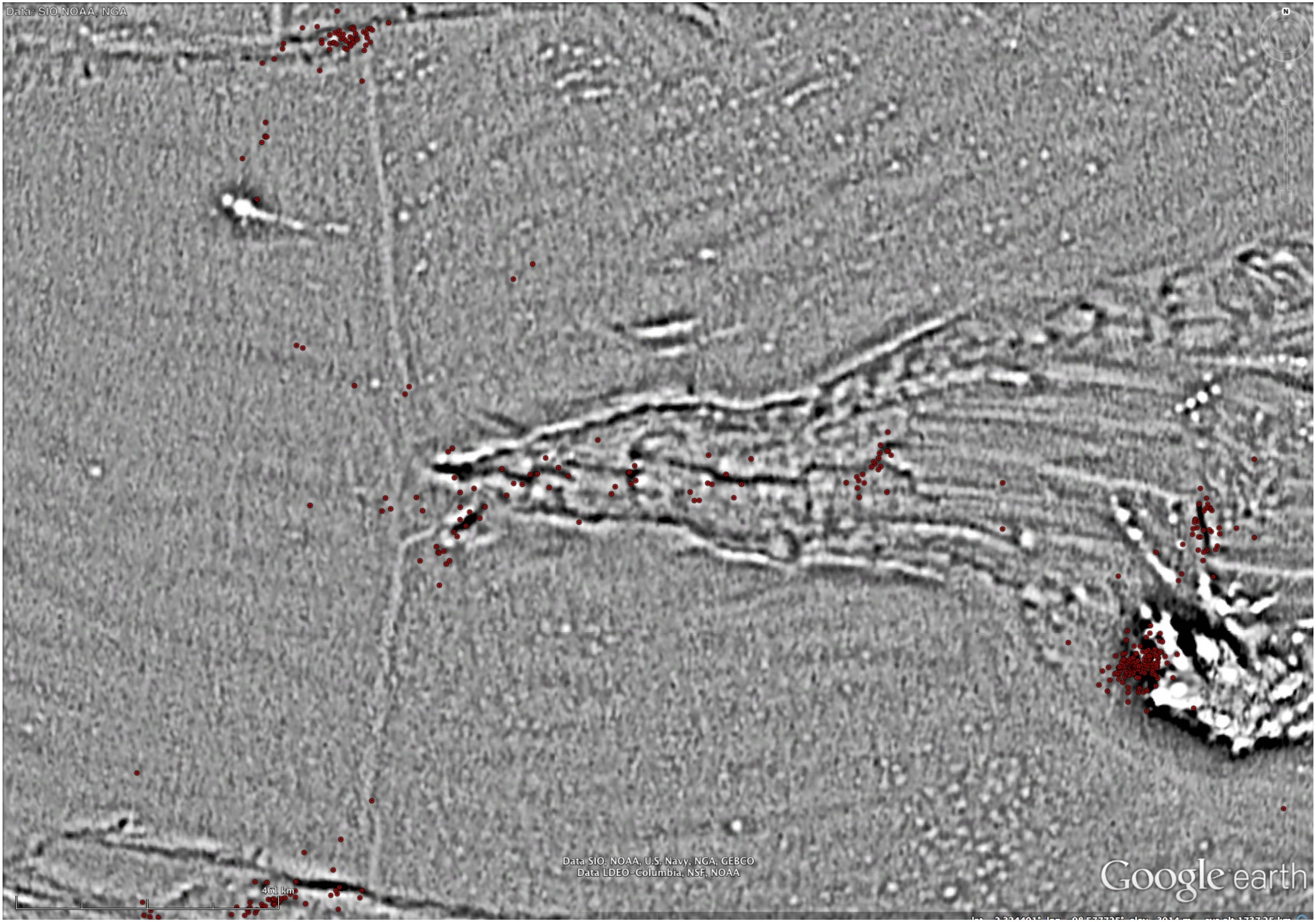
VGG.kmz – Vertical gravity gradient derived from satellite altimetry used to highlight plate boundaries and fracture zones.

Tectonics.kmz – Digitized fracture zones and other features used to develop global plate reconstructions.

