SEISMOLOGY

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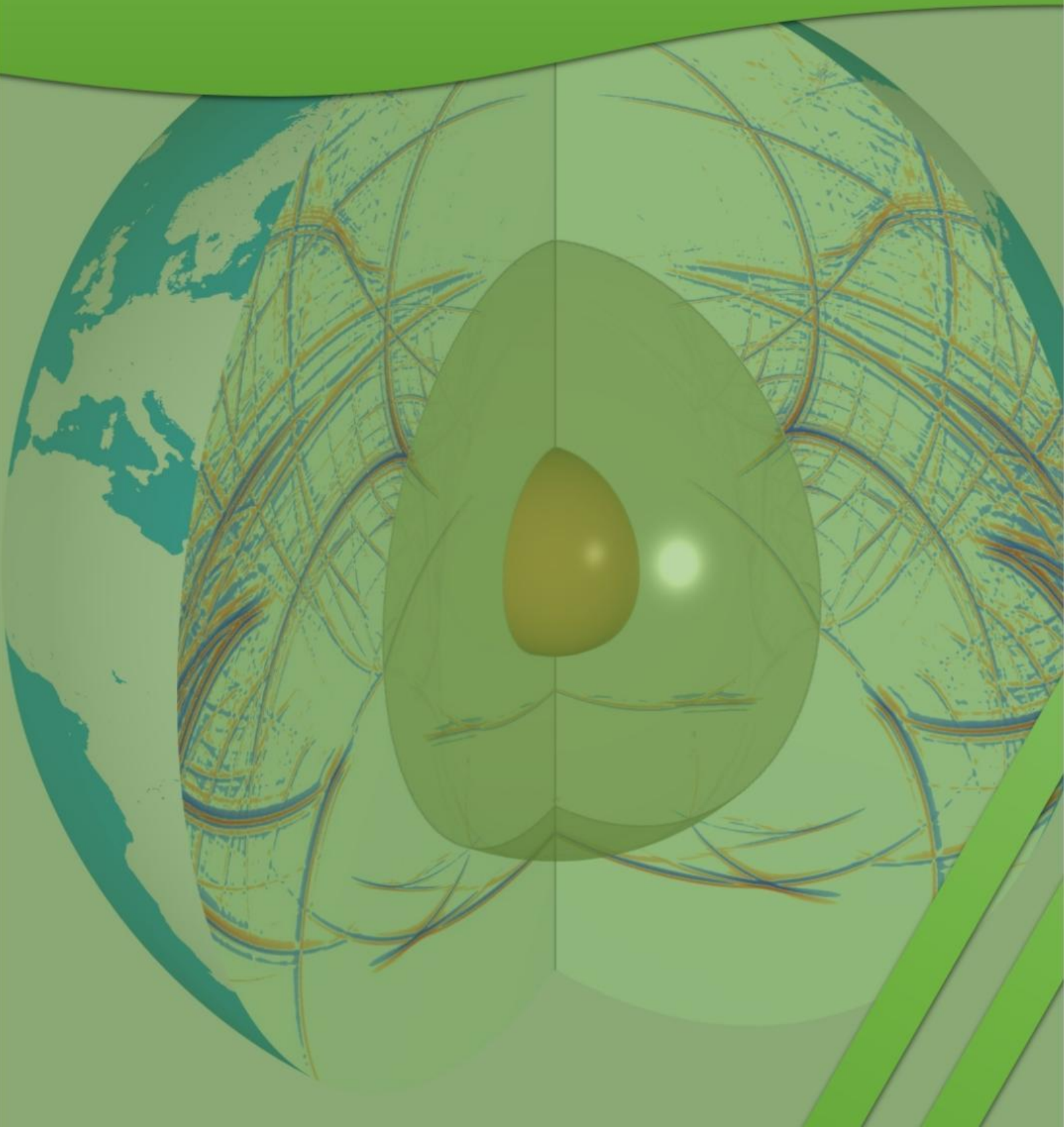


EARTHQUAKES

- **Seismology**: the science dealing with earthquakes
- **Seismograph (or accelerograph)**: instrument for recording EQ's (depends on ground acceleration)
- **Seismogram**: earthquake record (in case of ground acceleration recording the accelerogram)
- **Tsunami**: waves on sea induced by earthquake the focus of which is under the sea bottom
- **Mikroseisms**: permanent Earth's surface vibration
- **Earthquakes**: unpredictable phenomena, sudden release of energy in the earth interior which cause ground vibration on the surface (if energy exceeds physical limits: stress & phase transition limits)
  - The Earthquakes may have ***natural (passive)*** or ***artificial (active)*** origin as a consequences of technological processe, natural phenomena, meteorite, aircraft, bomb…etc
  - **Observed as** surface vibrations
  - **enable the Earth's interior research** (Earth's crust, mantle, external core, internal core)
  - The nature of earthquakes can be explained by means of the plate tectonic theory
- **Physical models of the earthquake:** rheology
- **Rheology:** Physical models of the earthquakes, study the deformation & behavior of matters
- A general study of earthquakes involves many scientific disciplines that deal with the problem:

Seismology ↔ Engineering ↔ Economy ↔ Psychology

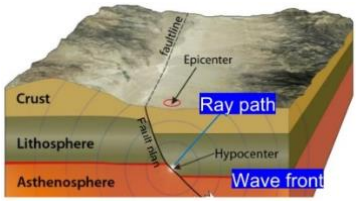
  - The damage to building have several economic, social, psychological, & political effects
  - **EQs Causes** harm, loss on human assets (live, health), property, infrastructure, environment
  - Earthquake is the most devastating natural hazards if considered in relation with structures
  - The problem arises from the structure under seismic excitation & not the earthquake itself
  - The EQ has begun to become a problem for humans since they started to build structures
- **Seismic engineering:** the discipline the aim of which is to construct infrastructures & buildings resistant to earthquake & similar phenomena impacts & by this way to protect human lives, health, & human property
  - Branch of engineering devoted to mitigating earthquake hazards, It covers the investigation & solutions of problems of damaging structures
- **Earthquake parameters**: focal depth, size, & geographic coordination of epicenter
- **Size of Earthquakes are measured by:**
  - Intensity (I), Energy (E_T), & stress drop ($\Delta\sigma$)
  - Seismic Energy (E), & Moments (Mo)
  - Magnitude (M) : by Reichert scale
  - Acceleration (a), velocity (v), & displacement (d)
- The relative movements of rocks & plates cause sudden energy released in the form acoustic waves & this waves than transformed into the earth's surface which cause an earthquakes
- In general, the Earthquakes can do not kill people, but unsafe structures do!

NATURE OF EARTHQUAKE

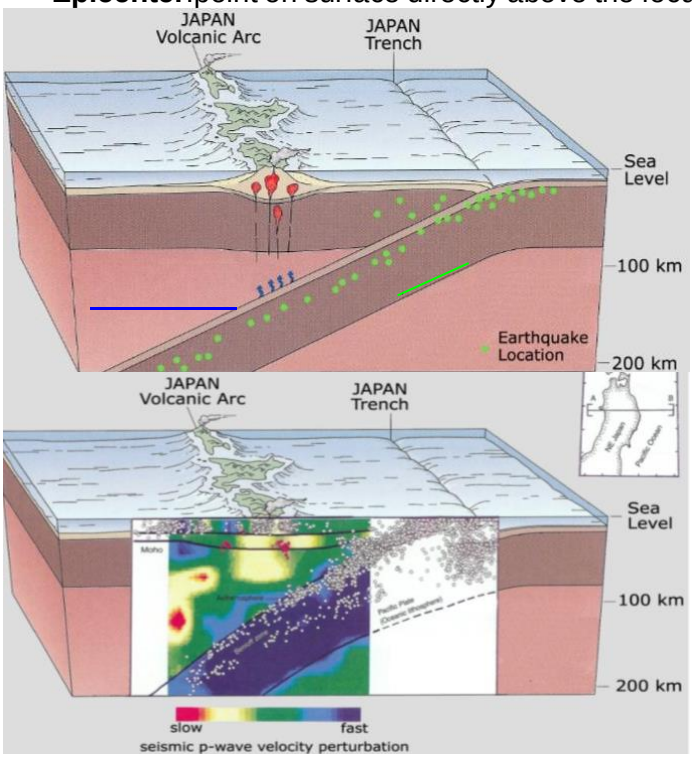
- **Earthquake foci**: mostly on lithosphere boundaries
  - **Daily**: 8000 earthquakes ≤2 magnitude

Annually Earthquakes	Magnitude	Frequency
Medium	≥4	7000-9000
Strong	6-7	18-20
Very strong	≥1	≥8

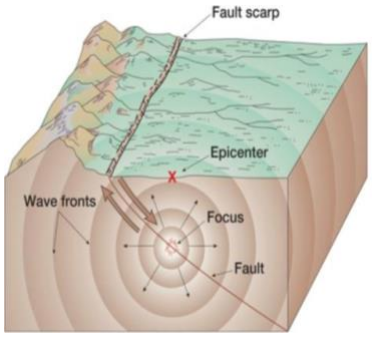
- **Focus (hypocenter):** Location within the Earth where the earthquake occurred or location on a fault where slip first occur



