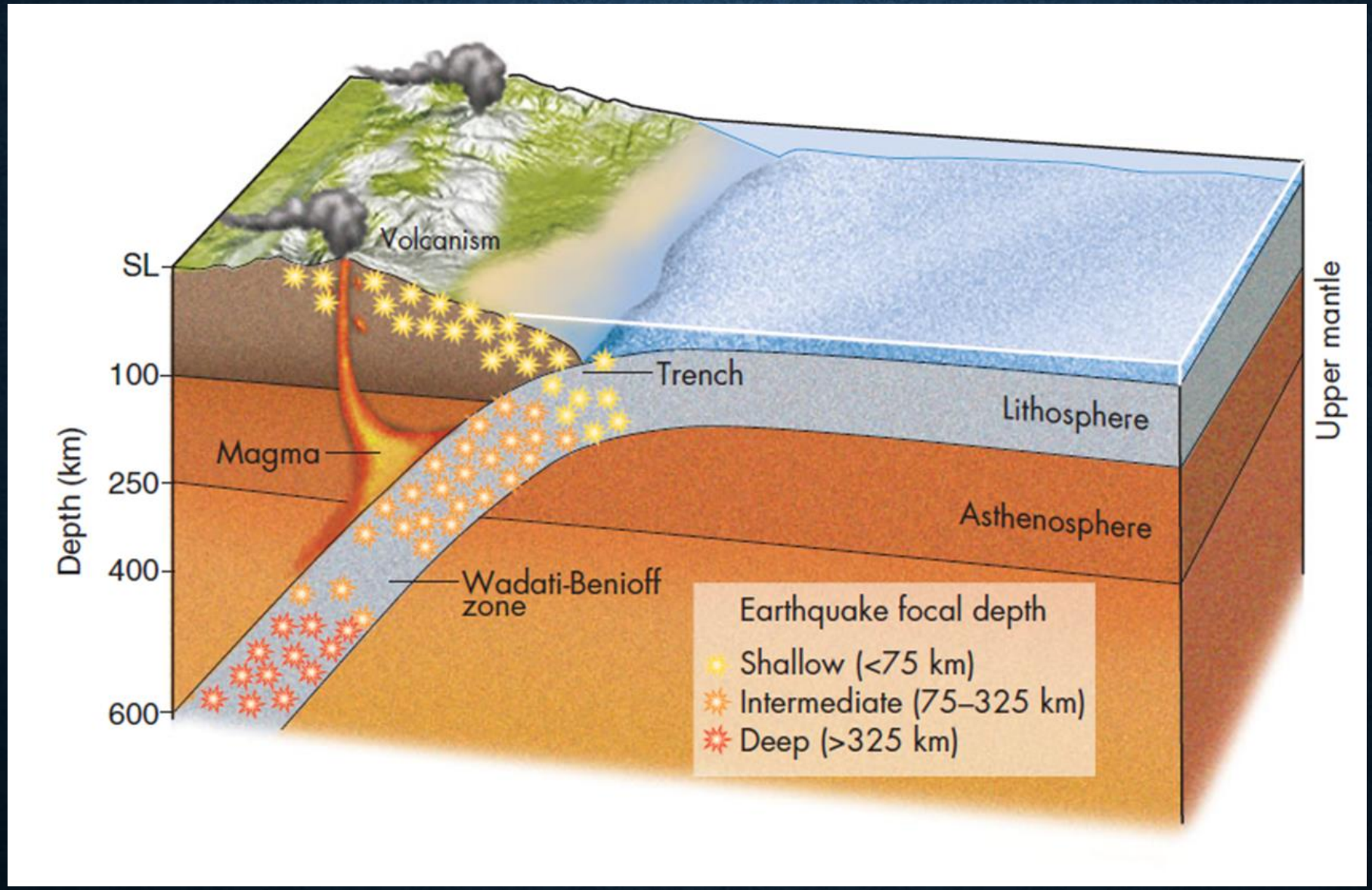
COURSE: GEO-INFORMATICS IN EARTH SCIENCE, TECTONIC HAZARD AND INFRASTRUCTURE MANAGEMENT

LECTURE 4 – The Science of Earthquake

Lecturer: Dr. Tingneyuc Sekac, Ph.D. PNG University of Technology

What is Earthquake

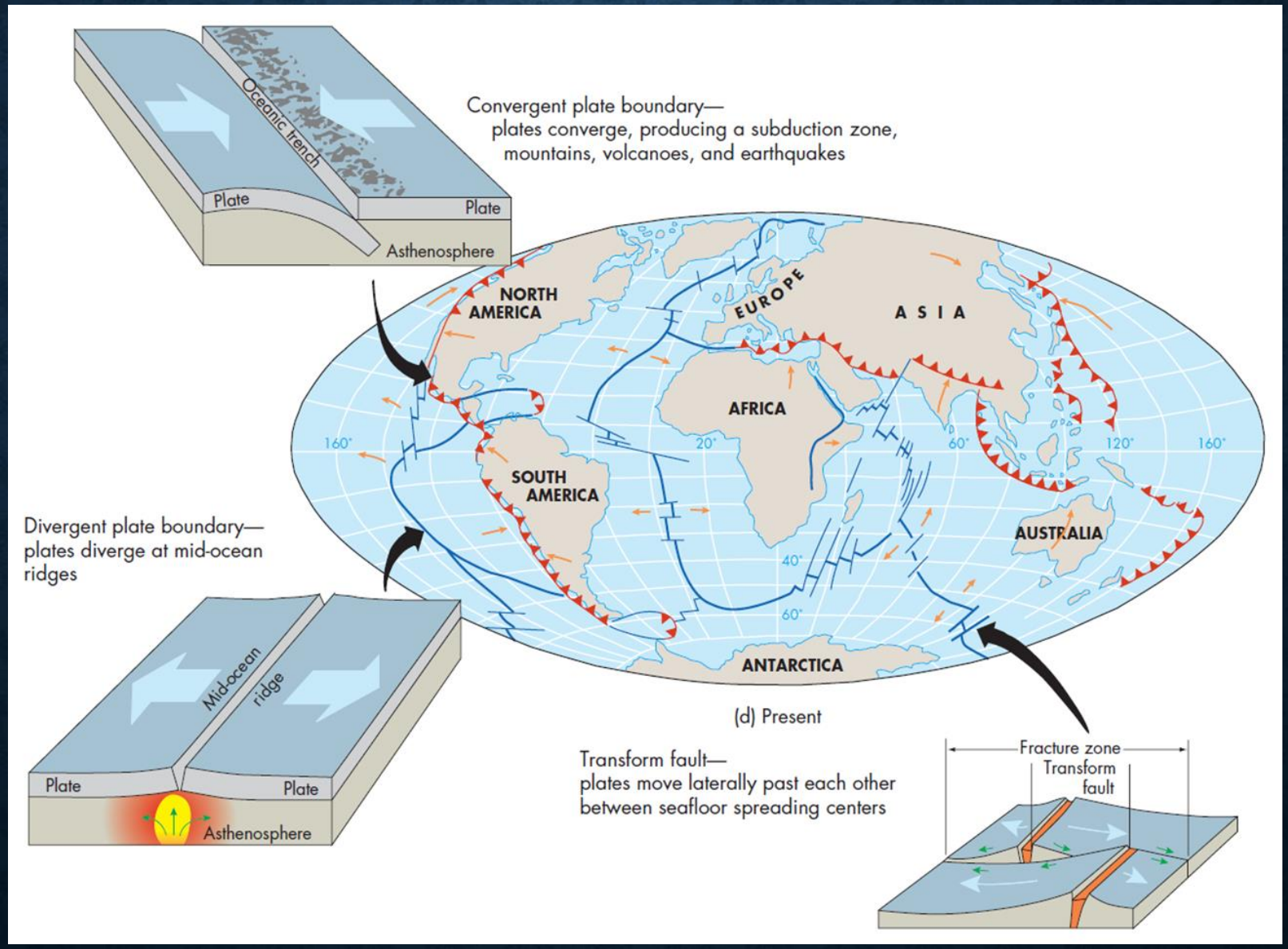


Source: Edward A. Keller, Duane E. Devecchio, Robert H. (CON) Blodgett, 2012, 3rd edition

What is Earthquake

- Earthquakes are natural geological phenomena characterized by the sudden release of energy in the Earth's crust,
- Resulting in the generation of seismic waves.
- Seismic waves propagate through the Earth, causing the ground to shake.
- Shaking resulting in significant ground motion, which can lead to damage to structures, people and the Earth's surface.

What is Earthquake



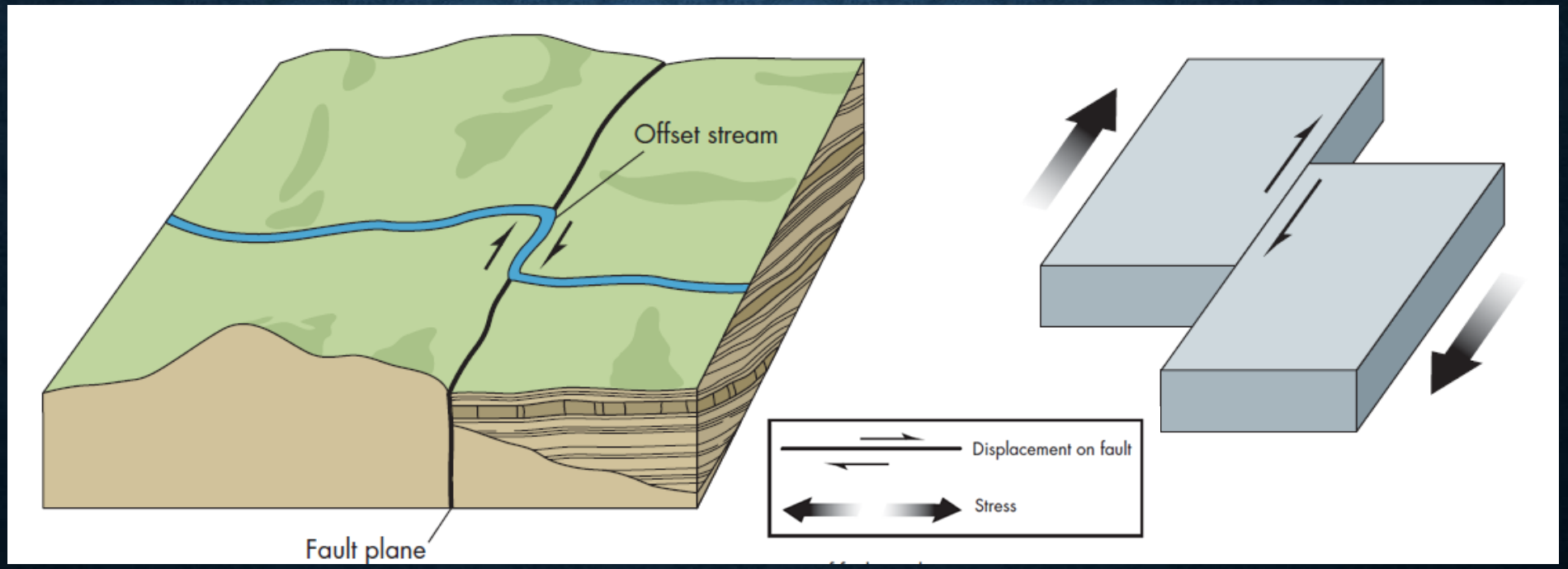
Dietz, R. S., and Holden, J. C., (1970).