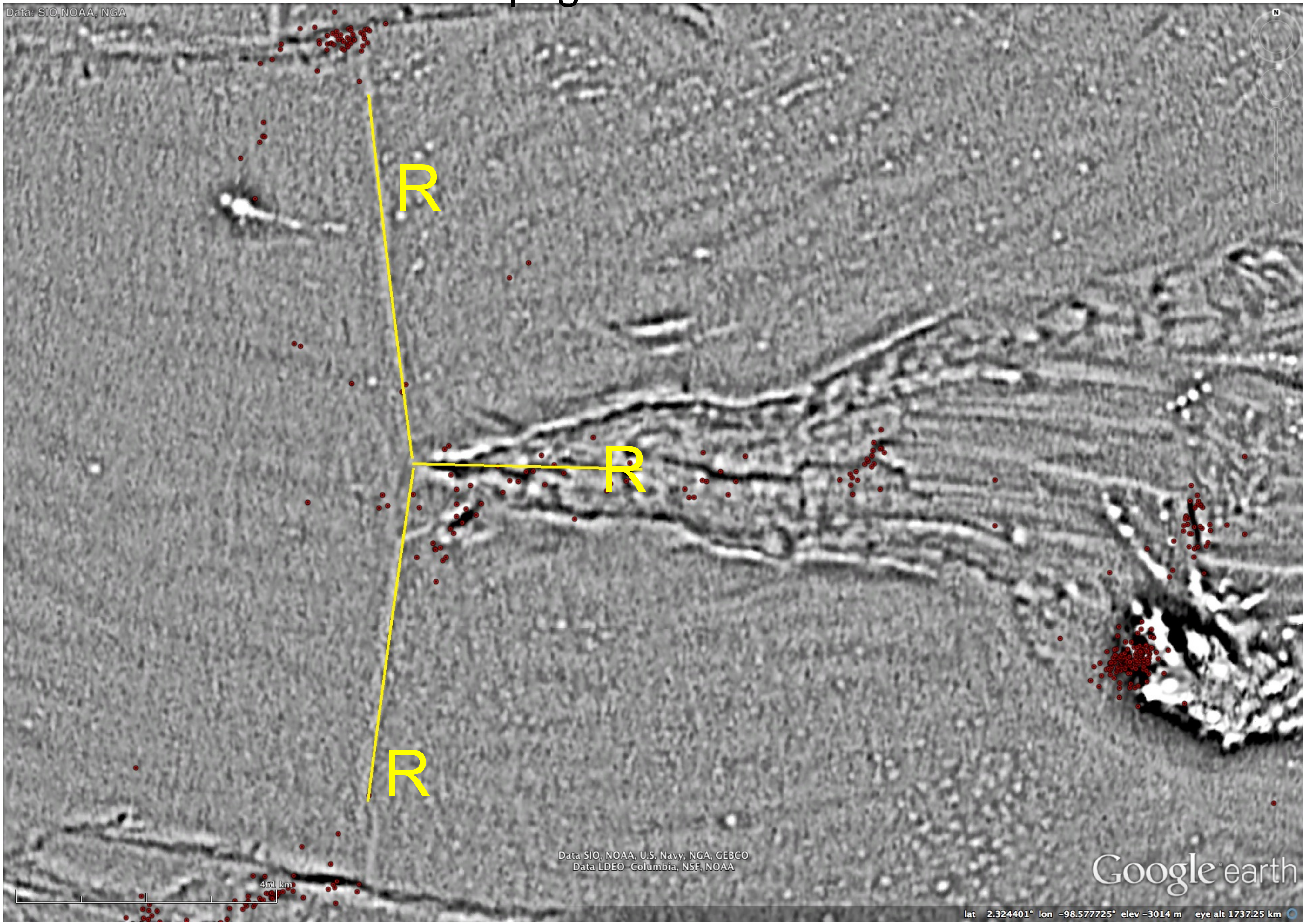
age.kmz – Global seafloor age based on marine magnetic anomalies and digitized fracture zones

Earthquakes.kmz - Global relocated earthquakes with magnitude > 5.5 from Engdahl et al., [1997] red - shallow (0-70 km); green intermediate (70 - 300 km); blue deep (300 - 700 km). (not included – too large)

