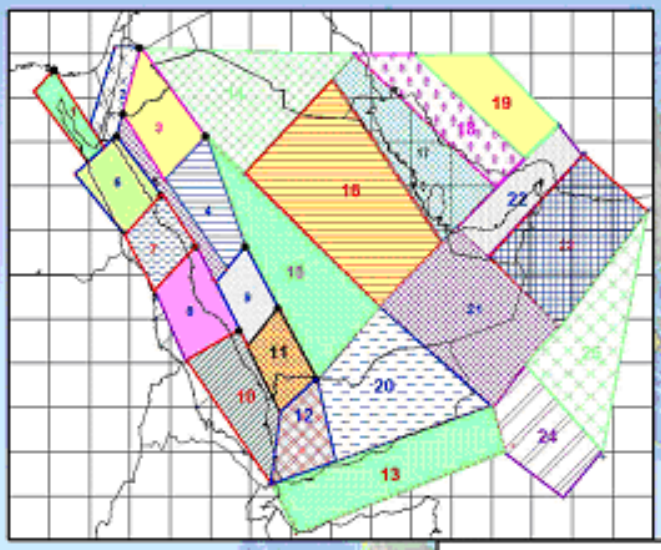
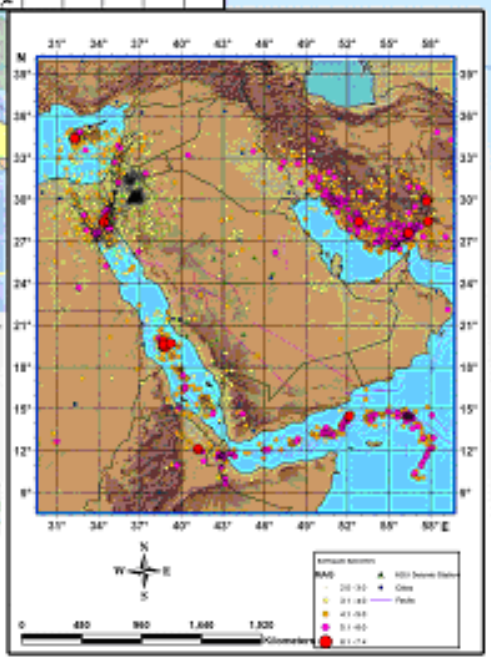
Seismic Zones In The Arabian Peninsula



النطاقات الزلزالية

في

شبه الجزيرة العربية



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المشرف على مركز الدراسات الزلزالية

جامعة الملك سعود

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النطاقات الزلزالية في شبه الجزيرة العربية

ملخص

تعتبر شبه الجزيرة العربية جزءًا من الصفيحة العربية التي تتحرك نحو الشمال الشرقي نتيجة لإنفراج مركزي البحر الأحمر وخليج عدن واللذان يحددان الصفيحة من الجنوب الغربي. ونجم عن حركة الصفيحة العربية تصادم الصفيحتين العربية والأوراسية على إمتداد نطاقات زاغروس وبيتليس. أما خليج العقبة فيمثل الجزء الجنوبي من نطاق البحر الميت التحولي والذي يمتد لمسافة 1000كم تقريبًا والذي يشكل الحد الفاصل بين الصفيحة العربية وسيناء.

وتتركز معظم النشاطات الزلزالية على حدود الصفيحة العربية وبالأخص منطقتي خليج العقبة وجنوب غرب المملكة. وعلى الرغم من قلة النشاط الزلزالي في معظم مناطق المملكه الا أن قربها من المناطق النشطه زلزاليا في ايران وتركيا يتطلب دراسة دقيقة لزلزالية وتحديد مكامن الخطر الزلزالي بدقة عاليه للتقليل من أضرارها مستقبلاً.

