Basic Geophysics Behind Tsunami

August 9th, 2022

OUTLINE

01 Introduction

02 Earth interior and geodynamics

03 Plate Tectonics

04 Earthquakes

05 Tsunami

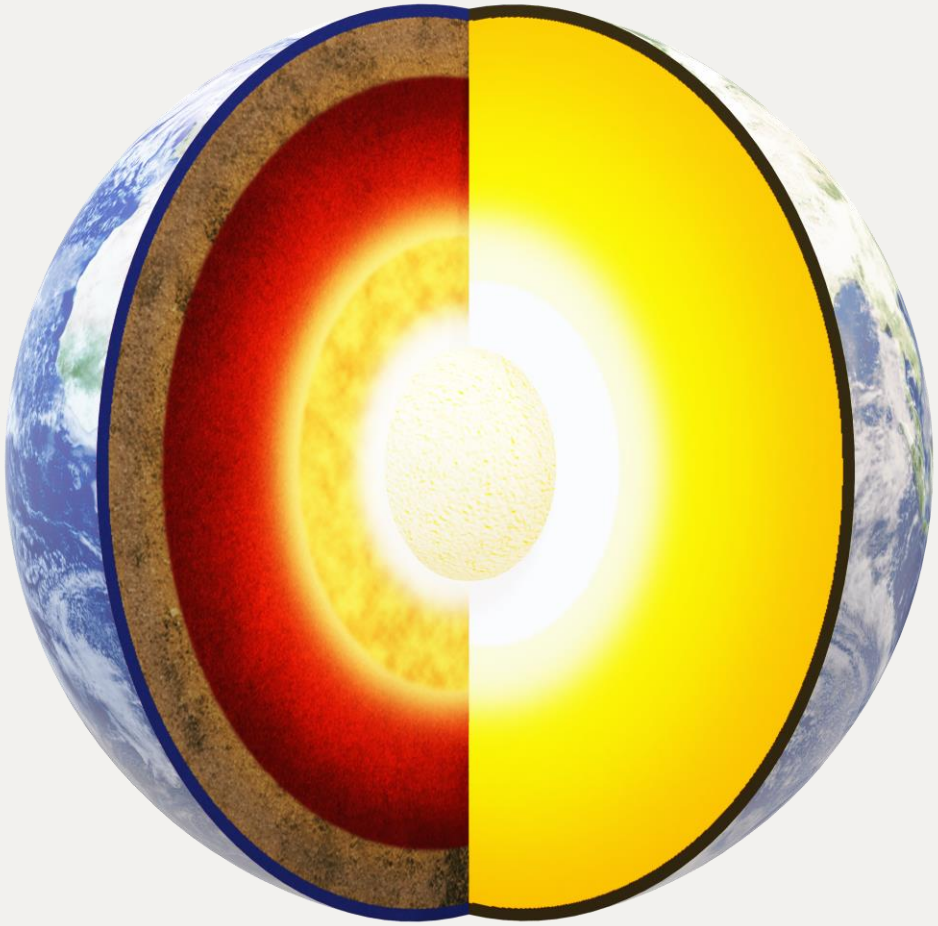
06 TSUNAMI EARLY WARNING SYSTEM

01 Introduction

What is a Tsunami?

02 Earth interior and geodynamics

THE STRUCTURE OF THE EARTH

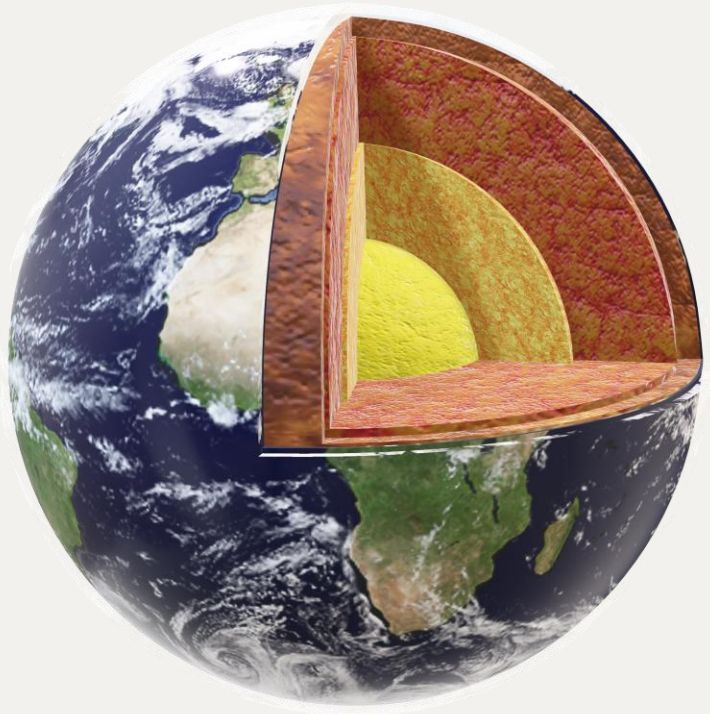


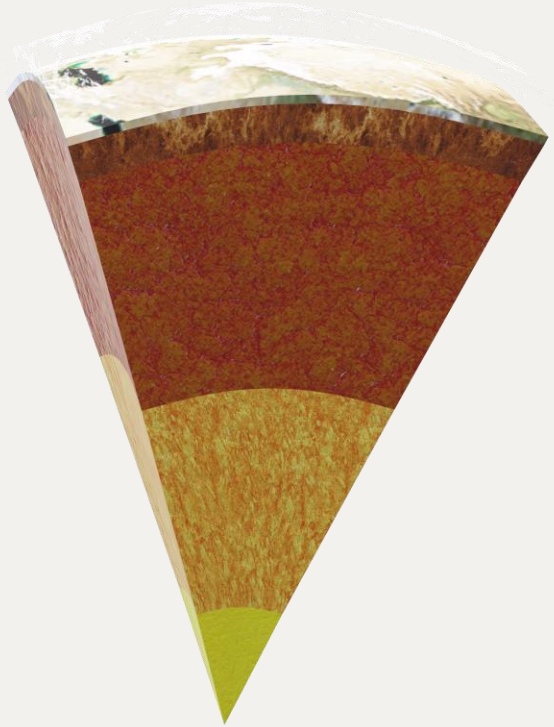
THE STRUCTURE OF THE EARTH

- The crust is composed of two rocks. The continental crust is mostly granite. The oceanic crust is basalt. Basalt is much denser than the granite. Because of this the less dense continents ride on the denser oceanic plates.

- The Mantle is the largest layer of the Earth. The middle mantle is composed of very hot dense rock that flows like asphalt under a heavy weight. The movement of the middle mantle (asthenosphere) is the reason that the crustal plates of the Earth move.

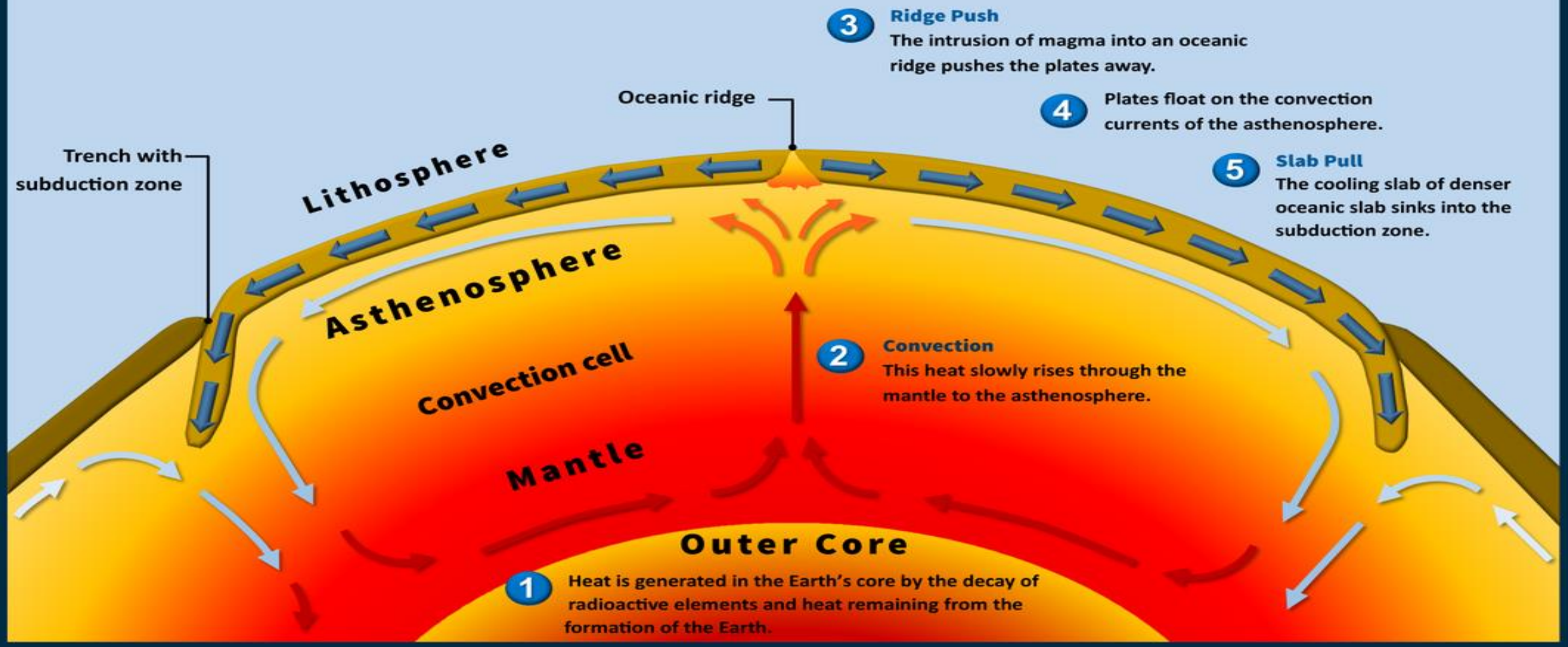
- The core of the Earth is like a ball of very hot metals. The inner core of the Earth has temperatures and pressures so great that the metals are squeezed together and are not able to move about like a liquid but are forced to vibrate in place like a solid. The outer core is so hot that the metals in it are all in the liquid state. The outer core is composed of the melted metals of nickel and iron.





THE CONVECTION CURRENT OF THE MANTLE

Scientists believe that tectonic plates move because of convection currents that flow up from the core of the Earth and circulate under the asthenosphere.