Galapagos TJ

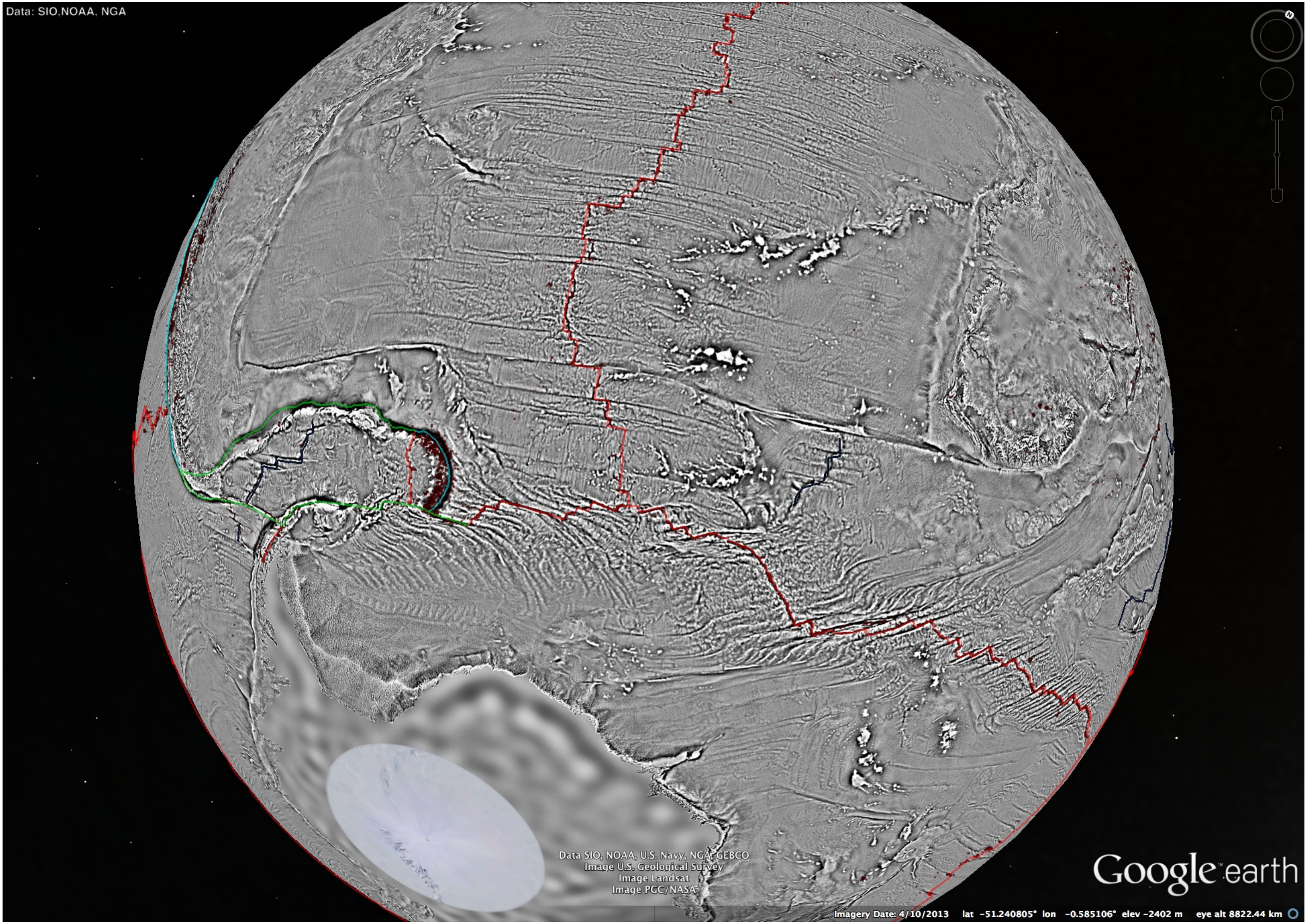


Galapagos TJ

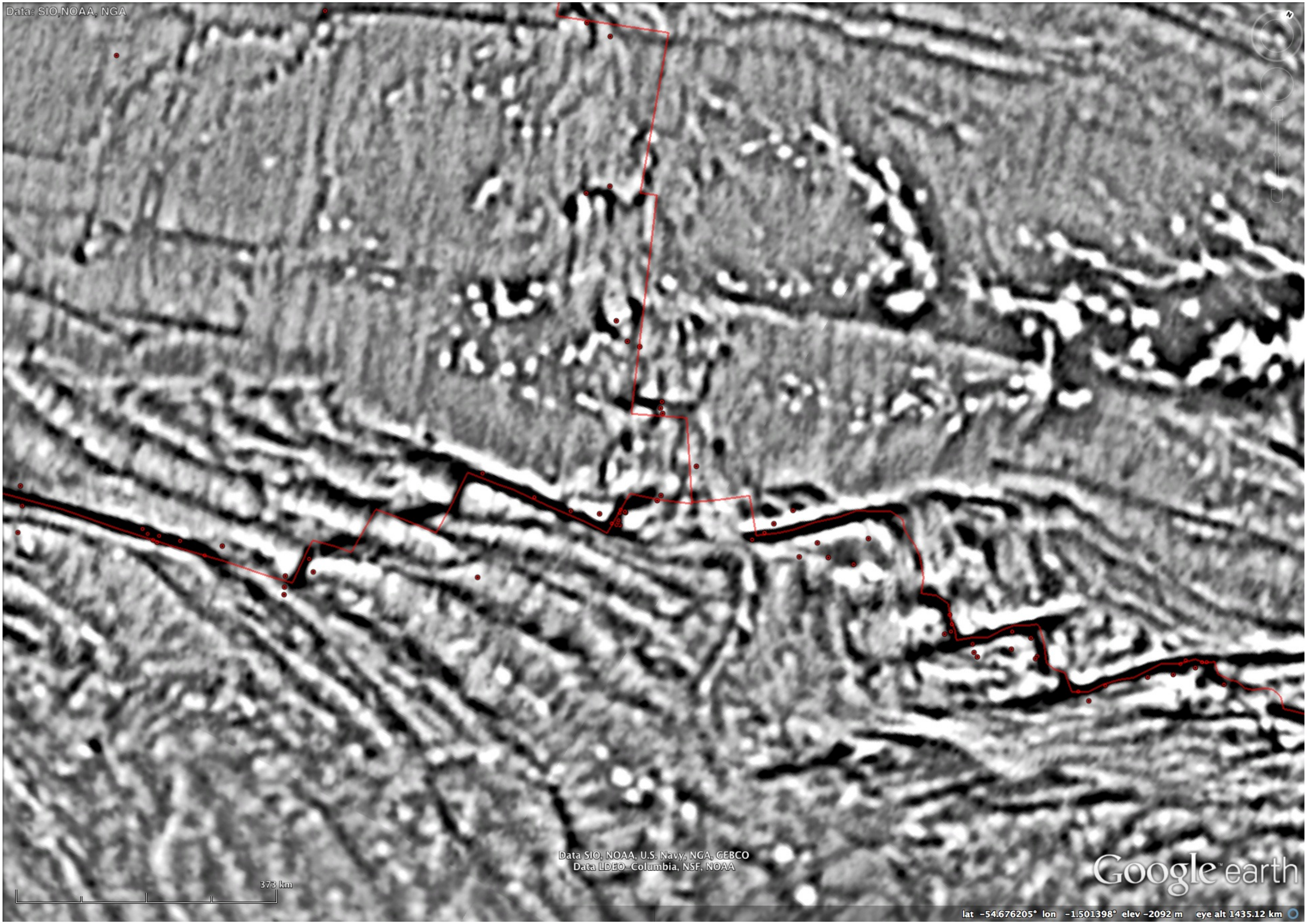


Solution to Galapagos TJ on blackboard

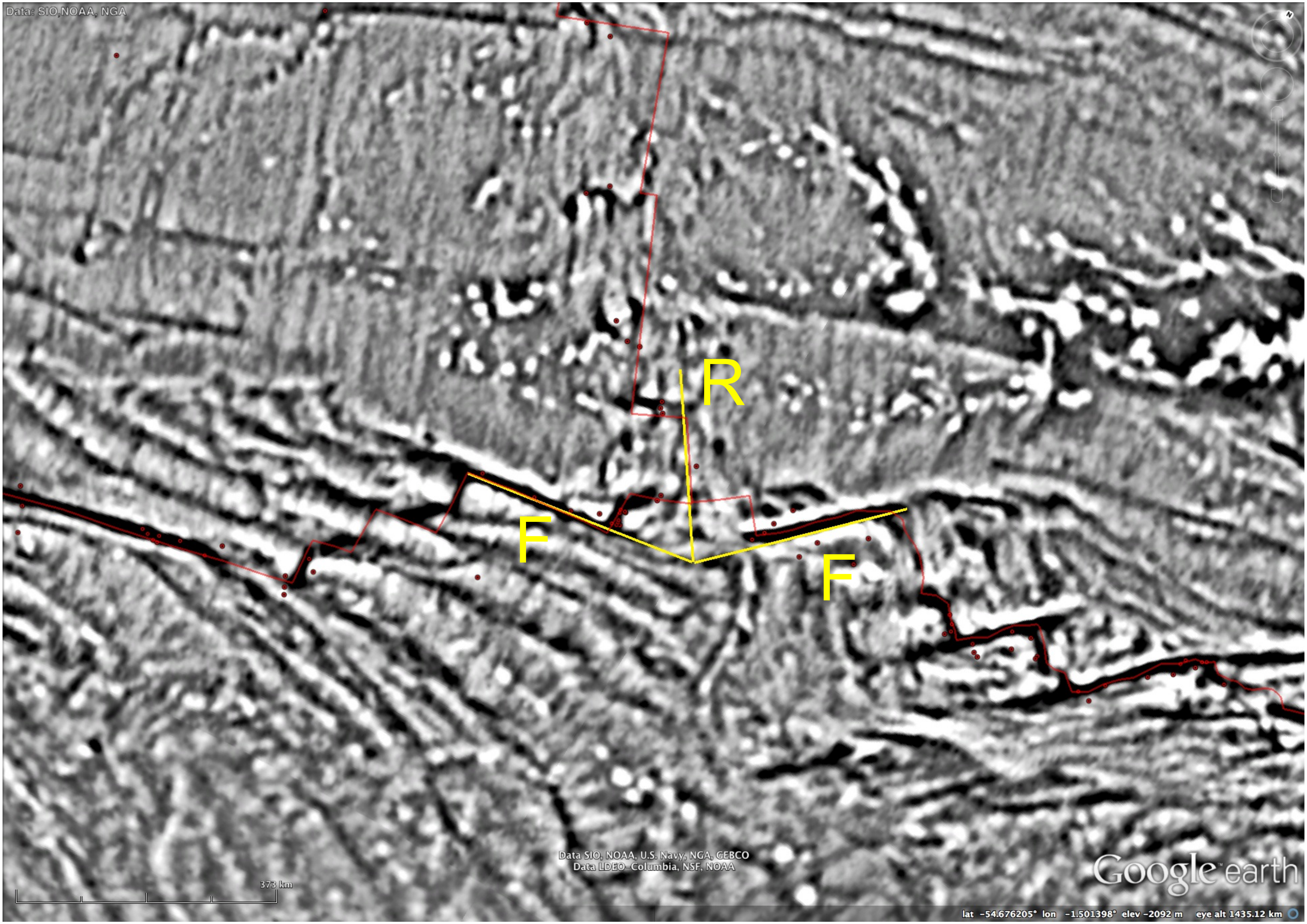
