Glossary in Seismology

Active fault
A fault that has moved in historic (e.g., past 10,000 years) or recent geological past (e.g., past 500,000 years).

Aftershock
An earthquake that follows a large magnitude earthquake called, 'main shock' and originates in or around the rupture zone of the main shock. Generally, major earthquakes are followed by a number of aftershocks, which show a decreasing trend in magnitude and frequency with time.

Amplitude
The maximum height of a wave crest or depth of a trough on a seismogram, used to estimate the strength of the earthquake.

Array
An ordered arrangement of seismometers or geophones, the data of which is fed to a central receiving station for recording and processing.

Arrival / Arrival Time
Arrival is the appearance of a wave, representing seismic energy, on a seismic record. The time at which a particular wave / phase arrives at a station or detector is called arrival time.

Aseismic
Not associated with an earthquake, as in 'aseismic slip'. Also used to indicate an area with no record of earthquakes, as in 'aseismic zone'.

Body wave
Waves, which propagate through the interior of a body. For the Earth, there are two types of seismic body waves: (1) Compressional or longitudinal (P wave) and (2) Shear or Transverse (S wave).

Central Angle
An angle with the vertex at the center of the Earth, with one ray passing through the hypocenter (and also the epicenter) and the other ray passing through the recording station.

Coda waves
Waves, which are recorded on a seismogram, after the passage of body waves and surface waves. They are thought to be back-scattered waves due to the Earth's inhomogeneities.

Consolidated / Unconsolidated
Consolidated - Tightly packed, composed of particles that can not be easily separated.
Unconsolidated - Loosely arranged particle matter, not cemented together; so particles separate easily.

Continental Drift
A hypothesis, first advanced by Alfred Wegener, that the Earth's continents were originally joined together as a single land mass, called 'Pangaea', which split into pieces and drifted (migrated) to form the present day configuration of continents.

Core
The innermost layer of the Earth below the mantle, with an approximate radius of 3500 km. Seismic wave studies led to a subdivision of the core into an 'outer core', which in relation to seismic waves acts as a fluid (no resistance to shear, i.e. no shear strength) and an 'inner core' which acts as a solid. The radius of the Earth is

about 6371 kilometers. The core-mantle boundary also represents a sharp thin discontinuity in physical properties such as a precipitous fall of the compressional wave velocity from 13.7 to 8.1 km/s and cessation of shear waves.

Crust
It is the rigid outermost layer of the Earth. Beneath the oceans, the crust varies in thickness, between 5-8 km. Thickness of the crust beneath continents is much more variable but averages about 25-40 km; under large mountain ranges, such as the Alps or the Sierra Nevada, however, the base of the crust can be as deep as 60-70 km. Like the shell of an egg, the Earth's crust is brittle and can break.

Disaster
Grievous impact of a sudden (sometimes prolonged, as in the case of drought) adverse event leaving considerable damage and destruction in its wake as well as other debilitating consequences (epidemics, erosion of life support systems, etc.). Severity of a disaster, whilst subject to the magnitude (amount of energy unleashed) of the event, therefore largely depends on the resilience of the affected community (assimilated knowledge and understanding to anticipate future hazards and preparedness to cope with them).

Disaster mitigation
It encompasses all acts necessary for eliminating, minimizing and reducing the possible adverse impacts of a potentially disastrous event which may be anticipated or impending or has already happened. It calls for a planned, sustained and orchestrated applications of knowledge, technology (including information and communication systems), community education and management principles, to reduce vulnerability by enhancing hazard consciousness and by progressive assimilation of hazard resistant land use plans, building and slope grading codes and advance warning systems in the life and works of communities exposed to natural hazards.

Earthquake
Earthquakes are the manifestations of sudden release of strain energy accumulated in the rocks over extensive periods of time in the upper part of the Earth. Earthquakes are classified as, **Slight (M<5.0), Moderate (5.0≤M≤6.9) and Great (M≥7.0)** depending upon the magnitude on Richter's scale. An earthquake having a magnitude, **M<2.0** is termed as **microearthquake.**

Earthquake Early Warning System (EEWS)
An earthquake monitoring system that is capable of issuing warning message after an earthquake occurred and before the strong ground shaking begins.

Earthquake precursor
Observable anomalous phenomenon preceding an earthquake. They include changes in various seismological, geophysical, geochemical and meteorological parameters measured in and around the earthquake source regions.

Earthquake prediction
A statement, in advance of the event, of the time, location and magnitude of a future earthquake.