3 Ridge Push
The intrusion of magma into an oceanic ridge pushes the plates away.

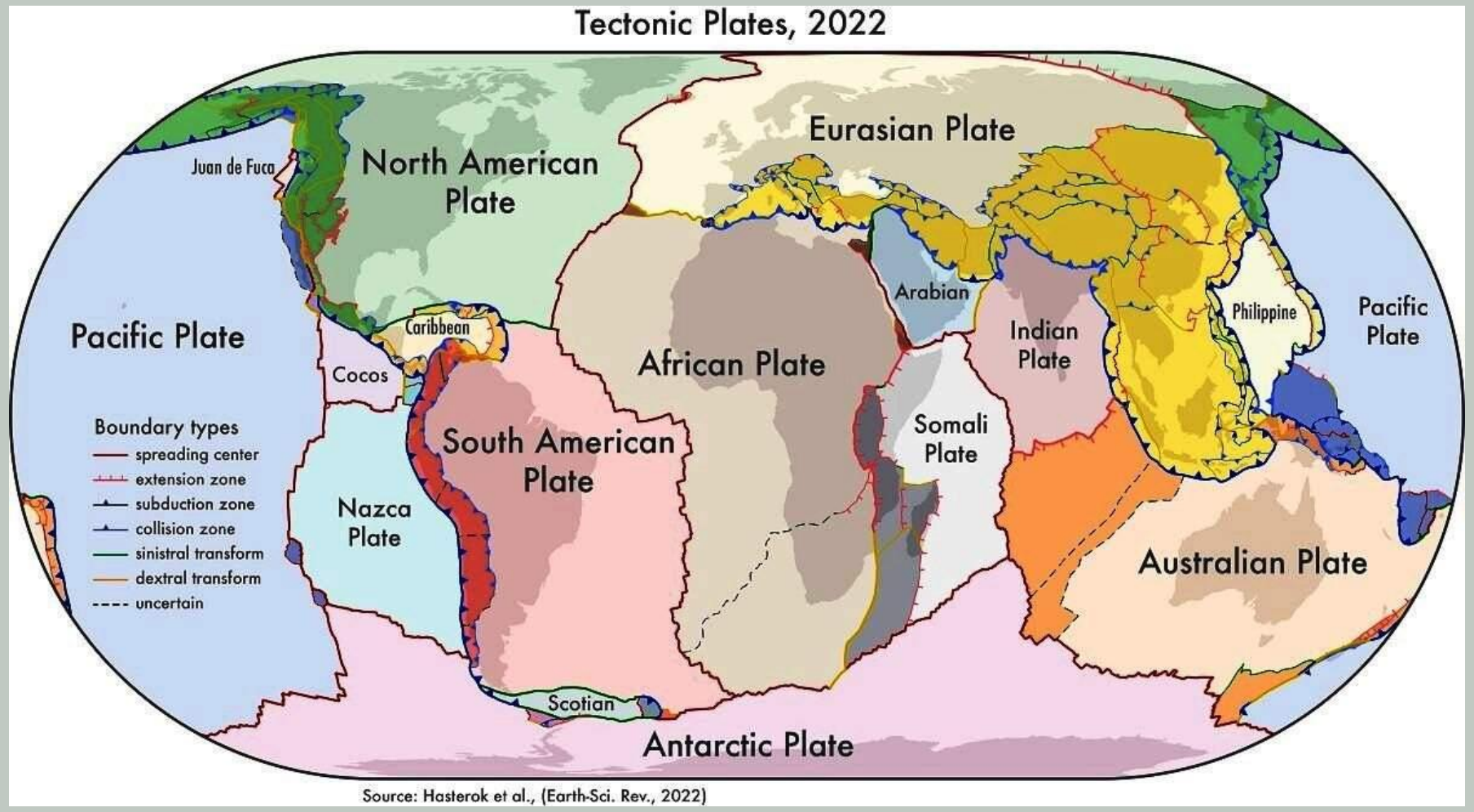
4 Plates float on the convection currents of the asthenosphere.

5 Slab Pull
The cooling slab of denser oceanic slab sinks into the subduction zone.

2 Convection
This heat slowly rises through the mantle to the asthenosphere.

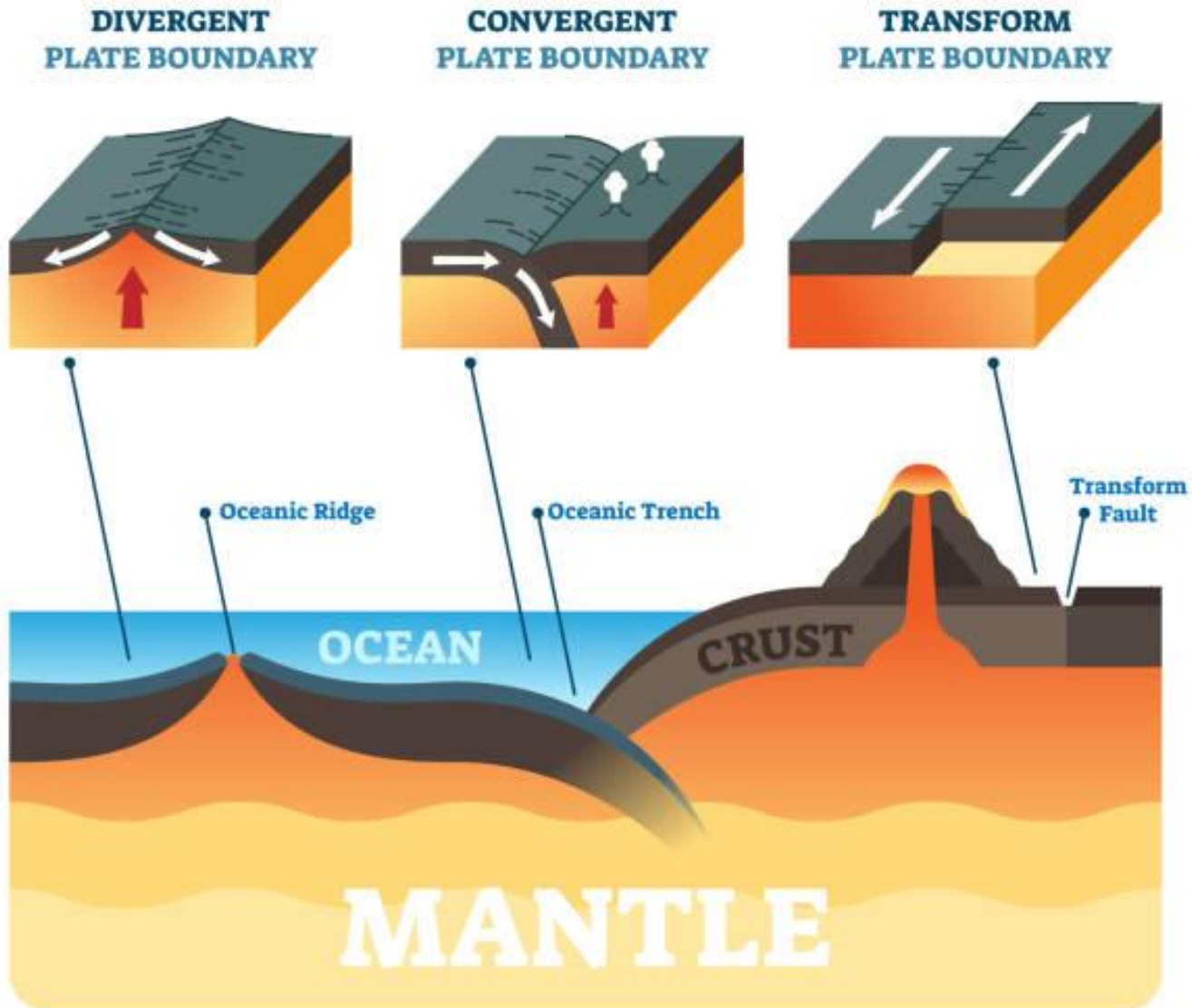
1 Heat is generated in the Earth's core by the decay of radioactive elements and heat remaining from the formation of the Earth.

03 Plate Tectonics



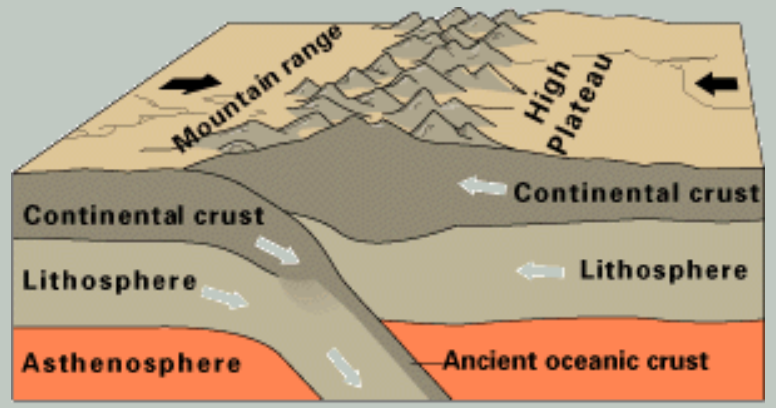
- The Earth's crust is divided into 12 major plates which are moved in various directions.
- This plate motion causes them to collide, pull apart or scrape against each other.
- Each type of interaction causes a characteristic set of Earth structures or "tectonic" features.
- The word tectonic refers to the deformation of the crust as a consequence of plate interaction.