Bouvet Triple Junction



Bouvet Triple Junction

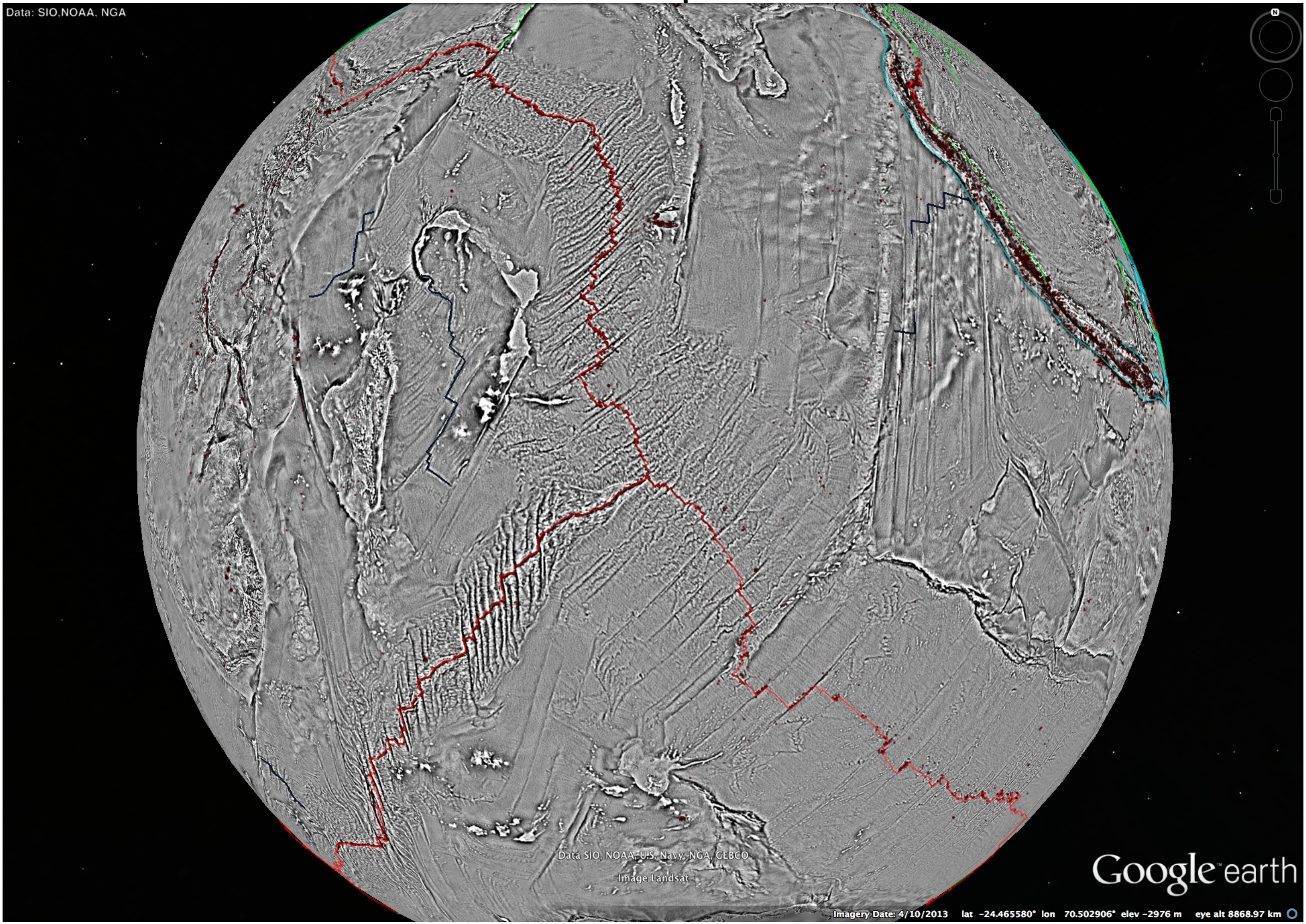


Bouvet Triple Junction

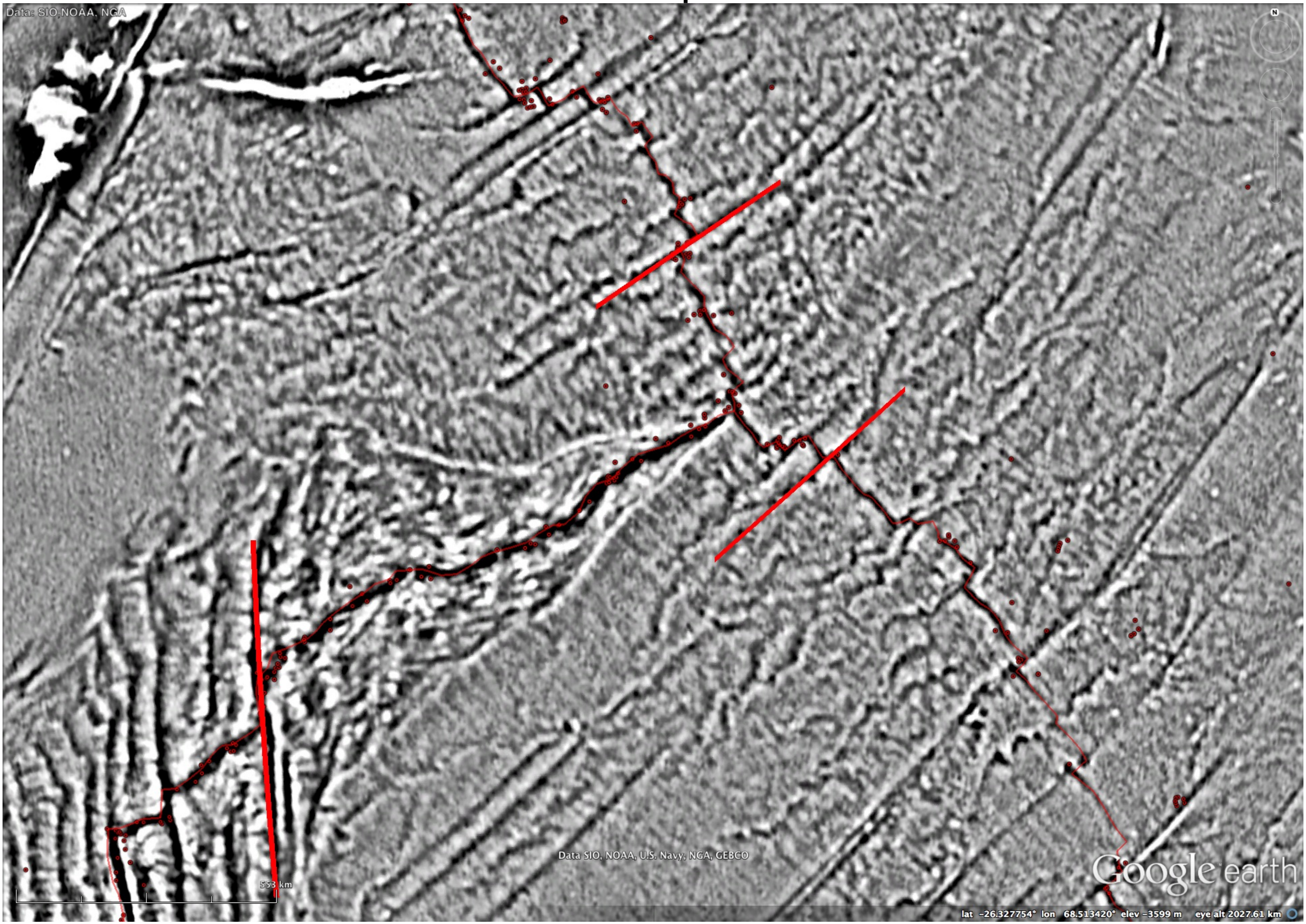


Solution to Bouvet TJ on blackboard

