COURSE: GEO-INFORMATICS IN EARTH SCIENCE, TECTONIC HAZARD AND INFRASTRUCTURE MANAGEMENT

LECTURE 2 – Introduction to Tectonic Structure and Hazard

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Tectonic

Tectonics encompasses the examination of the origin and organization of Earth's extensive structural characteristics, such as:

- Folds and faults
- Fractures and cracks
- Mountain ranges
- Continents
- Earthquake belts

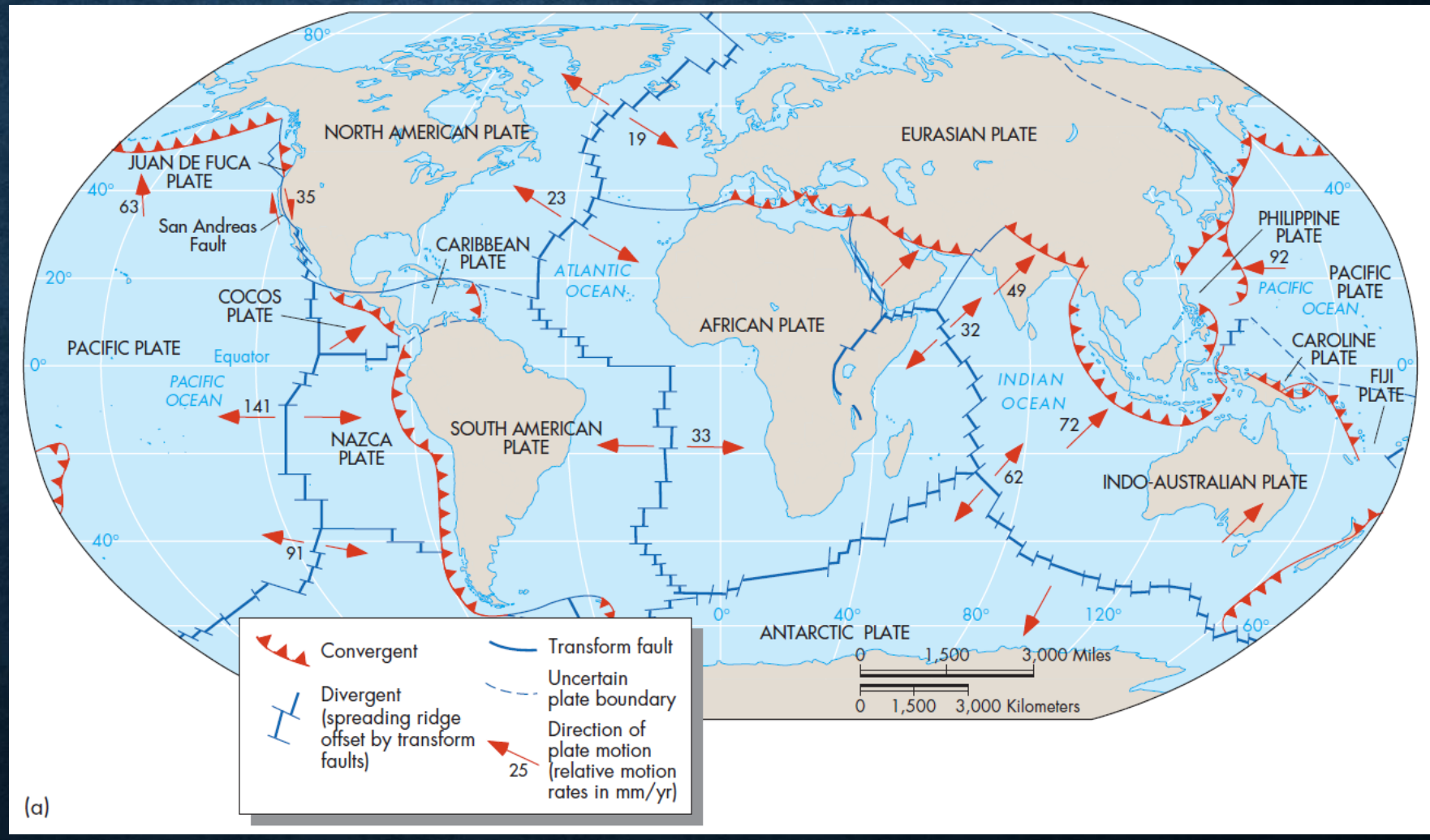
Tectonic plate

There are several major tectonic plates on Earth:

- Pacific Plate,
- North American Plate,
- Eurasian Plate,
- African Plate,
- South American Plate,
- Antarctic Plate,

Tectonic plate and Structure

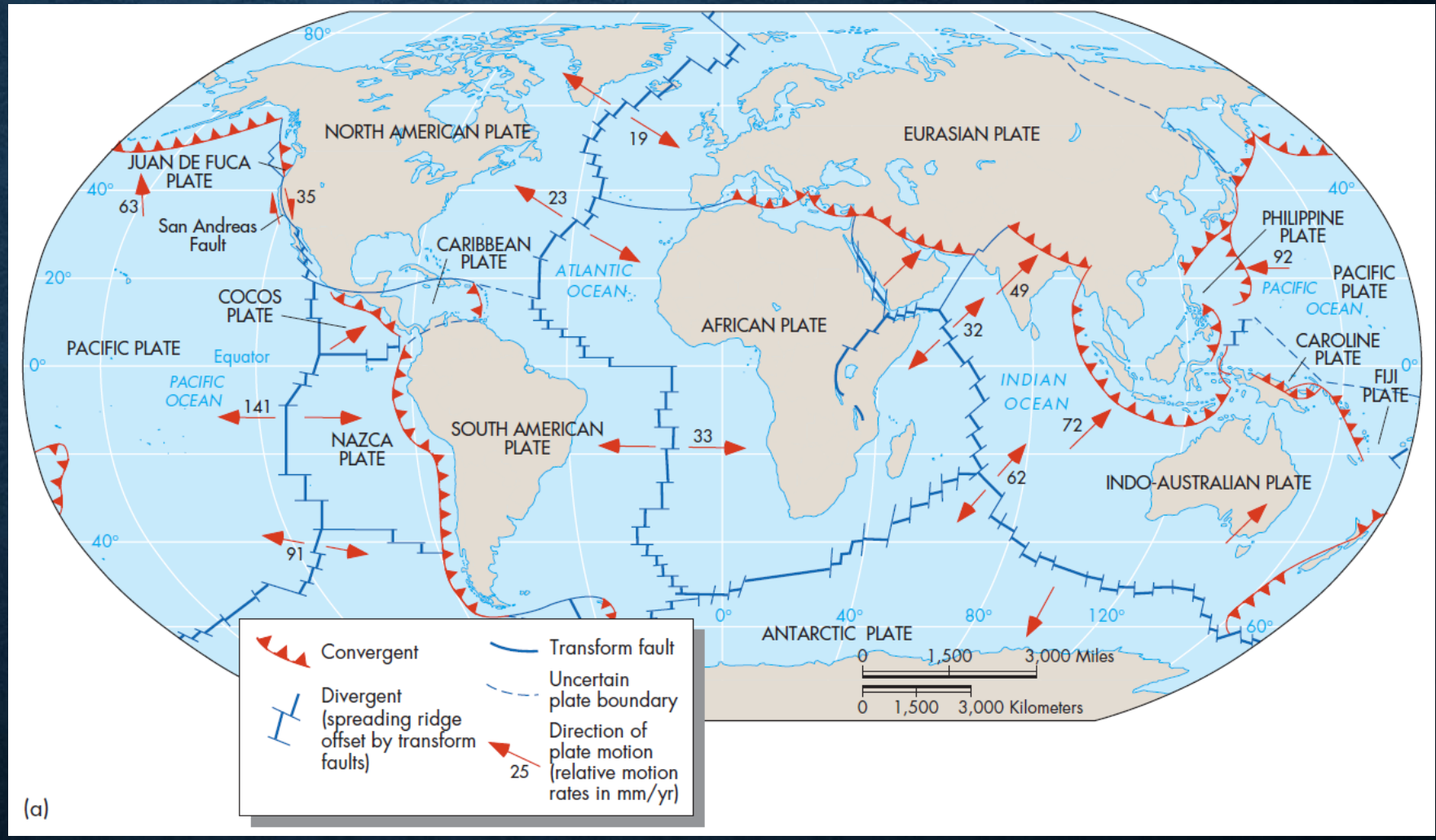
- Tectonic plates are large, rigid pieces of the Earth's lithosphere that float on the semi-fluid asthenosphere beneath them.