- **Epicenter**:point on surface directly above the focus



- **Focal depth:** distance between the focus & the epicenter
- **Epicenter distance**: distance between a site & epicenter
- **EQ locations**: starts at the focus which is the fault zone along which the EQ slips

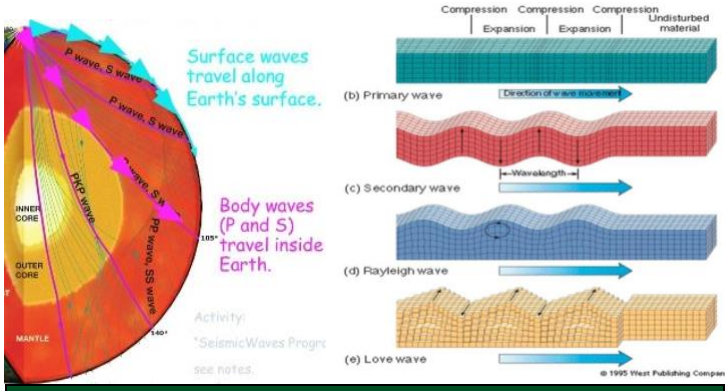


- **EQ is completely described by 2 parameters (the most common are magnitude, & intensity)**
- **EQs are often located by epicenter** (point on the surface of the earth right above the focus) by tangential method
  - **The separation in time of 1st arrival of the P- & S-waves** correlates directly with the distance of EQ from the station & the distance can be graphed on *travel-time curve*
  - Several stations necessary to pin-point the location of EQ by *drawing a circle* with *radius = distance between the epicenter & the station*
  - The point of intersection of the 3 circles is the epicenter

SEISMIC WAVES

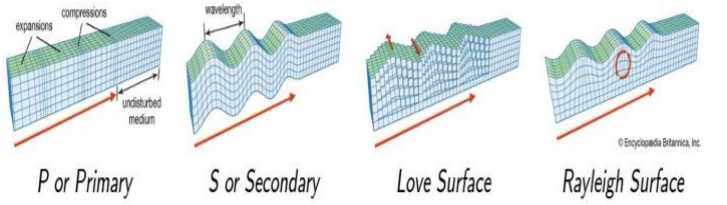
- **A waves**: is a displacement or ripples
- **Earthquake's waves**: body & surface waves
- تم تقسيم الموجات الزلزالية بناء على اي وسط تمشي به (السطح او داخل الصخور) وعلى سرعتها وايضا على الية وشكل الحركة

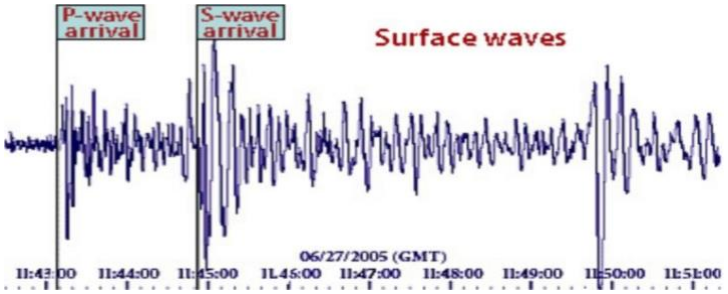
Body waves	Travel from focus in all directions (radiate outward in all directions, go inside the bodies) • Slower than body waves • Velocity of wave depend on λ • Cause most damage because produce more ground movement & travel more slowly, so they take longer to pass
Surface waves	Travel around the earth rather than through it (travel along surface of the Earth & decrease in amplitude with depth, go on the surface) • Faster, & travels at one velocity



Types of Body waves	
P-wave	• Called ***Primary*** or ***Compressional Waves*** • **Characterized by** vibrations parallel to the propagation direction of wave so it fastest • Travels at 5-7km/s near the surface • Can pass through the liquid & solid • Are a horizontal waves
S-wave	• Called ***Secondary*** or ***Shear Waves*** • **Characterized by** a series of sidewise or shearing movements so it slower than P • Cannot pass through a liquid • Are a vertical waves

- **Types of Surface waves:** love & rayleigh waves





- تقسم الموجات الزلزالية الى passive وهي الزلازل التي تحدث بشكل طبيعي و active وهي زلازل من صنع الانسان, وترصد موجات ال earthquake في ال passive اما ال geophone في ال active stations التي تحتوى غالبا strong motion sensor

CLASSIFICATION OF EQ

- *Aristotle* classified earthquake into 6 categories based on observed surface movement, & Chinese scientist *Chen* constructed instrument for earthquake registration

Earthquakes	Depth [Km]	Classification of earthquakeson the bases of foci depth
Shallow	0 – 50	
Intermediate	50 – 450	
Depth	450 – 750	

- **Magnitude:** measure of released energy during EQ & doesn't related to epicentral distance or damage
  - ***Richter Scale***: Max amplitudes of P & S waves (height of the waves) 100 km from an epicenter
  - 1 magnitude → 10 times ground motion (displacement) → 32 times more energy

Descriptor	Magnitude	Avg.Annually (frequency)
Great	8 - >8	1 (observations 1900)
Major	7 – 7.9	17 (observations 1990)
Strong	6 – 6.9	143 (observations 1990)
Moderate	5 – 5.9	1319 (observations 1990)
Light	4 – 4.9	13,000 (estimated)
Minor	3 – 3.9	130,000 (estimated)
Very Minor	2 – 2.9	1,300,000 (estimated)
Δmagnitude	**ΔEnergy**	**Displacement (ground)**
1.0	32 times	1.0 times
0.5	5.5 times	3.2 times
0.3	3.0 times	2.0 times
0.1	1.4 times	1.3 times

$$M_L = log\frac{A}{A'}$$

M: local magnitude, A: amplitude (μm), A': amplitude of 0 magnitude

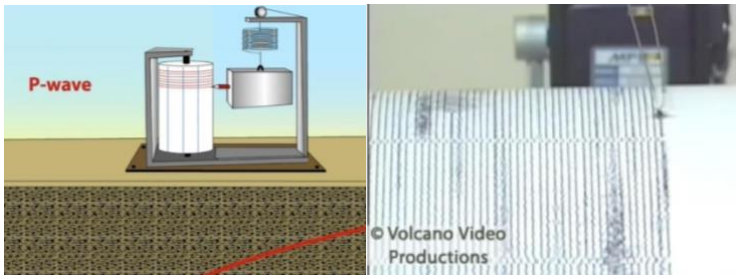
- **Intensity:** actual observations of earthquake effects (performance of builduing structures, natural phenomena, & human perceptions)
  - It depends on the epicentral distance, local soil conditions, geology, & topography (the largest intensity is observed near the epicentre)
  - The intensity scale consists of series of certain key response such as awaking, movement of failure, damages or total destruction
  - The most famous intensity scale is ***Modified Mercalli Intensity*** (MMI) Scale (12 levels)
  - It does not have a mathematical basis. It is an arbitrary ranking based on observed effects

Level	Damage & Affect
1, i, Instrumental	Detected only by seismographs
2, ii, Feeble	Noticed only by sensitive people
3, iii, Slight	Resembling vibrations caused by heavy traffic
4, iv, Moderate	by people walking, & rocking of standing things
5, v, Rather Strong	Sleepers awakened & bells ring
6, vi, Strong	Trees sway, by overturning & falling things
7, vii, Very Strong	General alarm, cracking of walls
8, viii, Destructive	Chimneys fall & some damage to buildings
9, ix, Ruinous	Ground crack, houses collapse & pipes reak
10, x, Disastrous	Ground badly cracked & many buildings are destroyed with some landslides
11, xi, Very Disastrous	Few building remain standing; bridge & railway destroyed; water, gas, & electricity out of action
12, xii, Catastrophic	Total destruction; shaking, & ground's distortion

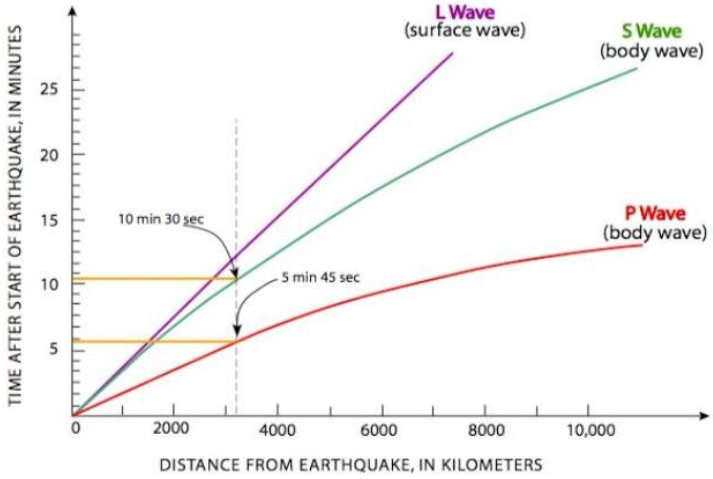
Magnitude	Intensity
Based on motion with instruments (seismographs)	Based on observations of EQ effects on building & human perceptions
unique indicator of a size of EQ. Each EQ characterized with a single value which indicates its magnitude	It's not a unique indicator of a size of EQ. Each EQ is characterized with various intensities, depending on the location from the epicentre
modern indicator. not measures of historical EQ	evaluated for historical EQ basing on the analysis of written source