PLATE BOUNDARIES



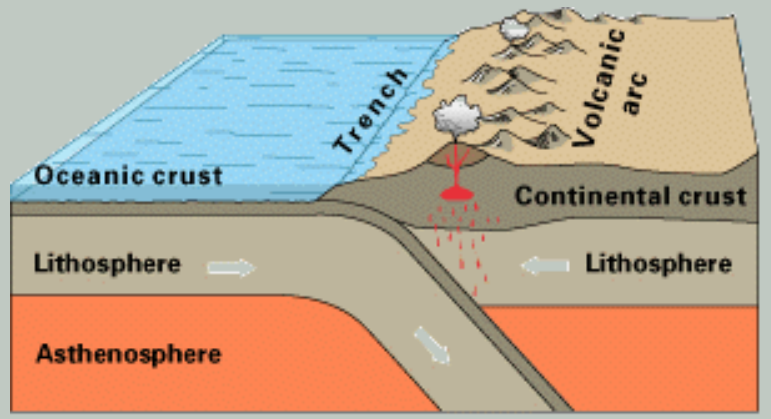
CONVERGENT BOUNDARIES

Styles of Convergent Plate Boundaries



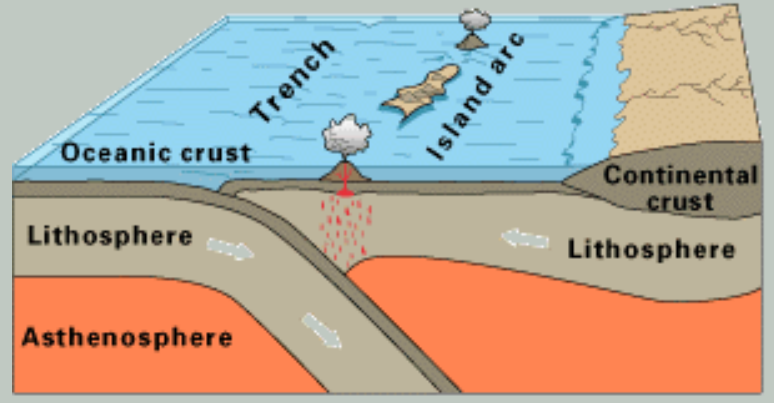
Continental-continental convergence

- Continent-Continent Collision Forms mountains, e.g. European Alps, Himalayas



Oceanic-continental convergence

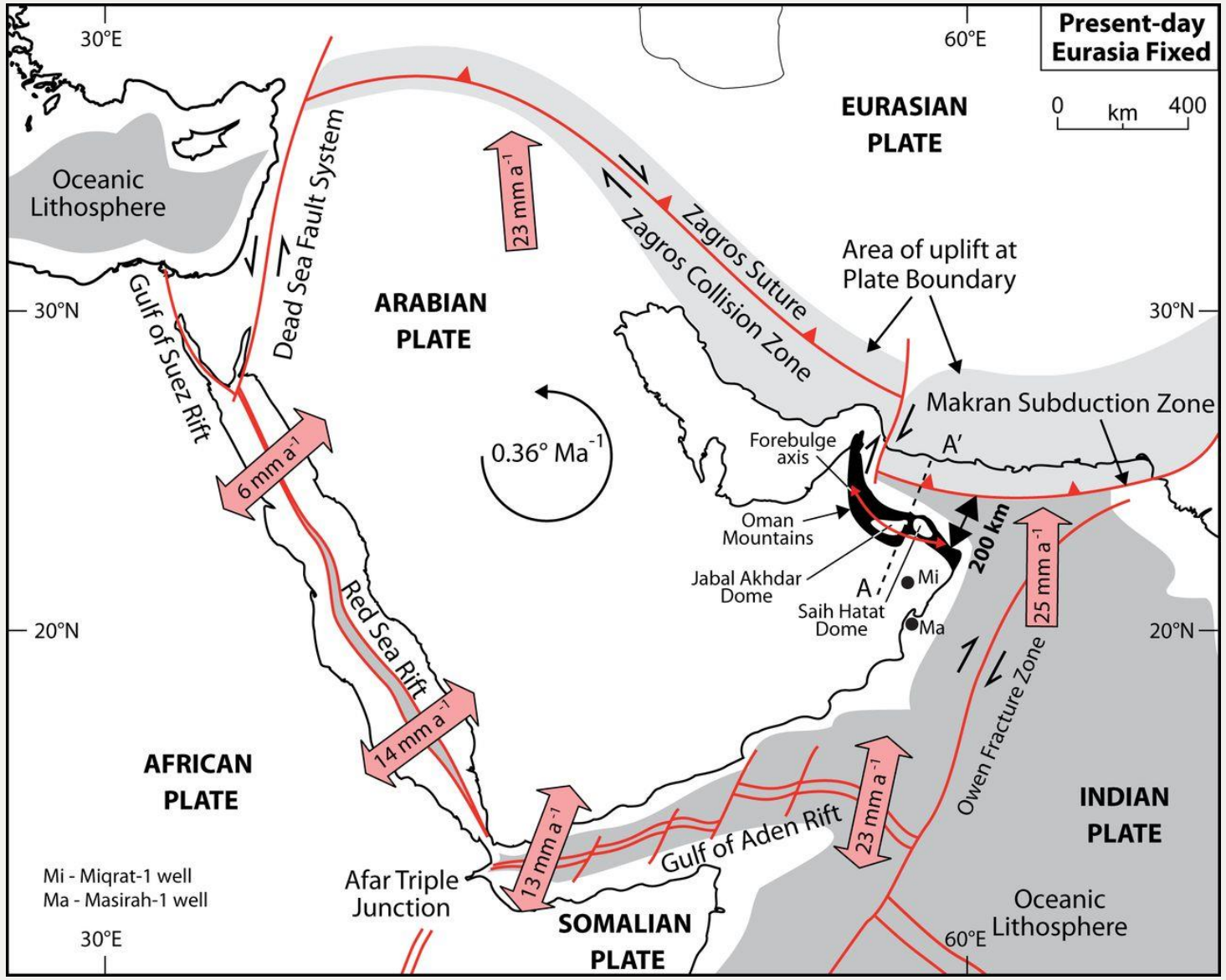
- Oceanic lithosphere subducts underneath the continental lithosphere.
- Oceanic lithosphere heats and dehydrates as it Subsides.
- The melt rises forming Volcanism.



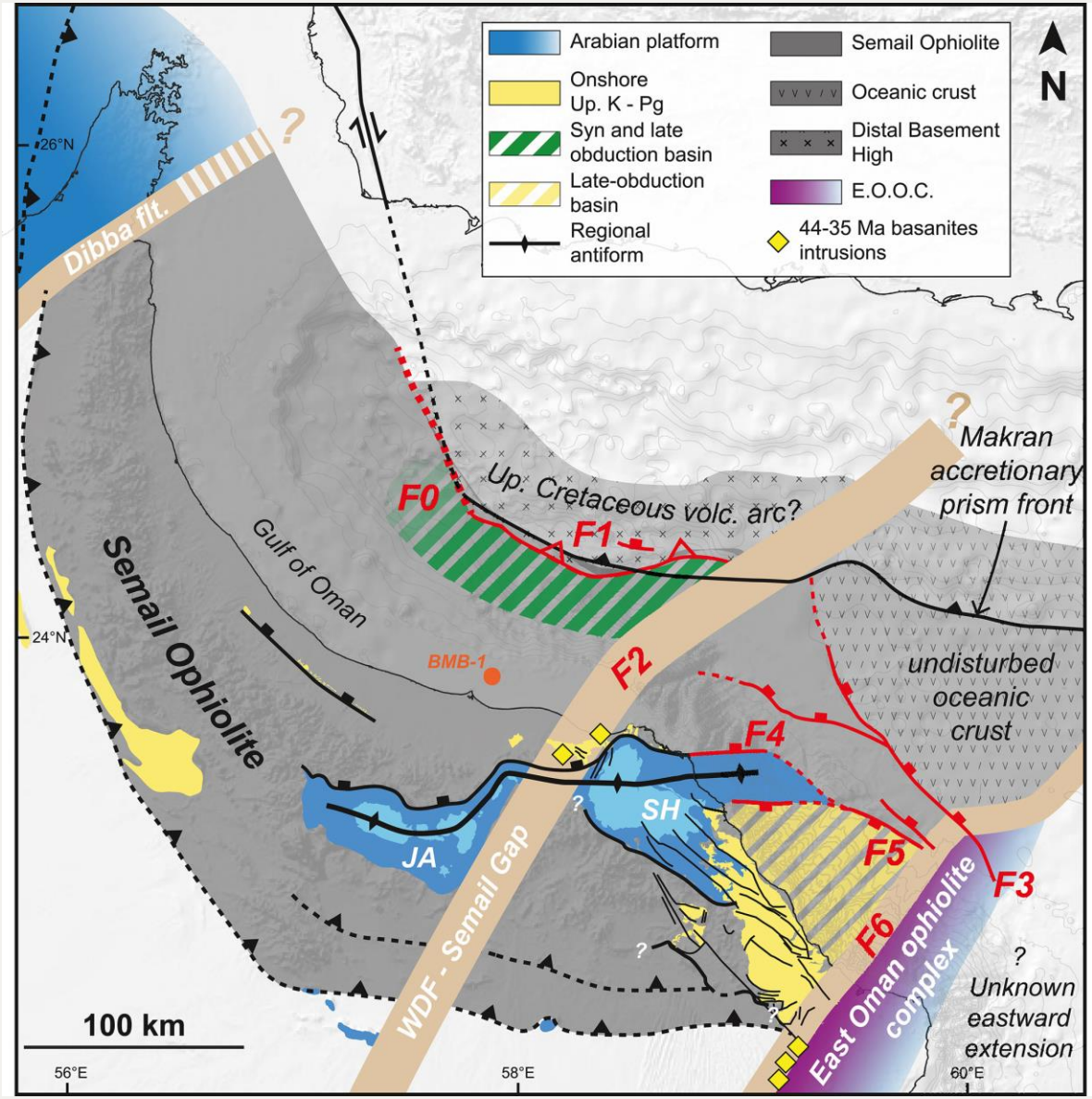
Oceanic-oceanic convergence

- When two oceanic plates collide, one runs over the other which causes it to sink into the mantle forming a subduction zone.
- The subducting plate is bent downward to form a very deep depression in the ocean floor called a trench.
- The worlds deepest parts of the ocean are found along trenches. E.g. The Aleutian Trench

TECTONIC SYSTEM AROUND OMAN



MAKRAN SUBDUCTION ZONE

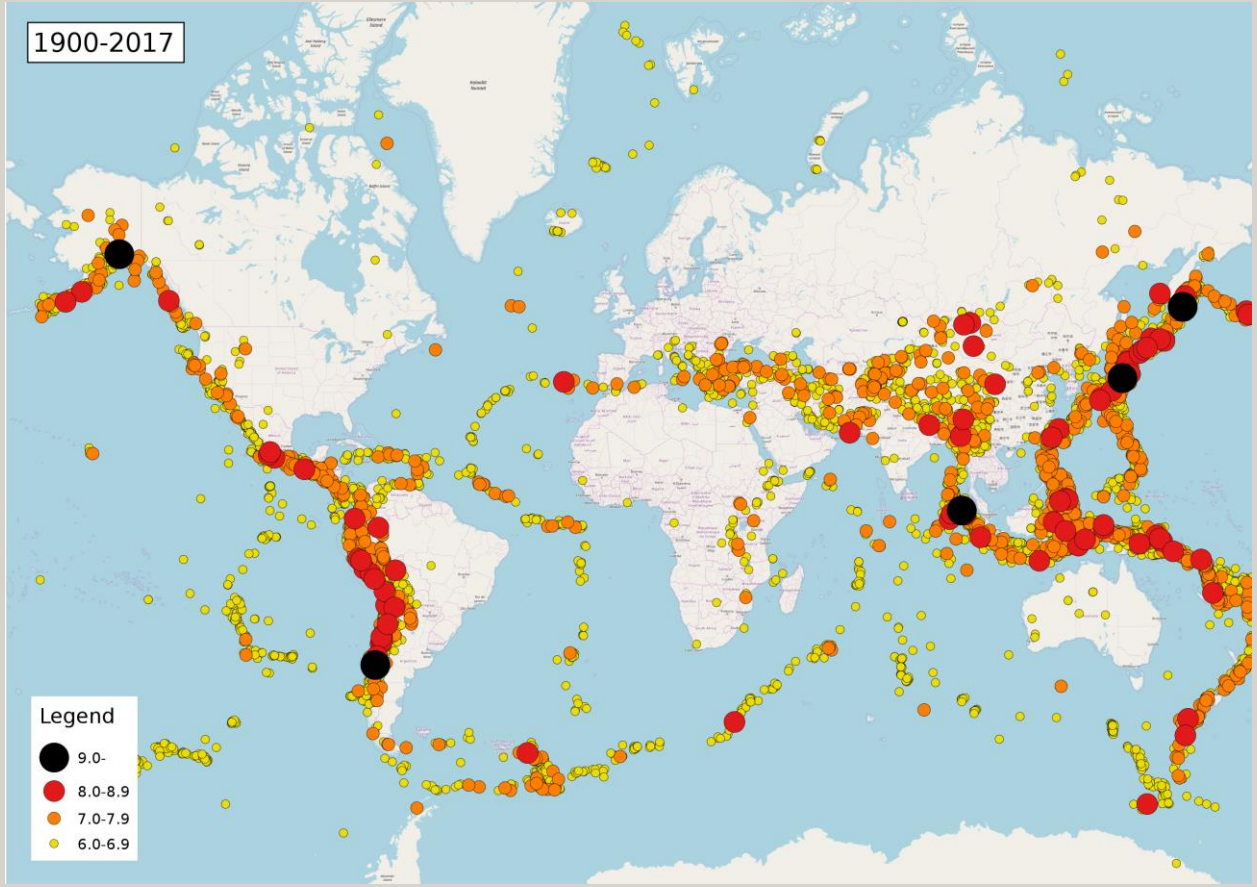


The oceanic crust of the Arabian Plate is subducting beneath the continental crust of the Eurasian Plate.

04 Earthquakes

As with volcanoes, earthquakes are not randomly distributed over the globe. At the boundaries between plates, friction causes them to stick together. When built up energy causes them to break, earthquakes occur.