Source: Christopherson, R. W. 1994. Geosystems, 2nd ed. Englewood Cliffs, NJ: Macmillan

Tectonic plate and Structure

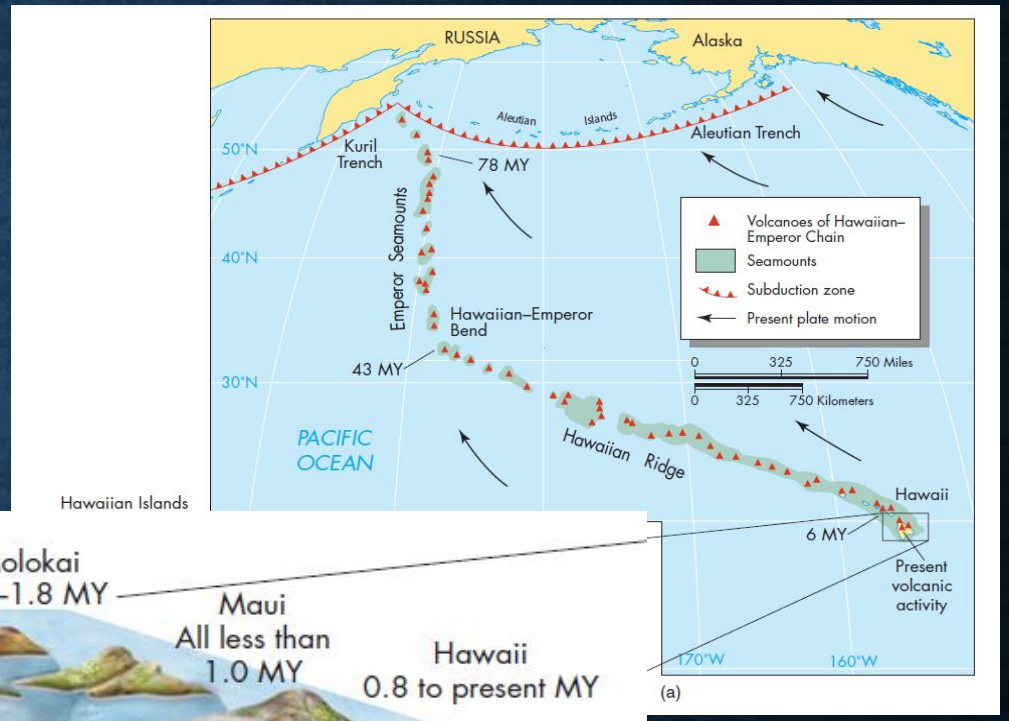
- The plates are composed of oceanic and continental crust, varying in size, shape, and thickness.

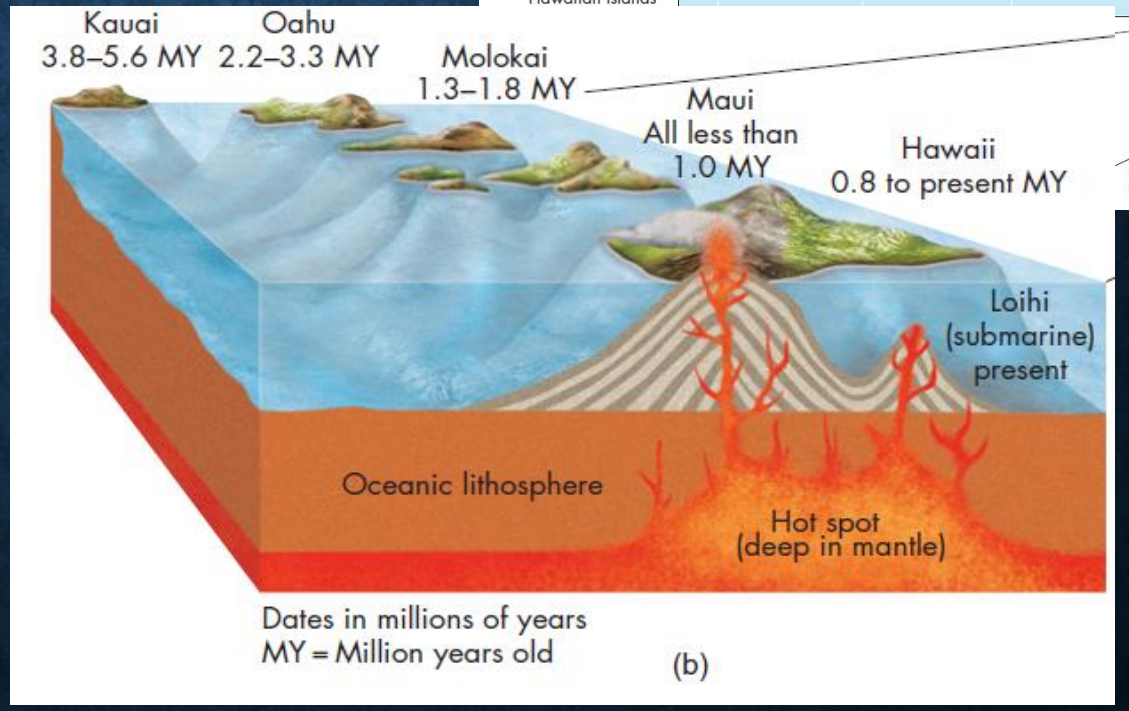


Source: Christopherson, R. W. 1994. Geosystems, 2nd ed. Englewood Cliffs, NJ: Macmillan

Tectonic Plate Movement Results

- Plate Tectonics Shapes Continents and Dictates the Location of Mountain Ranges Movement of the lithospheric plates is responsible for the present shape and location of the continents.



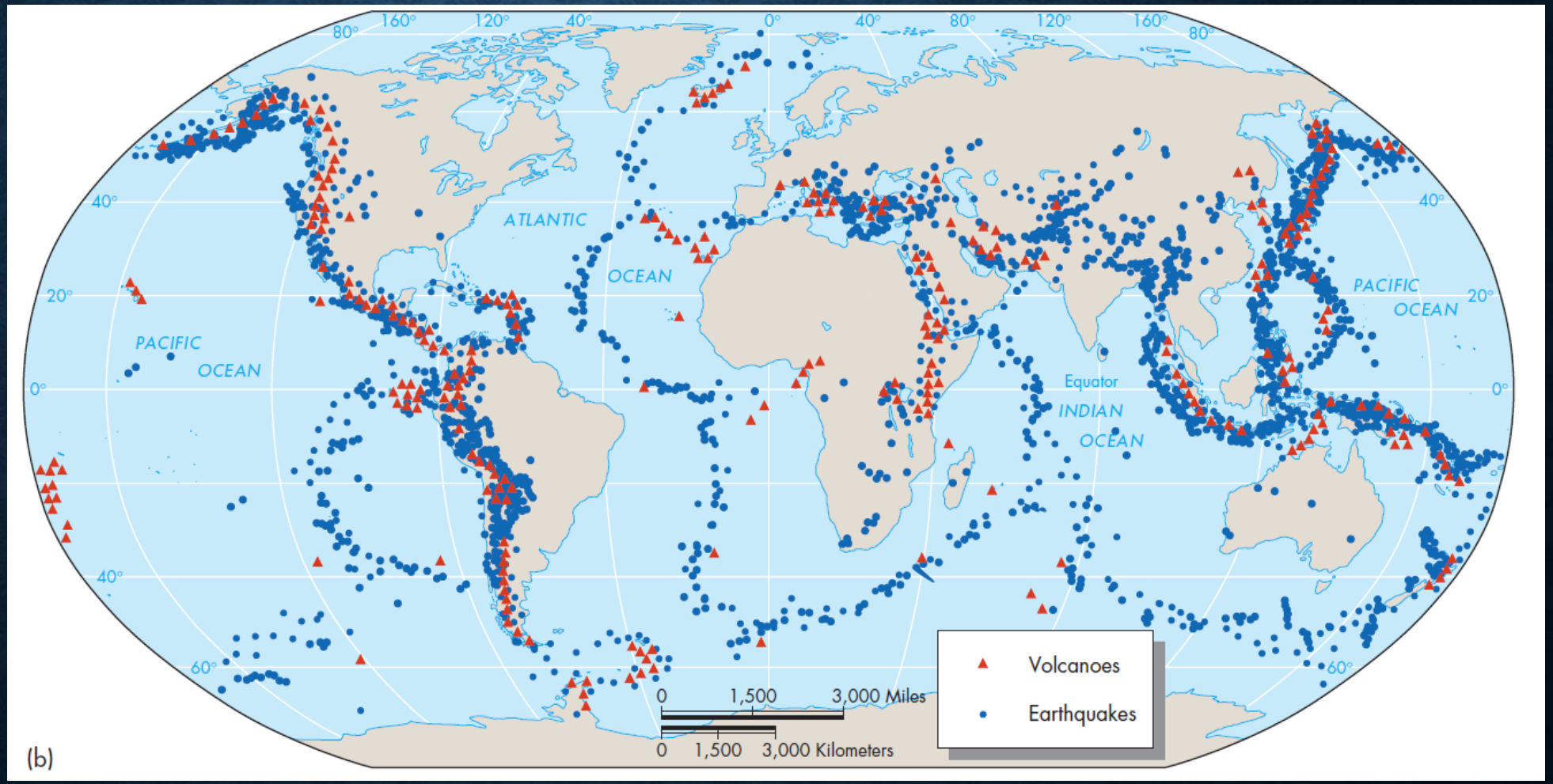


Source: Edward A. Keller, Duane E. Devecchio, Robert H. (CON) Blodgett, 2012, 3rd edition

(Modified after Claque, D. A., Dalrymple, G. B., and Moberly, R. 1975.