هناك ثلاثة شروط يجب توفرها لتحديد إمكانية حدوث الكارثة الزلزالية. الشرط الأول هو كمية القدر الزلزالي حيث أن الأحداث الزلزالية الصغيرة لا ينتج عنها هزات أرضية عنيفة بصورة كاملة وحادة لكي تتسبب في الدمار الشامل. الشرط الثاني هو قرب المصدر الزلزالي. الشرط الثالث هو أن الحدث الزلزالي يعتمد على درجة الإستعداد للكارثة.

لا تعتمد خطورة الزلزال على مدى زلزالية المنطقة أو الإقليم فحسب ولكن أيضًا على الكثافة السكانية والنمو الإقتصادي. فبالرغم من أن الزلزالية تظل ثابتة، فإن الكثافة السكانية والنمو الإقتصادي

يزداد بشكل سريع. ومن أهم العناصر الضرورية للتهيؤ للكوارث هو قابلية التأثير vulnerability أي تخفيف عواقب الزلازل المدمرة. لكي نقوم بتقليل المخاطر الزلزالية بطريقة منطقية فإنه من الضروري الفهم الواضح والإدراك الكامل والتام بالظاهرة الطبيعية المرتبطة بحدوث الزلزال وآثارها الضارة والمدمرة، فالعنصر الأساسي لدرء مخاطر الزلازل هو القدرة على تقييم وتقدير المخاطر الزلزالية بإستخدام حلول منطقية ولكي يتم التعامل مع المخاطر الزلزالية فإنه من الضرورة معرفة ما يلي:

- مصادر الزلازل المدمرة.
- مواقع الأحداث الزلزالية.
- تردد الأحداث الزلزالية المختلفة في الحجم.
- طبيعة الحركة الأرضية بالقرب من مصدر الزلزال أو التوهين مع المسافة.
- تاثير جيولوجية الموقع على شدة الهزة الأرضية.
- أنواع المخاطر الزلزالية.
- الخصائص الرئيسية التي من الممكن أن تعرف مقدار التدمير الناتج عن الهزة الأرضية.

لنمذجة خواص المصادر الزلزالية تم إستخدام طريقتين هما الطريقة الزلزالية وطريقة الكسور. بالنسبة للطريقة الزلزالية تم إستخدام مجموعة من البيانات الزلزالية في كل نطاق وذلك لتحديد وتعيين علاقة القدر الزلزالي – التردد وكذلك لتقدير الإزاحة الخطية السيزمية ومقادير العزم الزلزالي.تم تحديد المعاملات الزلزالية لإيجاد العلاقة بين التراكيب والمصدر الميكانيكي للزلزال.

أما بالنسبة للطريقة الثانية فقد تم فحص وإختيار التراكيب التي يشملها كل نطاق على اساس الخرائط الجيولوجية التكتونية المتوفرة وذلك لمعرفة العلاقة بين أنواع المصدر الميكانيكي للزلزال

وزلزالية مصدر المساحة Area source . دلت النتائج على أن هناك نوعين من المصادر بالنسبة للنموذج التكتوني وهذان النوعان هما المصدر الخطي Line source ومصدر المساحة Area source. بالنسبة للمصدر الخطي يشمل الصدع العرضي Transcurrent والصدوع العادية. أما بالنسبة لمصدر المساحة Area source فهي تشمل الأحداث الزلزالية التي لها علاقة بالفوالق والكسور الصخرية والتي حدث لها إزاحة مما أدى إلى تغير موقعها داخل النطاقات السيزمية.

وبأخذ الاعتبارات الجيولوجية والسيزمية وتطبيق النماذج الرياضية المختلفة تم تحديد 25 نطاق زلزالي وتم تعريفها وتخطيطها في الجزيرة العربية على النحو التالي :

رقم النطاق	أسم النطاق
1	خليج السويس
2	خليج العقبة – البحر الميت
3	تبوك
4	النطاق البركاني في الشمال الغربي
5	وسط الحجاز
6	ضبا والوجه
7	ينبع
8	جنوب البحر الأحمر – جدة
9	مكة المكرمة
10	جنوب البحر الأحمر – الدرب
11	أبها – جيزان