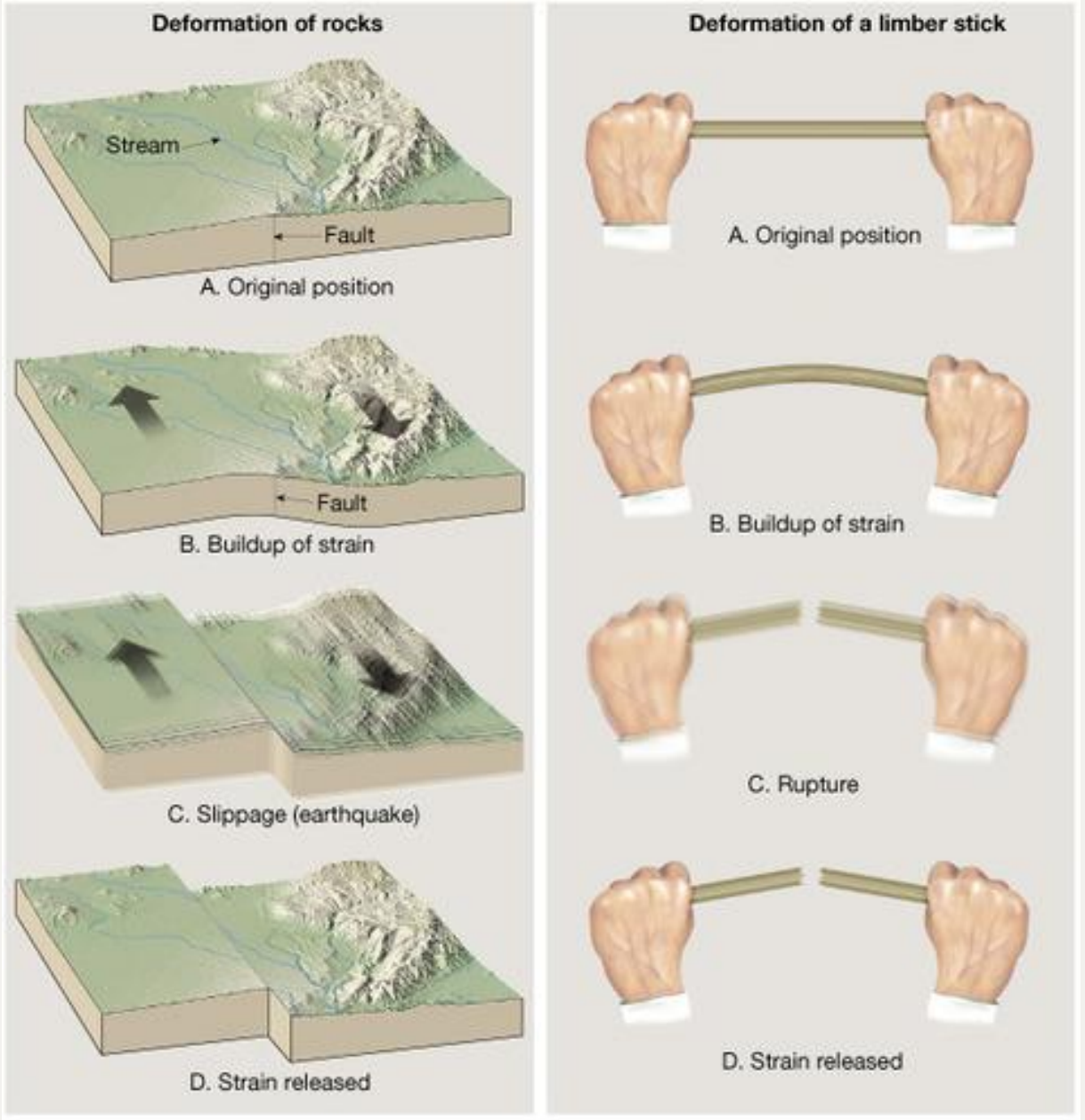
GLOBAL SEISMICITY



- 80% of all earthquakes occur in the circum-Pacific belt
- 15% occur in the Mediterranean-Asiatic belt
- Remaining 5% occur in the interiors of plates and on spreading ridge centers
- More than 150,000 quakes strong enough to be felt are recorded each year

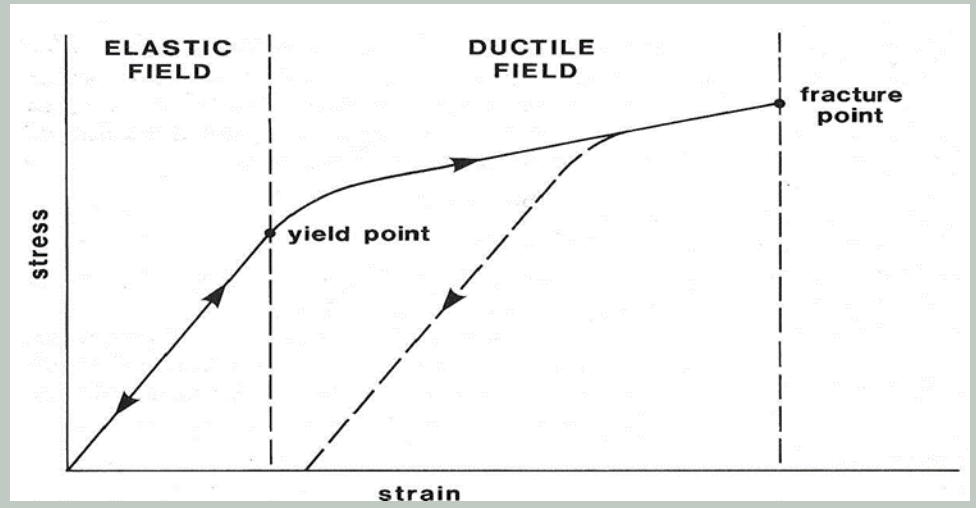
ELASTIC REBOUND THEORY

- The segment of earth's strata is subjected to external forces, it is strained
- When the elastic limits are exceeded, the resultant stresses are suddenly released causing the earthquake

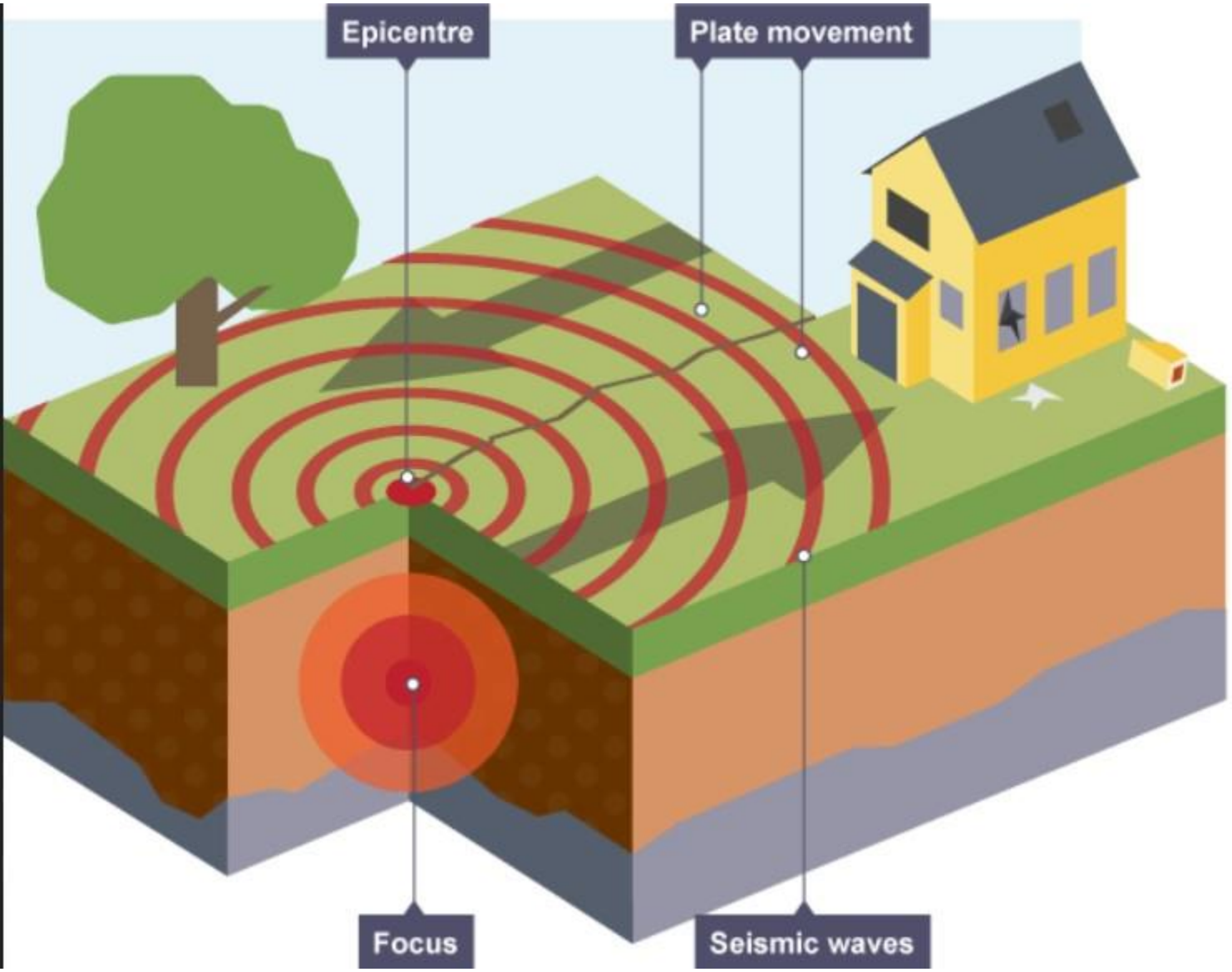


ELASTIC REBOUND THEORY

Increasing shear forces on two blocks separated by a fault:
a. increase of distortion (strain/deformation) but because of friction no movement initially
b. fracture/rupture (strain becomes more than the fault can support)



Earthquakes

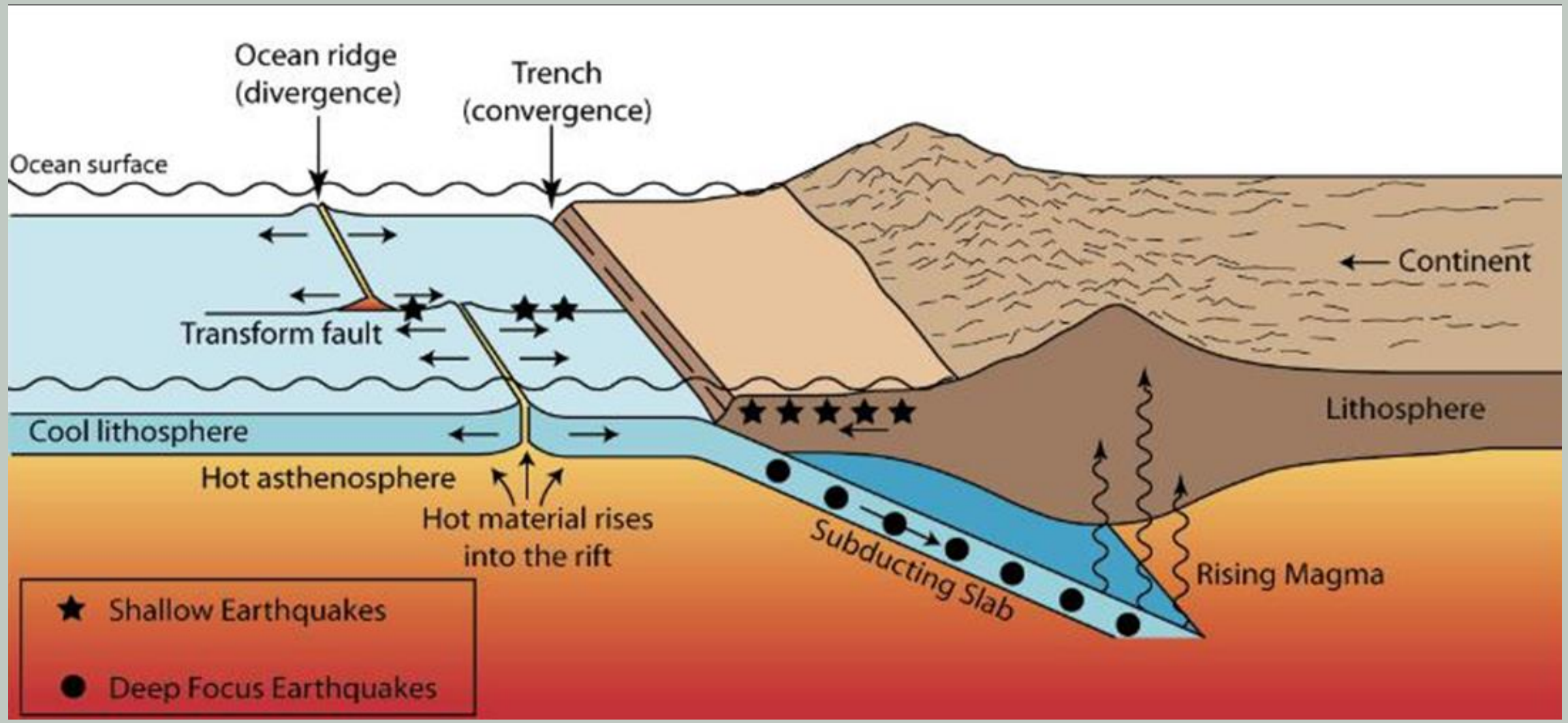


Focus (Hypocenter): The point within the Earth where an earthquake rupture starts.