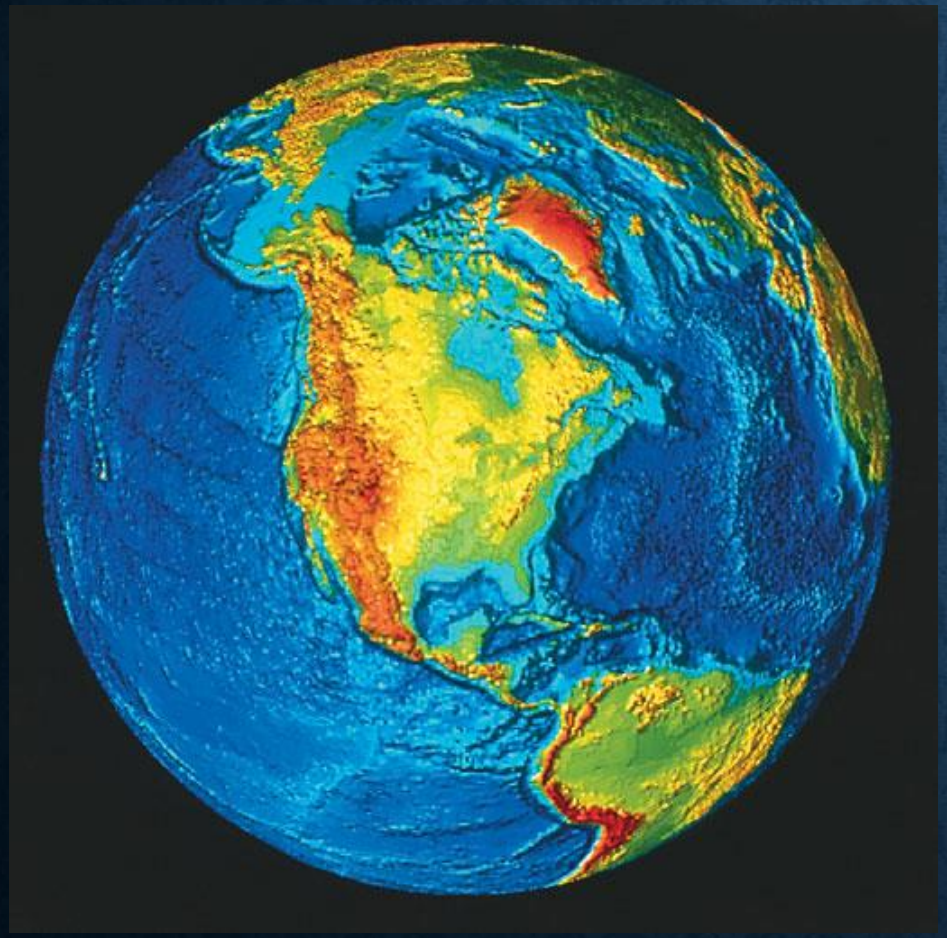
What is Tectonic plate and Hazard

- Where there is a plate boundary, the hazard Results

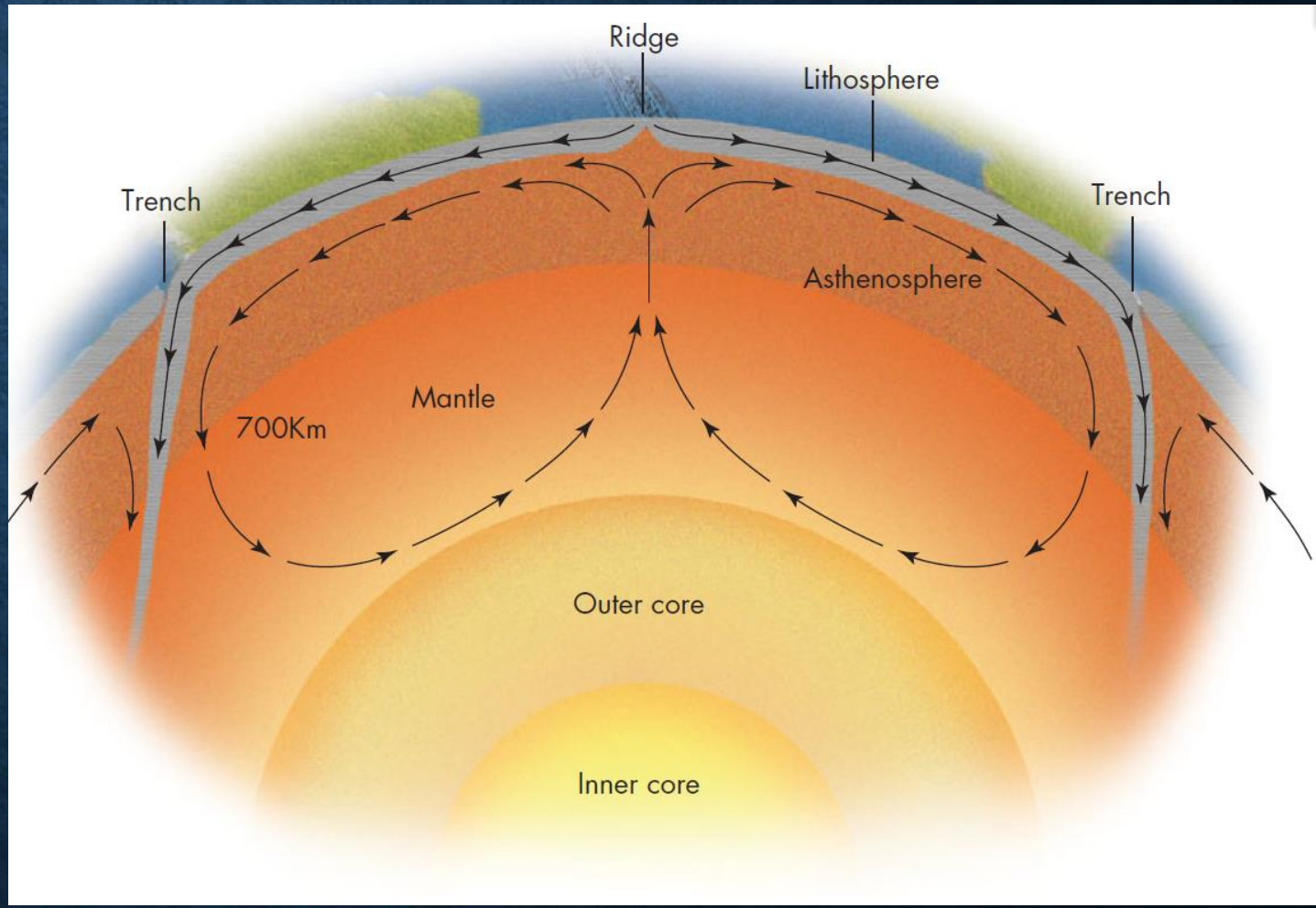


Source: Hamblin, W. K. 1992. Earth's dynamic systems, 6th ed. New York: Macmillan

Convention current and Plate Movement



Source: National Geophysical Data Center, NOAA



Source: Grand, S. P. 1994

Convention current and Plate Movement

Plate boundaries are the areas where tectonic plates interact.

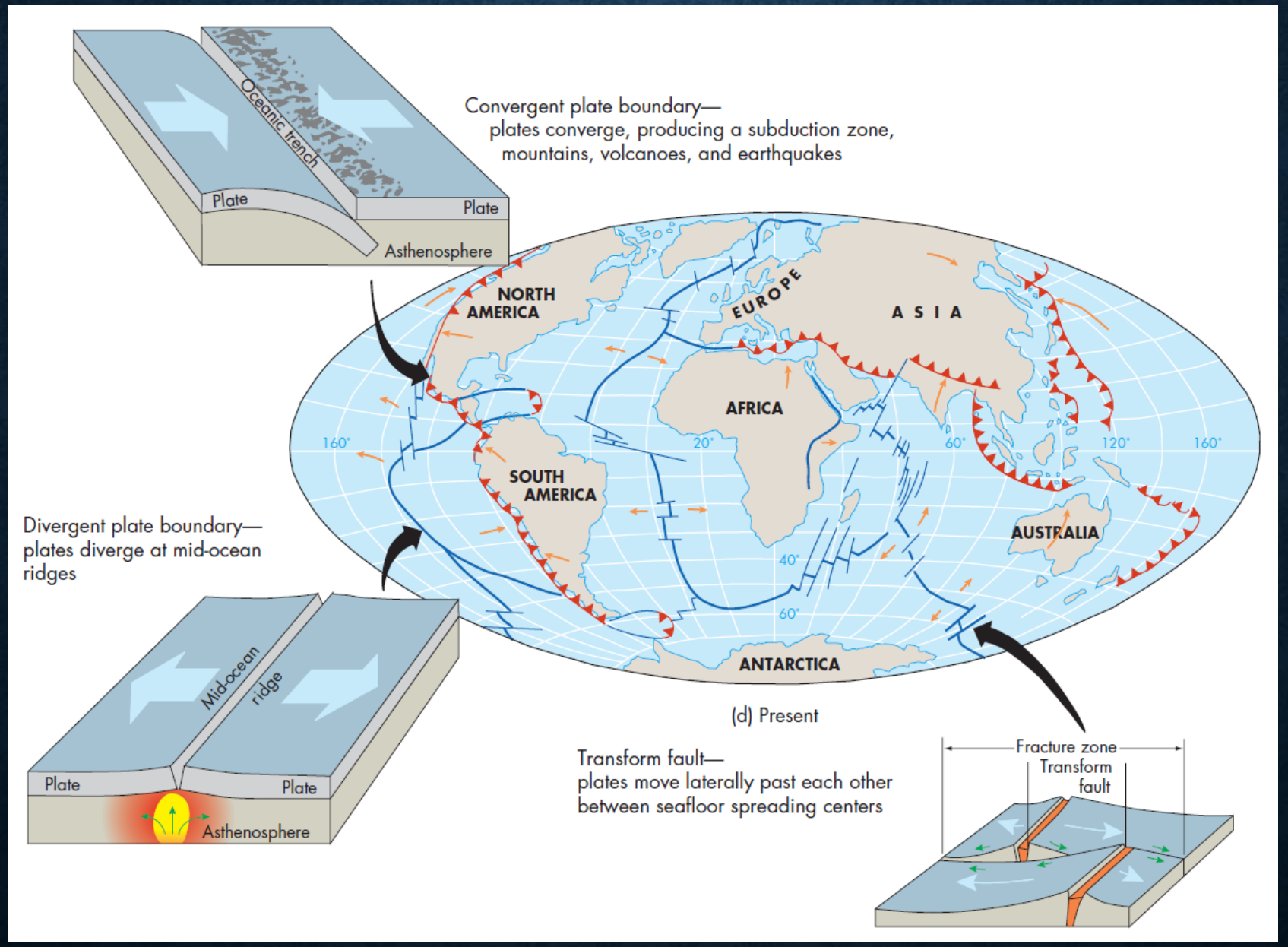
There are three main types of plate boundaries:

1. divergent boundaries (plates move apart),

2. convergent boundaries (plates move toward each other), and

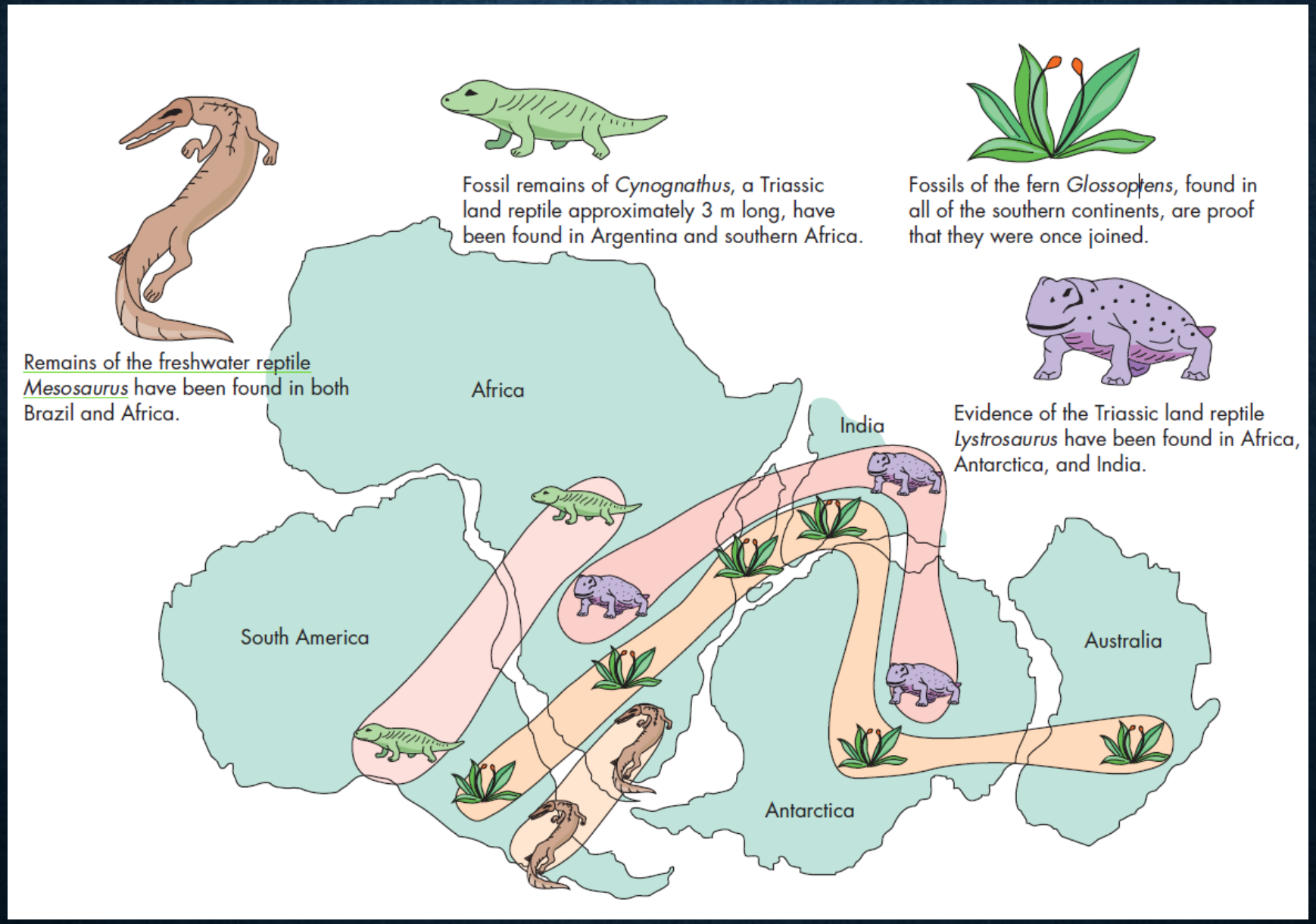
3. transform boundaries (plates slide past each other).

Convention current and Plate Movement



Source: From Dietz, R. S., and Holden, J. C. 1970

Convention current and Plate Movement

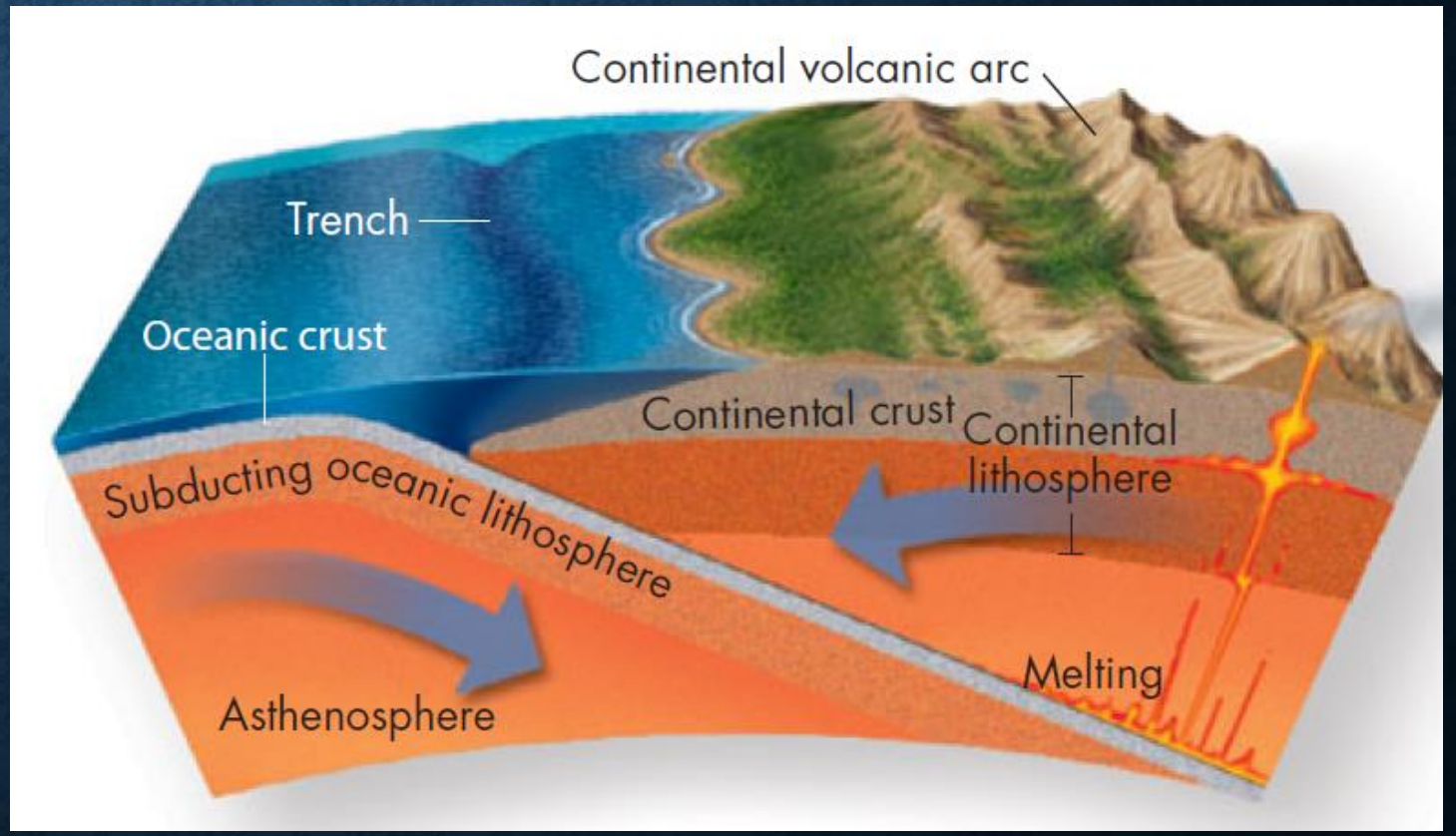


Source: From Hamblin, W. K. 1992. Earth's dynamic systems, *6th ed. New York: Macmillan*

Convergent Plate Boundaries

Continental to Oceanic Plate Collision

- Oceanic plates, denser than continental plates, subduct beneath the continental plates.
- Subduction creates deep oceanic trenches and volcanic arcs on the continental side.
- Commonly associated with powerful earthquakes and volcanic eruptions.