Earthquake swarm
A series of low magnitude tremors occurring within a limited area over time periods from a week or so to several months. An earthquake swarm shows no pronounced main shock and the frequency of shocks gradually increases until a maximum is reached and then the activity gradually dies out.

Elastic wave
A wave that is propagated by some kind of elastic deformation, leading to changes in shape that disappear when the forces are removed. A seismic wave is a type of elastic wave.

Epicenter
It is the point on the surface of the Earth, vertically above the place of origin (Hypocenter or Focus) of an earthquake. This point is expressed by its geographical coordinates in terms of latitude and longitude.

Fault
A fracture or fracture zone (a weak plane) in the Earth's crust or upper mantle, along which the two sides have been displaced relative to one another. Faults are caused by earthquakes and earthquakes are likely to recur on pre-existing faults, where stresses are accumulated.

Far-field
Observations made at large distances from the hypocenter, compared to the wave-length and/or the source dimension.

Fault slip
The relative displacement of points on opposite sides of a fault, measured on the fault surface.

Focal mechanism
A description of the orientation and sense of slip on the causative fault plane derived from analysis of seismic waves.

Focus (Hypocentre) / Focal Depth
A point inside the Earth, where the rupture of the rocks takes place during an earthquake and seismic waves begin to radiate. Its position is usually determined from arrival times of seismic waves recorded by seismographs. Focal depth is the vertical distance between the Hypocentre (Focus) and Epicentre.

Foreshock
A relatively small tremor (or an earthquake) that commonly precedes a relatively large magnitude earthquake (called the 'main shock'), by seconds to weeks or months and originates in or near the rupture zone of the main shock.

Hazard (Earthquake /Seismic)
Earthquake hazard, H (X,t,T,I) in a region, area or site is represented by the percentage probability reckoned at the current epoch (t) with which the prescribed values (I) of ground motion (displacement, velocity, acceleration, spectral amplitudes) at the site (X), arising from any (or all) anticipated earthquakes in the region, will not exceed over a given time interval (T) of say 20, 50, 100, 500 years in the future. These are usually expressed as maps, showing contours of a specified ground-motion parameter, called 'seismic hazard map'.

Hypocenter
Same as Focus.

Intensity
A subjective measure of the effects of an earthquake at a particular place on humans, structures and (or) the land itself. The intensity at a point depends not only upon the strength of the earthquake (magnitude) but also on the distance from the earthquake to the point and the local geology at that point. Intensity grades are commonly given in Roman numerals (in the case of the Modified Mercalli Intensity Scale, from I for "not perceptible" to XII for "total destruction"). (See Modified Mercalli Intensity Scale.)

Inter-plate & Intra-plate earthquakes
Earthquakes directly associated with forces acting along the plate boundaries are called 'inter-plate' earthquakes. About 80% of the seismic energy is released by inter-plate earthquakes. In contrast, earthquakes which occur at rather large distances from the respective plate margins are called 'intra-plate' earthquakes. These earthquakes can be large and because of their unexpectedness and infrequency can cause major damage.

Isoseismal
A line connecting points on the Earth's surface, along which the intensity due to an earthquake is the same. It is usually a closed curve around the epicenter.

Landslide
An abrupt movement of soil and / or rock masses downhill in response to gravity. Landslides may be triggered by an earthquake or other natural causes. Undersea landslides can also lead to tsunamis.

Latitude
The location of a point north or south of the equator. Latitude is shown on a map or globe as east-west lines parallel to the equator.

Leaking mode
A seismic (surface) wave which is imperfectly trapped so that its energy leaks or escapes across a layer boundary causing some attenuation, or loss of energy.

Liquefaction
The process in which a solid (soil material) takes on the characteristics of a liquid as a result of an increase in pore pressure and a reduction in stress. In other words, solid ground turns to jelly. This usually takes place due to strong ground shaking caused by large earthquakes.

Lg Wave
A surface wave which travels through the continental crust.

Longitude
The location of a point east or west of the prime meridian. Longitude is shown on a map or globe as north-south line left and right of the prime meridian, which passes through Greenwich, England.

Love wave
A type of surface wave in which the particle motion is in a horizontal direction, that is shear or transverse, to the direction of propagation (travel), named after AEH Love, a British mathematician (1911). It's the fastest surface wave and moves the ground from side-to-side.

Low-velocity zone
Any layer in the Earth, in which seismic wave velocities are lower than in the layers above and below.