Earthquake Sources

Types of Geological Fault

Strike-Slip Fault:

- A strike-slip fault with Horizontal displacement along the fault plane



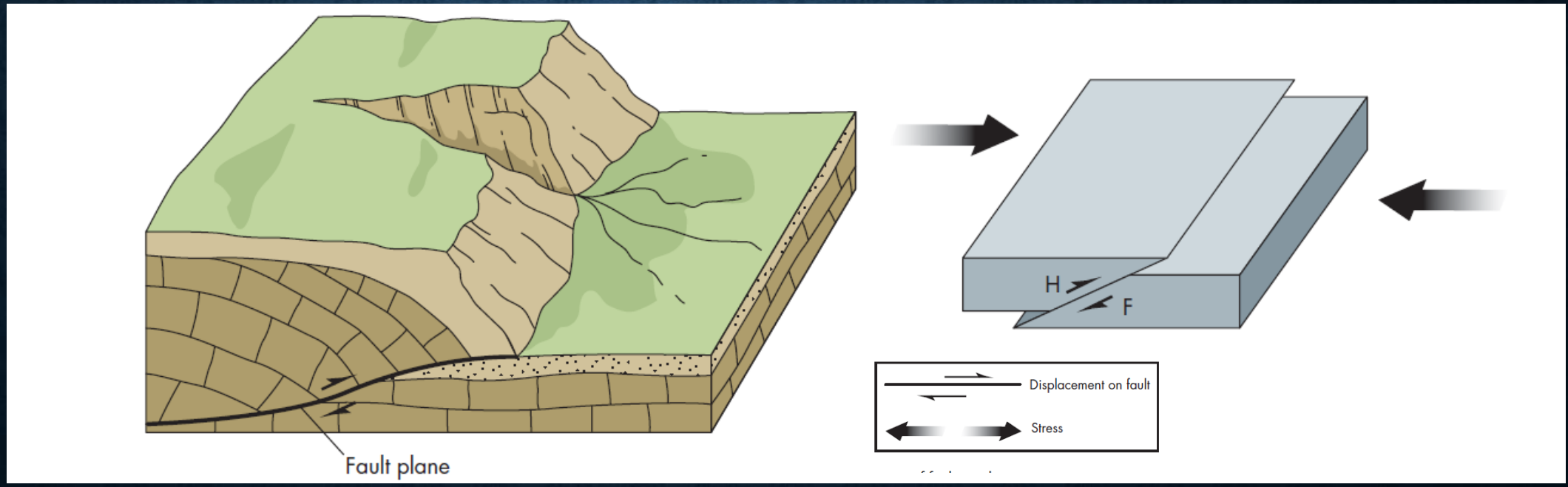
Source: Edward A. Keller, Duane E. Devecchio, Robert H. (CON) Blodgett, 2012, 3rd edition

Earthquake Sources

Types of Geological Fault

Thrust Fault:

- A thrust fault in which the hanging-wall (H) above the fault has moved up and over the footwall (F) below the fault;



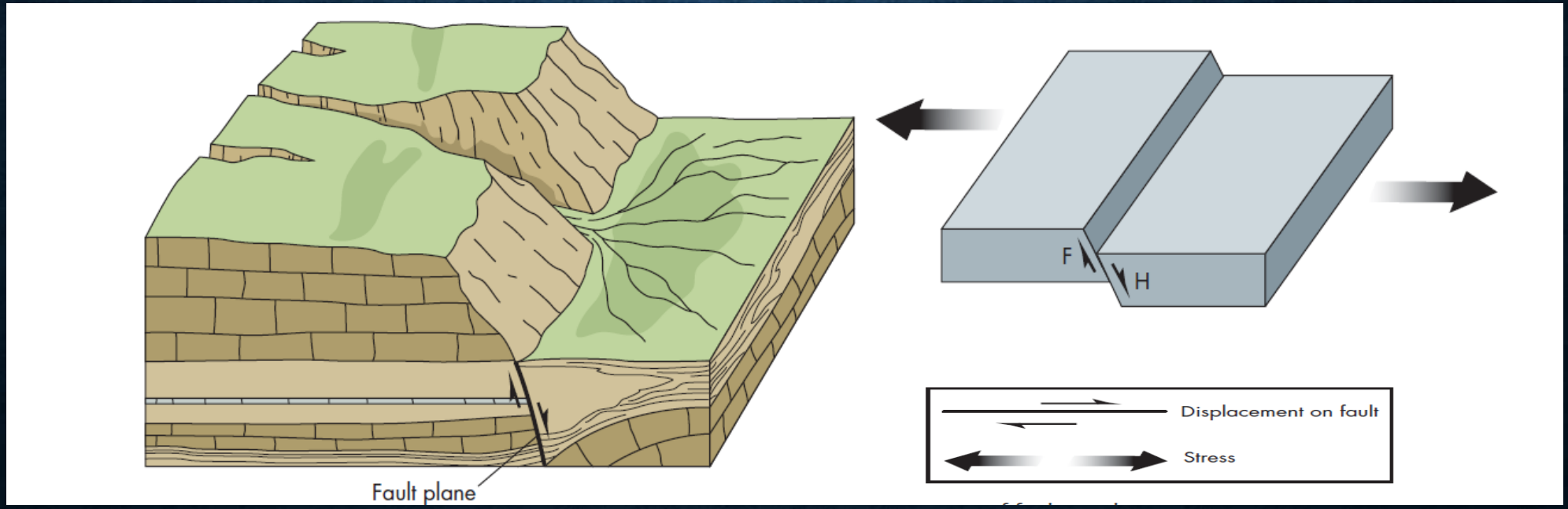
Source: Edward A. Keller, Duane E. Devecchio, Robert H. (CON) Blodgett, 2012, 3rd edition

Earthquake Sources

Types of Geological Fault

Normal Fault:

- A normal fault in which the hanging-wall (H) on the right side of the fault has dropped down

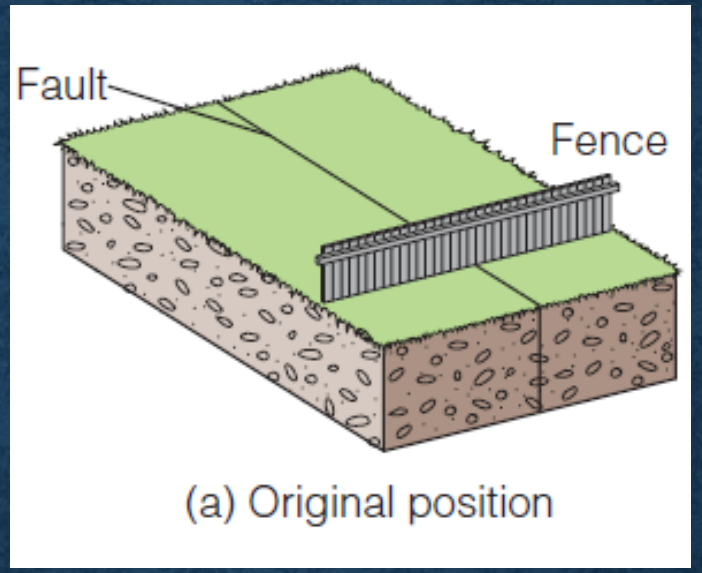


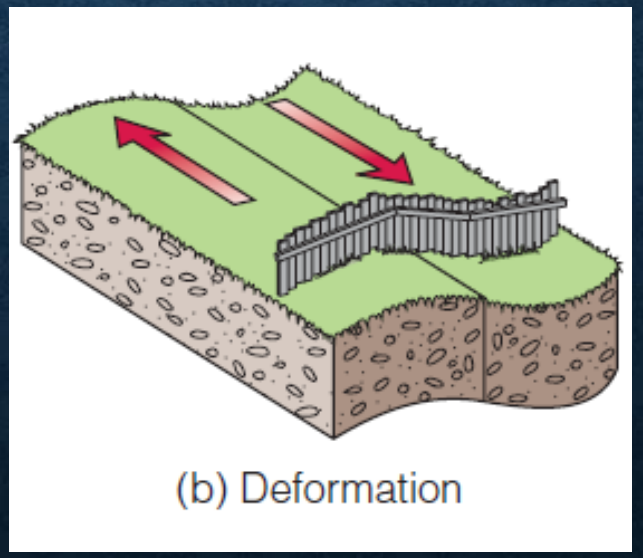
Source: Edward A. Keller, Duane E. Devecchio, Robert H. (CON) Blodgett, 2012, 3rd edition

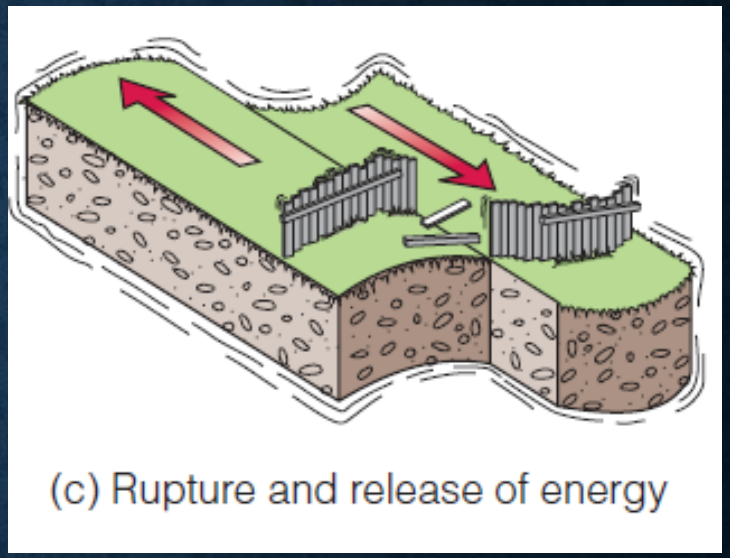
Earthquake Sources

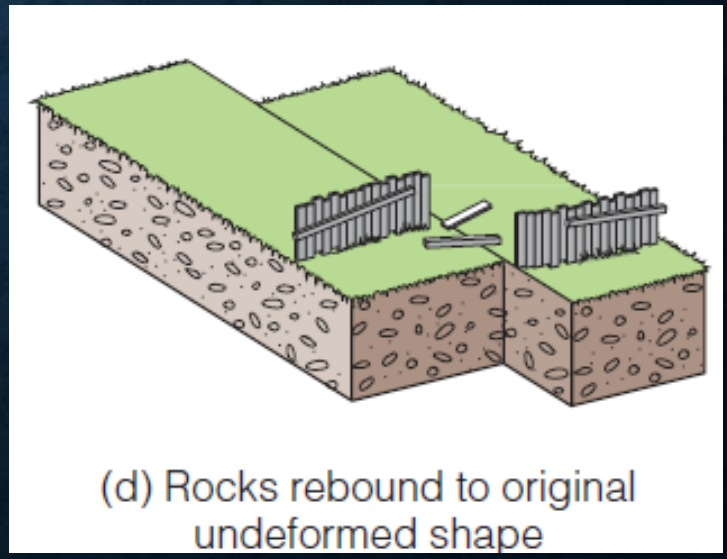
Elastic Rebound Theory:

- Rocks near a fault are slowly bent elastically until the fault breaks during an earthquake; the rocks on each side then slip past each other, relieving the stress.
- Distortion of the Earth's crust can extend over tens of kilometers outward from the main fault.