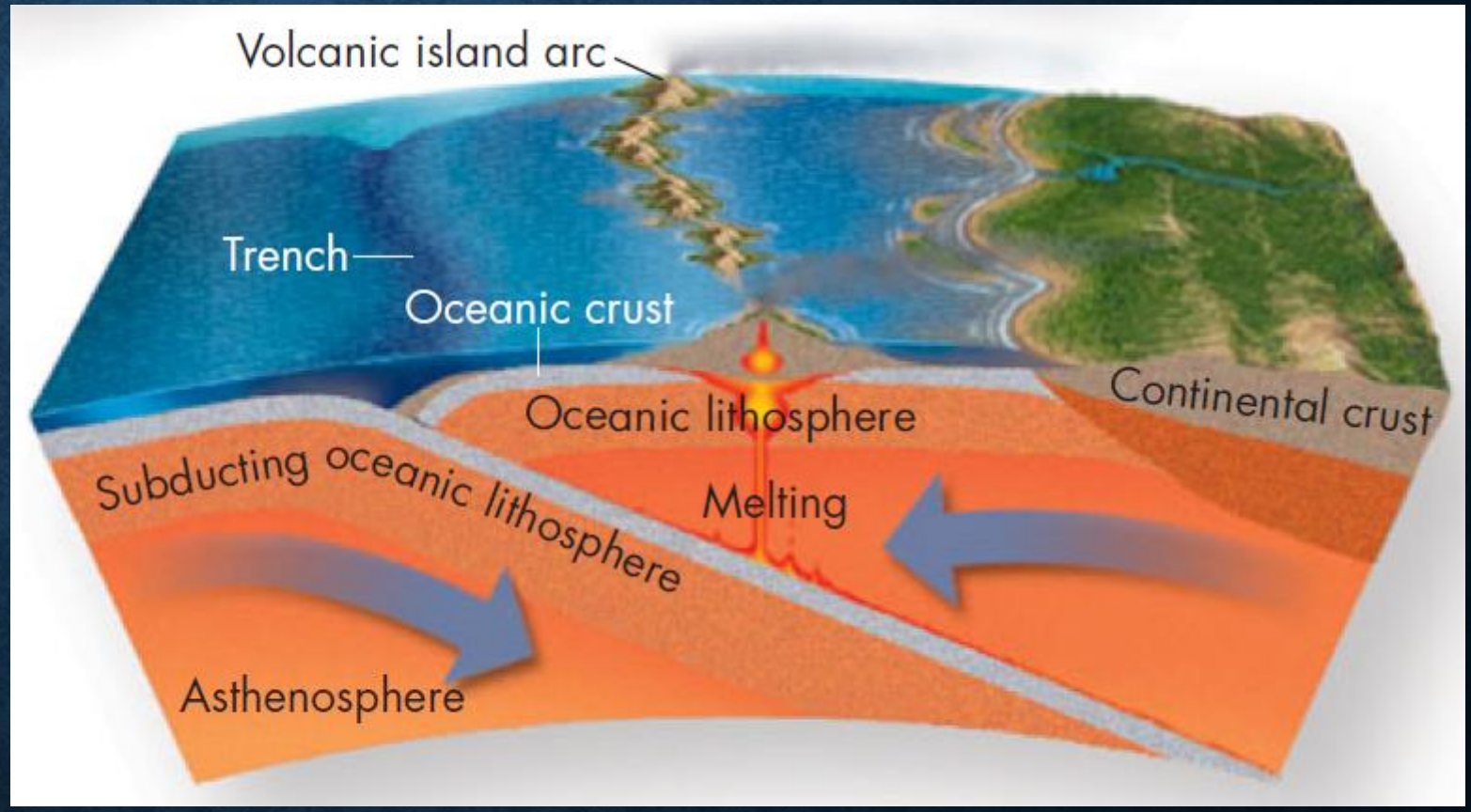


Source: Edward A. Keller, Duane E. Devecchio, Robert H. (CON) Blodgett, 2012, 3rd edition

Convergent Plate Boundaries

Oceanic to Oceanic Plate Collision

- Two oceanic plates collide, and one subducts beneath the other due to differences in density.
- Subduction zones create deep-sea trenches and volcanic island arcs.
- Earthquakes and volcanic activity are prevalent.

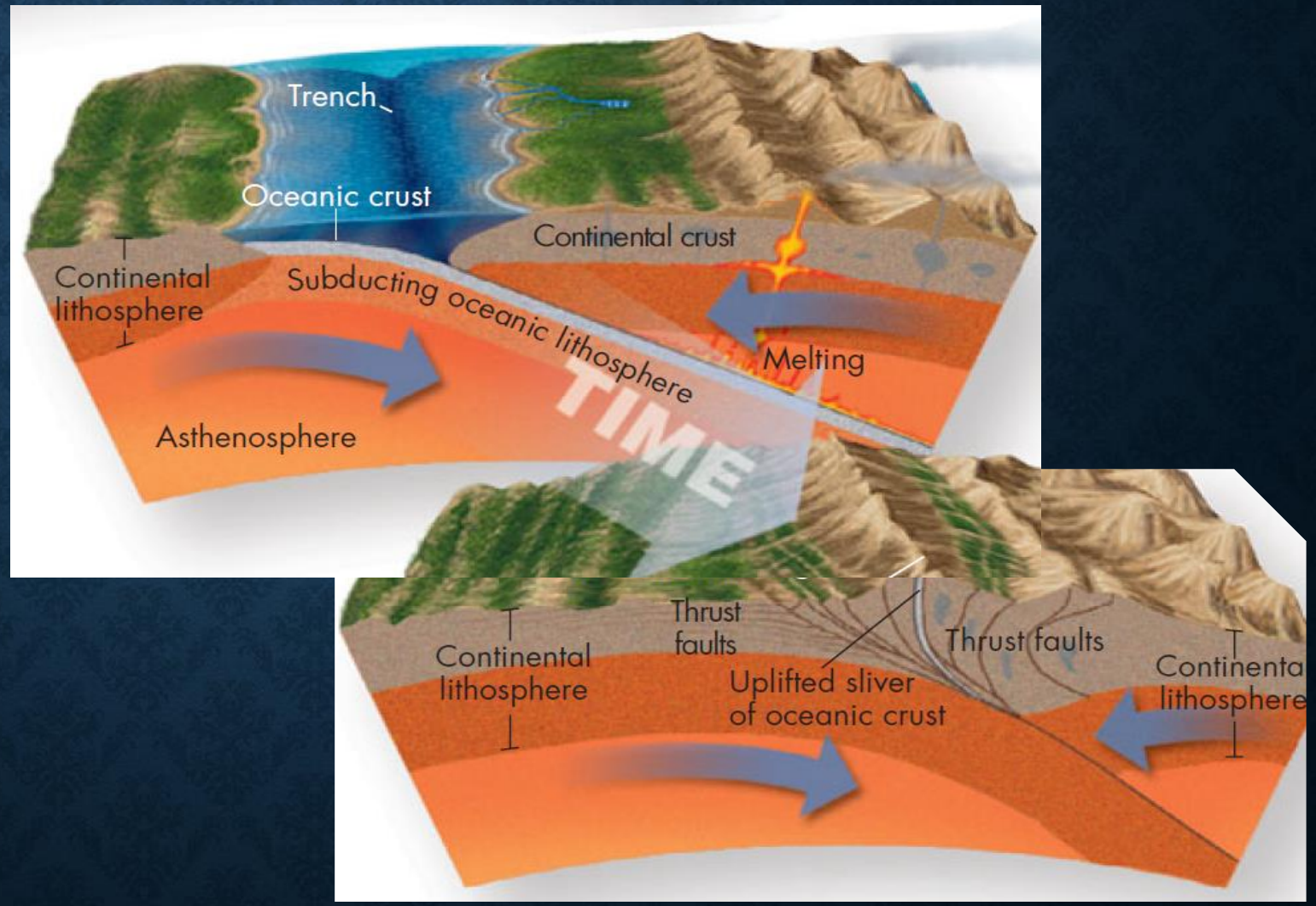


Source: Edward A. Keller, Duane E. Devecchio, Robert H. (CON) Blodgett, 2012, 3rd edition

Convergent Plate Boundaries

Continental to Continent Plate Collision

- Two continental plates collide, and neither is dense enough to subduct.
- Instead, they crumple and compress, leading to the formation of high mountain ranges.
- Intense pressure causes earthquakes, and the uplift results in the creation of mountains.



Source: Edward A. Keller, Duane E. Devecchio, Robert H. (CON) Blodgett, 2012, 3rd edition

Convergent Plate Boundaries

Continental-to-Continent Plate Collision

❖Himalayas Example:

The Himalayan mountain range is a prominent example of a continental-continental convergent boundary formed by the collision of the Indian Plate and the Eurasian Plate.

Credit: Maria Ly (Flickr:mariachily)
Source: http://www.flickr.com/photos/mariachily/3330744786/

Tectonic plate and Hazard

The movement of tectonic plates is responsible for the shaping of the Earth's surface and the occurrence of geological phenomena like;

Most Common:

- earthquakes,
- volcanoes,
- mountain formation,
- creation of ocean basins.