Magnitude
A measure of the strength of an earthquake or strain energy released by it, as determined by seismographic observations. The amplitude on a seismogram, the magnitude and the energy released are related through a log-linear relationship, which was originally defined by Charles Richter in 1935. An increase of one unit of magnitude (for example, from 4.6 to 5.6) represents a 10-fold increase in wave amplitude on a seismogram or approximately a 30-fold increase in the energy released. In other words, a magnitude 6.7 earthquake releases over 900 times (30 times 30) the energy of a 4.7 earthquake - or it takes about 900 M:4.7 earthquakes to equal the energy released in a single 6.7 earthquake! This is an open-ended scale and hence there is no beginning or end to this scale. However, rock mechanics seems to preclude earthquakes smaller than about -1 or larger than

about 9.5. An earthquake of magnitude -1.0 releases about 900 times less energy than a M:1.0 quake. Except in special circumstances, earthquakes below M:2.5 are not generally felt by humans. Depending upon the range of magnitude, epicentral distance and the type of seismic waves considered in the computation, there are several magnitude scales in use as: Local magnitude (Ml or ML), commonly referred to as "Richter magnitude", Surface-wave magnitude (Ms), Body-wave magnitude (mb), and Moment magnitude (Mw). The first three magnitude scales Ml, Ms and mb make use of amplitudes and time periods of seismic wave and suffer from the saturation effect. They have some or other limitation with regard to their applicability uniformly to all magnitude ranges, epicentral distances and focal depths. To avoid the saturation effect and standardize the magnitude scales, a magnitude scale based on seismic moment (Mo) was proposed by Kanamori (1977). The moment magnitude (Mw) scale is estimated using the formula, **Mw=(log Mo –16)/1.5,** where Mo, is the seismic moment in dyne-cm. Since seismic moment is a measure of strain energy released from the entire rupture surface, a magnitude scale based on seismic moment most accurately describes the size of large earthquakes. Since Mo does not saturate, so also Mw. The moment magnitude scale is the most preferred magnitude scale in case of large earthquakes.

Mantle
The dense and hot layer inside the Earth that lies between the crust and the outer core of the Earth. It is approximately 2900 kilometers thick and is the largest of the Earth's major layers. The mantle, which contains more iron, magnesium and calcium than the crust, is hotter and denser because temperature and pressure inside the Earth increase with depth.

Microseism
A more or less continuous motion of the ground that is unrelated to an earthquake and that has a period of 1.0 to 9.0 seconds. It is caused by a variety of natural and artificial phenomena, such as wind, cyclonic storms, etc.

Microzonation (Seismic)

The ‘Seismic Hazard and Risk Microzonation’ (SHRM) is a process of classifying the given geographic domain into small units of likely uniform Hazard (H) level (Peak Ground Acceleration - PGA, Spectral Acceleration - Sa), nature of hazard (susceptibility to liquefaction and slope failure) and Risk. The objective of Seismic Microzonation is to provide (a) probabilistic estimate of the hazard for each microzone due to earthquake shaking, (b) extent of likely damage to the built environment (dwellings, community structures, lifelines, industrial structures, monuments, heritage structures, etc.) and define damage ratio and people living in structures susceptible to damage, (c) retrofitting measures for the existing structures to render them safe and (d) specific guidelines for design and construction of earthquake resistant structures in various microzones.

Modified Mercalli Intensity scale (MMI scale)
Although numerous intensity scales have been developed over the last several hundred years to evaluate the effects of earthquakes, the one mostly used is the Modified Mercalli Intensity scale (MMI Scale). It was developed in 1931 by the American seismologists Harry Wood and Frank Neumann. The scale, which is composed of 12 increasing levels of intensity that range from ‘imperceptible shaking’ to ‘catastrophic destruction’, is designated by Roman numerals I to XII. It does not have a mathematical basis; instead it is an arbitrary ranking based on observed effects.

Mohorovicic discontinuity (Moho)
The boundary surface or sharp seismic-velocity discontinuity (pronounced as Mo-ho-ro-vi-chich) that separates the Earth's crust from the underlying mantle, named after Andrija Mohorovicic, the Croatian seismologist, who first suggested its existence.

Moment tensor
A symmetric second-order tensor that characterizes an internal seismic point source completely. For a finite source, it represents a point source approximation and can be determined from the analysis of seismic waves, whose wavelengths are much greater than the source dimensions.

Near-field
A term for the area near the causative rupture of an earthquake, often taken as extending a distance from the rupture equal to its length. It is also used to specify a distance to a seismic source comparable or shorter than the wavelength concerned. In engineering applications, near-field is often defined as the area within 25 km of the fault rupture.

P-wave
P waves are the fastest body waves and arrive at a station before the arrival of the S waves, or secondary waves. P-waves are also called as Primary, longitudinal, irrotational, push, pressure, dilatational, compressional, or push-pull type wave. The P waves carry energy through the Earth as longitudinal waves, leading to the movement of particles in the same direction as the direction of propagation of the wave. P waves can travel through solid rock and fluids and are generally felt by humans as a bump.