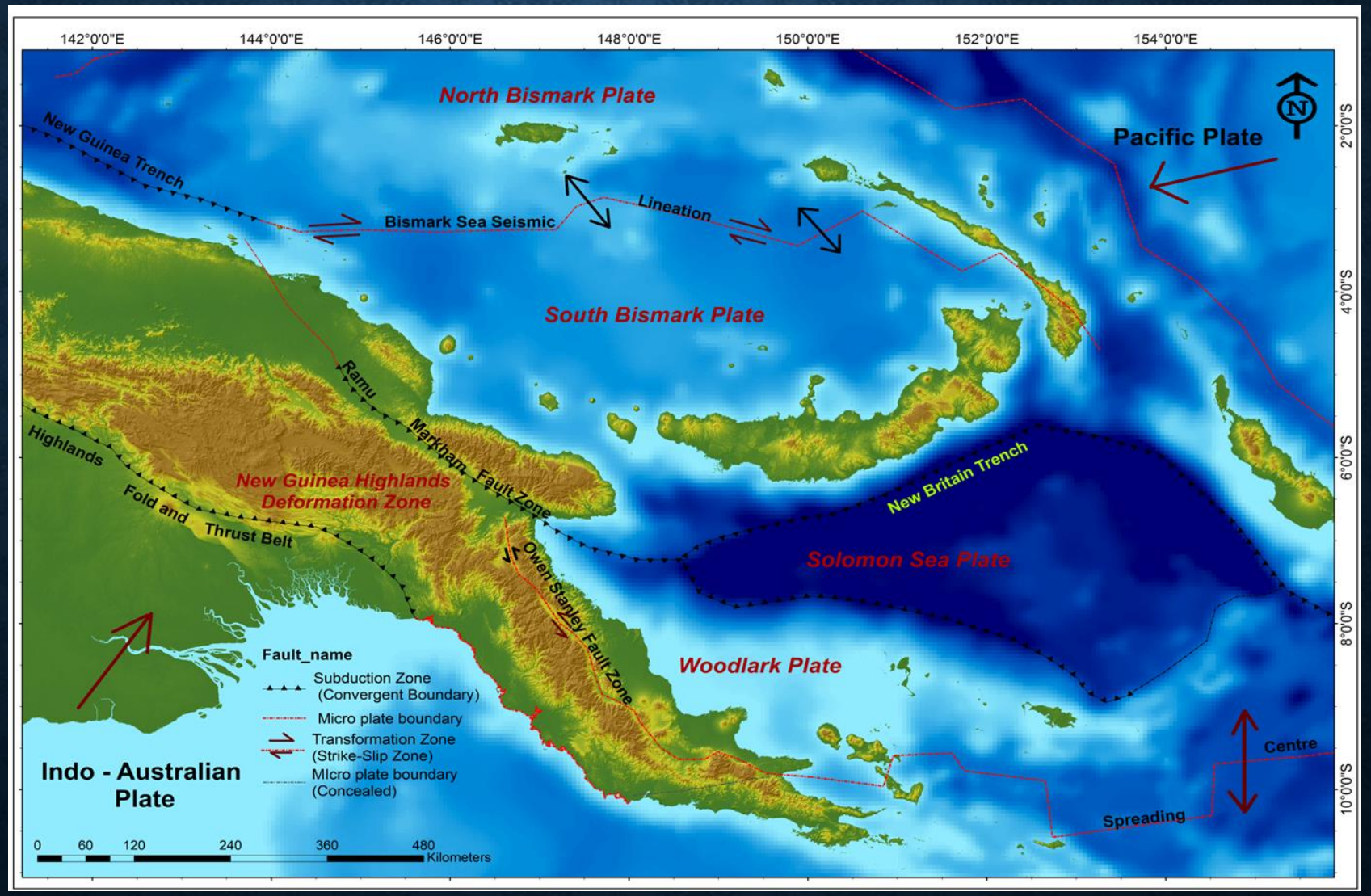




Source: Hyndman. D., and Hyndman. D., (2007), modified from Pipkin & Trent, (2001)

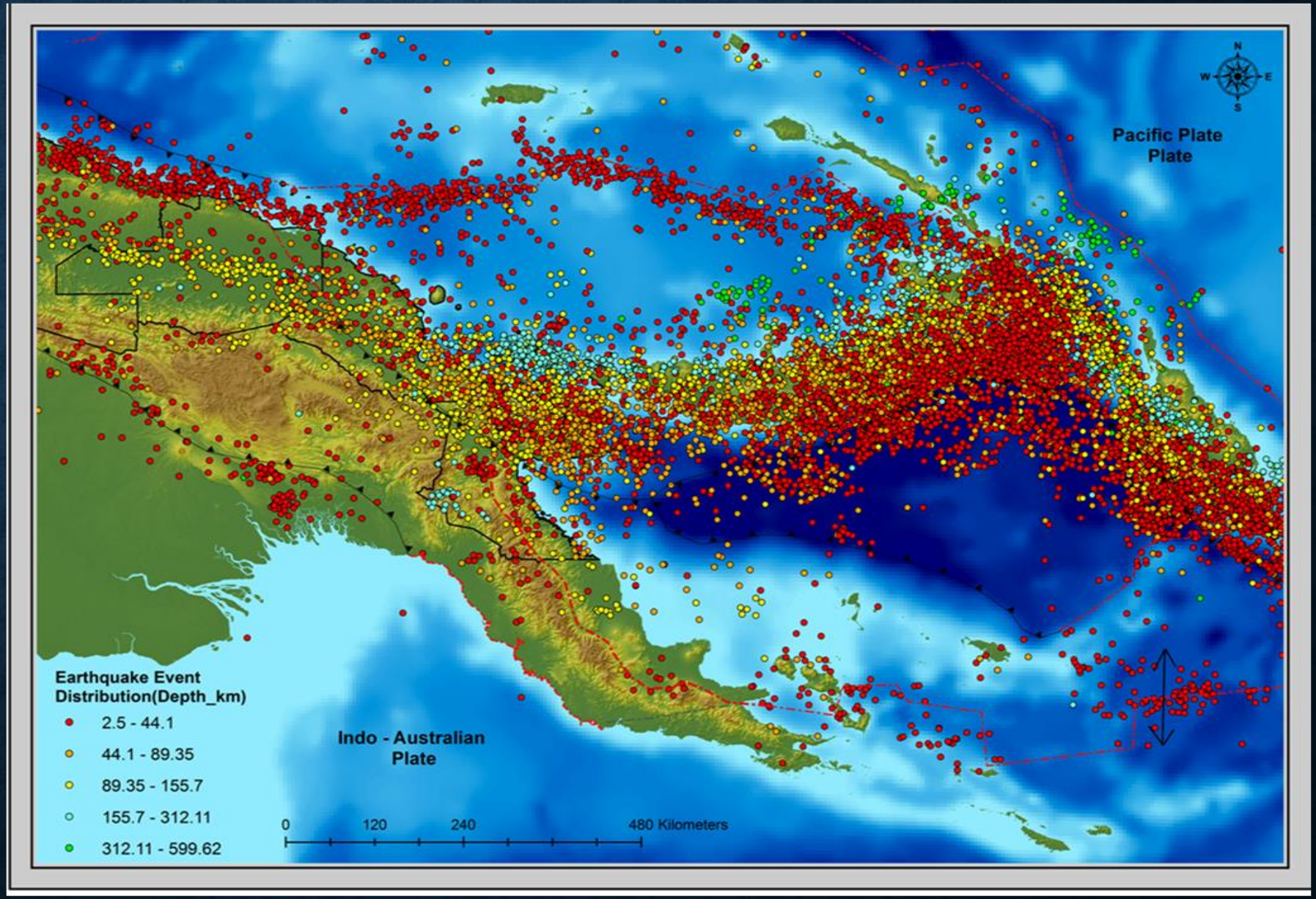
Earthquake Sources

Types of Geological Fault



Earthquake Occurrences

- Earthquake occurs More along Fault or fold structure



Earthquake Disaster in PNG

- Massive destruction due to Ms. 7 earthquake event In 1998 that triggered up to 10.5 meters in Aitape, Sandaun Province, PNG

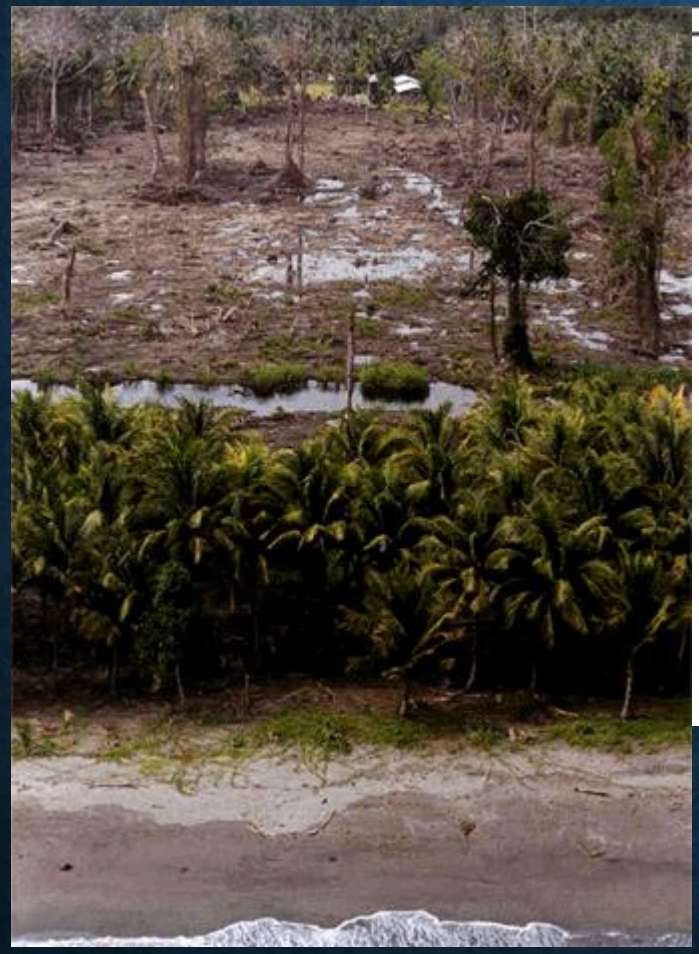


Image Source: Davies, 1998

Earthquake Disaster in PNG

Date of Earthquake Events	Magnitude	Depth (km)	Fatality	Damages Done (Cost-USD)
17th July 1998	7.1	13	2, 202	50 million USD in Economic loose
13th October 1993	7.2	40	.....	5, 000 US Dollar
9th February 1987	7.4	32	.....	2, 625 US Dollar
31th October 1970	6.9	60	.....	1, 750 US Dollar
11th May 1985	7.1	30	.....	1,000 US Dollar
24th June 1986	5.8	.....	.....	500 US Dollar

Source: (a) GLC – WFP (2011) (b) (Davies, 1998).

Earthquake Disaster

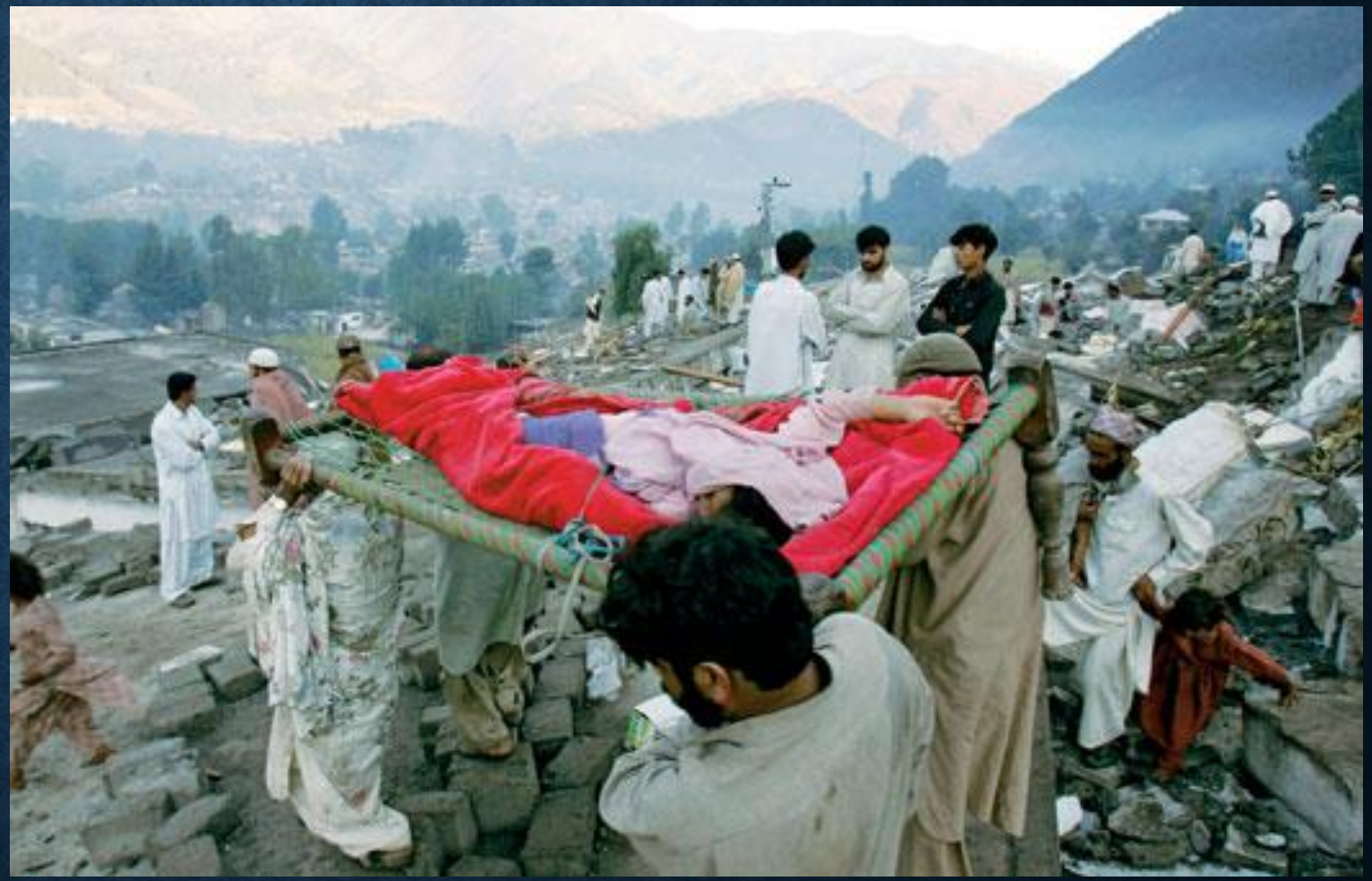
earthquake damage in Italy that killed several hundred people; (Ho/Reuters/Newscom)

collapsed buildings from 2008 earthquake in China that killed about 87,500 people; (Greg Baker/AP Images)

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

Earthquake Disaster

- On October 8, 2005, a catastrophic earthquake struck northern Pakistan.
- Although the epicenter was in Pakistan, extensive damage also occurred in Kashmir and India
- More than 80,000 people were killed and over 30,000 buildings collapsed. Entire villages were destroyed, some buried by landslides triggered by the violent shaking.