رقم النطاق	أسم النطاق
12	جنوب غرب الدرع العربي
13	خليج عدن
14	طريف – وادي السرحان
15	صدع نجد
16	منخفض وسط المسطح العربي
17	الخيج العربي
18	جبال زاجروس
19	سلسلة سنندج إيران
20	جنوب اليمن
21	حوض الربع الخالي
22	ديبا – بندر عباس
23	مكران – حواسنة
24	مرتفعات شرق شيبه
25	صدع المسيره

إعتبرت نطاقات المصادر الزلزالية 1 و2 و6 و8 و10 و13 و18 و19 و22 و24 مناطق نشطة زلزالياً خلال الفترات التاريخية والحديثة . تتميز نطاقات المصادر الزلزالية هذه بوجود واحد أو أثنين من ميكانيكيات المصادر المحتملة مثل نظم الصدع (rift) وصدوع عمودية وإنزلاقية ونطاقات تصادمية .

التوزيع الفراغي والزمني للأحداث الزلزالية في نظام الصدع تبدو كثيفة ولكن يوجد تشوه قشري عبر محور الصدع (rift) بينما مواقع البؤر الزلزالية في منطاق التصادم تعتبر تقريباً منتظمة التوزيع . وتتراوح قيمة الـــ b لهذه المناطق الزلزالية بين 0.7 و 1.2 .

ويلاحظ أن باقي مناطق المصدر الزلزالي تعتبر غير نشطة زلزالياً من حيث وقوع أحداث زلزالية ضعيفة إلى متوسطة خلال الفترات التاريخية والحديثة بالرغم من أن بعض نطاقات المصدر الزلزالي هذه (16 و15 و12 و 9 و7 و 5 و4) تحتوي على نظام صدع معروف وتقع في منطقة بركانية . وتتراوح قيمة الـ b في مناطق المصدر الزلزالي هذه تقريبا من 0.35 – 0.6 ماعدا المناطق البركانية التي يبدو أنها تتبع نظام الصدع rift.

ABSTRACT

The Arabian Peninsula presents several interesting seismological problems. On the west, rifling in the Red Sea has split a large Precambrian Shield. Active rifling is responsible for the geometry of the plate margins in the west, and southwest. To the south, similar rifling running in a more east-west direction through the Gulf of Aden has separated the Arabian Peninsula from Africa. In the northwest, the Gulf of Aqabah forms the southernmost continuation of the Dead Sea transform. The northern and northeastern boundaries of the Arabian Plate are areas of continental collision, with the Arabian Plate colliding with the Persian Plate.

Earthquake hazard depends not only on the seismicity of a region, but also on population density and economic development. Even though seismicity remains constant, both population and economic development are increasing rapidly. Identifying sources of vulnerability and taking steps to mitigate the consequences of future earthquake disaster are the most essential elements of disaster preparedness. Because the existing facilities represent the main earthquake risk, research and performance evaluation have much desire to be done in this critical area.

In order to reduce earthquake hazards in a rational way, it is necessary to have a clear understanding of the phenomena associated with earthquakes and their adverse effects. The key element in coping with earthquake hazard is the ability to assess seismic hazard. To make rational decisions in coping with earthquakes, it is necessary to know the answers to some questions related to:

- **Sources of destructive earthquakes**
- **Locations of earthquake occurrences**
- **Frequency of various size of earthquakes**

- **Nature of the severe ground motion near the source and its attenuation with distance**
- **Influence of local geology and site condition on the severity of ground shaking**
- **Types of earthquake hazards**
- **Main characteristics that define the damage potential of earthquake shaking**