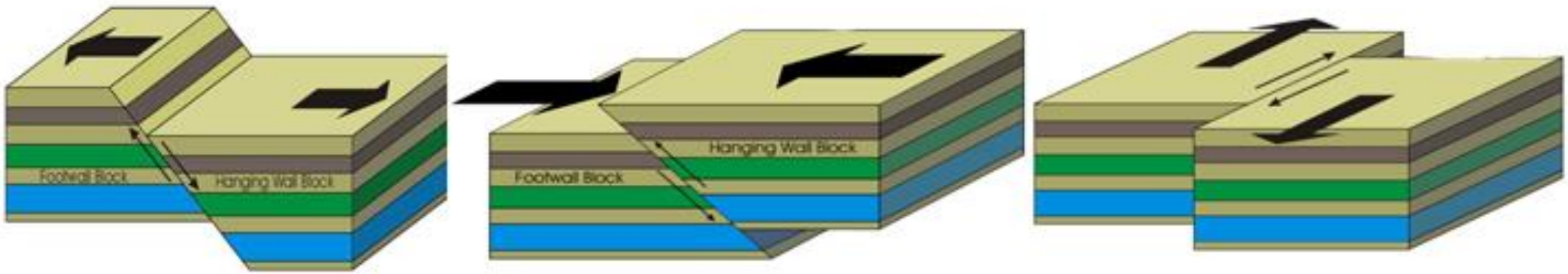
Epicenter: The point at the surface of the Earth above the focus.

Seismic waves: Waves that transmit the energy released by an earthquake.

Where do Earthquakes form?



What are the three main types of faults?



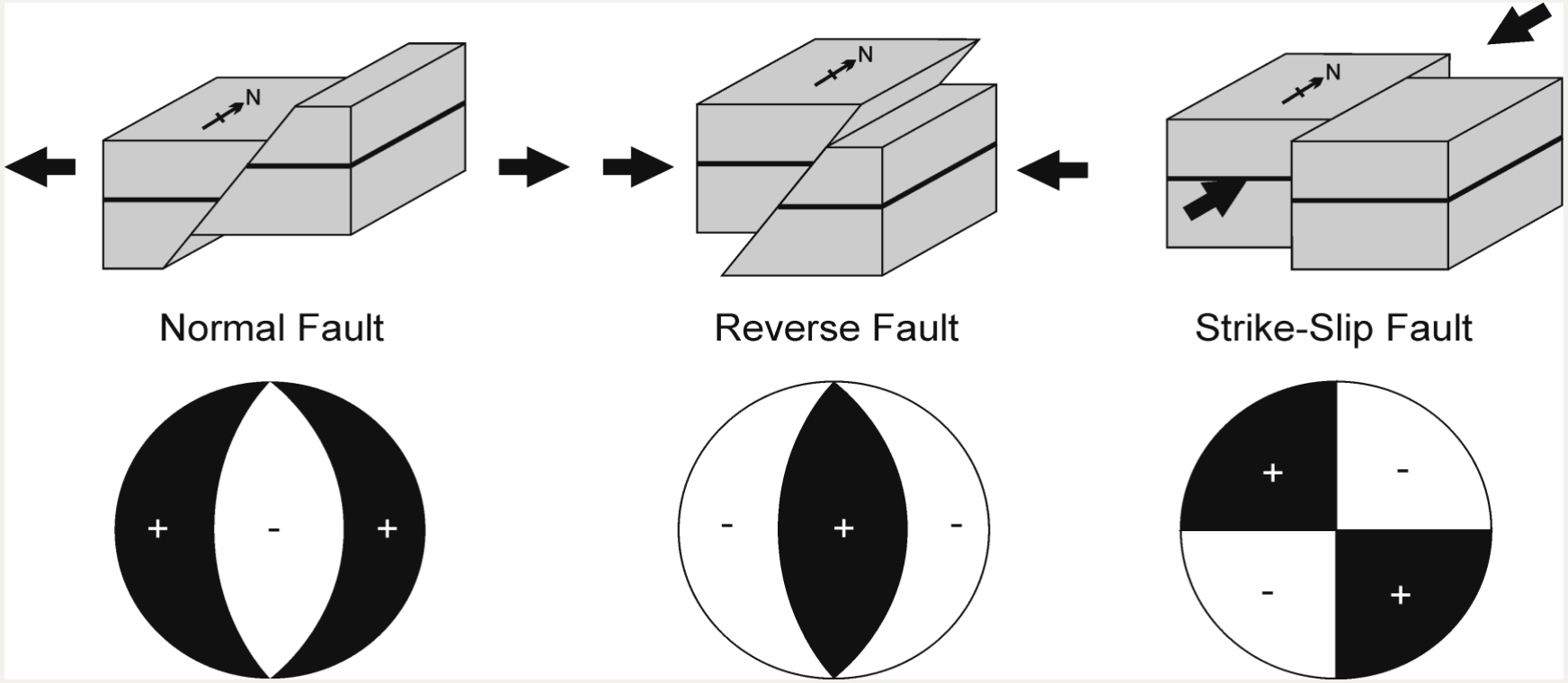
Normal fault

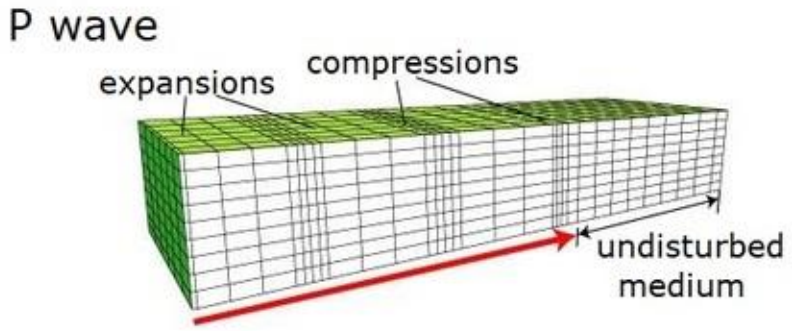
Reverse fault

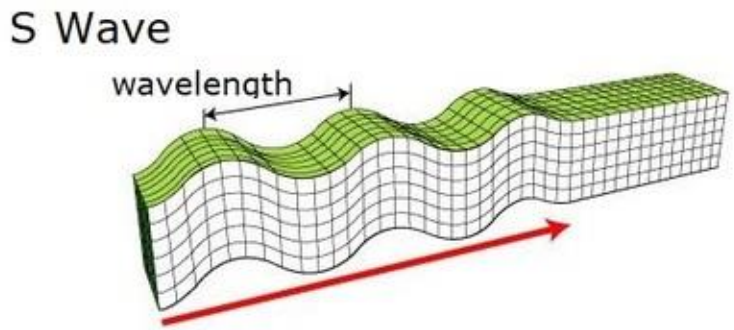
Strike-slip fault

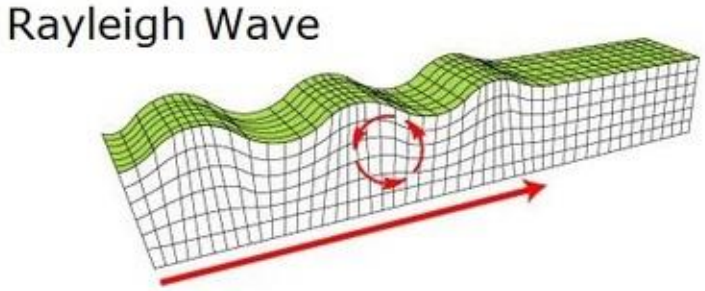
Focal mechanism

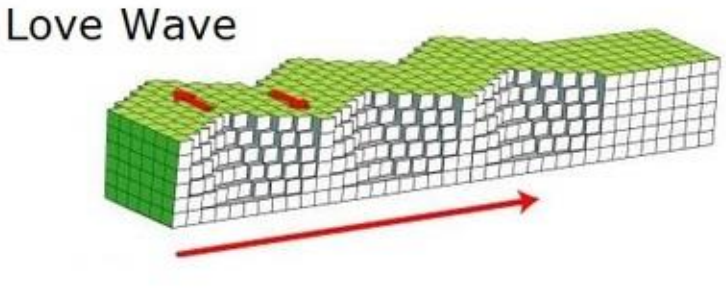
Focal mechanism: The geometry and mechanism of the fault in a simple diagram.











TYPES OF SEISMIC WAVES

P waves travel away from the focus of an earthquake where the rocks first fractured by compressing and expanding the rocks as they travel through solids, liquids and gases. P waves travel through all parts of the Earth.

S waves travel in a motion similar to a rope held tight at one end while the other end is lifted rapidly back and forth. S waves only travel through solids and do not travel through the liquid outer core of the Earth.

surface waves

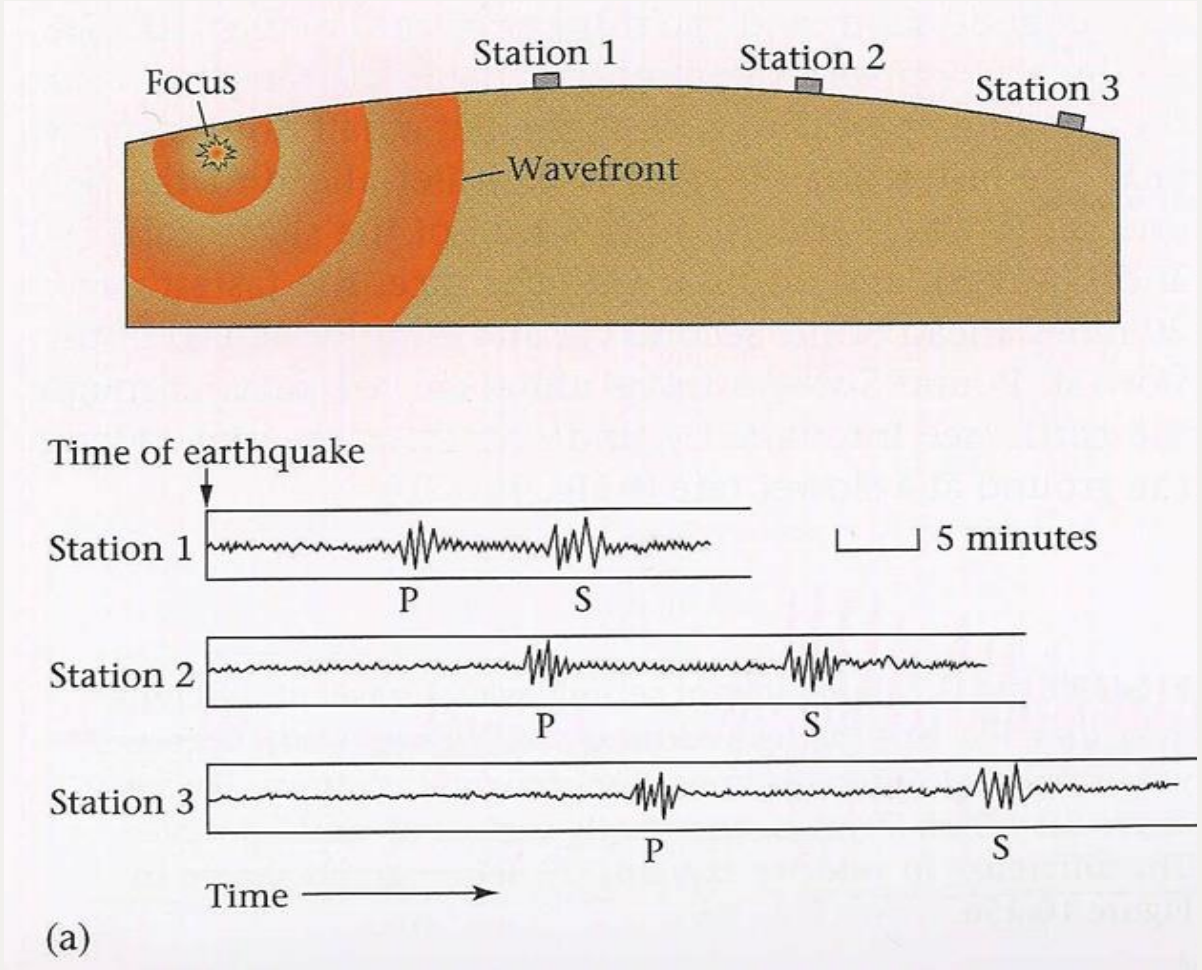
Love waves move back and forth in the direction they are traveling.