DETECTION-PRODUCTION

- When an EQ occurs, the seismic waves travel through the Earth to the seismic station where the information is transmitted to distant computers
- **vertical seismometer** record P & S waves arrivals

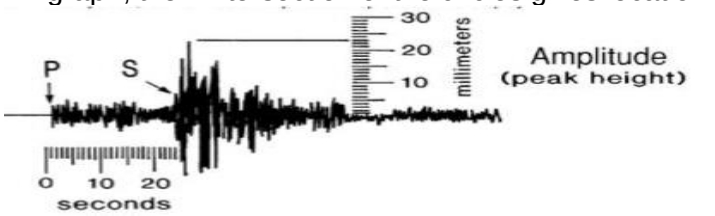


- Seismologists determine travel times for seismic waves by analyzing wave from thousands of EQ's



Use S-arrival time minus P-arrival time to determine the distance from the travel-time curves

- **To locate the earthquake**: Determine distance of EQ from 3seismic stations by calculating S-P arrival times (distance in time), Plot them on travel-time graph, then Intersection of the circles gives location



- Most of the energy is released by around 20 magnitude 7 or larger earthquakes every year

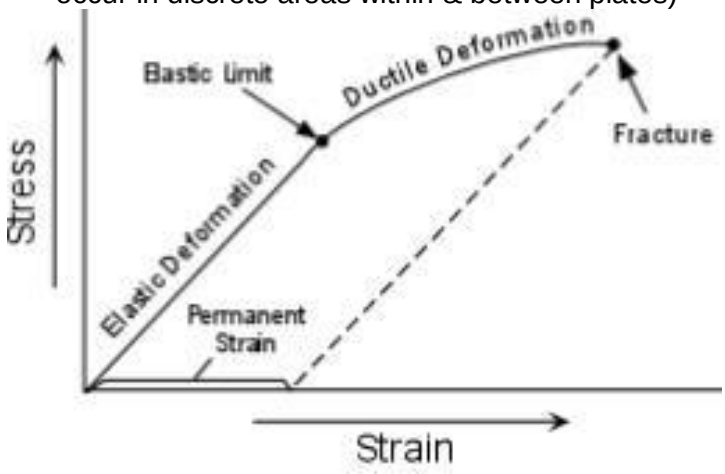
ممكن ان تحدث زلازل اكثر من 8 ولكن دمارها يشمل المراصد لذا لا ترصد، والزلازل الاقوى الممكن ان تحدث في الاردن هي Moderate

- **Earthquake prediction eludes us**: interplay of forces, faults, & friction is unpredictable, if rocks on fault move, elastic energy is being stored & released in earthquake
- If we determine the history of earthquakes on a particular fault, we can forecast the probabilities of earthquakes occurring on segments of fault. Earthquake forecasting is valuable because this tells us where we must construct earthquake-resistant buildings, highways, & bridges
- **Travel time curve-f (A, h):** dependence of time spreading the real wave on epicentral (hypocentral) distance & depends on wave type

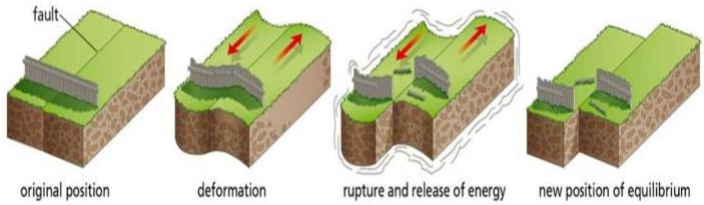
$$t(r) = T - H,\ travel\ t = t_{site} - t_{focus}$$

EQ'S MECHANISMS

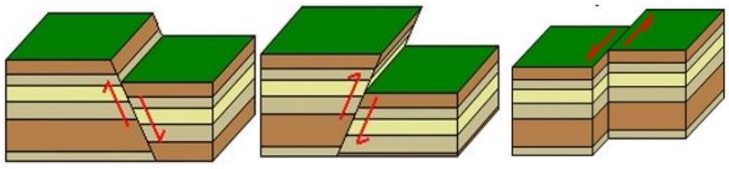
- Earthquakes occurs due to brittle diffraction of a lithospheric plates (e.g. Subduction-zone EQ's occur in discrete areas within & between plates)



- The EQ mechanism related to force, fault, friction
- **Fault:** break in the rock where there is movements (Cracks along which rocks slip, may break through the ground surface, or remain deed within earth)
- **Elastic rebound:** The earth is elastic body which can be strained during plate tectonic processes
  - Fault zone at the boundary of large lithospheric plates lock despite the motion of the plates
  - large strains accumulate in rocks next to fault zone, & stresses become so large at the locked fault zones rupture & slip & This rapid slippage releases strain energy which was accumulated over a long period of time in a process called ***elastic rebound***
  - slips seismic waves are released at fault zone
  - EQ are vibrations that caused by the fracture of the crust or by sudden movement along a fault
  - The fracture or slippage emits large amounts of energy in the form of seismic waves that travel through the earth's interior & across surface



The most common mechanisms of earthquake sources	
Normal faults	The block above (hanging wall) moves down relative to the block below (foot wall) • ***Tensional force*** & results in ***Extension***
Reverse faults	The block above the fault (foot wall) moves up relative to the block below (hanging wall) • ***Compression force,*** result in ***Shortening***
Strike-Slip	The movement of blocks is horizontal • Caused By ***shearing forces***
Oblique-Slip	Suggests both dip-slip & strike-slip faulting • By ***combination of shearing & tension or compressional forces***



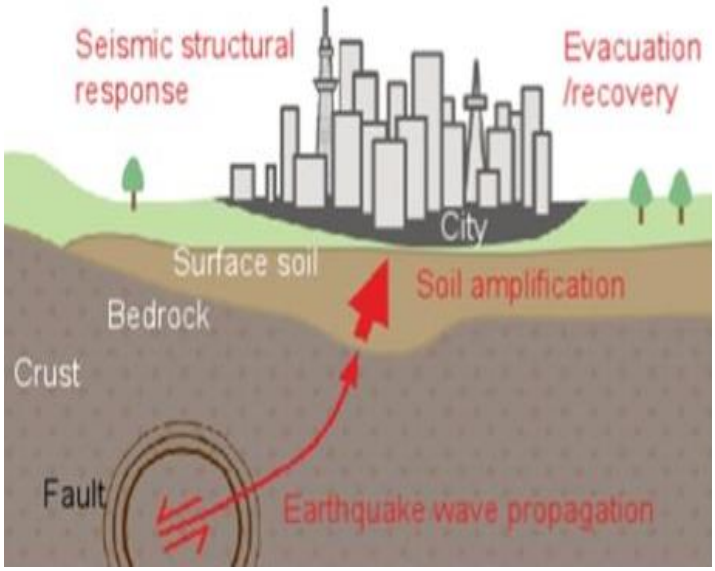
DISTRIBUTION OF EQ

تتركز البؤر الزلزالية عند حدود الصفائح لكن يمكن ان توجد داخل الصفيحة عند مناطق ال fault او المناطق النشطة جيولوجيا
كلما كانت البؤرة اقرب للسطح كلما كان الزلزال اقوى
ال subduction هو نطاق غطس ينتج عن التقاء صفيحتين احدهما قارية والاخرى محيطية وتغطس المحيطية (الاكثر كثافة) او محيطية مع محيطية وتغطس الاقدم (وهي الاكثر كثافة)