The activities in the seismic regionalization of the Arabian Peninsula was partitioned and conducted into two primary stages. These are the identification and delineation of the seismogenic source zones and determination of the seismicity and other related parameters of seismic concern. In the identification and delineation of the seismogenic source areas, some criteria were followed and utilized as guidelines. These are mainly the seismological and geological parameters, and to lesser extent is the consideration of the geophysical parameters when needed. The seismological parameter is chiefly composed of the planar spatio-temporal distribution of earthquakes that indicates both seismogenic provinces and seismo-active faults, and occurrences of large earthquakes, the level of which depends upon the seismic activity in the region. The geological parameter is primarily a map of regional tectonics that shows the location of joints, faults, lineaments, and rift systems that are associated with the seismic activities in the area. In reference to these two parameters as criteria and guidelines, the boundaries of each seismogenic source zone are drawn in such a way that a cluster or more clusters of earthquakes are included and traversed the region of minimum density of epicenters, but do not intersect the main tectonic provinces. From these considerations, there are a total of twenty five (25) seismogenic source zones that were identified and delineated for the western and eastern Arabian Peninsula. Numerically arranged and namely described as follows:

Zone Number	Zone Name
1	Gulf of Suez
2	Gulf of Aqabah-Dead Sea System
3	Tabuk Region
4	Northwestern Volcanic Zone
5	Midyan-Hijaz Region
6	Duba-Wajh Area
7	Yanbu Area
8	Southern Red Sea-Jeddah Area
9	Makkah Area
10	Southern Red Sea-Al Darb System
11	Abha-Jizan Area
12	Southwestern Arabian Shield
13	Gulf of Aden
14	Sirhan-Turayf-Widyan Basins
15	Najd Fault Zone
16	Central Arabian Graben Zone
17	Arabian Gulf
18	Zagros Fold Zone
19	Sanandaj-Sirjan Ranges
20	Eastern Yemen
21	Rub Al Khali-Ghudun Basins
22	Dibba-Bandar Abbas Region
23	Hawasina-Makran Thrust Region
24	East Sheba Ridge System
25	Masirah Fault System

The seismic source zone characterization scheme for the different source areas is also composed of two fundamental aspects. These are the seismicity and tectonic aspect in each seismogenic source zone. The description and characterization for the seismicity aspect requires the statistical and deterministic analysis of the seismic activity in each source area.

Henceforth, the required seismic data are collected and compiled separately for each identified seismic zone.

In general, the seismic source zones (1, 2, 6, 8, 10, 13, 18, 19, 22, 24) can be considered as seismogenically active within the period of observation. These seismogenic source zones are characterized by the presence of one or two of the probable source mechanisms such as rift systems, strike-slip/normal faults, subduction and collision zones. The spatio-temporal distribution of seismic events in the rift systems shows intense but scattered crustal deformation taking place along the axial rift, while epicenters location in subduction and collision zones are more or less uniformly distributed. The b-values for these seismic source areas range from 0.7-1.2. The other seismogenic source zones are observed to be seismically inactive in terms of moderate to strong earthquake events within the duration of the period of observation, although some of these seismic source zones (16, 15, 12, 9, 7, 5, 4) contained prominent fault systems and or located in volcanic areas. The b-values found for these seismic source areas range approximately from 0.35-0.6, except for volcanic areas which seemed to be affiliated to rift systems.

Earthquake Glossary

Acceleration – a force with the units of gravity that denotes the rate of change in time of the movement of the ground during an earthquake.

Accelerogram – refers to a seismic record from an accelerometer, a device in recording the time history of ground acceleration at a site. Peak acceleration is the largest value of acceleration on the record and typically used in design criteria. Ground velocity and displacement time histories can be derived analytically from an accelerogram.

Acceptable risk – probability of occurrence of physical, social, or economic consequences of an earthquake that is considered by authorities to be sufficiently low compared to significant effects.

Aftershocks. Earthquakes that follow the largest shock of an earthquake sequence. They are smaller than the mainshock and within 1-2 fault lengths distance from the mainshock fault. Aftershocks can continue over a period of weeks, months, or years. In general, the larger the mainshock, the larger and more numerous the aftershocks, and the longer they will continue.