Rayleigh waves also move on the surface but are closer to how waves in the ocean move. Their movement is circular in motion as they move through the Earth, but the circular motion is retrograde meaning the waves circle backward as they move forward.

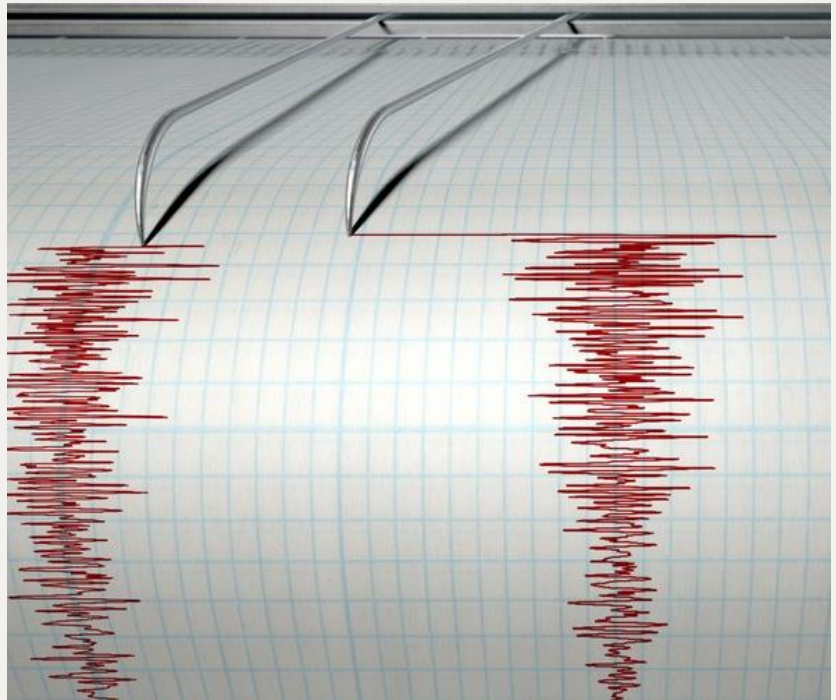
Locating an earthquake

using P-S arrival-time differences

Locating an earthquake (Method 2: using P-S arrival-time differences)
S-waves travel more slowly than P-waves > the more distant the earthquake from the receiver the greater the time lag of the S after the P arrival



Measuring earthquake magnitude and intensity



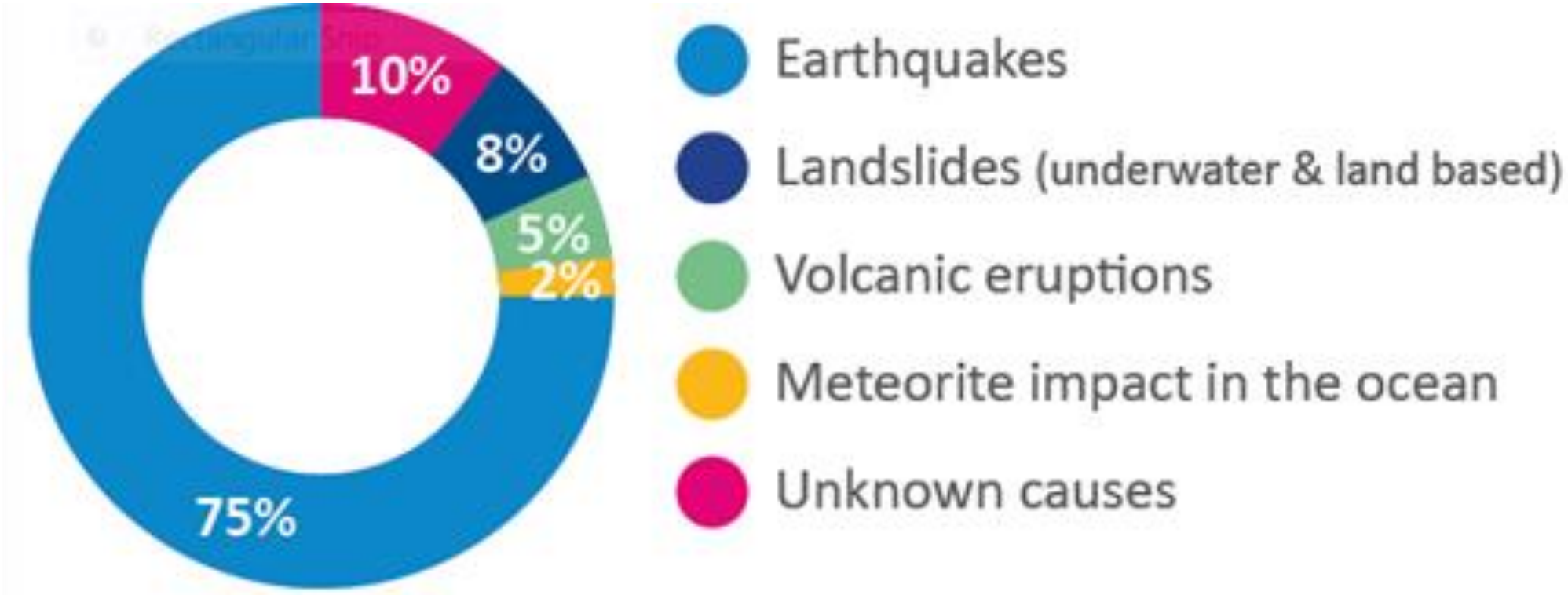
Magnitude measures the energy released at the source of the earthquake. Magnitude is determined from measurements on seismographs

Intensity measures the strength of shaking produced by the earthquake at a certain location. Intensity is determined from effects on people, human structures, and the natural environment.

05 TSUNAMI

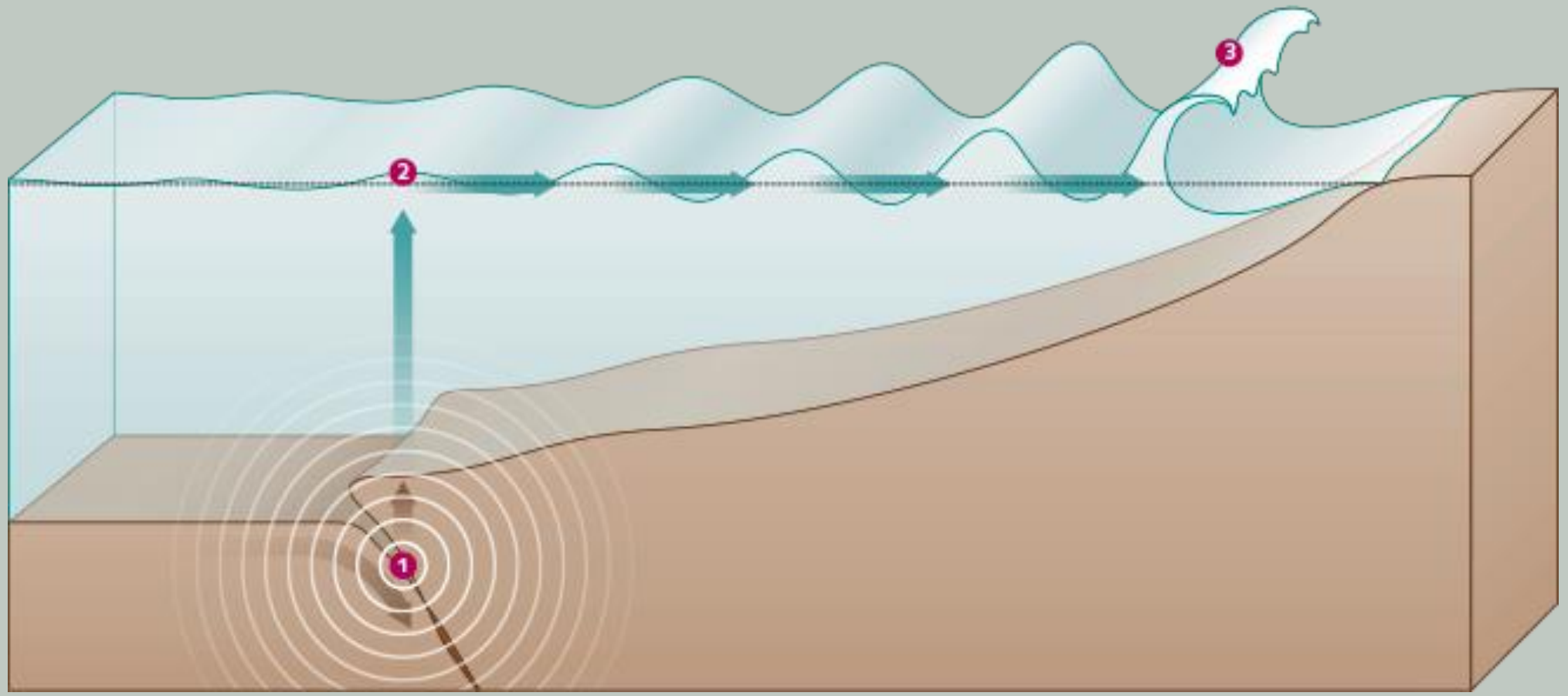
Tsunamis are giant waves caused by earthquakes or volcanic eruptions under the sea. Out in the depths of the ocean, tsunami waves do not dramatically increase in height. But as the waves travel inland, they build up to higher and higher heights as the depth of the ocean decreases.

Causes of Tsunami

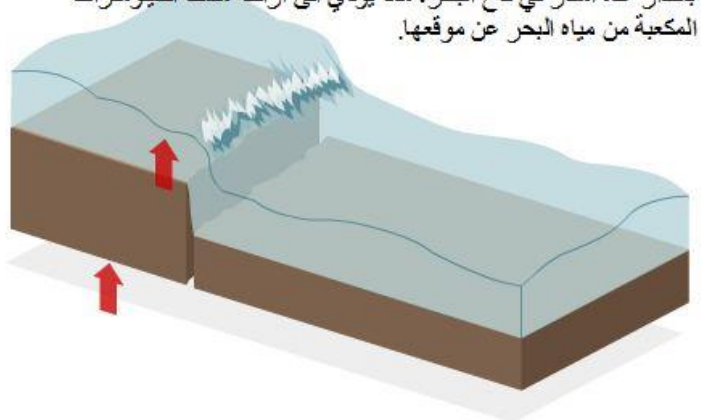


How a tsunami is formed

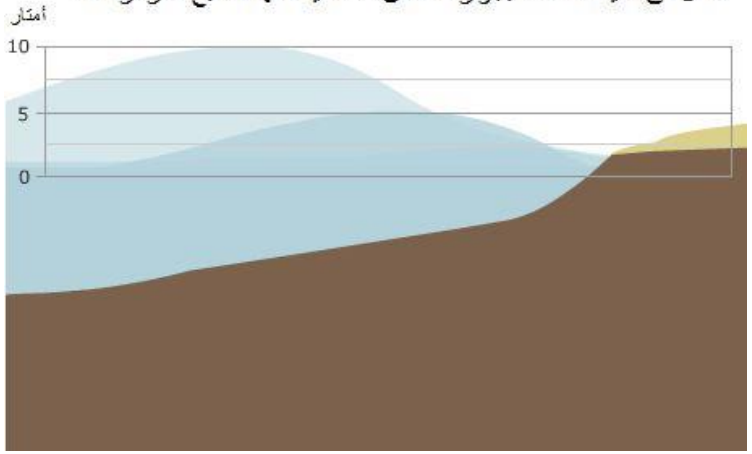
1. Through a vertical motion of the continental plates a pressure impulse is produced in the water column.
2. The impulse propagates as a tsunami through the ocean.
3. When the wave nears the shore, it is slowed down and rises vertically.