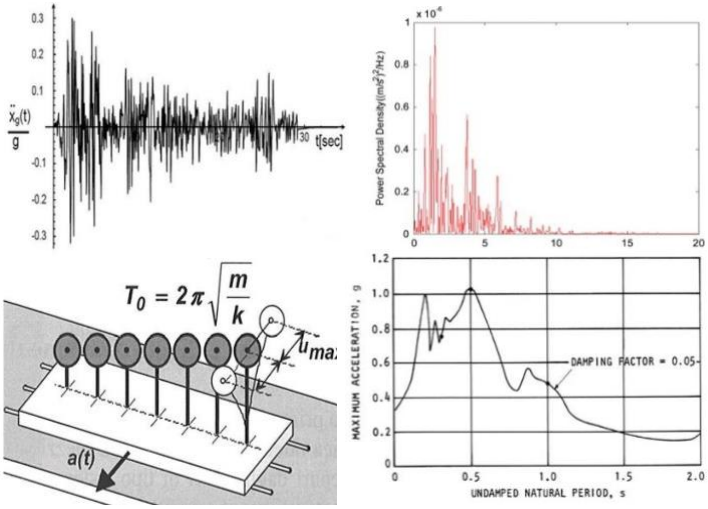
- **Recorded seismic events:** natural EQs, induced EQ's (man-made), & artificial explosions
- **Natural EQs:** tectonic origin (90%), volcanic origin (7%), & collapse of underground spaces (3%)
  - The most harms & losses on human assets are caused by tectonic earthquakes
  - Concentrated at plate boundaries, & Mostly occur along edge of oceanic-continental plates
- **Induced EQs**: artificially triggered seismicity
  - **Cause**: the perturbation of underground mechanical equilibrium, due to industrial activity (mining, dams, geothermal, hydrocarbon reservoirs) induce deformation of involved sites
  - located in different tectonic settings
- **Induced earthquakes types:**
  1. reservoir induced seismicity(eg.Lake Kremasta)
  2. rockbursts, mining, rockfalls, shaking, bumps, outbursts (methane release)
  3. seismicity triggered by injection of fluids into rocks, special technology of mining
  4. seismicity triggered by withdrawn of fluids from surface formation, special technology of mining
  5. earthquakes stimulated by seismic vibration signals, by special technology of mining
  6. earthquakes that stimulated by artificial explosions (mining regions, test sites)
- The stress increases where plates bump into each other, pulling awayor past from each other
- **reason of high seismic hazard in Mediterranean** is collision of African-EuroAsian plates
- **Earthquake prediction**: Because lithospheric plates slip past each other at a well known rate, it is possible to determine the frequency with which large faults slip must slip in order to keep up the general motion of lithospheric motion
  - Because most large faults are locked, infrequent earthquake slip will take up slip accumulated over a long period of time
  - Based on size of EQs, slip can be released as often as once every dozen years to 300-400yr
  - With such information geophysicists can make predictions about when the next EQs will occur
- **Worldwide distribution of EQs:** Earthquakes can occur most anywhere in the crust of the earth
  - most of the very large EQs occur in several belts (boundary of the large lithospheric plates)
  - On a map of world wide EQs distribution, the most concentrated belt is circum Pacific belt, & Another major concentration of earthquakes is in Mediterranean Himalayan belt
  - Shallow focus EQ's occur along summit of MOR
  - Deep focus EQs found below ocean trenches in steeply dipping zones called Benioff zones

EQs CHARACTERISATION

- Most EQ rather short in duration, often lasting only a few seconds & seldom more than minute or more
- The intensity of EQ is measured in terms of energy released at the ground fault, the critical effects on the given structures is determined by ground movements at the location of the structure
- The effect of the movements is affected mostly by the distance of the structure from the epicentre, & by geological conditions directly beneath structure
- Acceleration is the most common representation in one horizontal direction plotted as a function of elapsed time (measured by accelerogram "a-gram")

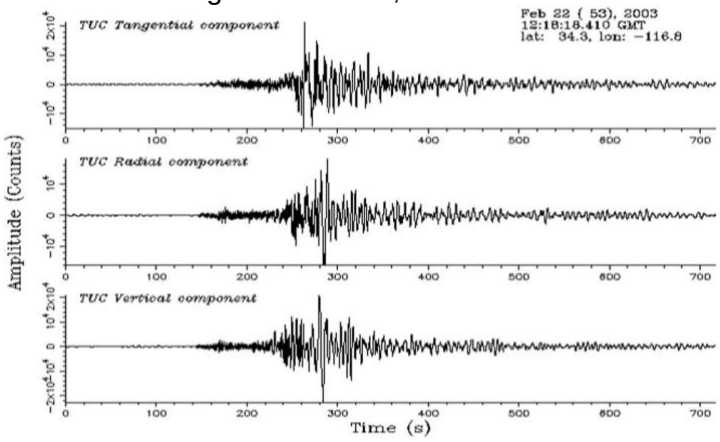


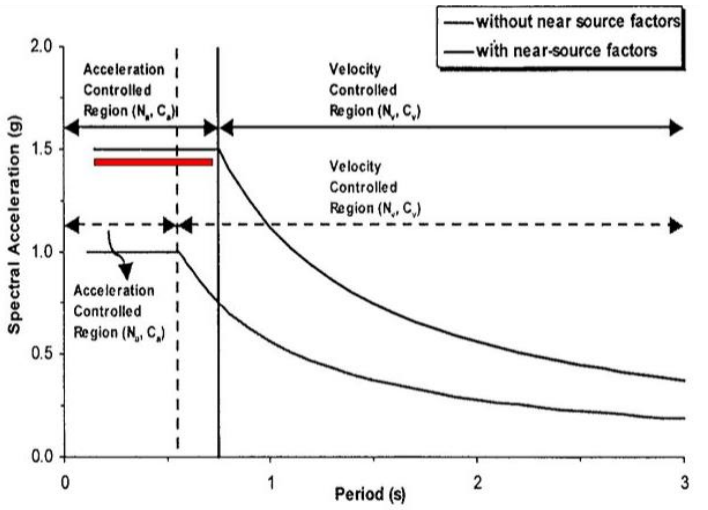
- How can we say if an a-gram is hard for a structure
  - **Peak Ground Acceleration (PGA)**: The peak value in absolute value terms
  - **Strong motion Duration**: Structural damage strongly depends on the number of load cycles
  - **Fourier Spectrum:** representation of a time history into the frequency domain & defined as *Fourier Transform of ground motion time history*
  - **Analysis of frequency content**: is the description of the frequency composition
  - **Acceleration Response Spectrum**: peak of acceleration of a series of oscillators of varying natural frequency, that are forced into motion by the same ground motion. it may be considered the main tool to evaluate seismic load



EQ'S FOCI & WAVES

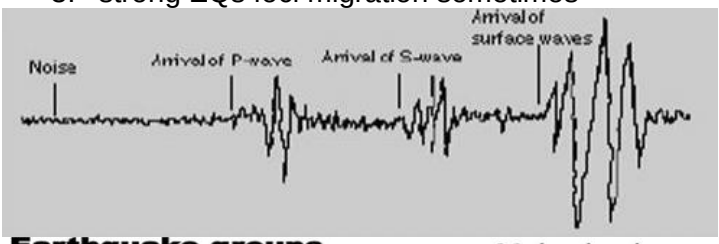
- **Length of time interval P-S inputs depends on** epicentral distance & recording place
  - As increase of epicentral distance seismogram complexity increase as a consequence of recording the reflected, surface & other waves

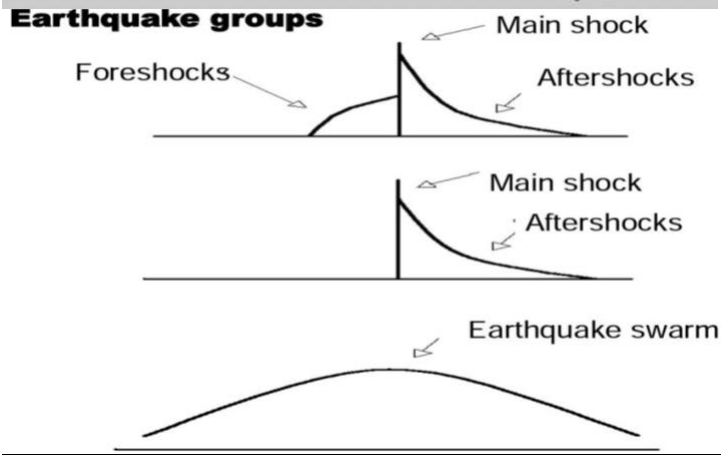




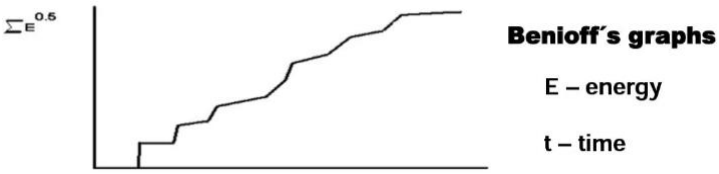
- The earthquake foci concentrate to regions called "**focal provinces-zones or regions**", & The boundary of focal provinces are defined as a boundary that surrounds:
  1. all known EQ foci occurring in the historical time & case when they're evidence on prehistorical foci from the research of paleoseismicity
  2. the region in which the EQ with the same characteristics of seismic regime occur
  3. the region with the same geological, tectonic, & recent movements characteristics
- **Findings from research of earthquakes**
  1. From EQ foci space distribution it follows that EQ foci are mostly connected with faults
  2. In recent period only certain parts of faults are seismoactive in both vertical & horizontal plane
  3. EQs often originate on fault crossing, Mostly one of the fault is preferred in historical time form earthquake occurrence viewpoint
  4. In most cases, after strong EQs connected with fault it follows EQs connected with other fault
  5. Isoseismal form in epicentral zone depends on fault, plane mechanisms, in distance zone on material properties-boundary r = 2.5h
  6. Isoseismal surface size depends on EQs size & focal depth & indirectly on intensity attenuation,

- **Seismic regime of focal zones**: variable in time & space, has a certain prevailing character in each focal zone, & described by the following:
  1. Benioff's graphs & occurrence frequency
  2. EQs group type & space-time foci distribution
  3. strong EQs foci migration sometimes