Tectonic plate and Hazard

Least Common:

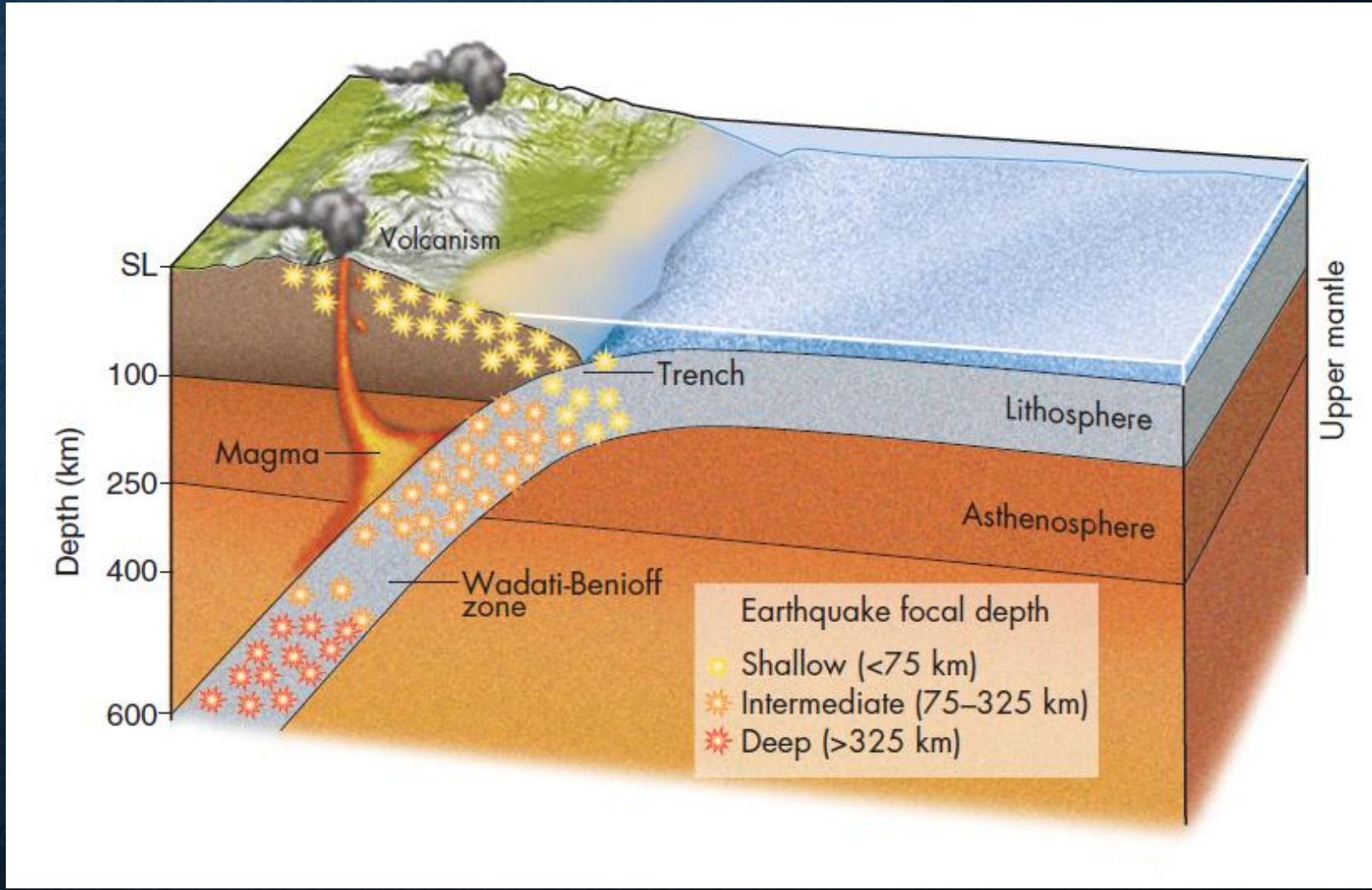
- Tsunami
- Landslides and Debris Flows:
- Tectonic Subsidence:
- Faulting and Ground Rupture:
- Volcanic Ashfall and lava flow:
- Ground Shaking-Induced Hazards:

Tectonic Hazard

Earthquake

SUBDUCTION ZONE:

Idealized diagram of a subduction zone showing the Wadati-Benioff zone, which is an array of earthquake foci from shallow to deep that delineate the subduction zone and the descending lithospheric plate.



Source: Edward A. Keller, Duane E. Devecchio, Robert H. (CON) Blodgett, 2012, 3rd edition

Tectonic Hazard

Earthquake

- Sudden release of energy along fault lines or plate boundaries.
- Causes ground shaking, ground rupture, and tsunamis.
- Can result in building collapse, infrastructure damage, and loss of life.

Tectonic Hazard

Volcano Eruption

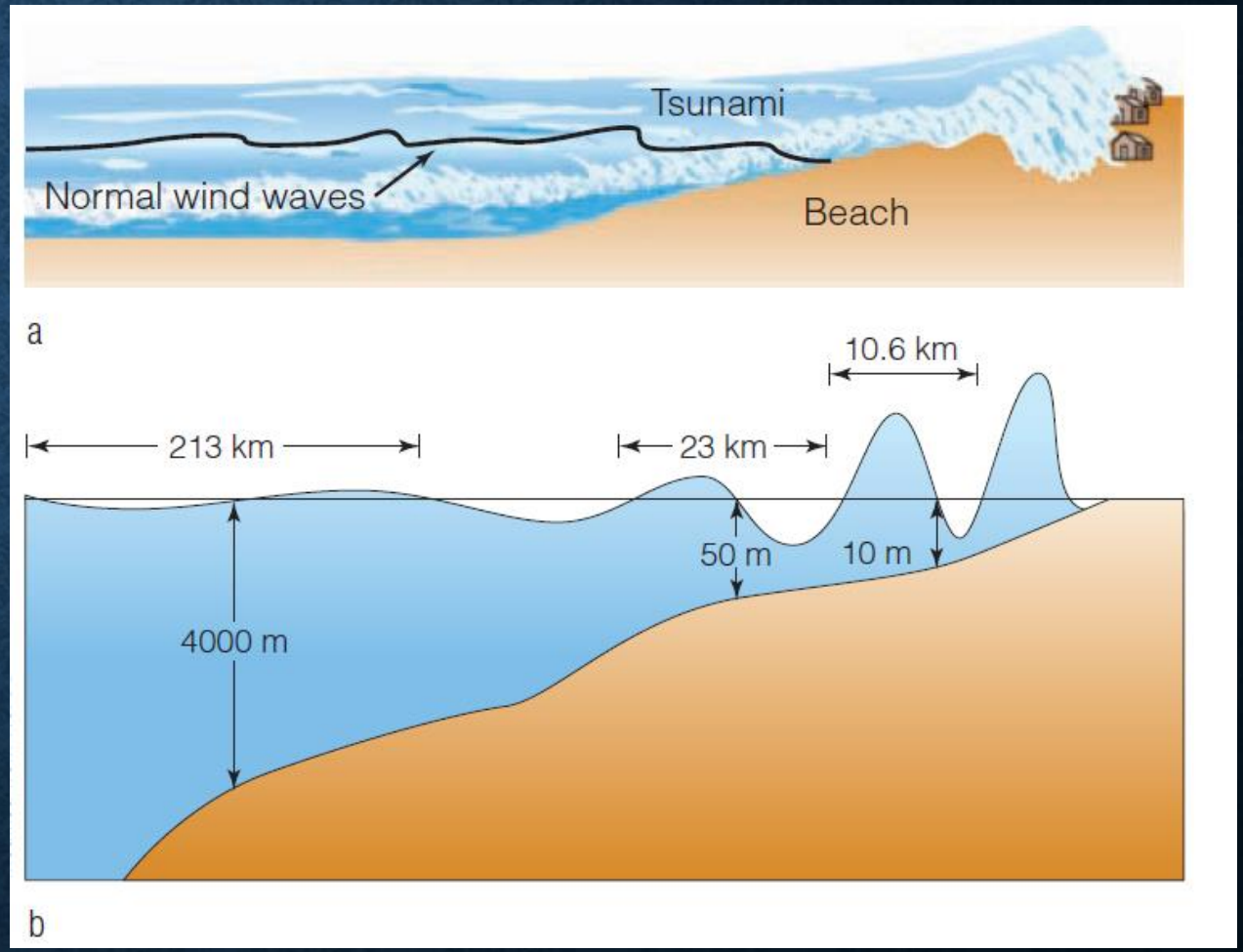
- Ejection of molten rock, ash, and gases from a volcano.
- Leads to the formation of volcanic cones and lava flows.
- Can disrupt air travel, impact agriculture, and pose health risks.

Image Source: John Seach, 2009
http://volcanolive.com/rabaul.html

Tectonic Hazard

Tsunamis

- Large ocean waves generated by undersea earthquakes, volcanic eruptions, or landslides.
- Can inundate coastal areas, causing extensive damage and loss of life.



Modified from NOAA

Source: Donald Hyndman and David Hyndman, 2009, Second Ed.