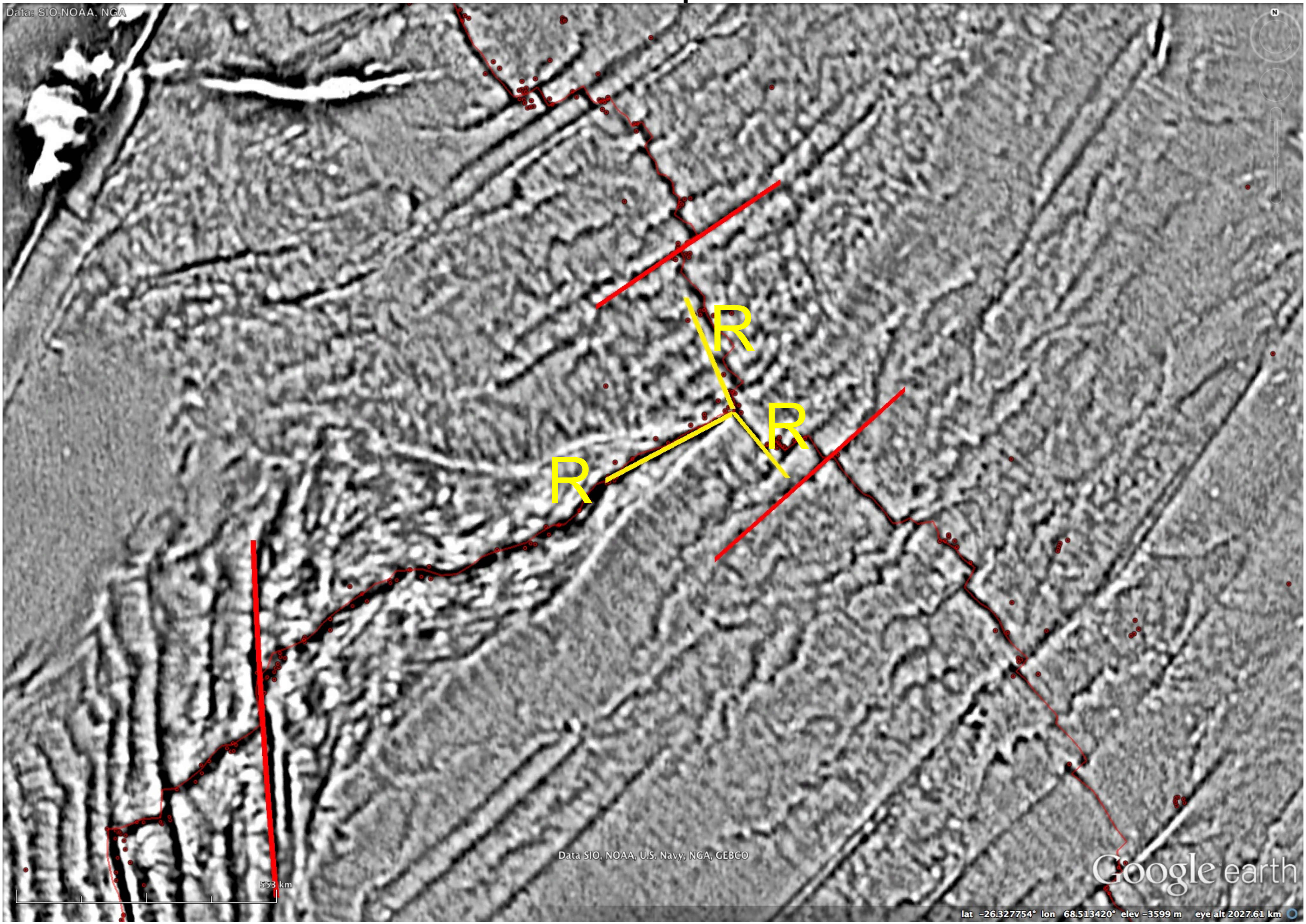
Indian Ocean Triple Junction



Indian Ocean Triple Junction



Indian Ocean Triple Junction



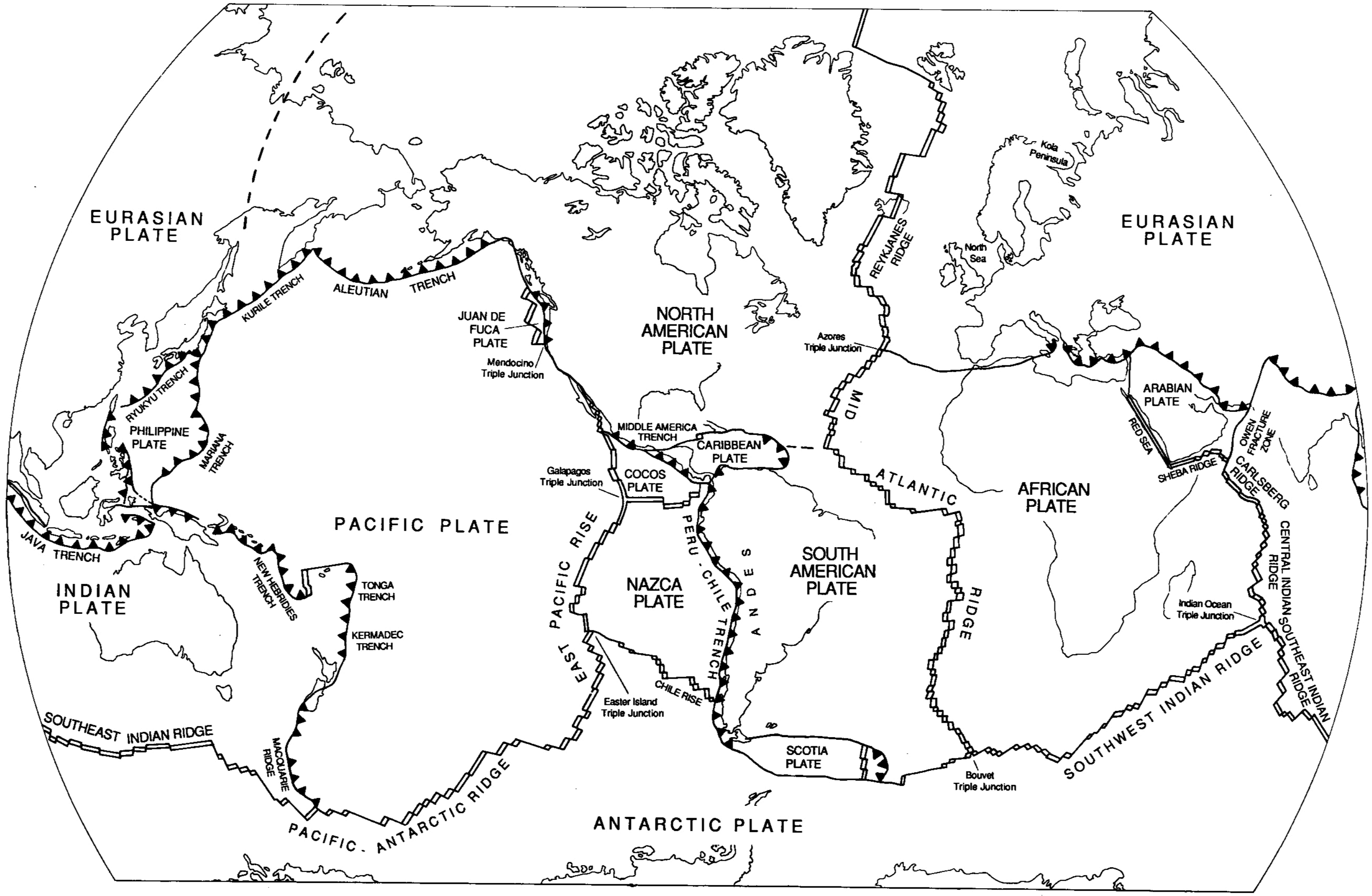