Source: B.K. Bangash/AP Images

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

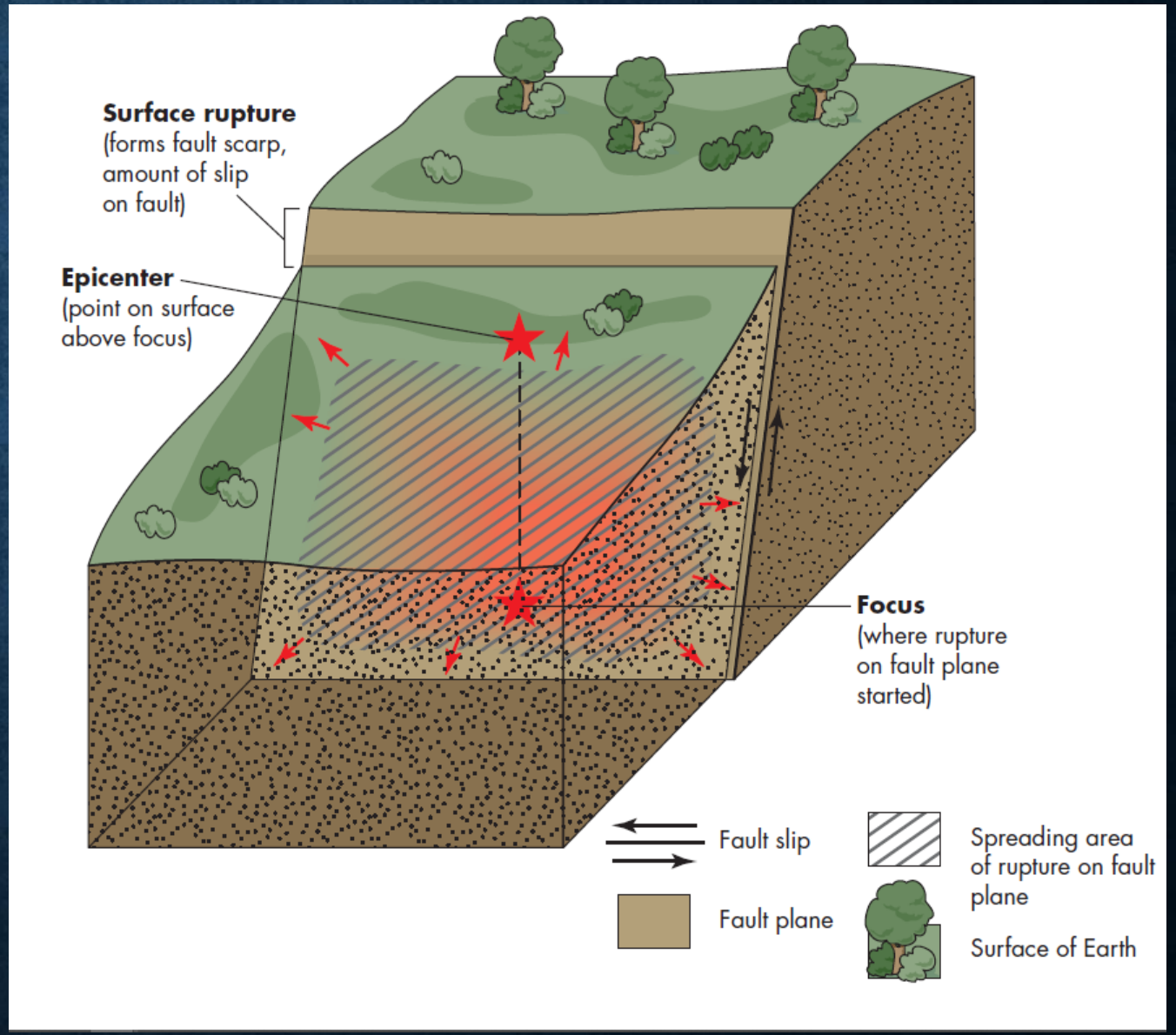
Earthquake Disaster

- A sixteenth century earthquake in China reportedly claimed 850,000 lives.
- More recently, a 1923 earthquake near Tokyo killed 143,000 people,
- 1976 earthquake in China killed several hundred thousand.

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

Basic Earthquake Features

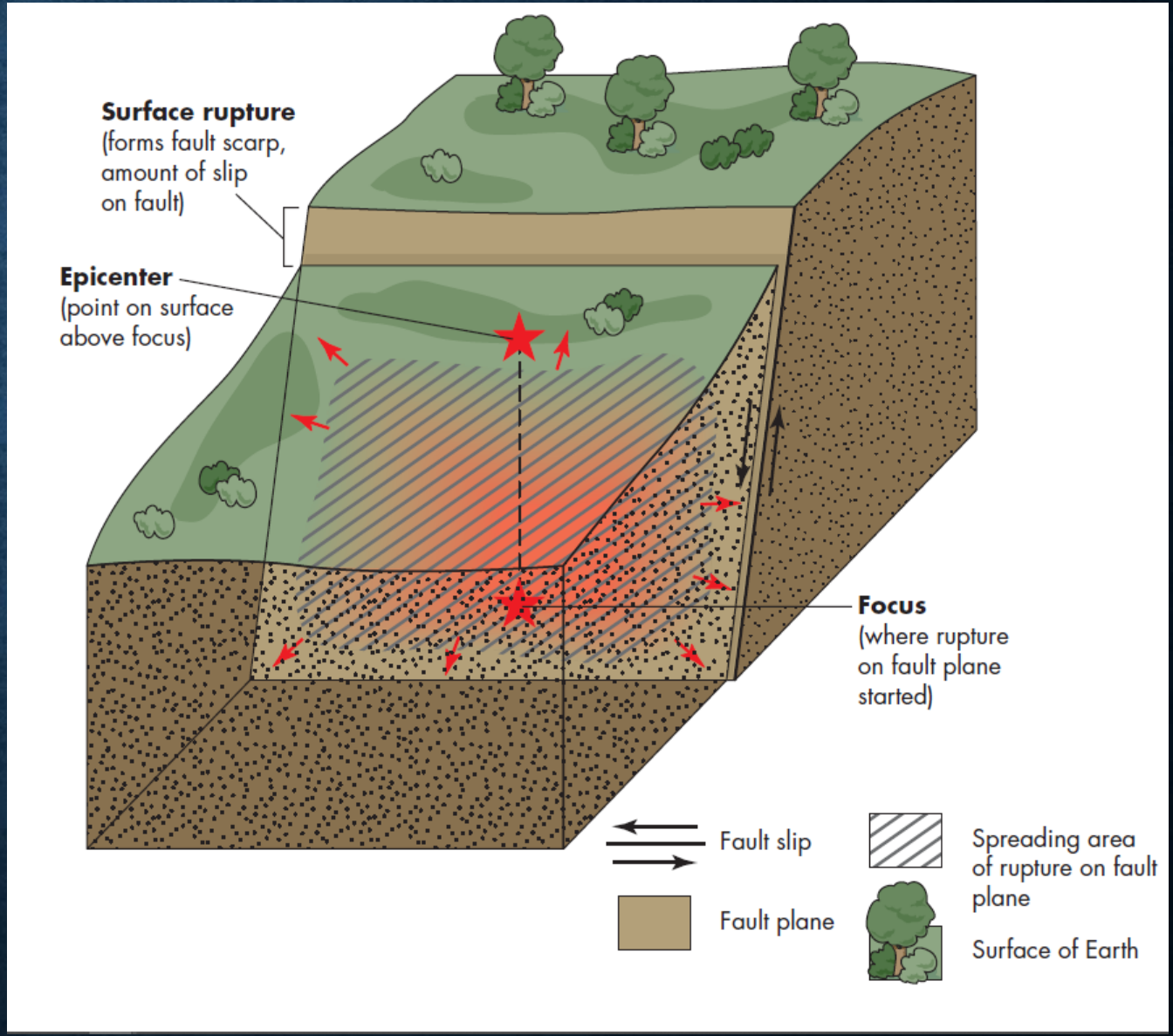
- Block diagram showing fault plane (light tan surface);
- Amount of displacement, rupture area (gray, closely spaced diagonal lines);
- Focus (lower red star); and epicenter (upper red star).



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

Basic Earthquake Features

- Rupture starts at the focus and propagates (red arrows) up, down, and laterally.
- During a major or great earthquake, slip may be 2 to 20 m along a fault length of 100 or more kilometers.
- Rupture area may be 1000 km2 or more.



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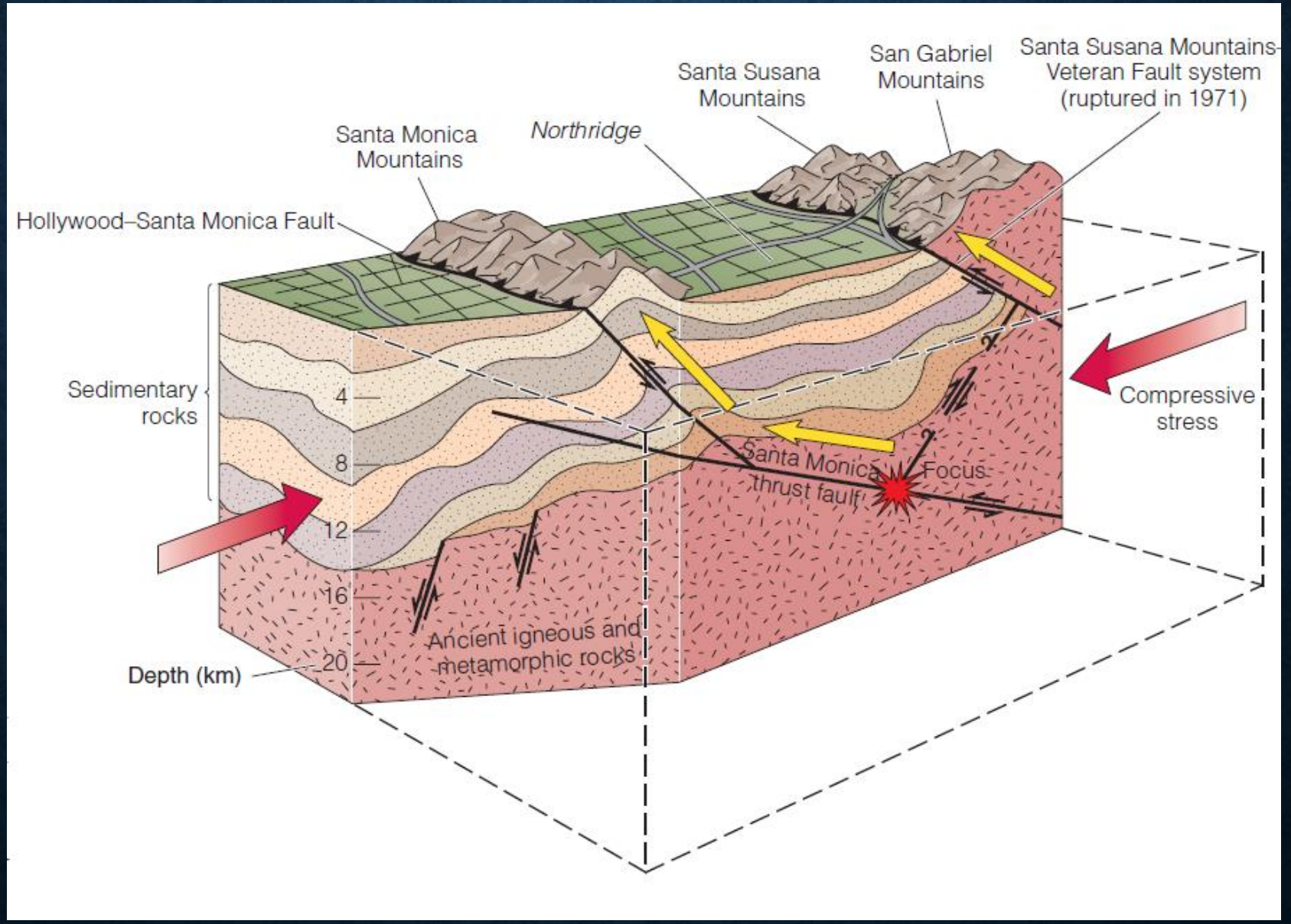
Basic Earthquake Features