Tectonic Hazard

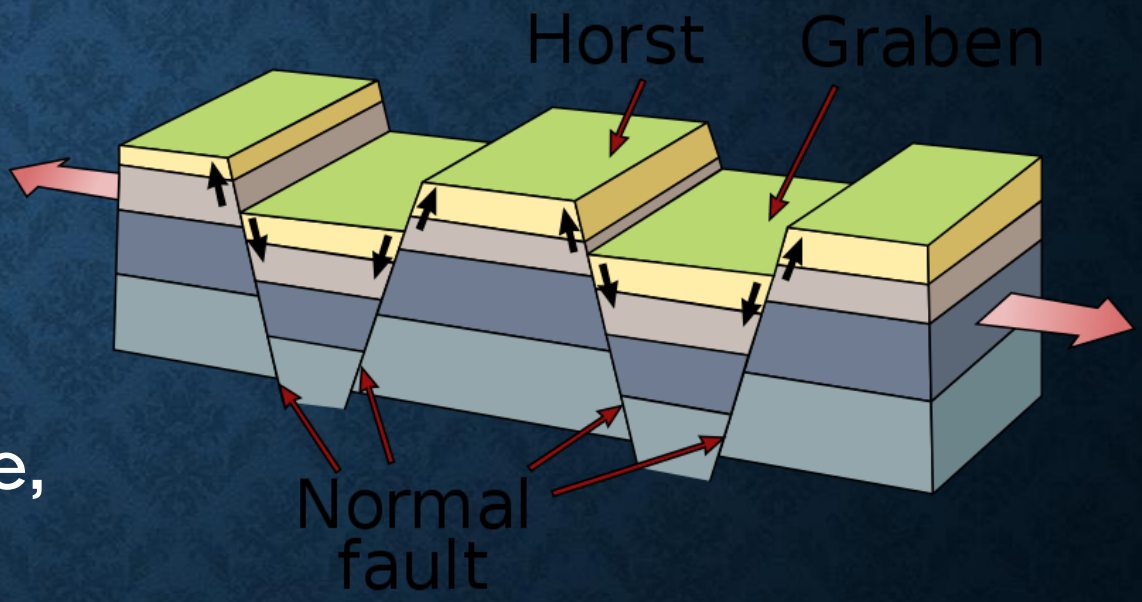
Landslides and Debris Flows:

- Rapid downslope movement of rocks, soil, and debris.
- Often triggered by heavy rainfall, earthquakes, or volcanic activity.
- Can bury communities and block transportation routes.

Tectonic Hazard

Tectonic Subsidence

- Gradual sinking or settling of the Earth's crust.
- Can lead to coastal land subsidence, affecting coastal communities and infrastructure.



Source: USGS, 2011
https://commons.wikimedia.org/wiki/File:Fault-Horst-Graben.svg

Geo-Informatics for Tectonic Hazard Analysis

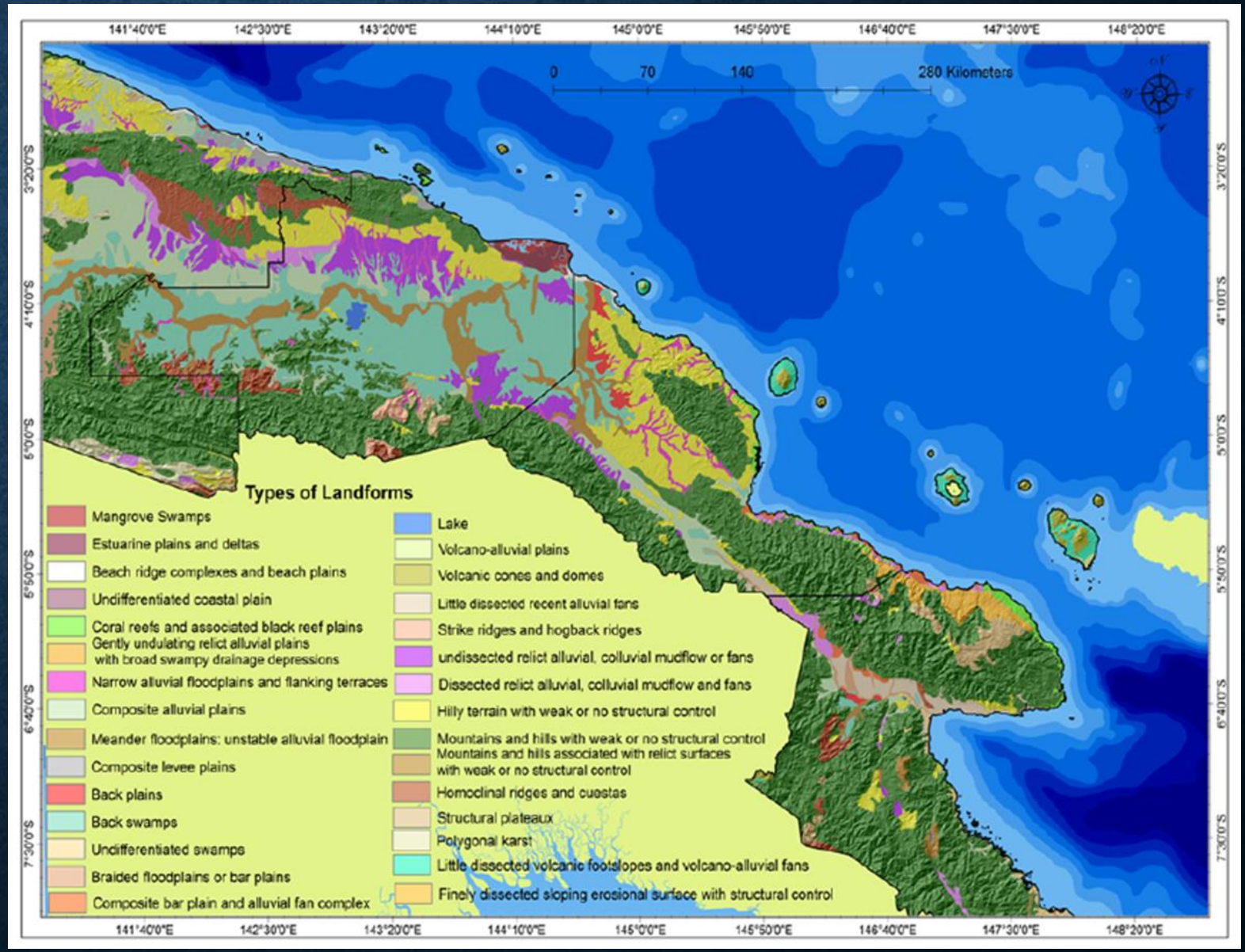
- Natural phenomena initiated inside the earth and/or near the surface can produce various natural hazards.
- These include earthquakes, volcanoes, floods, etc…
- Advances in using tectonic geomorphology, remote sensing, and geospatial analytical applications allow fundamental knowledge acquisition in our appreciation of the role of tectonic Evolution.

Source: Bashir, B, et al, (2023)

Geo-Informatics for Tectonic Hazard Analysis

Evaluating Landform patterns to Understand Tectonism

- Analyzing landforms using geospatial knowledge is essential for understanding tectonism, as it provides valuable insights into the Earth's dynamic processes and the effects of tectonic activity on the landscape.

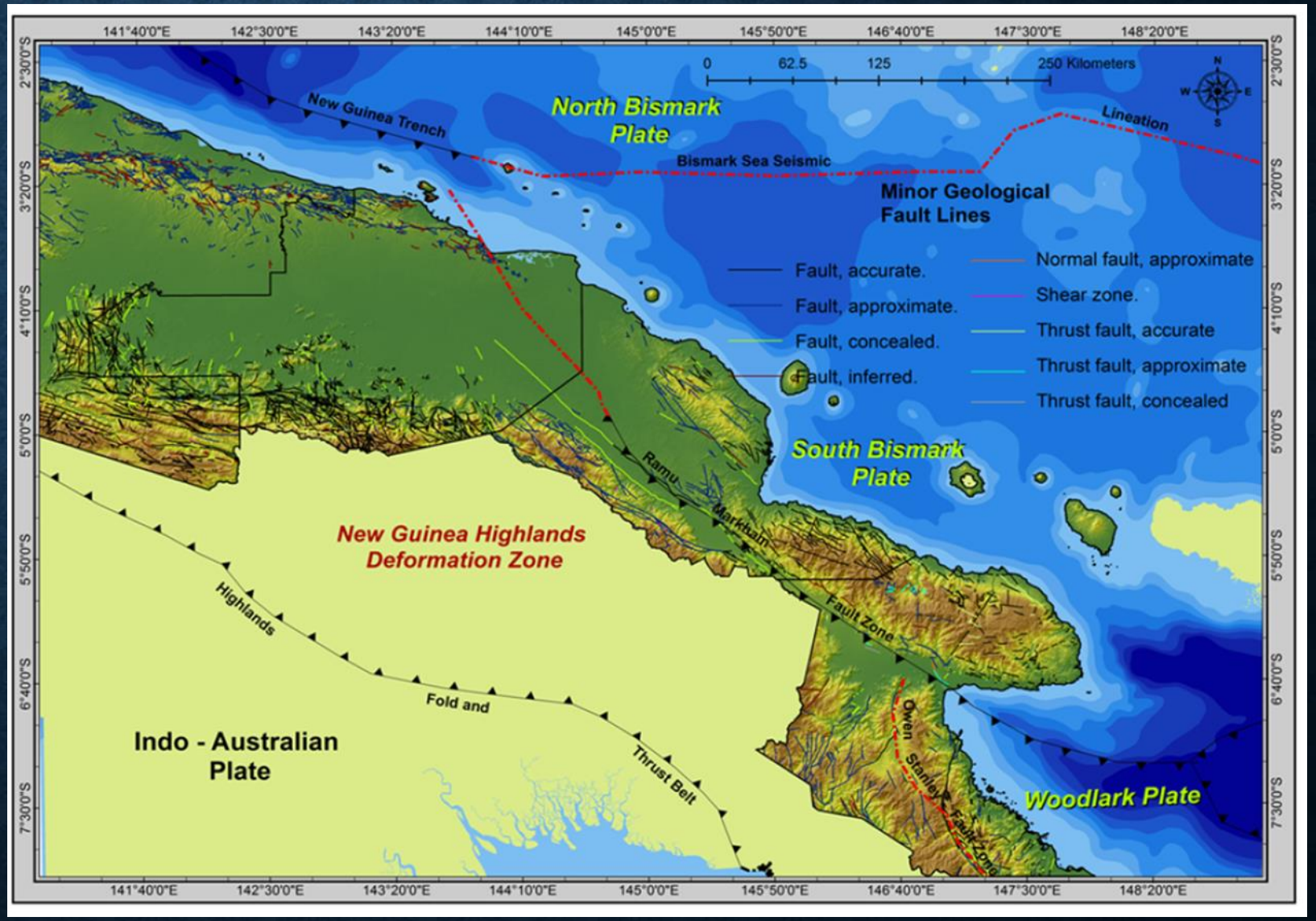


Geo-Informatics for Tectonic Hazard Analysis

Understand Tectonic Structure

Faults:
Identification and Mapping:

- Geospatial tools, including satellite imagery and remote sensing, aid in locating and mapping faults on the Earth's surface.
- These maps help create fault zone models for seismic hazard assessment.