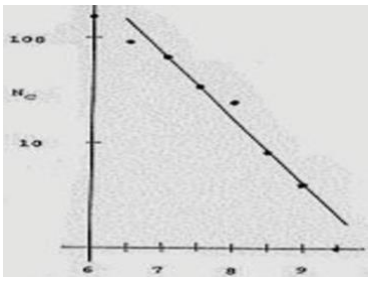




Viewpoint is determined by value of stress drop:	
High Δg	• low value of the highest aftershock • low number of aftershocks
Low Δg	• high value of the highest aftershock • great number of aftershocks



- **Frequency graph**: distribution of EQs number according to the EQs size (used cumulative frequency in which the sum starts at the biggest EQ)



- **Maximum EQs in focal zone:** predetermined by physical focal zone condition by the following ways
  1. sum of size of Max observed EQs & 1° MSK-64
  2. extrapolation of oscillations of Benioff's graph
  3. curvature of magnitude-frequency graph
  4. correlation of max observed EQ with seismic activity by selected level of earthquake activity
  5. theory of extreme values & Geodynamic factors
  6. correlation of max EQs size with fault length

Max observed intensities map (seismic zoning)

Aftershock & Foreshock Area

SEISMIC RISK

- Seismic risk is defined as the potential economic, social & environmental consequences of hazardous events that may occur in a specified period of time

$$R = H \; x \; V \; x \; E$$

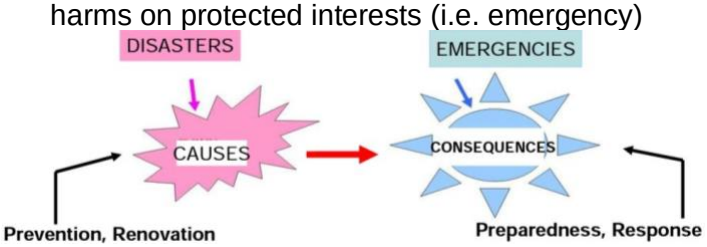
R: risk, H: hazard, V: Vulnerability, E: Exposure

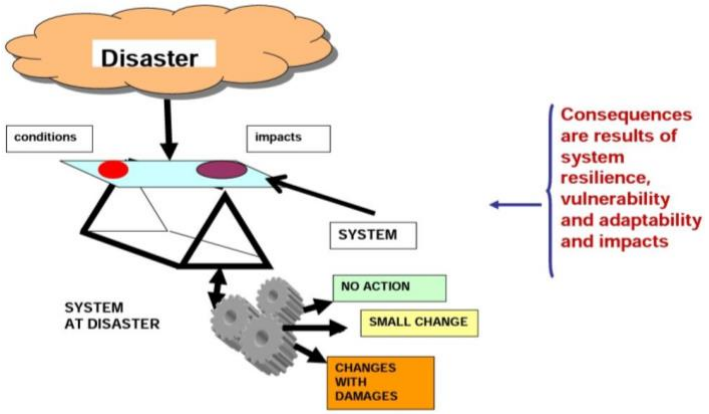
- **Hazard:** Occurrence of EQ of sufficient magnitude capable of causing damage to the structures

Disasters – Hazard | **Risk - Emergency**

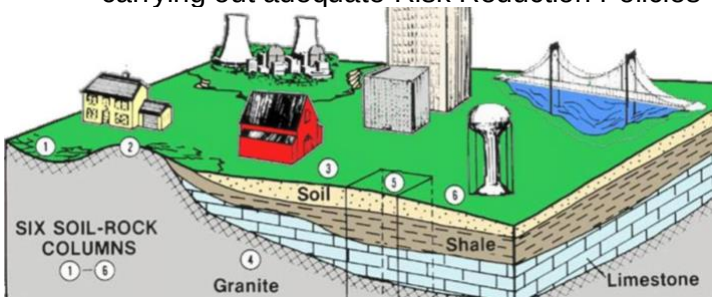
Related to risk sources | Related to protected interests

- **Vulnerability**: Damageability of structures under action of hazard, weaker EQ being more vulnerable
- **Exposure:** Assessment of economical & social consequences. A count of exposed system & value
- Human system is open dynamic system in which there are processes, actions, phenomena, & events the sources of which there are inside & outside of system, & The disasters are their results
- **The disaster** occurrence in a certain site & time causes in dependence on disaster size, physical nature, & amount & vulnerability of protected interests in a given site the looses, damages, & harms on protected interests (i.e. emergency)

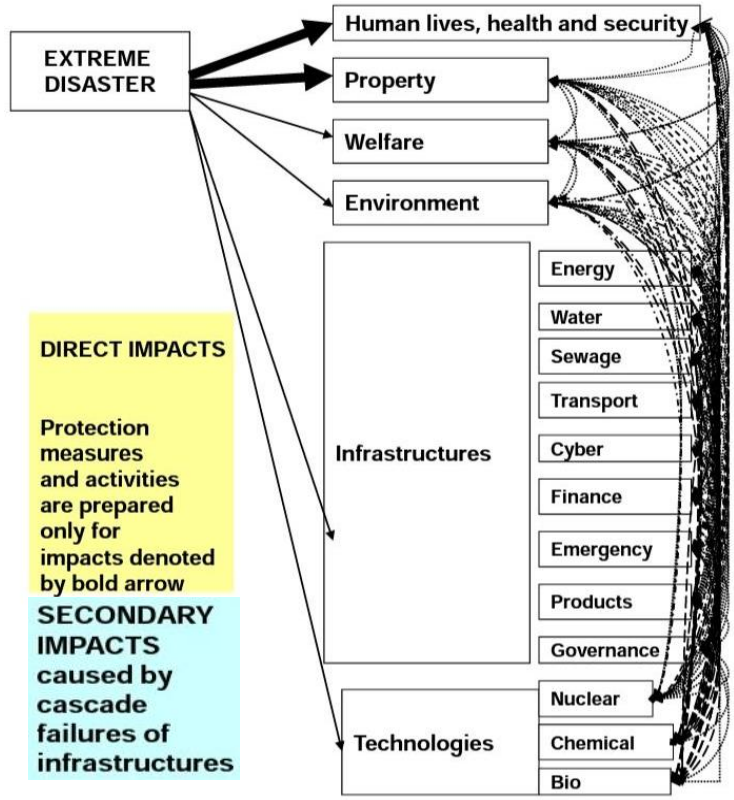


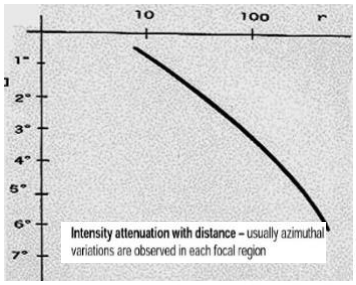


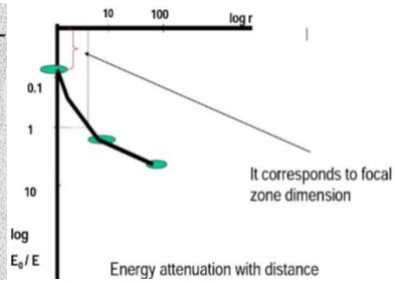
- How can we cut the seismic risk down?
  - ➢ Is not possible to avoid or predict occurrence of EQ, or to eliminate presence of man & structure
  - ➢ It is possible to limit EQ effect (Vulnerability) carrying out adequate Risk Reduction Policies