Source: Hyndman. D., and Hyndman. D., (2007), Pipkin & Trent, (2001), modified from USGS

Earthquake Waves/Seismic Waves

- When a fault slips, the released energy travels outward in seismic waves from the place where the fault first slipped, called the focus, or hypocenter, of the earthquake.
- The epicenter is the point on the map directly above the focus

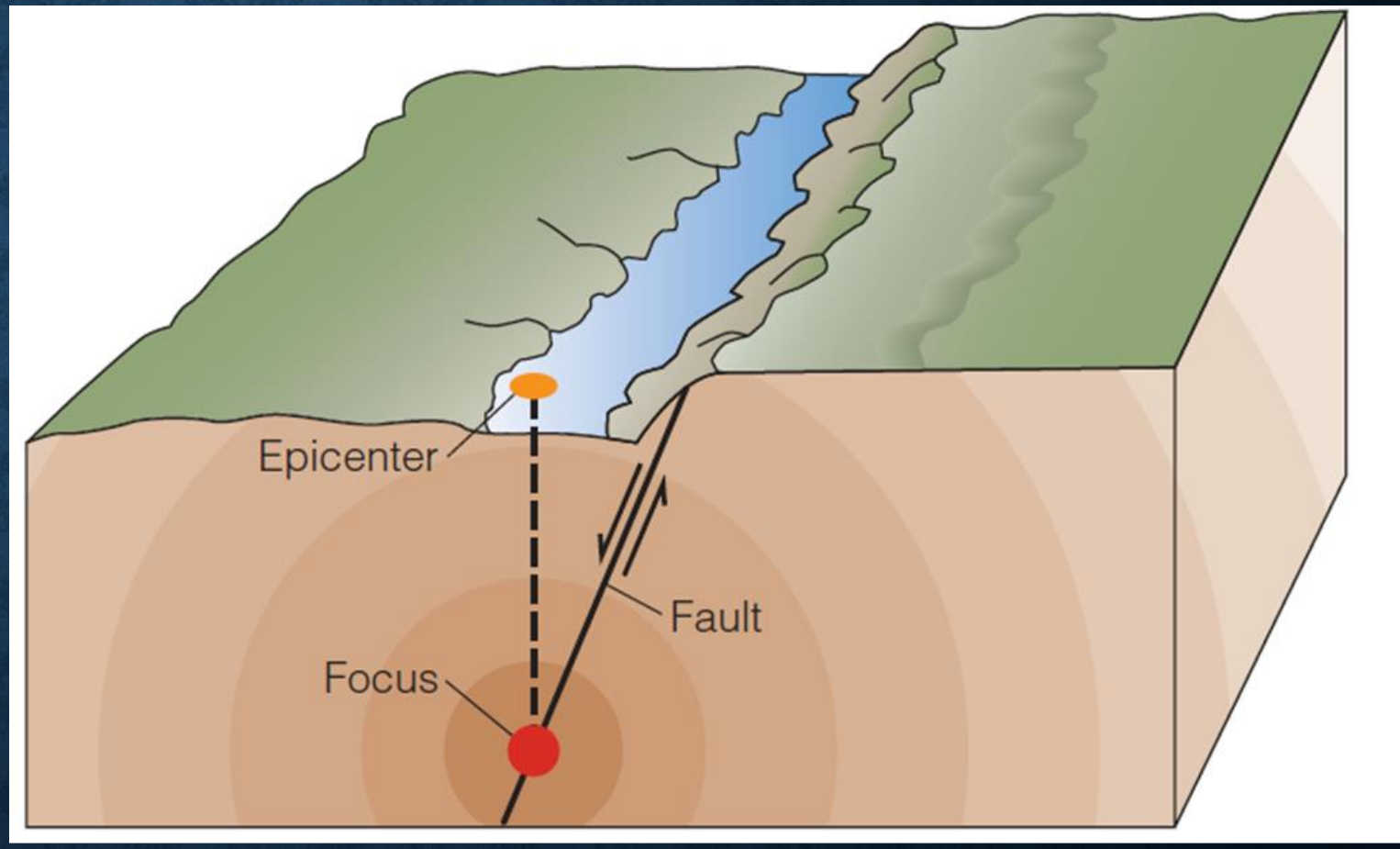


Image Source: Hyndman. D and Hyndman. D (2007)

Earthquake Waves/Seismic Waves

Two (2) common types of Seismic waves generated:

1. Body waves

    - P-Wave
    - S-Wave/shear wave

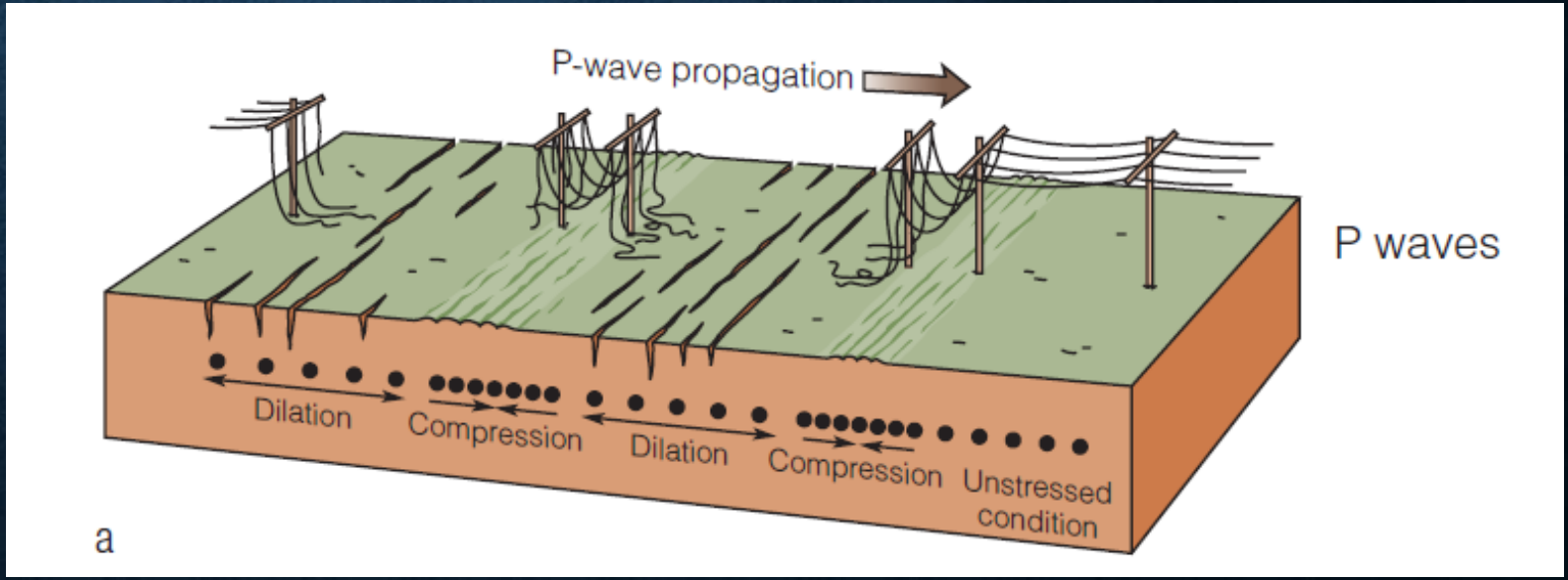
2. Surface Waves

    - Rayleigh waves
    - Love waves

Earthquake Waves/Seismic Waves

P-Waves / Primary Wave

- The fi rst event is the arrival of the P waves, the primary or compressional waves, which come as a sudden jolt.
- P waves consist of a train of compressions and expansions
- P waves travel roughly 5 to 6 kilometers per second in the less dense continental crust and 8 kilometers per second in the dense, less compressible rocks of the upper mantle

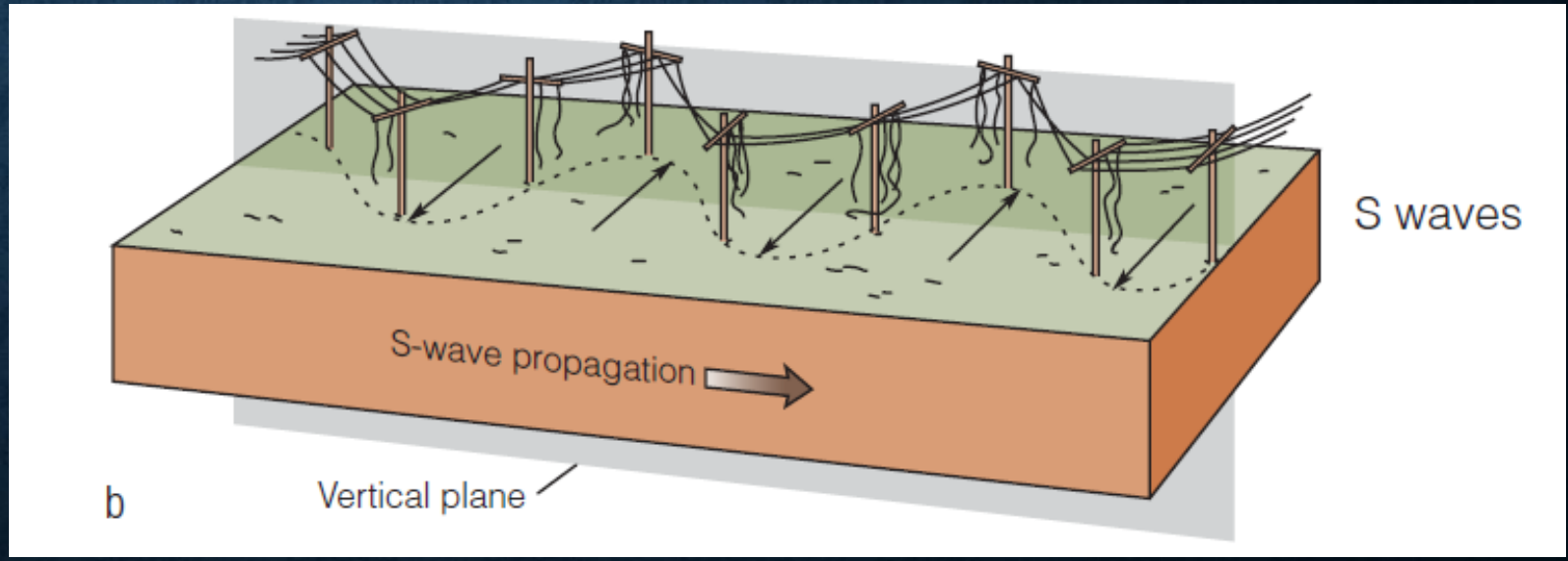


Source: Hyndman. D., and Hyndman. D., (2007), Pipkin & Trent, (2001)