Amplification. Most earthquakes are relatively small, in fact, so small that no one feels them. In order for seismologists to see the recording of the movement of the ground from the smaller earthquakes, the recording has to be made larger. It's like looking at the recording through a magnifying glass, and the amount that it is magnified is the amplification. Shaking levels at a site may also be increased by focusing of seismic energy caused by the geometry of the sediment velocity structure, such as basin subsurface topography, or by surface topography.

Attenuation. When you throw a pebble in a pond, it makes waves on the surface that move out from the place where the pebble entered the water. The waves are largest where they are formed and gradually get smaller as they move away. This decrease in size, or amplitude, of the waves is called attenuation.

Artificial – type of an earthquake that is produced when explosive devices are detonated.

Attenuation – a decrease in the strength of seismic waves and seismic energy with distance from the source.

Azimuth – angle made by the longitude of the epicenter and the line joining the epicenter and recording station measured in a clockwise manner.

Built Environment – defines the temporal and spatial distribution of buildings and lifeline system exposed to hazards.

Body-wave Magnitude – when the magnitude value is determined from the body-waves.

Creep. Slow, more or less continuous movement occurring on faults due to ongoing tectonic deformation. Faults that are creeping do not tend to have large earthquakes.

Depth of focus – vertical distance between focus and epicenter.

Disaster – occurrence of a hazardous event which adversely affects a community to such a degree that essential social service and functions of physical structures are disrupted.

Displacement. The difference between the initial position of a reference point and any later position. The amount any point affected by an earthquake has moved from where it was before the earthquake.

Duration – length of time between the onset and departure of a natural hazard.

Duration Magnitude – when the magnitude value is evaluated from seismic trace duration of a recorded earthquake event.

Earthquake - transient vibrations of the earth's crust due to the release of the stored strain energy in a focal volume. The energy is transmitted in all directions by means of the generated seismic waves. There are three classifications of earthquakes. These are classified as tectonic, volcanic, and artificial.

Earthquake Hazards – the primary and secondary physical effects generated by an earthquake such as ground shaking, differential ground movements, landslides, tsunami, and etc).

Elements at Risk – the people, ecosystem, environment, natural structures and man-made buildings that are exposed to natural and technological hazard.

Epicenter – is the location of an earthquake on the surface of the earth. It is directly above the focus. It is represented as a point that is defined by its geographical coordinates.

Epicentral Distance – distance between epicenter and a seismic recording station.

Exceedance probability – probability that an earthquake will generate a level of ground motion that exceeds a specified reference level during a given exposure time.

Exposure Time – the period of time that a structure or community is exposed to potential earthquake and other natural hazards.

Fault – a fracture or a zone of fractures in the earth which displacement of the two sides relative to one another has occurred as a consequence of compression, tension, or shearing stress. A blind fault is the term used to describe a fault system that is not visible at the surface of the ground. An active fault is one that exhibits physical characteristics such as historic earthquake activity, surface fault rupture, geologically recent displacement of stratigraphy or topography, or physical association with another fault system judged to be active.

Foreshocks. Foreshocks are relatively smaller earthquakes that precede the largest earthquake in a series, which is termed the mainshock. Not all mainshocks have foreshocks.

Ground Failure – term referring to the permanent, inelastic deformation of the ground triggered by ground shaking.

Ground Shaking – refers to the dynamic , elastic, vibratory movement of the ground in response to the arrival of the different seismic waves.
Hazard – potential threat to humans and their welfare. The threat could be due to natural and technological origin.

Hazard Assessment – an estimate of the range of the threat such as the magnitude, frequency of occurrence, and duration of the natural and technological hazard to humans and their welfare.

Hazard Environment – defines the physical characteristics of the source, path, and site effects.

Hypocenter/Focus – a point in the earth where the earthquake originates. The hypocenter is a simple representation of the focal volume of an earthquake where strain energy is stored. The focal point can be assumed to be where the first break of rupture happens when an earthquake occurs.

Hypocentral Distance – distance between focus and a seismic recording station.

i or e – prefix to the international symbols used in the identification of the different seismic phases. i and e means an impulsive/sharp and emergent/gradual beginning of the initial onset of a recorded seismic phase on a seismogram respectively.