Paleomagnetism
The study dealing with the natural magnetic field traces in the rocks that reveal the intensity and direction of the Earth's magnetic field in the geologic past, from which the age of the rocks is also estimated.

Paleoseismology
The study of ancient (prehistoric) earthquakes.

Period
The time between two successive wave crests or troughs.

Phase
The change in amplitude or period or both, on a seismogram, indicating the arrival of a seismic wave.

Plate / Plate tectonics
The upper most rigid layer (called, lithosphere) of the Earth, consisting of crust and a part of the upper Mantle material extending to a depth of about 50-150 km. There are about a dozen or so irregularly shaped pieces called major Plates, which are in constant relative motion with a velocity of 2-10 cm./year. The Indian sub-continent is situated on the Indian plate, which is moving at an average velocity of ~ 5 cm./year. 'Plate tectonics' is a theory which explains a number of related factors including the relative motion of these plates and the resulting deformation and earthquakes along the plate boundaries and adjacent regions.

Rayleigh wave
A type of surface wave having a retrograde elliptical motion of the particle, as the wave travels through the Earth's surface. These are the slowest, but often the largest and most destructive, of the wave types caused by an earthquake. They are usually felt as a rolling or rocking motion and move the ground up and down and side-to-side in the same direction that the wave moves. They are named after Lord Rayleigh, the English physicist, who predicted their existence in 1885. They are similar to the waves caused when a stone is dropped into a pond.

Recurrence Interval
The approximate average time interval between earthquakes in a seismically active area.

Richter's scale
It is a mathematical formulation (not a physical device), developed by Charles Richter in 1935, as a means of which the strength (Magnitude) of local earthquakes is measured. The Richter (or) local magnitude (ML) is

defined as the logarithm of the maximum amplitude measured in microns on a seismogram written by Wood-Anderson seismograph with free period of 0.8 second, magnification of 2,800, damping factor of 0.8 calculated to be at a distance of 100 kms. The relative size of events is calculated by comparison to a reference event of M_L=0, using the formula, M_L=log A-log A_o, where A is the maximum trace amplitude in micrometer recorded on a standard seismograph and A_o is a standard value, which is a function of epicentral distance (Δ) in kilometers.

Risk (Seismic)
The term represents an overall estimate of all that is at risk; specifically, the value of all potential losses in a given context: life, property, lifelines and those due to disruption of social and economic activities. Risk from a hazardous event is, thus, determined by the magnitude of the event, as well as our ability or otherwise to cope with its consequences. For example, risk faced by a community or settlement, who have well designed land use patterns, buildings and support systems, would be low even in a region of high hazard potential and vice versa. Risk minimization essentially implies vulnerability reduction. Accordingly, 'Earthquake Risk' (R) is expressed as a generalized product (the mathematical operation of convolution, denoted by the symbol *) of Hazard (H) and Vulnerability (V) in respect of all Elements (E) at Risk (R): life, property, economic activities, lifelines. Or, R = (H*V)*E.

Rupture Zone
The area inside the Earth, where two blocks of rock mass slip and give rise to occurrence of an earthquake. For very small earthquakes, this zone could be very small, but in the case of a great earthquake, the rupture zone may extend to several hundred kilometers in length and tens of kilometers in width.

S wave
S-waves are the type of body waves, which move slowly in comparison to P waves (other type of body waves), but are usually bigger (in an earthquake). S-waves are also called as Shear, secondary, rotational, tangential, equivoluminal, distortional, transverse, pull or shake waves. S waves carry energy through the Earth as transverse waves, leading to the movement of particles in a direction perpendicular to the direction of propagation of the wave. S waves cannot travel through the outer core because these waves cannot exist in fluids, such as air, water or molten rock.

Seiche
A free or standing wave / oscillation of the surface of water in an enclosed basin that is initiated by local atmospheric changes, tidal currents or earthquakes, similar to water sloshing in a bathtub.

Seismic constant
It is a parameter used in designing building codes against earthquake hazards; a pre-determined acceleration value (in units of gravity) that a building is designed to withstand.

Seismic moment
It is equal to rigidity times the fault slip integrated over the fault plane. It can be estimated from the far-field seismic spectrum at wave lengths much larger than the source size. It can also be estimated from the near-field seismic, geologic and geodetic data. Also called as, "scalar seismic moment" to distinguish it from moment tensor.

Seismic Sea Wave
A sea wave (or tsunami) generated by an undersea earthquake. See Tsunami.