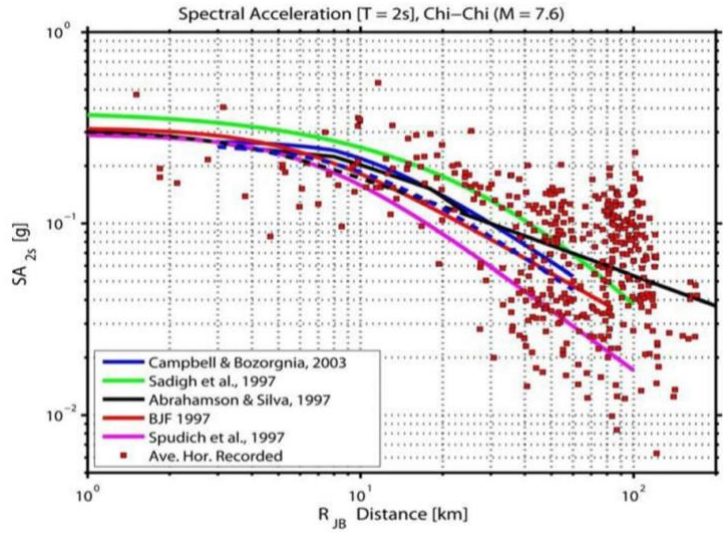


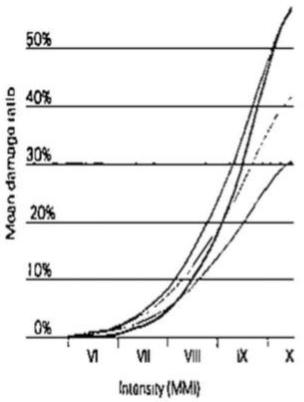
Items for seismic protection

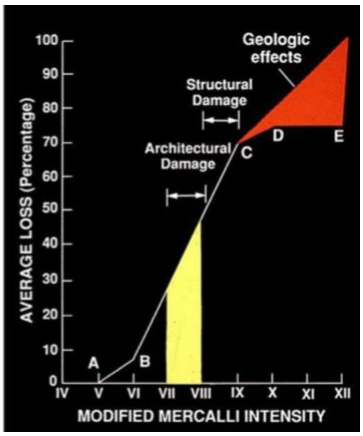










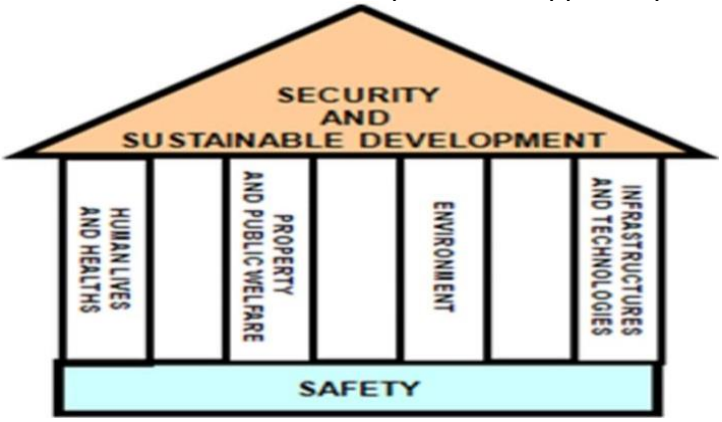


PROTECTION PRINCIPLES

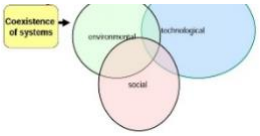
- **Distinguish causes & consequences**

Causes	• Is a Phenomena (Earthquake = Disaster) • Characterized by quantity hazard
Consequences	• Is an events, & emergency situations • Characterized by quantity risk

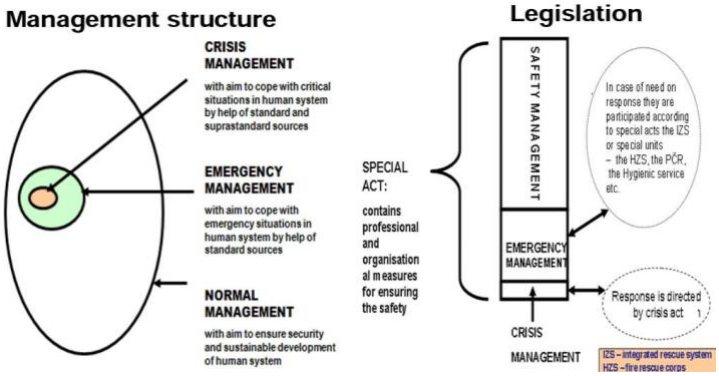
- **human protection:** we must protect public assets & to consider all disasters (all hazard approach)



- **To consider that reality is system of systems (set of system that are mutually interconnected)**



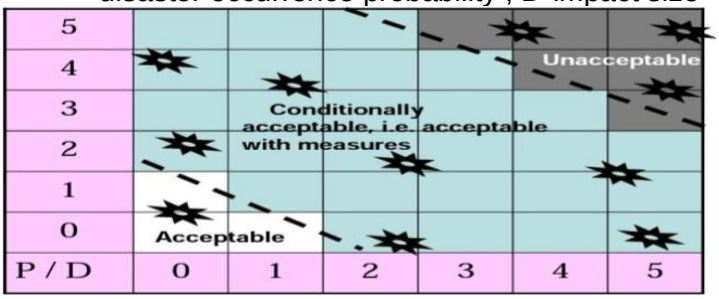
  - ➢ to consider vulnerability, resilience, & adaptation capacity & the reality that we need to ensure coexistence of systems
- To use the 3rd step management & legislation for effective emergency & crisis management



- **Safety Cycle**

Response	• Implementation of measures putting the disaster impacts under control with adequate losses & adequate sources • Alam, life, Reduction of disaster's Impact, Information dissemination, Communication
Rehabilitation	• Temporary rehabilitation, re-established transport system & communication routes
Post disaster	• Damage assessment, follow rehabilitation
Re-construction	• Permanent rehabilitation, infrastructures & building reconstruction, reinforcement
Prevention & Mitigation	• Introduction of protection measure against disasters occurrences & disasters impacts enhancements, active, & passive • Risk assessment, Spatial Planning, Eco-structural measure, awareness, Education
Preparedness & Readiness	• Introduction of measures enhancing our capability to put disasters under the control • Risk forecasting, Organization, Resources & emergency planning,Training,awareness
Renovation	• Implementation of measures for assurance of area reconstruction return to stabilized condition, further society development

- **The effectiveness of measures & activities**
  - ➢ Effectiveness of measure & activity is different
  - ➢ the most effective measures & activity by that we can avert disaster occurrences & mitigate impacts are preventive measures (procurators), the effectiveness of which is the following
  1. **Technical measures** use in the area of land (use planning 60 – 80 %)
  2. **Population education & training** (20 – 30 %)
  3. **Emergency & crisis management** (strategic planning) 25 – 40 %
  4. **Installation of warning & alarm** 9-40%
- **Human technical, & financial sources, forces, & means limited good governance is necessary (tool decision matrix DM)**
  - ➢ **DM for design disaster management:** P-disaster occurrence probability , D-impact size

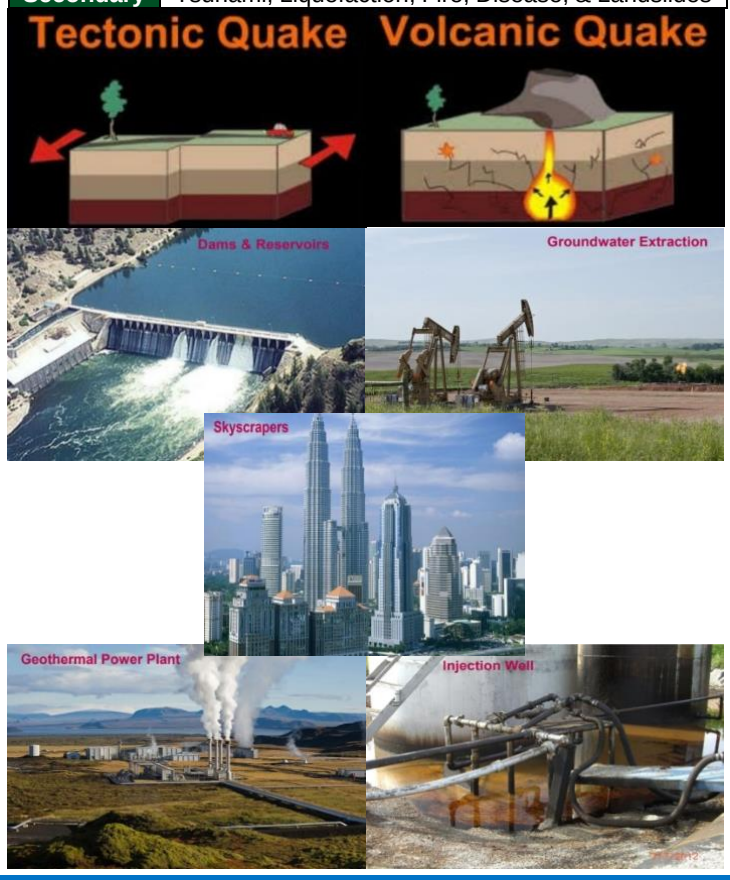


- **To use all state tools for safety support:**
  1. Strategic safety management with aim security & sustainable development
  2. Training & education of population
  3. Specific training technical & senior managers
  4. Technical standards, norms, & regulations (i.e. the regulation of processes that can or could result to an occurrence of disaster)
  5. Research (theoretically, & experimentally)
  6. Inspections
  7. Efficient forces for putting the disasters under control (fire-fighter, police, medical doctors)
  8. Emergency & crisis managements belonging to standard state strategic management
- **Reserves for crisis management**
  1. Emergency management uses standard forces, sources, & means
  2. Crisis management uses standard + beyond standard forces, sources, & means
- **RESEARCH**: Seismic tests, shaking table
- **State safety management system** ensuring the disaster protection in the EQ & its Member States:
  1. Protect the human lives & health, property, environment, & technical infrastructure
  2. Considers relevant disaster with possible occurrence on territory & against relevant disasters it carries out prevention & preparedness with regard to impacts
  3. Forms the professional base, managerial structure, efficient forces means, substances, & sources to ensure protection of human lives & health, property, environment & of the state
  4. Forms professional base, managerial structure, efficient forces, means, substances & sources to ensure renovation after disaster & after crisis

EQs CAUSES & AFFECTS

- EQs is a sudden violent shaking of the ground, causing great destruction, as a result of movements within the earth's crust or Volcanic action