Intensity – a measure of the local ground motion effects on man and its environment, to all types of building structures, and on free nature. There are different intensity scales used in the seismological community. The scales are named after their respective founders or country of origin. Intensity scales are composed of grades/degrees expressed in the Roman numerals. Each grade described the limitation/extent of the observable effects to man and its environment, to building structures, and to free nature.

Landslide – refers to the falls, topples, flows of rocks from unstable slopes.

Local Magnitude – when based from Richter magnitude scale.

Love (LQ) – a wave that moves on a horizontal plane perpendicular to the direction of motion. It is prominently recorded in the horizontal components of a LP seismograph.

Liquefaction – refers to loss of soil bearing strength that occurs mainly in young, shallow, loosely compacted, water saturated sand and gravel deposits when subjected to ground shaking.

Magnitude. A number that characterizes the relative size of an earthquake. Magnitude is based on measurement of the maximum motion recorded by a seismograph. Several scales have been defined, but the most commonly used are (1) local magnitude (ML), commonly referred to as "Richter magnitude," (2) surface-wave magnitude (Ms), (3) body-wave magnitude (Mb), and (4) moment magnitude (Mw). Scales 1-3 have limited range and applicability and do not satisfactorily measure the size of the largest earthquakes. The moment magnitude (Mw) scale, based on the concept of seismic moment, is uniformly applicable to all sizes of earthquakes but is more difficult to compute than the other types. All magnitude scales should yield approximately the same value for any given earthquake.

Mainshock. The largest earthquake in a sequence, sometimes preceded by one or more foreshocks, and almost always followed by many aftershocks.

Microzonation. The identification of separate individual areas having different potentials for hazardous earthquake effects.

Mitigation – range of policies, legislative acts, professional practices, and social adjustments that are designed to minimize the effects of earthquakes and other natural hazards on a community.

Moment Magnitude – measure of the size of an earthquake referred from the moment of the equivalent body force and the over-all source spectrum of an earthquake.

Natural Hazard – potential threat to humans and their welfare caused by slow and rapid onset events having natural origin (atmospheric, geologic, and hydrologic) on a global, regional, and local scales (typhoons and storms, earthquakes and volcanic eruptions, floods, and tsunami run up).

Origin Time – time of occurrence of an earthquake. It is expressed in hours, minutes, and seconds in the universal coordinated time (UTC) or Greenwich meridian time (GMT).

Percent "g". G or g is the force of gravity. When there is an earthquake, the forces caused by the shaking can be measured as a percentage of the force of gravity, or percent g.

Poisson distribution. A probability distribution that characterizes discrete events occurring independently of one another in time.

Preparedness – refers to using mitigation processes on a community to plan for emergency response, recovery, and rehabilitation after a disastrous earthquake.

Primary Wave – is the first wave to arrive at a recording seismic station. It is a longitudinal type of wave that moves in a push and pull manner along the direction of motion. There are different types of p-wave in accordance to the mode of travel. These are the Pg, P*/Pb, Pn, and P.

Pg – a direct longitudinal wave in near epicentral distance.

P*/Pb – a guided longitudinal head wave that travels along the Conrad discontinuity.

Pn – a guided longitudinal head wave that travels along the Mohorovicic discontinuity.

Policy Environment – defines the community's hazards risk management policies and practices.

Recurrence interval. The average time span between large earthquakes at a particular site. Also termed return period.

Rayleigh (LR) – a wave that moves in an elliptical manner along the direction of motion. It is prominently recorded in the vertical component (Z) of a long period (LP) seismograph.

Response Spectrum – a graph of the output of a mathematical model which shows how an idealized ensemble of lightly damped, simple harmonic vibrating building responds to a particular ground motion. The source of

ground motion is an accelerogram that is used to excite the model in the period range 0.05-10 seconds, a period range of interest to engineers. The concept of response spectrum is used in building codes and design of essential and critical structures.