Seismic waves
They are the waves of energy caused by the sudden breaking of rock within the earth or by an explosion. They carry the released energy and travel through the earth and are recorded on seismographs. There are many types of seismic waves, viz., body waves, surface waves, coda waves, etc.

Seismic Zone
A region in which earthquakes are known to occur. Bureau of Indian Standards [IS-1893 (Part-1): 2002], based on various scientific inputs from a number of agencies, has grouped the country into four seismic zones viz. Zone-II, -III, -IV and –V. Of these, Zone V is the most seismically active region, while zone II is the least. The Modified Mercalli (MM) intensity, which measures the impact of the earthquakes on the surface of the earth, broadly associated with various zones is as follows:

Seismic Zone	**Intensity on MM scale**
II (Low intensity zone)	VI (or less)
III (Moderate intensity zone)	VII
IV (Severe intensity zone)	VIII
V (Very severe intensity zone)	IX (and above)

Seismicity
Earthquake activity.

Seismogram
Seismogram is a continuous written record of an earthquake recorded by a seismograph.

Seismograph
Instrument, which detects and records ground motion (and especially vibrations due to earthquakes) along with timing information. It consists of a seismometer, a precise timing device and a recording unit (often including telemetry).

Seismology
The word 'Seismology' is derived from the Greek word 'Seismos' meaning earthquake and 'Logos' meaning science. Thus, it is the science of Earthquakes and related phenomena.

Seismometer
A sensor which responds to ground motion and produces a signal that may be recorded.

Signal-to-noise ratio
The ratio of the amplitudes of the (useful) seismic signal and the noise caused by seismic unrest and (or) the seismic instruments.

Source parameters (of an earthquake)
Source parameters of an earthquake include origin time, epicenter, focal depth, magnitude, focal mechanism and moment tensor for a point source model. They include fault geometry, rupture velocity, stress drop, slip distribution, etc. for a finite fault model. The parameters specified for an earthquake source depend on the assumed earthquake model.

Spreading Center
An elongated region, where two Plates are pulled away from each other. New crust is formed as molten rock is forced upward into the gap. Examples of spreading centers include the Mid-Atlantic Ridge and the East African Rift.

Subduction
The process in which one lithospheric plate collides with and is forced down under another plate and drawn back into the Earth's mantle. Examples include, the Indo-Burmese and Peru-Chile Trench subduction zones.

Surface waves
Waves, which propagate along the surface of a body or along a subsurface interface. For the Earth, there are two common types of seismic surface waves: Rayleigh waves and Love waves.

Tectonics
Branch of Earth science, which deals with the structure, evolution and relative motions of the outer part of the Earth, the lithosphere. The lithosphere includes the Earth's crust and part of the Earth's upper mantle and averages about 100 km thick. See 'Plate tectonics'.

Teleseism
An earthquake, whose epicenter is usually more than 20 degrees from the recording station.

Travel time
The time taken by a wave train to travel from its source to a point of observation.

Tsunami
A system of gravity waves formed in the sea due to large scale disturbance of sea level over a short duration of time. Tsunamis are caused by earthquakes under the sea bottom, submarine volcanic eruptions, displacement of submarine sediments, coastal landslides and meteor impact. However, not all coastal earthquakes produce Tsunamis. The word tsunami has its origin from Japan, meaning "harbor wave." When an earthquake of large magnitude occurs under the sea, due to large displacements of the sea floor, the water column is disturbed and sea waves, called 'Tsunamis', are generated. Tsunamis can savagely attack coastlines, causing devastation to property and loss of life. These waves travel long distances and when they reach shallow waters, their amplitude increases. At any given place, the amplitudes may range from a few meters to a few tens of meters depending upon several factors including the magnitude of the event, the type of faulting, depth of water column and bathymetry of the coast.

UTC
Coordinated Universal Time. The time scale based on the atomic second and corrected periodically to keep it in approximate sync with the earth's rotation. The corrections show up as the leap seconds put into UTC - usually on New Year's Eve. In the most common usage, the terms GMT and UTC are identical. The Indian Standard Time (IST) is related to UTC by, IST=UTC+5.30 Hours.

Vulnerability (Opposite of Resilience)
The state of a community or region, expressing its **liability to suffer damage**, on a scale of 0 (**No damage**) to 1 (**Total loss**), in the wake of a hazardous event, due to failure of buildings, utilities and lifelines. Vulnerability in terms of man-made structures can be more easily quantified by their ability to withstand specified hazard levels due to future earthquakes with permissible (to be prescribed) level and type of damage.

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