Types Of Earthquake	
Tectonic	occurs when the earth's crust breaks due to geological forces on rocks & adjoining plates that, & cause physical & chemical changes • Around 90% of natural earthquakes • Most common, & most destructive • Occurs at plate boundaries or within continents • Chemical changes occur due to thermal metamorphism near strike slip faults, or by partial melting in the convergent plates
Volcanic	by magma movement (injection, or withdrawal) • Around 7% of natural earthquakes • The movement results in P-changes in rock around where magma experienced stress • Occur in continents due to Hotspot activities
Collapse	are small EQs occuring in regions of underground caverns & mines • The immediate cause of ground shaking is the collapse of the roof of the mine or cavern
Explosion	Results of nuclear & chemical devices. • Occurs when enormous energy is released
Causes Of Earthquake	
Natural Cause	• Slow-moving processes within the Earth • Earth was hot when it formed, & has been cooling ever since (T rises by 30°C/Km depth) • Earth's cooling causes the portions of earth to move, & that movement is what we call EQs
Induced (Human-made)	• Reservoirs (such as dams) • Extraction (such as Groundwater & Oil) • Geothermal Power Plant • Injection Well & Skyscrapers
Effects Of Earthquakes	
Primary	The immediate damage caused by the quake which kill people (collapsing buildings, roads, & bridges) • Can suffer badly from shock and panic
Secondary	Tsunami, Liquefaction, Fire, Disease, & Landslides



QUESTIONS

5. **The energy released by EQ travels in vibrations called** ____ _____ (SEISMIC WAVES)
6. **A break in a mass of rock along which movement occurs is called** _____ (A FAULT)
7. **The location beneath the earth's surface where an EQ states is called** _____ (THE FOCUS)
8. **Types of waves from EQ that are longitudinal waves similar to sound waves that can travel through solids & liquids are called** _____ **waves** (P OR PRIMARY)
9. **The observations of intensity of shaking & damage done by EQs is done using** _____ **scale** (MERCALLI)
10. **What are 3 ways stress affect rocks** (PUSH THEM TOGETHER BY COMPRESSIONAL FORCES, PULL THEM APART BY TENSIONAL FORCES, PUSH THEM IN DIFFERENT DIRECTIONS BY SHEARING STRESS)
11. **Stress from moving tectonic plates produces** _____ **&** ____ (FAULTS, FOLDS)
12. **Characteristics of a fault** (A BREAK IN A MASS OF ROCK WHERE MOVEMENT OCCURS & MAY OCCUR ALONG PLATE BOUNDARIES)
13. **Characteristics of a fold** (BEND IN LAYERS OF ROCK WHERE ROCKS SQUEEZED BUT DO NOT BREAK)
14. **The location underground where EQ begin to occurs is called** _____ (FOCUS)
15. **The location on earth's surface directly above the focus is called** _____ (THE EPICENTER)
16. **Characteristics of P-waves** (LONGITUDINAL, SIMILAR TO SOUND WAVES, FASTEST, CAN TRAVEL THROUGH BOTH SOLID & LIQUIDS)
17. **Characteristics of P-waves** (TRANSVERSE, CANNOT TRAVEL THROUGH LIQUID)
18. **Characteristics of surface waves** (SLOWEST MOVING TYPE, DEVELOPS WHEN SEISMIC WAVES REACH THE SURFACE & PRODUCE GREATER GROUND MOVEMENT & GREATER DAMAGE)
19. **The 1st seismic waves to be detected at a distance are** ____ **waves** (P WAVES)
20. **What device is used by geologist to detect & measure seismic waves** (SEISMOGRAPH)
21. **Most EQ are concentrated along** _____ _____ (PLATE BOUNDARIES)
22. **The fastest type of EQ waves is** _____ (P WAVES)
23. **What is the earthquake?** (MOVEMENT OF EARTH'S CRUST, OCCUR WHEN ROCKS IN THE CRUST SUDDENLY SHIFT, RELEASING STORES ENERGY)
24. **What is the seismic waves?** (VIBRATIONS THAT CARRY ENERGY RELEASED DURING EQ)
25. **What is the STRESS?** (THE FORCES OF DEFORMATION ACTING ON THE ROCKS OF CRUST)
26. **True or False. All EQ occur along fault associated with plate boundaries** (F)
27. **Energy released from an earthquake event is mostly in the form of** (Seismic or Acoustic waves)
28. **True or False. After rupture occurs along a fault, rocks continue to deform indefinitely from the release of energy** (F)
29. **True or False. Earth's crust has been uplifted several times** (T)

30. **True or False. Most of the motion along faults can be explained by Plate Tectonics** (T)
31. **Who contributed greatly to our understanding of the mechanism of earthquake generation by proposing the Elastic Rebound Theory?** (Reid)
32. **Most EQs are caused by** (slippage along a fault)
33. **Major earthquakes are often preceded by a series of small vibrations called _____** (Foreshocks)
34. **Which earthquake body wave has the greater velocity?** (P wave)
35. **Which of the earthquake body waves cannot be transmitted through fluids?** (S wave)
36. **EQ body waves are divided into 2 types called** (primary or P-waves & secondary or S-waves)
37. Body waves move through the interior of Earth.
38. **True of False. Fluids (gases & liquids) cannot transmit P waves** (F)
39. **True of False. P waves arrive at a recording station after S waves** (False)
40. **Instrument used to record EQ is ____** (Seismograph)
41. **Which type of seismic wave typically causes the most damage to structural foundations** (Surface)
42. **P waves travel at a constant velocity in Earth** (F)
43. **P waves can be compared to the interaction between air & vocal cords to produce sound** (T)
44. **An earthquake with a magnitude of 6.5 releases about _____ times more energy than one with a magnitude of 5.5** (30)
45. **Choice The Correct Answer in the following**

- **The _____ is based on the amplitude of the largest seismic wave recorded on a seismogram.**
  1. Dynamic scale
  2. **Richter scale**
  3. Moment magnitude
  4. Modified Mercalli Intensity Scale
  5. None of the above
  6. All of the above
- **The epicenter of an EQ is located using the distances from a minimum of __ seismic stations**
  1. **Three**
  2. Four
  3. Five
  4. Six
  5. Seven
- **The farther a station is from EQ, the greater the difference in arrival times of the P & S waves**
  1. False
  2. **True**
     - NOTE. The difference in arrival times are used to determine the distance to epicenter
- **The moment magnitude of EQ is largely derived from the amount of displacement that occurs along a fault**
  1. False
  2. **True**
     - NOTE. The strength of the rock, the area of the fault, & the displacement are all part of the calculation
- **The difference in _____ of P & S waves provides a method for determining the epicenter of EQ**
  1. Sizes
  2. Foci
  3. **Velocities**
  4. Modes of travel
  5. Magnitudes
  6. Acceleration
- **Distribution of EQ epicenters are correlated with**
  1. Coastlines
  2. **Plate boundaries**
  3. Major cities
  4. Continental interiors
  5. None of the above
- **Which answer best describes the number of great earthquakes that occur annually?**
  1. 10
  2. **1**
  3. 0
  4. 1000
- **The Richter scale expresses the damage done using an increasing scale of Roman numerals**
  1. **False**
  2. True
     - The Mercalli Intensity Scale used
- **Intensity of an EQ event is determined by**
  1. Population density
  2. Building design and codes
  3. The Richter scale
  4. **A & b**
  5. All of the above
- **No reliable method of short-range earthquake prediction has yet been devised.**
  1. **True**
  2. False
     - We think the “Big One” might be coming, but many people are willing to take the chance
- **Structure damage is the result of (determined by)**
  1. Material that the structure rests upon (foundation/bedrock)
  2. Duration of vibrations & ground shaking
  3. Design of the structure
  4. Intensity of the earthquake
  5. **All of the above**
- **What can be done to mitigate the hazard in earthquake-prone areas?**
  1. Updated Uniform Building Codes
  2. Prohibit anyone from living near an earthquake
  3. Better land-use planning
  4. **All of the above**
- **Current tsunami systems**
  1. Include seismic observatories
  2. Make use of existing tidal gauges
  3. Exist all around the world
  4. **Both a & b**
  5. All of the above
- **Soft lake bed sediments decrease the strength & intensity of earthquake waves**
  1. **False**
  2. True
     - NOTE. Soft, loose sediments with water can amplify & cause more damage
- **Locked segments & sudden large EQ along San Andreas Fault provide examples of fault creep**
  1. **False**
  2. True
     - NOTE. creep is slow, gradual displacement
- **A tsunami is a**
  1. Wind-generated wave
  2. Tidal wave
  3. **Series of waves created by a large displacement in the ocean**
  4. Special shrimp found near Japanese hydrothermal vents