Earthquake Waves/Seismic Waves

S-Waves / Secondary Wave

- After the P waves, then come the S waves (secondary or shear waves), moving with a wiggling motion (shaking rope) that makes it hard to stand.
- S waves are slower than P waves, traveling at speeds of 3.5 kilometers per second in the crust and 4.5 kilometers per second in the upper mantle.
- These shear waves do not travel through liquids.
- Their wiggling motions make them more destructive than P waves

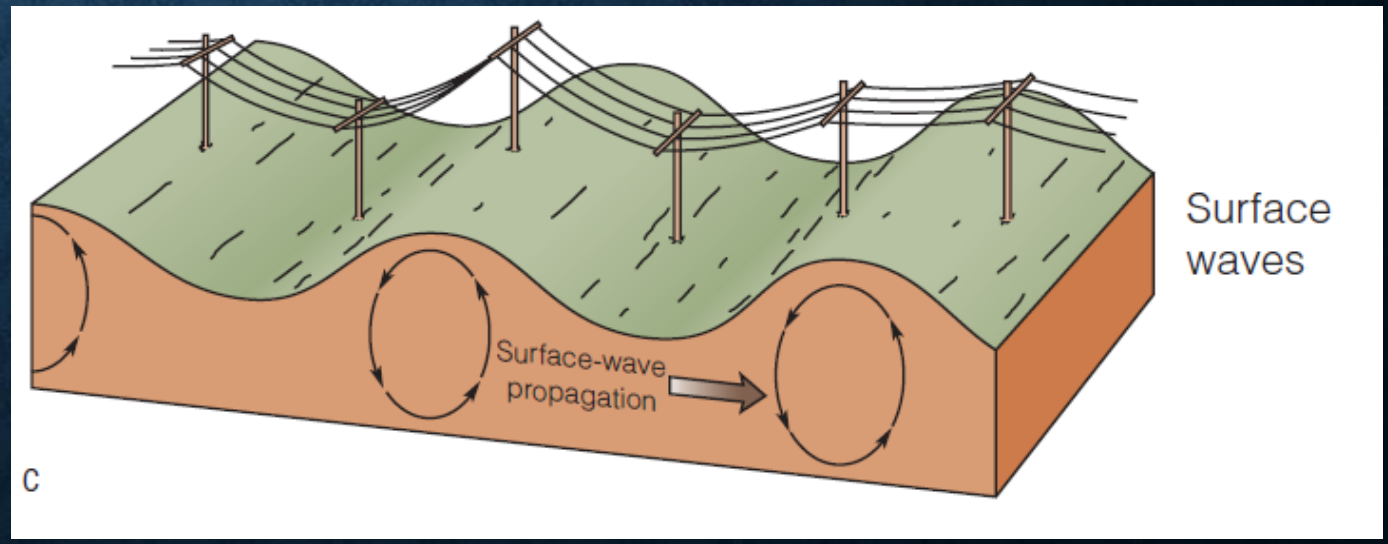


Source: Hyndman. D., and Hyndman. D., (2007), Pipkin & Trent, (2001)

Earthquake Waves/Seismic Waves

Surface Wave

- After the body waves, the surface waves arrive— a long series of rolling motions.
- Surface waves travel along Earth's surface and fade downward.
- Surface waves include Love and Rayleigh waves, which move in perpendicular planes.
- Love waves move from side to side, and Rayleigh waves move up and down in a motion that somewhat resembles swells on the ocean.

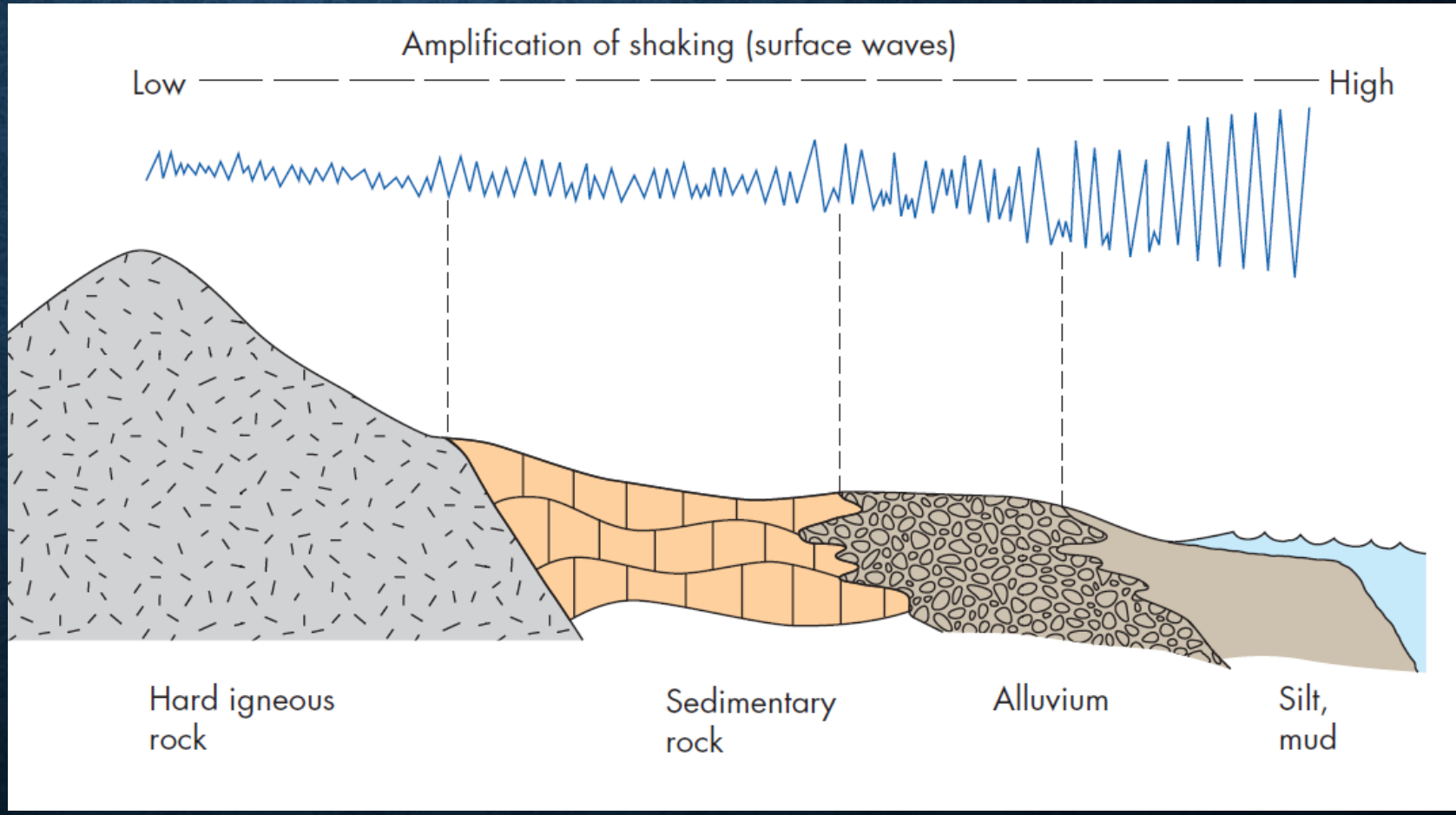


Source: Hyndman. D., and Hyndman. D., (2007), Pipkin & Trent, (2001)

Earthquake Waves/Seismic Waves and Site Soil Geology

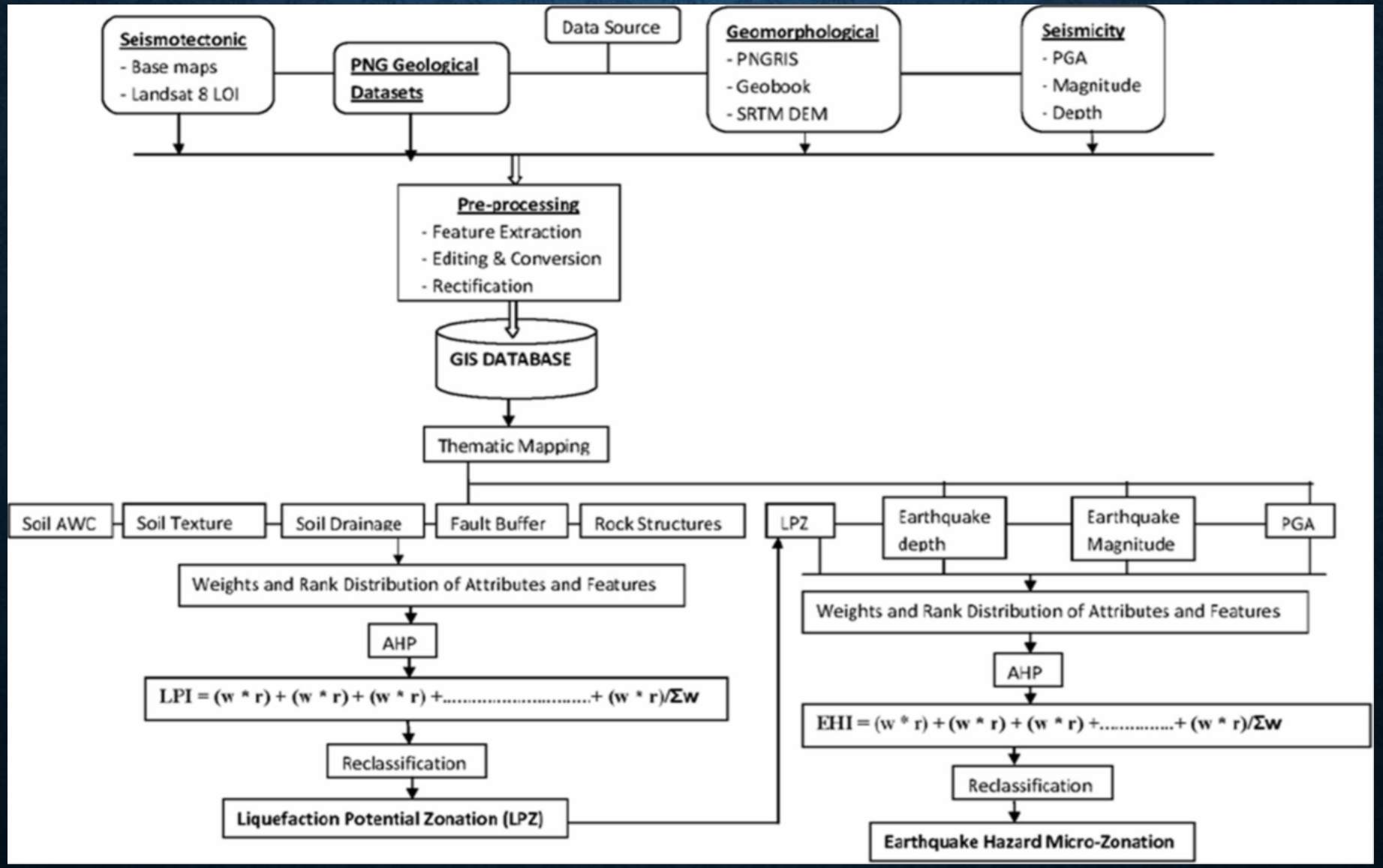
MATERIAL AMPLIFICATION OF SHAKING:

- Generalized relationship Between near-surface earth material and amplification of shaking during an earthquake.
- The material Amplification is highest in water saturated sediment.