Risk – probability of loss to the elements at risk from the occurrence of natural and technological hazard.

Risk Assessment – an objective scientific assessment of the chance of loss or adverse consequences when physical and social elements are exposed to potentially harmful natural and technological hazards. Risk assessment integrates hazard assessment with the vulnerability of the exposed elements at risk.

Risk Management – public process of implementing decisions that involves choices and actions designed to minimize potential losses when risk assessment indicates the risk.

S*/Sb – a guided transversal head wave that travels along the Conrad discontinuity.

Secondary Wave – the second wave to arrive at a recording seismic station. It is a transversal type of wave that moves in an up and down manner perpendicular to the direction of motion. It is also known as a shear wave. There are different types of secondary wave in accordance to their mode of travel. These are the Sg, S*/Sb, Sn, and S.

Seismic gap. A section of a fault that has produced earthquakes in the past but is now quiet. For some seismic gaps, no earthquakes have been observed historically, but it is believed that the fault segment is capable of producing earthquakes on some other basis, such as plate-motion information or strain measurements.

Seismic Station – a place or site where a seismograph is installed and operated, and maintained.

Seismic Waves – are motions of disturbance when an earthquake occurs. There are two kinds of seismic waves. These are the body and surface waves. The body wave moves through the body of the earth. The surface wave moves through the surface of discontinuities in layered media. The body wave is composed of two types. These are the primary (p) and

secondary (s) waves. The surface wave/long wave (L) is also composed of two types that were named after their discoverer. These are the Rayleigh (LR) and the Love (LQ) waves.

Seismic Zonation – the division of a geographic region into smaller areas or zones based on an integrated assessment of the hazard, built and policy environments of a region. Zonation maps are the results of a process that integrates data, results of research, built and policy environments. The maps contribute to risk reduction and sustainability of the growth and the new developments.

Seismogenic Structure – a geologic structure such as an igneous pluton dike, or sill that has earthquake activity associated with it.

Seismogram – a seismic record from a seismograph.

Seismograph – an instrument that records the relative motion of the ground.

Sg – a direct transversal wave in near epicentral distance SSS.

Sn – a guided transversal head wave that travels along the Mohorovicic discontinuity.

Shear stress. The stress component parallel to a given surface, such as a fault plane, that results from forces applied parallel to the surface or from reinote forces transmitted through the surrounding rock. If you lean against the edge of the door where the latch is, you are applying shear stress to the door.

Soil Amplification – a period-dependent property of the soil to ground motion. It is a function of the relative density of the soil to the base rock.

Soil/Structure Resonance – a physical phenomenon that increases the potential for destructiveness when the input seismic waves caused the soil and structure to vibrate at the same period.

Source Directivity – a physical phenomenon that increases ground shaking at a site due to the directional aspect of the fault rupture that cause most

of the energy to be released in a particular direction instead of in all direction.

Spectral acceleration or SA. PGA (peak acceleration) is what is experienced by a particle on the ground. SA is approximately what is experienced by a building, as modeled by a particle on a massless vertical rod having the same natural period of vibration as the building.

Strong motion. Ground motion of sufficient amplitude and duration to be potentially damaging to a building or other structure.

Surface-wave Magnitude – when the magnitude value is computed from the surface waves.

Surface Fault Rupture – a physical phenomenon of the rupturing fault breaking the surface of the ground and releases more energy on the side of the fault that is moving, thereby increasing ground shaking at the moving part than at the stationary block.

Tectonic – type of an earthquake that is generated when relative motion occurs among large deformed body of rocks.

Technological Hazard – potential threat to humans and their welfare caused by technological factors (chemical release, nuclear accidents, dam failure).

Volcanic – type of an earthquake that is generated due to magmatic movements in a volcano.

Vulnerability – potential loss in value of each element at risk from the occurrence and consequences of natural and technological hazards. The factors that influence vulnerability include demography, built and policy environments, social differentiation and diversity, and political and economical strategies. Vulnerability is a result of flaws in planning, siting, design, and construction.