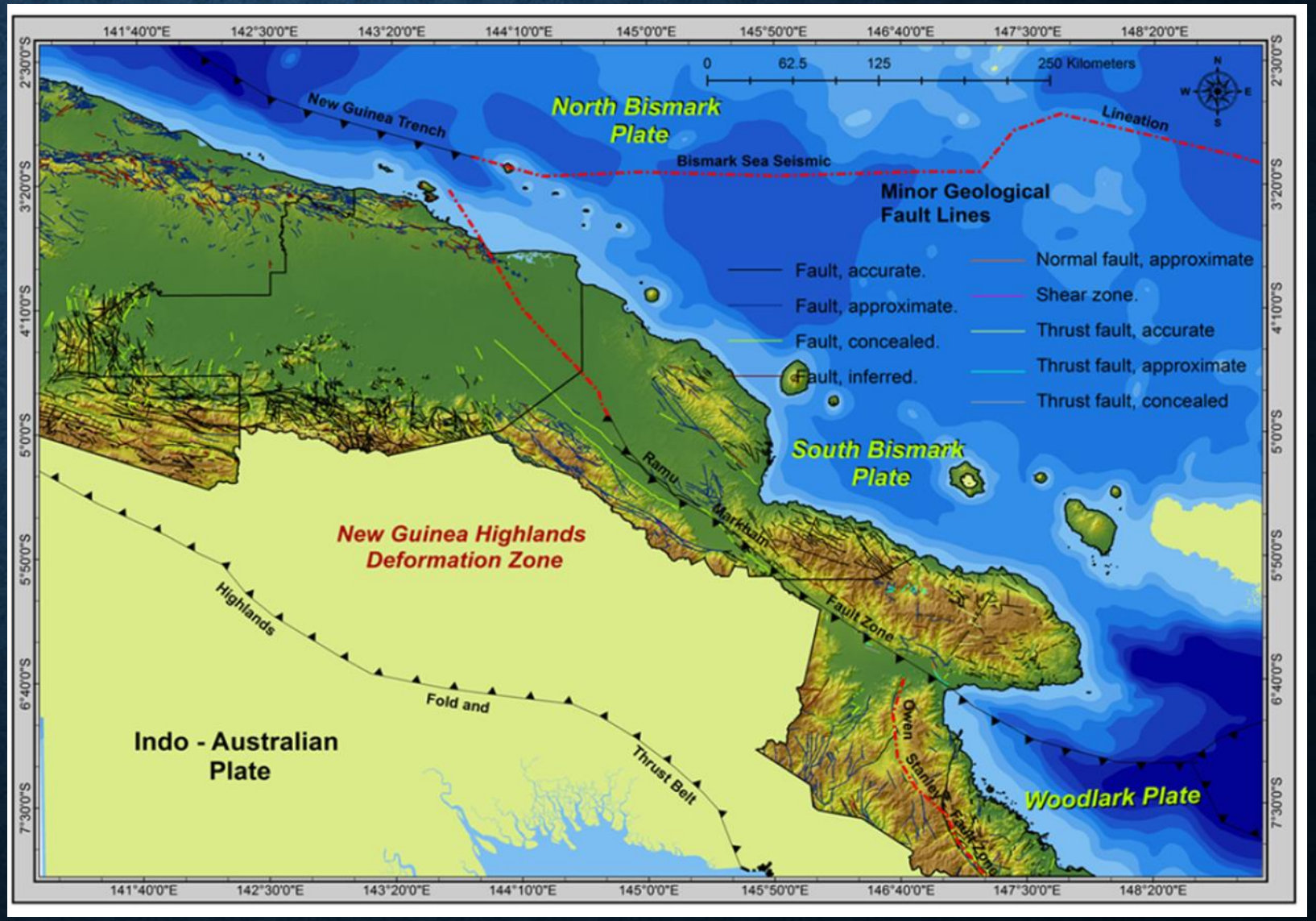
Geo-Informatics for Tectonic Hazard Analysis

Understand Tectonic Structure

Faults:

Seismic Hazard Assessment:

- Studying fault systems allows for the assessment of earthquake risk, as faults are often the source of seismic activity.
- Geospatial data helps predict potential earthquake magnitudes and ground shaking intensity.



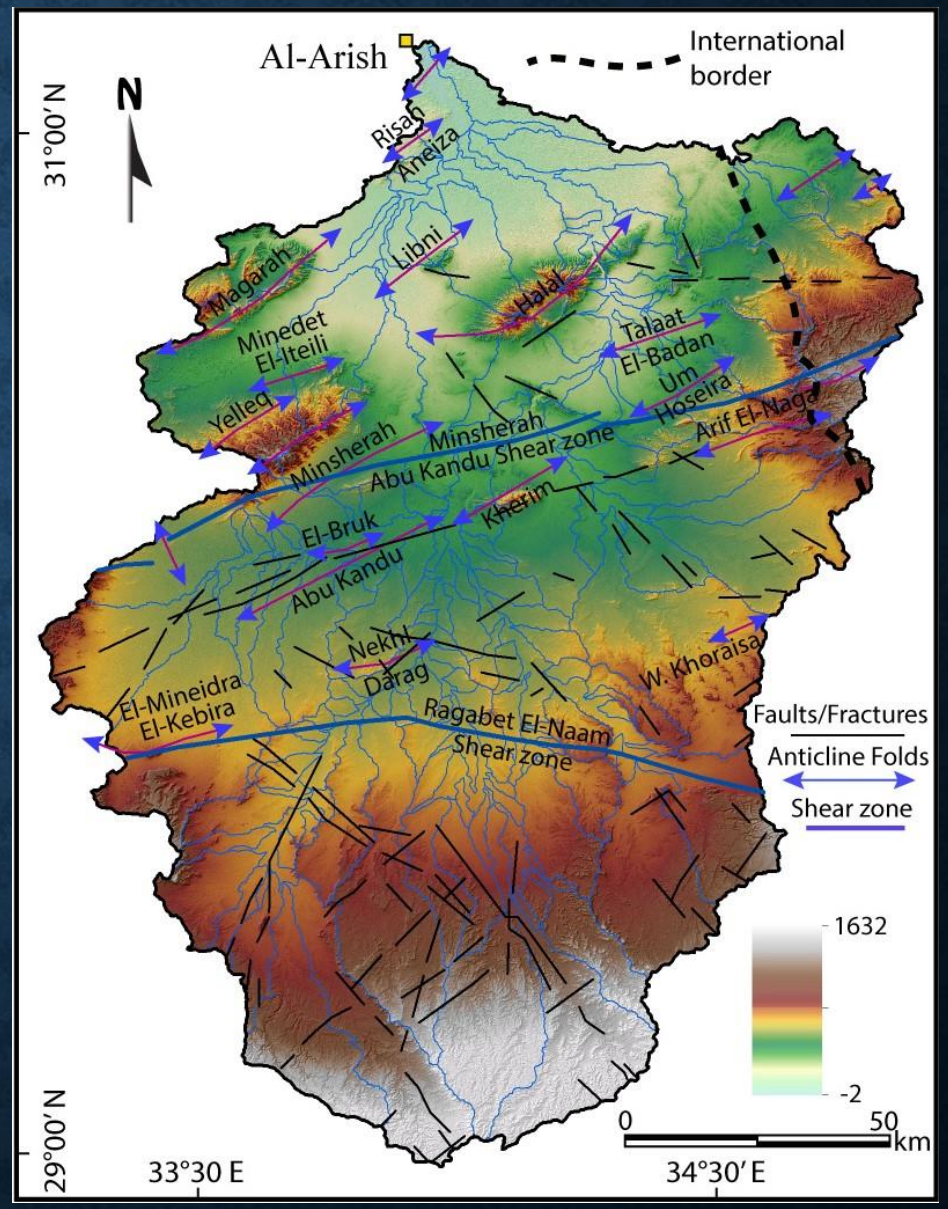
Geo-Informatics for Tectonic Hazard Analysis

Understand Tectonic Structure

Folds:

Topographic Analysis:

- Geospatial data and digital elevation models aid in studying the topographic expression of folded rock layers.
- Identifying and measuring folds helps researchers understand the magnitude of tectonic forces.



Map Source: Bashir. B, et al, 2023

Geo-Informatics for Tectonic Hazard Analysis

Understand Tectonic Structure

Folds:

Geological History Reconstruction:

- Folds in rock layers can reveal information about the deformation history of a region.
- Geospatial analysis helps reconstruct the sequence of folding events.

Geo-Informatics for Tectonic Hazard Analysis

Understand Tectonic Structure

Lineaments

- The most obvious geologic features observed on the satellite imagery are lineaments, which provide significant information about the structure and the tectonic framework of the area.

References:

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