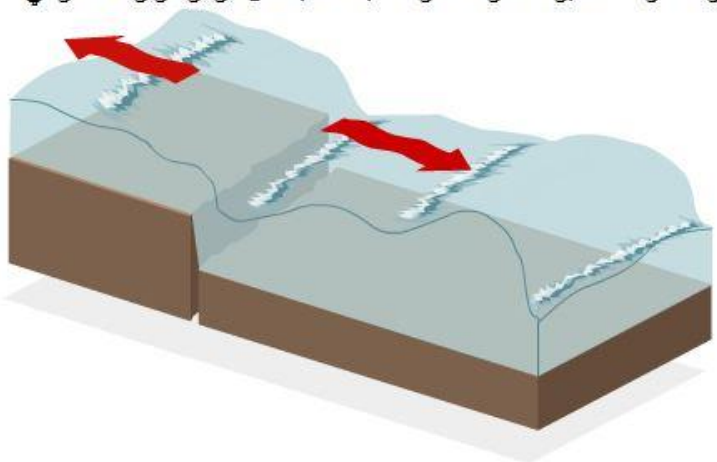
يتكون التسونامي عندما تؤدي الطاقة المتولدة من الزلزال إلى ارتجاج عمودي بمقدار عدة أمتار في قاع البحر، مما يؤدي الى ازاحة مئات الكيلومترات المكعبة من مياه البحر عن موقعها.



تتحرك موجات التسونامي بسرعة كبيرة في المياه العميقة، وتقل سرعتها عندما تصل الى المياه الضحلة بجوار المناطق الساحلية لكنها تصبح اكثر ارتفاعا



وتبدأ موجات كبيرة بالحركة عبر المحيط، بعيدا عن مركز الزلزال الخارجي.



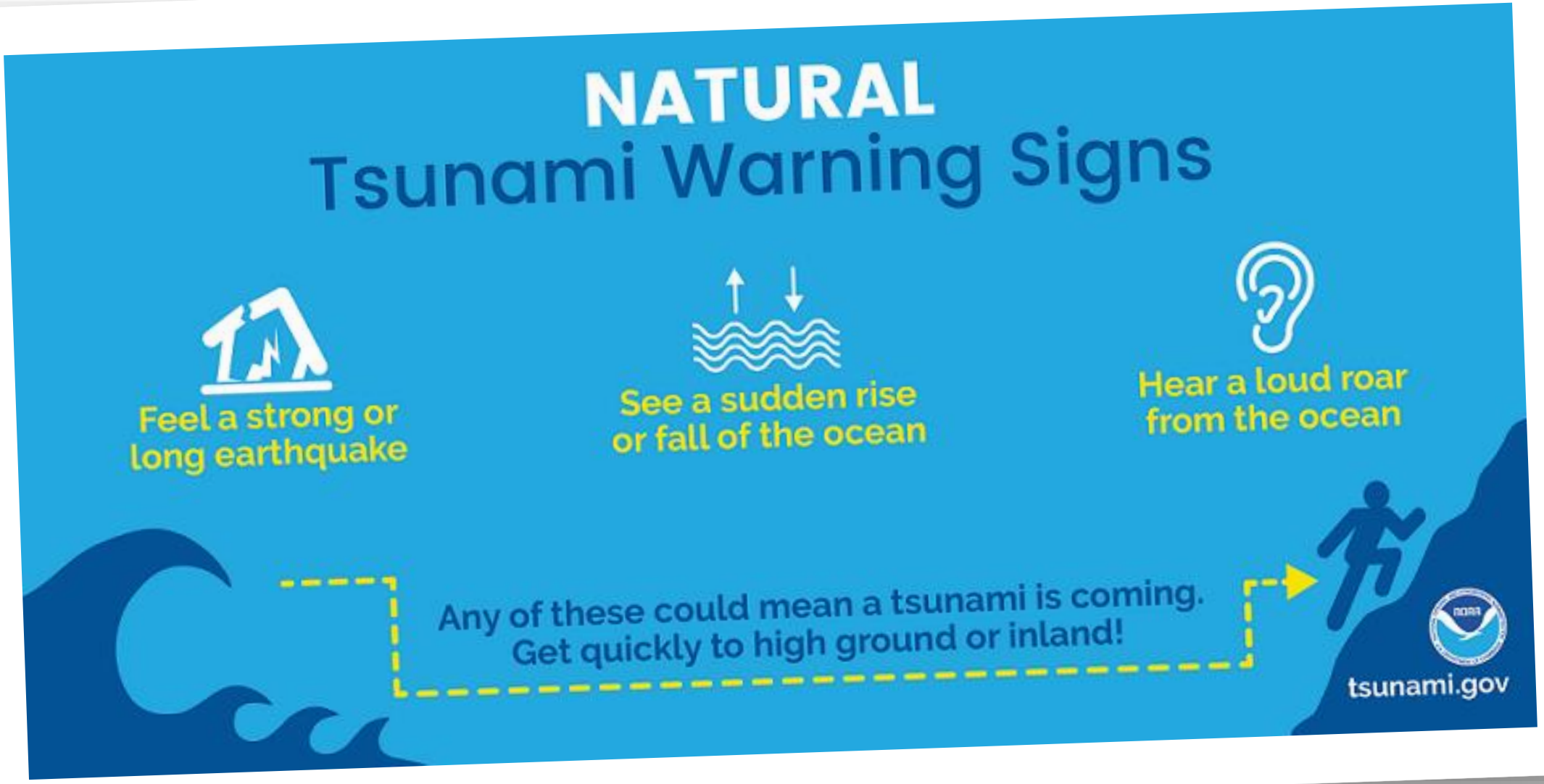
بعدها ضربت امواج التسونامي المنتجع على شكل دفعات تفصل بينها فترة أمدها من 5 الى 40 دقيقة. ووصلت مياه الامواج الى اكثر من كيلومتر في عمق الشاطئ بالمنتجع، الامر الذى سبب دمارا واسعا. المصدر: NOAA, USGS

كان التحذير الوحيد الذي تلقاه هذا المنتجع قبل ان تضربه امواج التسونامي مباشرة، حين بدأت المياه في الانحسار عن الشاطئ، وهو ما يعني ان هناك امواجا عالية قادمة.

بعض المناطق الساحلية، مثل منتجع كالوتارا في سريلانكا الذي نراه في صورة التقطتها الاقمار الصناعية، لم يتلق تقريبا اي تحذير من موجات التسونامي قبل تعرضه لها فى 26 ديسمبر/ كانون الأول 2004

Effects of a Tsunami

- Flooding in coastal areas
- Death of people
- Destruction of houses
- The decline of economic activities such as tourism and industries
- The high cost of rebuilding the economy after the occurrence of the tsunami


NATURAL
Tsunami Warning Signs
Feel a strong or long earthquake
See a sudden rise or fall of the ocean
Hear a loud roar from the ocean
Any of these could mean a tsunami is coming.
Get quickly to high ground or inland!
tsunami.gov

TSUNAMI NEAR BY OMAN

Tsunami simulation project in Makran subduction zone:

- Gives a scenario for the time arrival and the wave height for tsunami wave.
- Extend for 900 Km along Makran subduction zone.
- Based on longitude, latitude, depth and magnitude of the earthquake in the fault.

06 TSUNAMI EARLY WARNING SYSTEM

scesv@proc

Options View Help

Summary Events

2019-01-14 06:36:15 UTC

7 minutes and 54 seconds ago

Off Coast of Pakistan

M 5.3 15 km

Type	Value	+/-	Count
M	**5.3**	**-**	**15**
MLv	5.5	0.30	15
Mjma	4.5	0.24	2
Mw(Mwp)	-	-	-
Mw(mB)	5.4	0.40	14
Mwp	-	-	-
mB	5.8	0.32	14
mb	5.7	0.38	13

Latitude:	**23.81 ° N**	+/-	6 km
Longitude:	**64.26 ° E**	+/-	7 km
Depth:	**15 km**	+/-	9 km
Phase Count:	20		
RMS Residual:	1.0		

Agency:	DGMET
Status:	manual
First Location:	O.T. + 1m 53s
This Location:	O.T. + 4m 29s
EventID:	dgmet2019aygp

Show Details

Applications Places scesv@proc Mon 10:44

scolv@proc

File Edit View Settings Help

Preferred Current

2019-01-14 06:36:15

7m and 53s ago

M 5.3

Off Coast of Pakistan

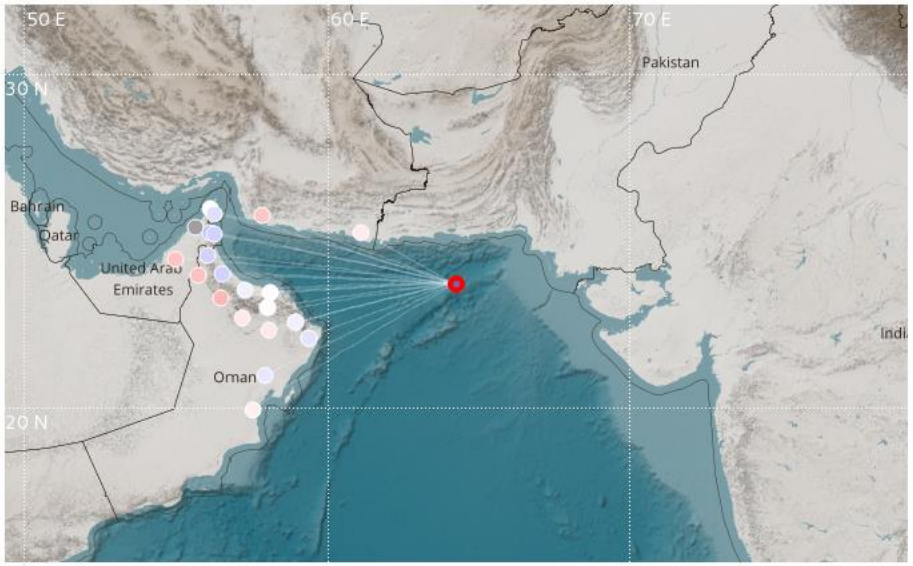
Depth 15 km

23.81°N 64.26°E

M	**5.3 (15)**
MLv	5.5 (15)
mb	5.7 (13)
mB	5.8 (14)
Mw(mB)	5.4 (14)
Phases:	**20**
RMS Res.:	1.0
Event ID:	dgmet2019ay
Agency ID:	DGMET
confirmed	manual

Location Magnitudes Event Events

Off Coast of Pakistan

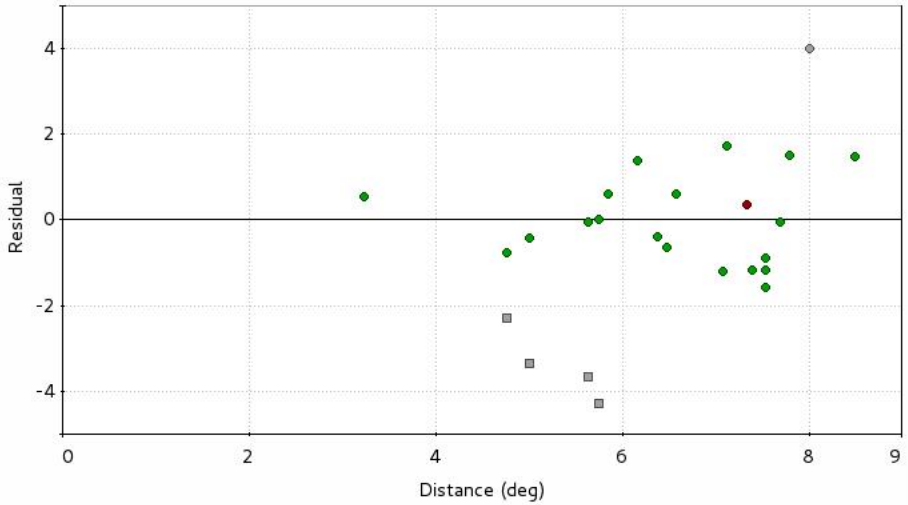


Time:	**2019-01-14 06:36:15**	
Depth:	**15** km	+/- 9 km
Lat:	**23.81** ° N	+/- 6 km
Lon:	**64.26** ° E	+/- 7 km
Phases:	**20** / 25	
RMS Res.:	1.0 s	
Az. Gap:	300 °	
Min. Dist.:	3.2 °	