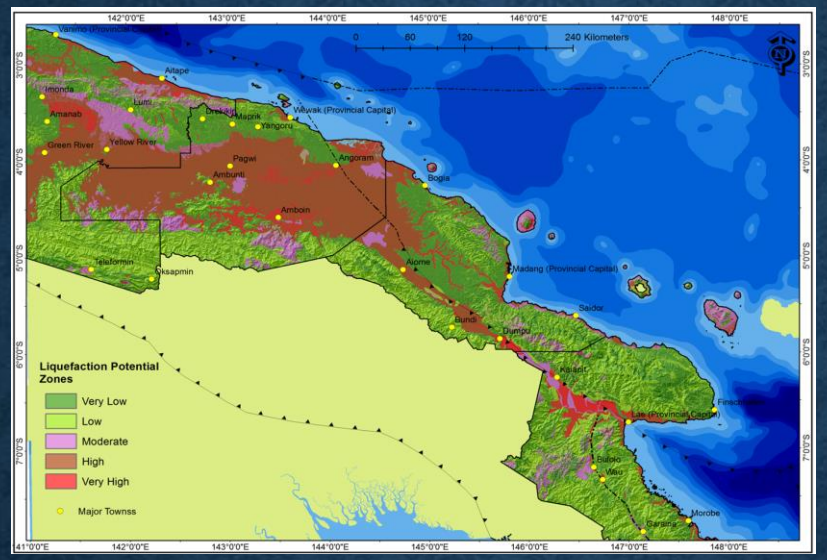


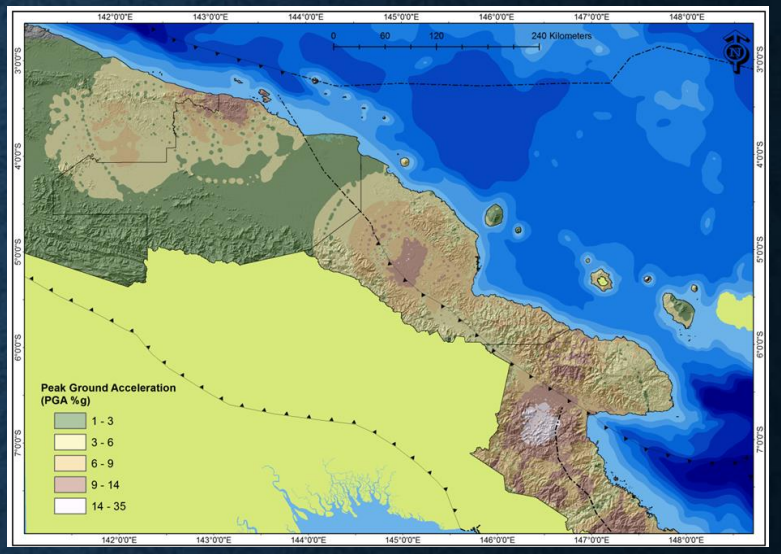
Source: Edward A. Keller, Duane E. Devecchio, Robert H. (CON) Blodgett, 2012, 3rd edition

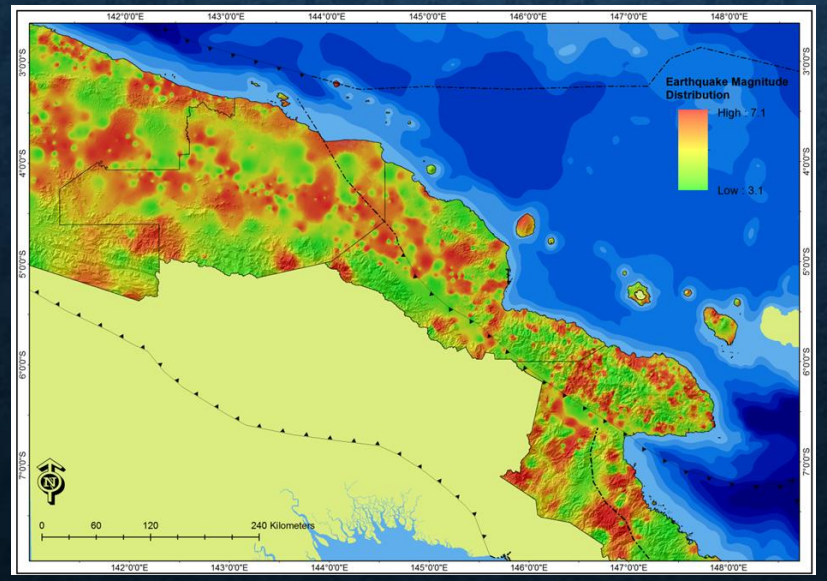
Earthquake Risk/Hazard Assessment Geo-spatial Technology