Figure 2.2. The major tectonic plates, midocean ridges, trenches and transform faults.

EXERCISE: Try all the triple junctions on this map. One could be on the quiz.

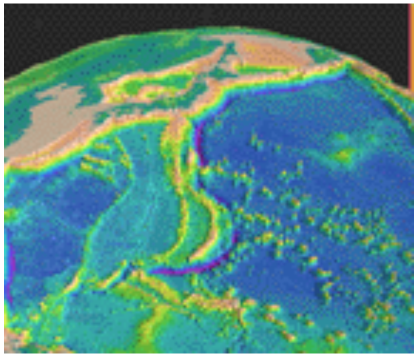


Plate Tectonics on a Plane

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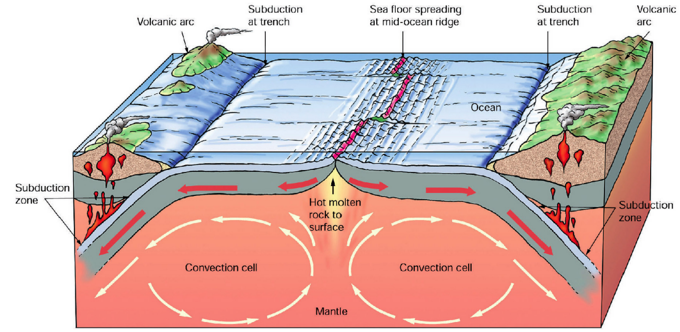

- What are the critical observations related to plate tectonics?

- Plate tectonic theory – what are the vector rules at the three types of plate boundaries?

- What is the equation for plate triple junction closure?