EventID:	dgmet2019aygp
Agency:	**DGMET**
Author:	**scolv@pc-spare.local**
Evaluation:	confirmed (M)
Method:	LOCSAT
Earth model:	iasp91
Updated:	2019-01-14 06:40:44

Distance Azimuth TravelTime MoveOut Polar FirstMotion

Filter is not active



Used	Status	Phase	Net	Sta	Loc/Cha	Res	Dis (deg)	Az	Time	+/-
☑	M	P	IR	NGCH	SHZ	0.54	3.23	299	06:37:06.4	
☑	M	P	OM	JLN	HHZ	-0.77	4.77	250	06:37:26.2	
☐	M	S	OM	JLN	HHZ	-2.29	4.77	250	06:38:20.6	
☑	M	P	OM	WBK	HHZ	-0.41	5.01	257	06:37:30.0	
☐	M	S	OM	WBK	HHZ	-3.33	5.01	257	06:38:25.7	
☑	M	P	OM	BID	HHZ	-0.05	5.63	268	06:37:38.8	
☐	M	S	OM	BID	HHZ	-3.66	5.63	268	06:38:40.6	
☑	M	P	OM	SMD	HHZ	0.02	5.75	263	06:37:40.6	
☐	M	S	OM	SMD	HHZ	-4.27	5.75	263	06:38:43.0	
☑	M	P	OM	JMD	HHZ	0.60	5.85	256	06:37:42.5	

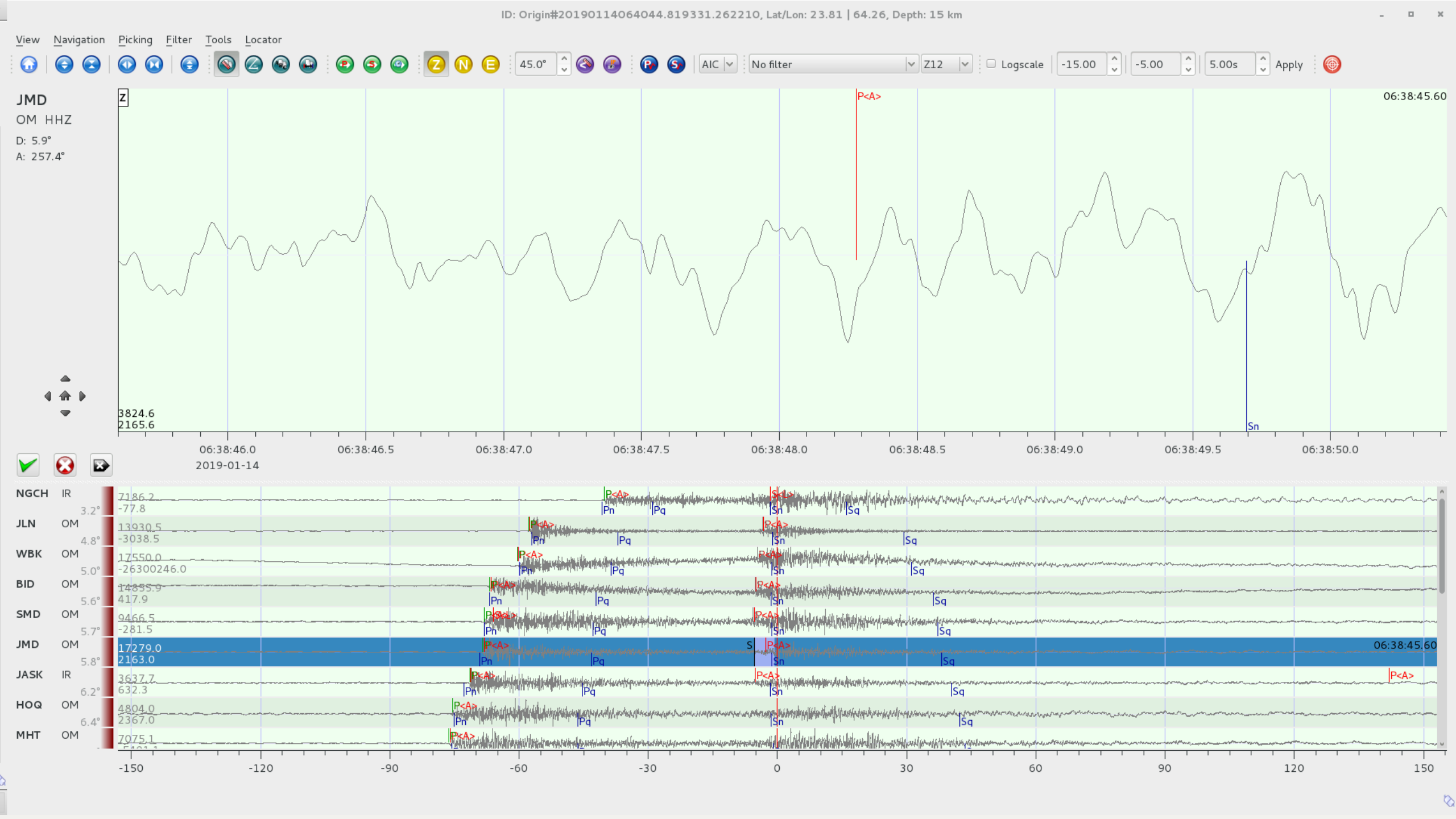
LOCSAT Profile: iasp91 Fix depth 15 km Distance cutoff 1000 km Ignore initial location

Relocate

Picker Import picks Compute magnitudes Commit

A new origin arrived at 2019-01-14 10:42:48 (localtime)

scesv@proc scolv@proc ID: Origin#20190114064044.8... sysop@pc-spare:~ 1 / 4


ID: Origin#20190114064044.819331.262210, Lat/Lon: 23.81 | 64.26, Depth: 15 km
View
Navigation
Picking
Filter
Tools
Locator
45.0°
AIC
No filter
Z12
Logscale
-15.00
-5.00
5.00s
Apply
JMD
OM HHZ
D: 5.9°
A: 257.4°
Z
P<A>
06:38:45.60
Sn
3824.6
2165.6
06:38:46.0
2019-01-14
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NGCH IR 3.2°
7186.2
-77.8
JLN OM 4.8°
13930.5
-3038.5
WBK OM 5.0°
17550.0
-26300246.0
BID OM 5.6°
14855.9
417.9
SMD OM 5.7°
9466.5
-281.5
JMD OM 5.8°
17279.0
2163.0
JASK IR 6.2°
3637.7
632.3
HOQ OM 6.4°
4804.0
2367.0
MHT OM
7075.1
Pn
Pg
Sn
Sg
S
-150
-120
-90
-60
-30
0
30
60
90
120
150

Applications Places TOAST en Mon 19:10

TOAST

File Settings Simulation Traces View Extras Help

2022-08-08 15:06:13

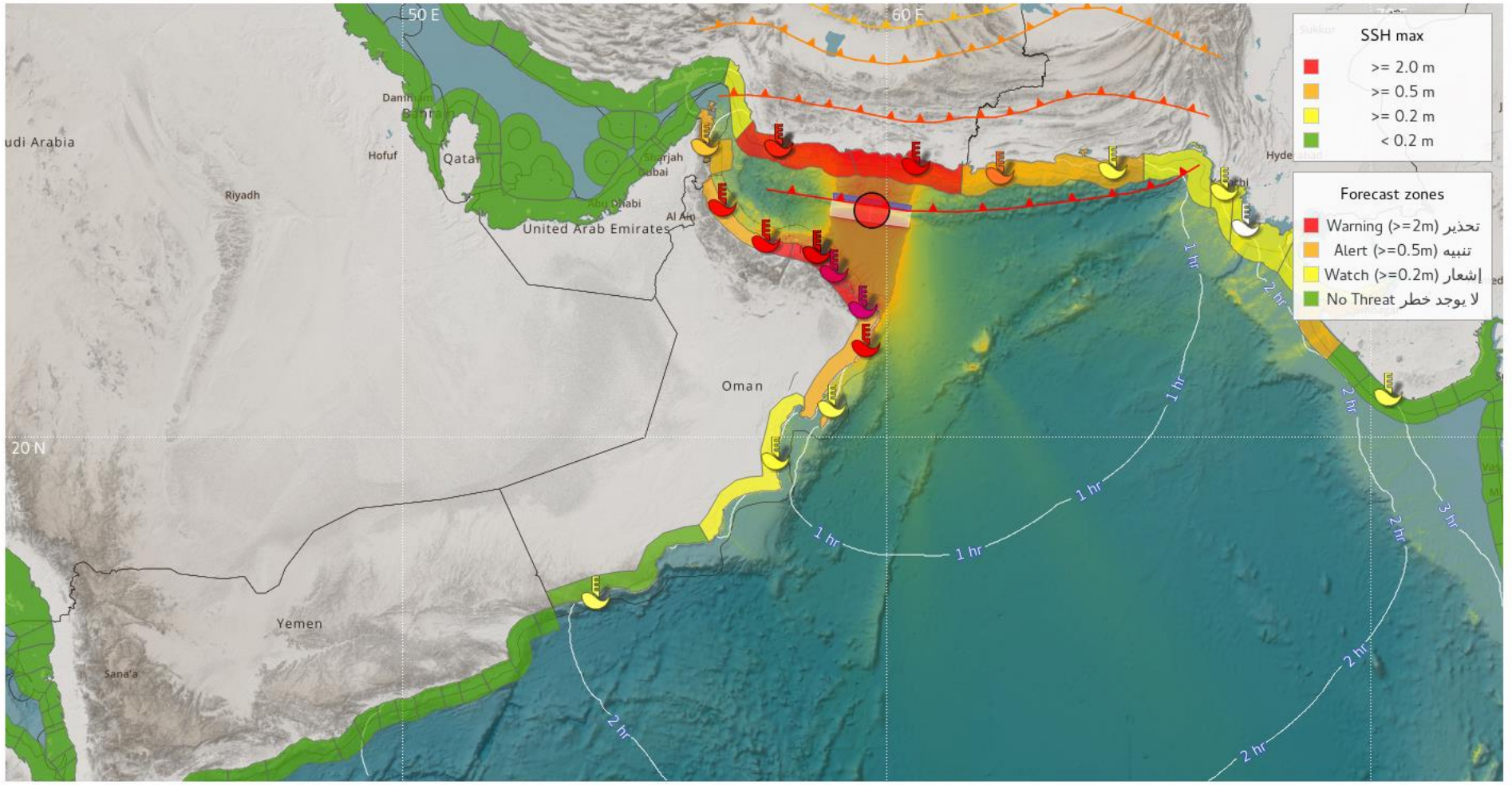
4m and 18s ago

Oman Sea

M 8.0 D 10 km

toast2022pnebte

Map | Traces | Arrivals | Forecast Zones | Bulletin 2 | Bulletin 3 | Bulletin 4 | DGMET Compare



Database – Simulations

Simulations: Show all

Sort by: Residual

M 8.0 D 0 km MHRAS 0.0 h

M 8.0 D 10 km EasyWave2 4.0 h

2/2 simulations shown

Map Layers

Color Profile: DgmetProfile

- Faults
  - Names
- Forecast zones
  - Fill
  - IDs

Wave Propagation

SSH max 0.00 m

Coordinate: 26.090° N 66.753° E | Operational | DGMET, OM

7/29/2023

sysop@toast:~ | TOAST | [DGMET Webmail :: إنشاء رسالة -... | Desktop | 1 / 4