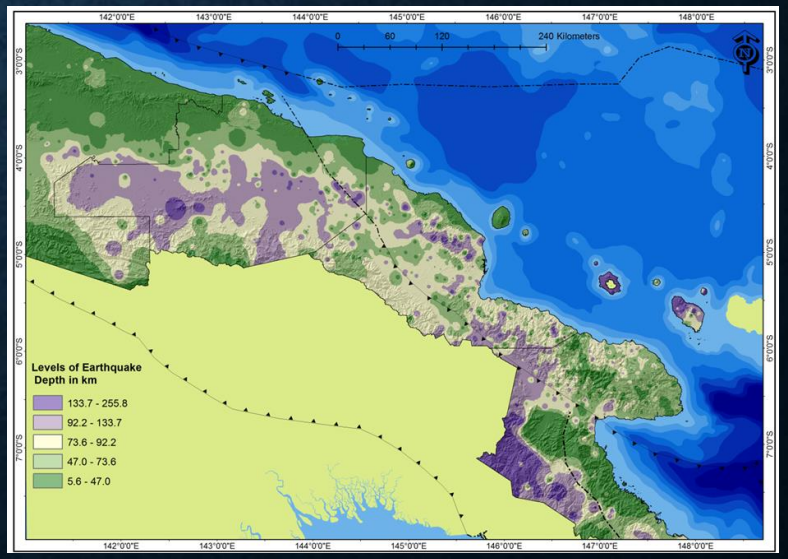


Earthquake Risk/Hazard Assessment Geo-spatial Technology

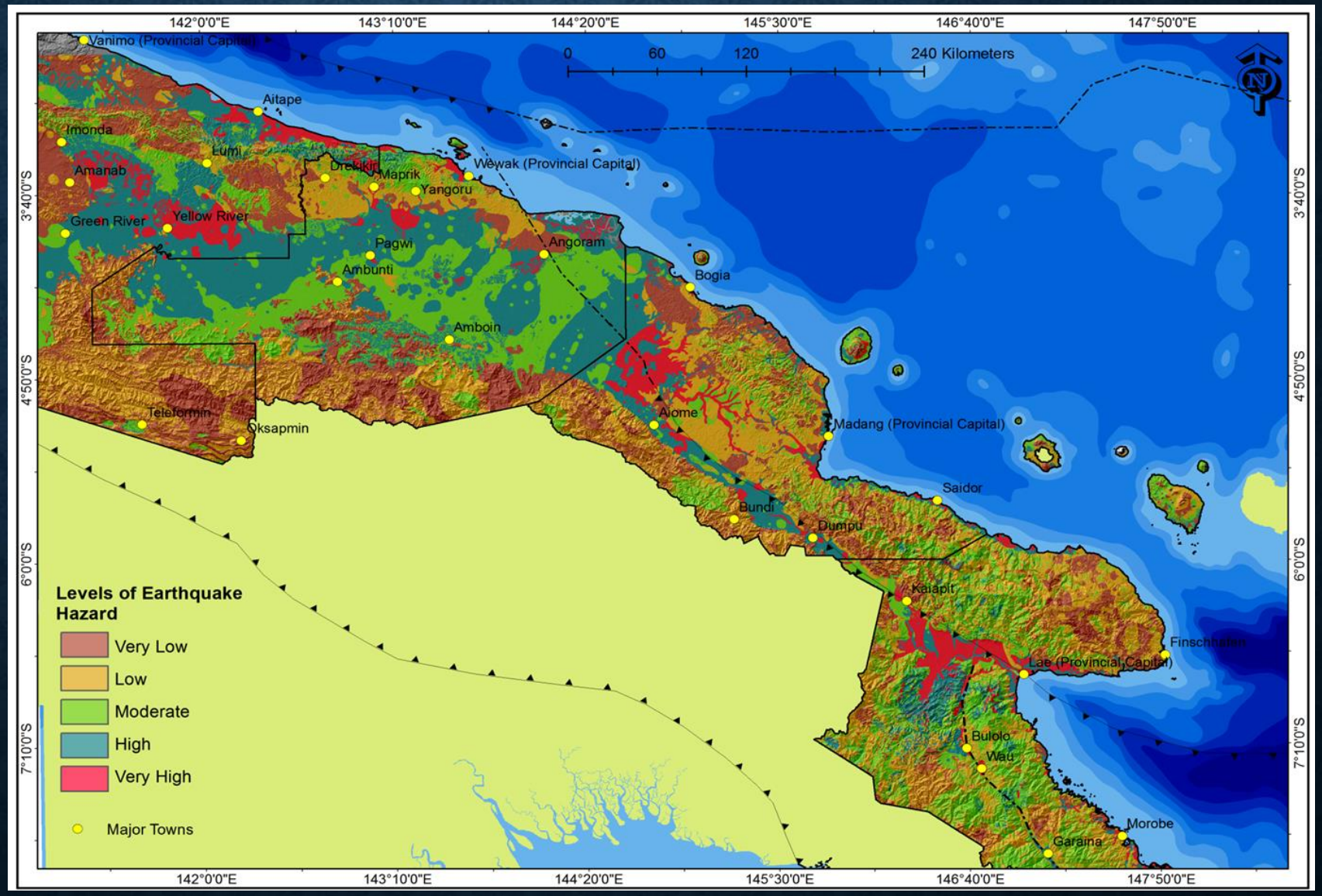




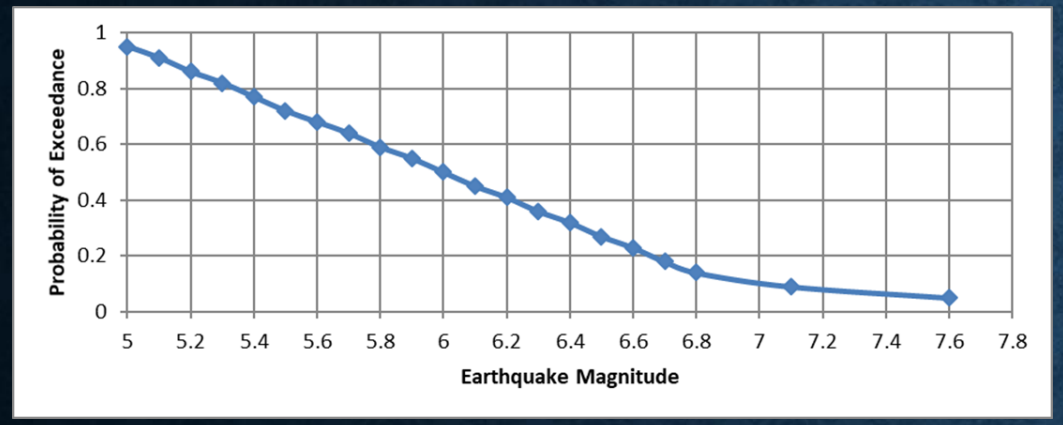


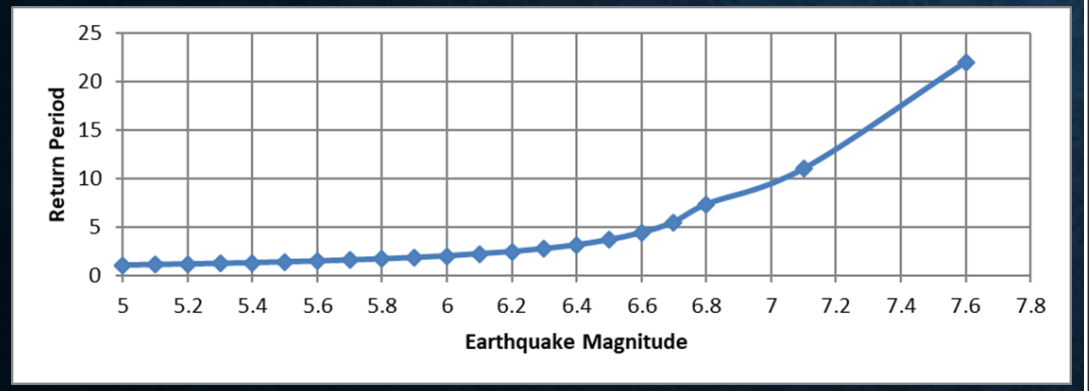


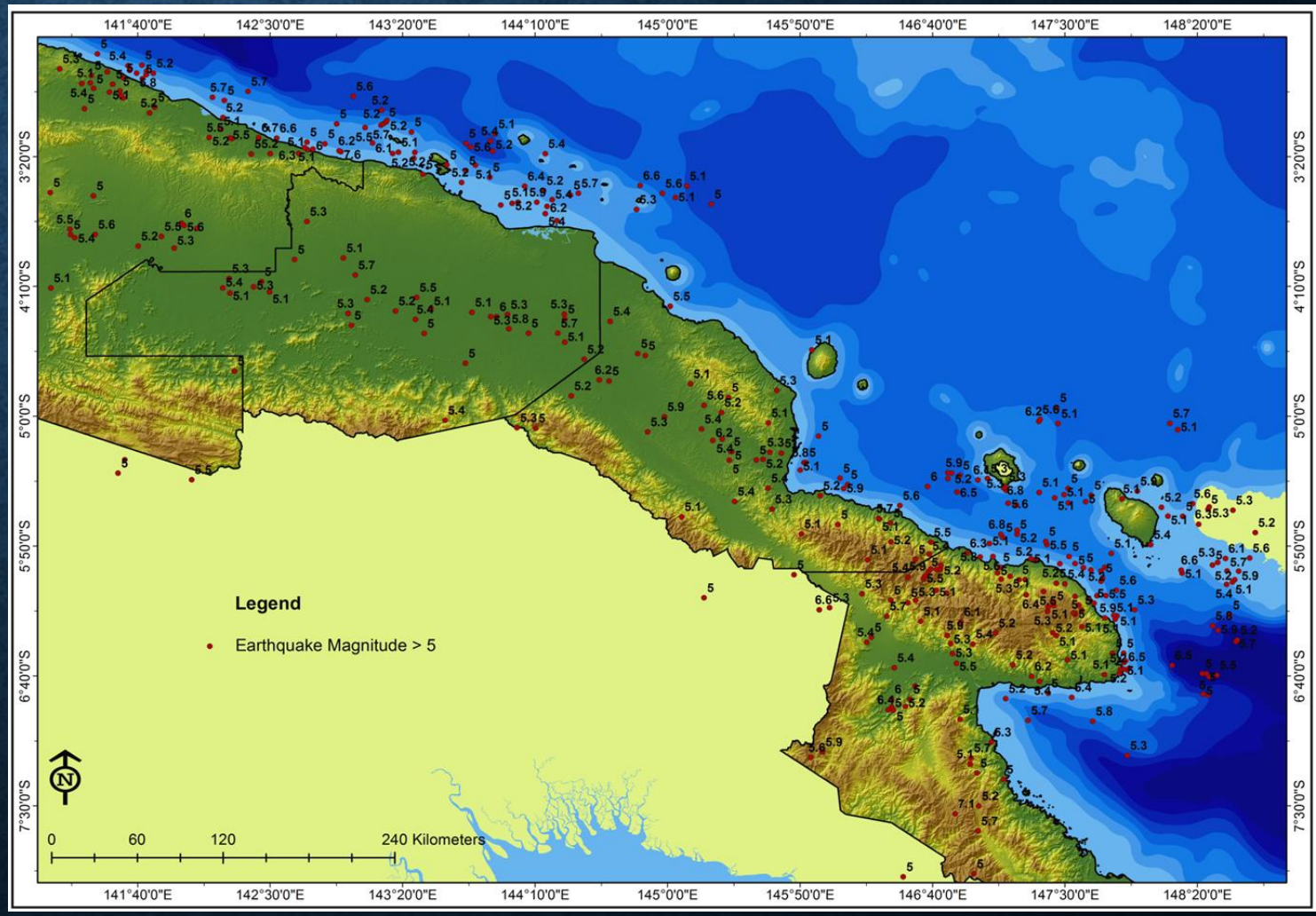
Earthquake Risk/Hazard Assessment Geo-spatial Technology



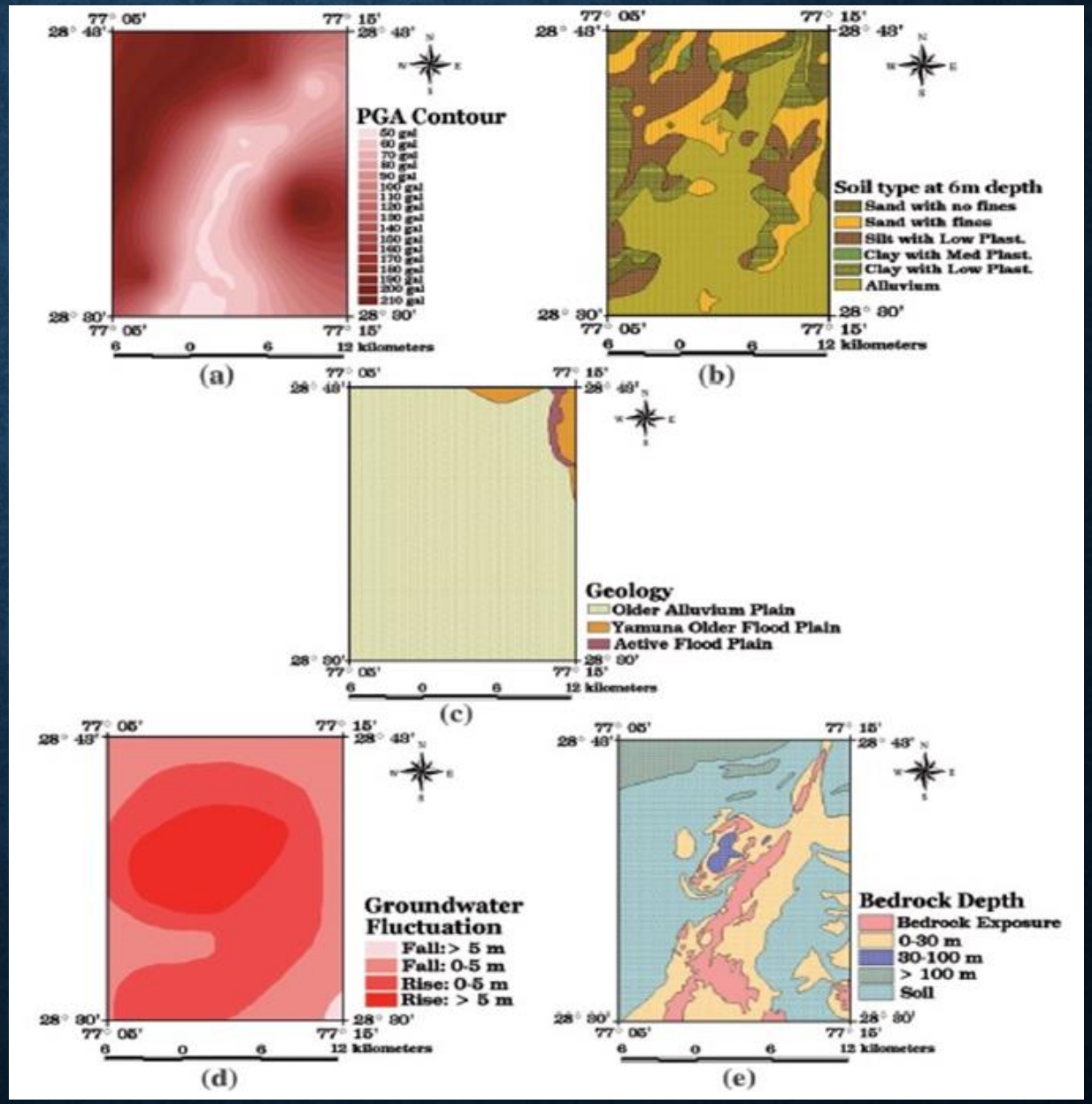
Earthquake Risk/Hazard Zone Geo-spatial Technology





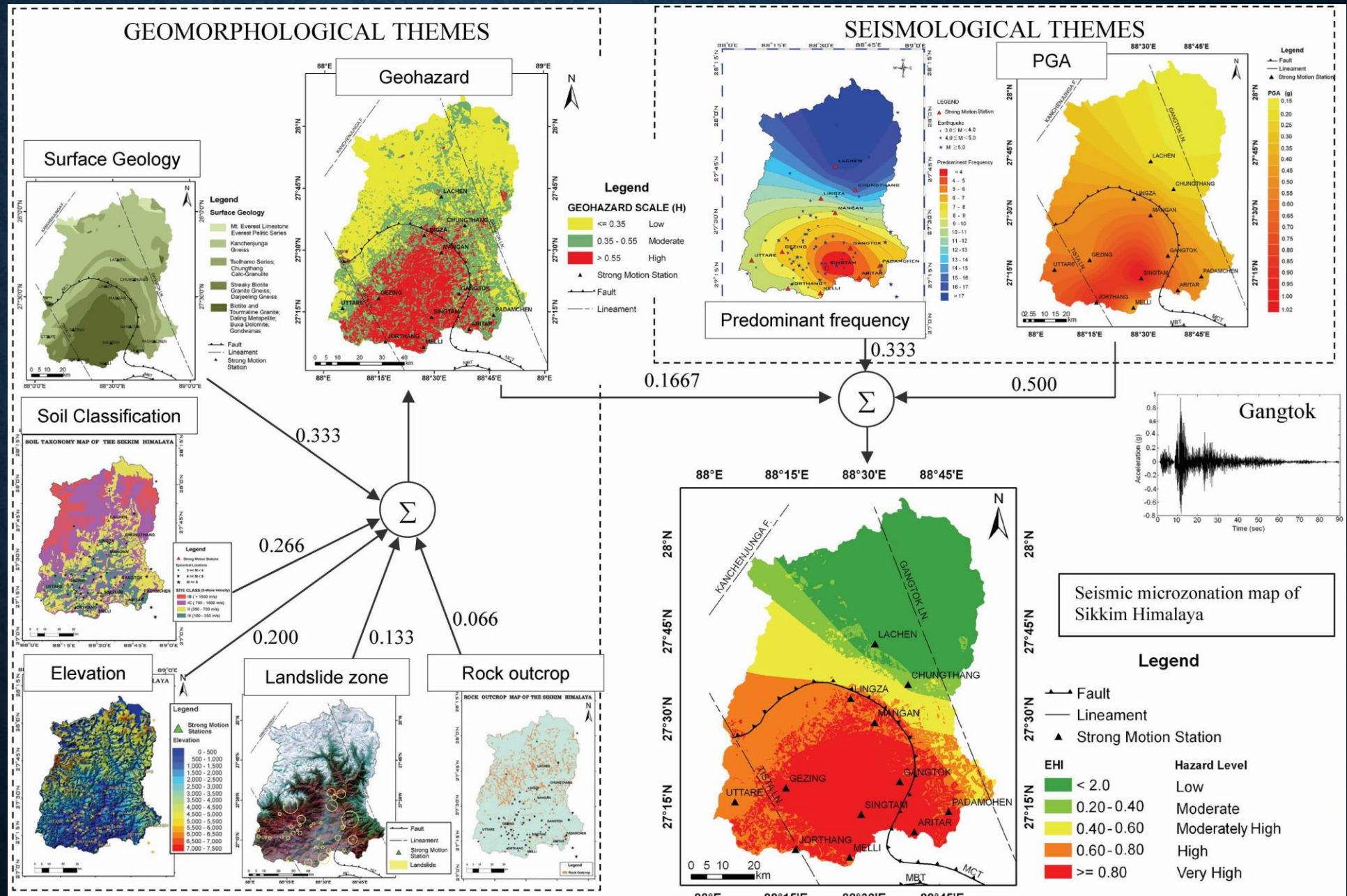


Earthquake Risk/Hazard Assessment - Geo-spatial Tech.



Source: Mohanty et al. 2006

Earthquake Risk/Hazard Assessment - Geo-spatial Tech.



Source: Nath and Thingbaijam, (2009)

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Nath, S. K., and Thingbaijam, K. K. S., (2009). Seismic hazard assessment – a holistic microzonation approach, Nat. Hazards Earth Syst. Sci., 9, 1445–1459, Online, https://doi.org/10.5194/nhess-9-1445-2009, 2009.