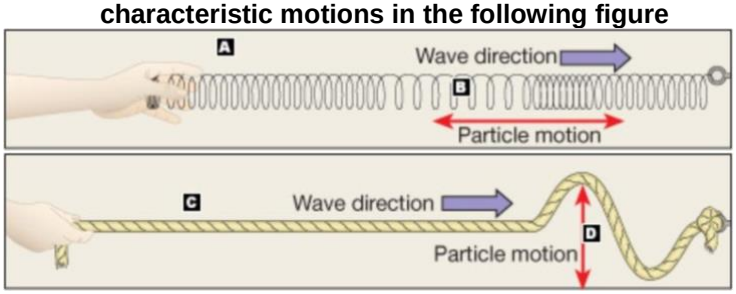
5. All of the above

- **Long-range EQ forecasts are based on the premise that earthquakes are repetitive**
  1. **True**
  2. False
     - NOTE. After EQ, stress & strain will start to build up along the fault plane again
- **Most of our knowledge of Earth's interior comes from the study of**
  1. **Seismic waves**
  2. Rocks
  3. Volcanoes
- **Compressional wave motion is achieved by**
  1. **Change in volume**
  2. Change in shape
  3. Both a and b
  4. Change in state
  5. All of the above
- **Differences in density and elastic properties of rock greatly influence velocity of seismic waves**
  1. **True**
  2. False
     - asthenosphere considered *low velocity zone*
- **With increasing distance from the focus, energy from a quake is**
  1. Disappears within a few miles
  2. Heats up
  3. Separates from the core
  4. Doubles in strength
  5. **None of the above**
- **Which one of the following regions has the greatest amount of seismic activity?**
  1. Southern Russia
  2. **The circum-Pacific belt**
  3. The central Atlantic basin
  4. The eastern United States
  5. Central Europe
- **Which of the following events are sometimes associated with tsunamis?**
  1. Meteorite impacts
  2. Volcanic eruptions
  3. Earthquakes
  4. Submarine landslides
  5. **All of the above**
- **Unreinforced masonry buildings are considered the most serious safey threat for populated areas during an earthquake.**
  1. **True**
  2. False
- **To locate an epicenter, the distance from 3 or more different seismic stations must be known**
  1. **True**
  2. False
- **Type of seismic wave propagates by "shaking" the particles of the material it is moving through at right angles to overall direction of movement**
  1. **S waves**
  2. Surface waves
  3. P waves
  4. Compressional waves
  5. B and d
- **The vibration of Earth produced by the rapid release of energy is called**
  1. Liquefaction
  2. Fault
  3. **Earthquake**
  4. Focus
  5. Discontinuity
- **The 2 types of seismic waves generated by the slippage of a rock mass are**
  1. P and surface waves
  2. Body and secondary waves
  3. P and S waves
  4. **Body and surface waves**
- **The study of EQ & EQ's waves is called**
  1. Seismicity
  2. Seismogram
  3. Seismograph
  4. Seismic science
  5. **Seismology**
- **The method used to determine the epicenter of an earthquake is called**
  1. Circulation
  2. Circumvention
  3. Time travel
  4. Seismology
  5. **Triangulation**
- **The mantle is solid because both P and S waves travel through it**
  1. **True**
  2. False
     - S waves cannot travel through fluids
- The adjustments of materials that follow a major EQ often generate smaller earthquakes called
  1. **Aftershocks**
  2. Foreshocks
  3. Tremors
  4. Body waves
  5. Surface waves
- **Most earthquakes occur along coastlines.**
  1. True
  2. **False**
     - Some coastlines & locations geologically active, but many coasts are not, rather most of the EQ are occurs at the plate boundaries
- **Earthquakes with a Richter magnitude less than 8 are usually not felt by humans**
  1. True
  2. **False**
     - 8 would be a major earthquake
- **Large fractures in Earth along which movement occurs or has occurred in the past are called**
  1. Slabs
  2. Slips
  3. Earthquakes
  4. **Faults**
  5. Foci
- **Intensity is a measure of degree of shaking in a location determined by the amount of damage**
  1. **True**
  2. False
     - Magnitude used to measure & compare the strength by the amount of energy released
- **EQs produced by rapid release of elastic energy**
  1. **True**
  2. False
     - Energy released as rocks suddenly rupture
- **The type of plate boundary where plates move apart, resulting in upwelling of material to create new seafloor, is _____ boundary**
  1. Transitional
  2. Convergent
  3. Gradational
  4. **Divergent**

5. Transform

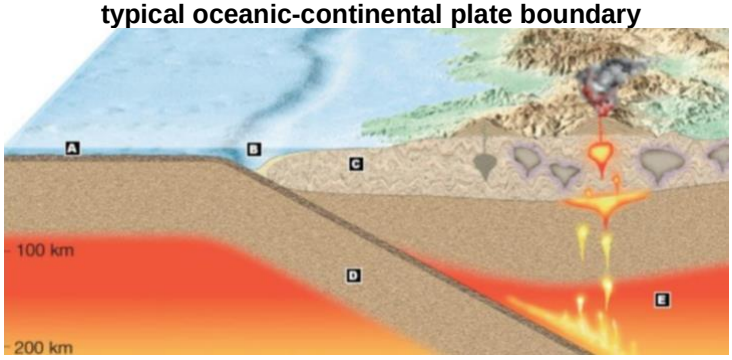
- **During oceanic-continental convergence, as the oceanic plate slides beneath the overriding plate, a _____ is often produced adjacent to the zone of subduction**
  1. Deep-ocean terrace
  2. Deep-ocean trench
  3. Divergent boundary
  4. Deep-ocean ridge
  5. Transform fault
- **Transform faults can join 2 segments of MOR**
  1. True
  2. False

46. **State the type of seismic waves & their characteristic motions in the following figure**



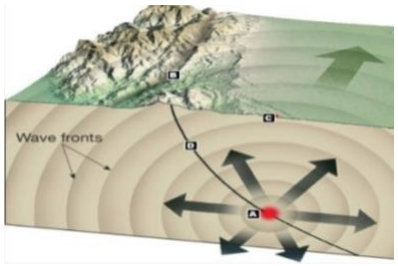
a. P-wave (Primary Wave)
b. Volume Change
c. S-Wave (Secondary Wave)
d. Shape Change

47. **Identify the Earth features illustrated along this typical oceanic-continental plate boundary**



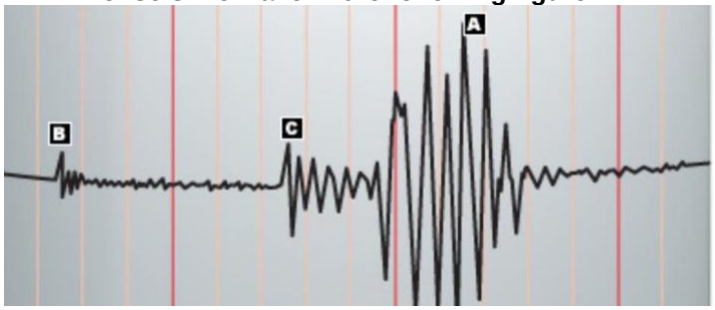
A. Oceanic Crust
B. Trench
C. Continental Lithosphere
D. Subducting Oceanic Lithosphere
E. Asthenosphere

48. **Identify Earthquake components in the figure**



A: Focus (Hypocenter)
B: Fault Scrap
C: Epicenter
D: Fault Plane

49. **Identify the type of seismic wave in the following figure**



A. Surface
B. B: P-wave (primary)
C. C: S-wave (secondary)

TESTBANK

QUIZ: 2020

- **EQs caused by sudden movement (rupture) along a**
  1. Lakes & Dams
  2. Stresses
  3. Fault plane
  4. Mountains
- **Earthquakes are concentrated along**
  1. Countries
  2. Plate Boundaries
  3. Hotspots
  4. Convergent Plates
- **Earthquakes are characterized by _____ that cause ground shaking & movement, which can result in significant damage**
  1. Magnitude
  2. Intensity
  3. Richter
  4. Seismic waves
- **Seismic & coastal hazards combine in formation of**
  1. Destructive Plates
  2. Divergent Plates
  3. Tsunami's
  4. Mid oceanic Ridge
- **An earthquake starts at the earthquake _____ which is the fault zone along which the earthquake slips**
  1. Focus
  2. Epicenter
  3. Hypocenter
  4. Hypocenter & focus
  5. 1+3
- **Earthquakes are located using a record of the earth vibration called a _____**
  1. Seismogram
  2. Seismograph
  3. Receiver
  4. Antina Richter
- **The most widely accepted indicators of the size of an earthquake are its _____ & _____**
  1. Focus & epicenter
  2. Epicenter & hypocenter
  3. Magnitude & intensity
  4. Richter & Mercali
- **The nature of earthquakes can be explained by means of _____**
  1. Plate tectonic theory
  2. Conviction Flow
  3. Mid oceanic Ridge
  4. Focus & Epicenter
- **Strain is a _____**
  1. Normalized Measure of Deformation of Material
  2. Deformed Caused by an Applied force
  3. The force is Removed
  4. Longitudinal Stress (F/A)
  5. Force per unit Area
  6. Shear stress
- **Surface waves are localized at the Earth's surface and can be divided into 2 types:**
  1. Rayleigh & Love waves
  2. P and S waves
  3. P & shear Waves
  4. S and shear Waves