

EARTHQUAKES

Causes, Consequences and Precautions



Faisal Awan



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Pakistan/Afghanistan

Foreword

Though earthquakes of light and moderate intensity are common in this part of the world, however, the books on this subject are very few and lack detailed information on the equipment, measurement & its monitoring. The writer of this book has made a tremendous effort to gather the relevant information and present them in a compact form, so that it is interesting and useful for the readers. The author has also taken into account the causes of earthquakes and enlisted those areas which are sensitive to earthquakes which is very important information. The book also contains in detail the precautionary measurements which are most important for the common reader particularly students.. It also discussed the preconceived assumptions and superstitions of common man and highlighted the scientific aspects of earthquake to give a comprehensive view of the subject.

Readers having interest in general science will find this book very useful which describes about earthquakes and the changes over the crust of the earth and its drift theory. I hope this book will be a good addition in libraries and for the knowledge and information of both scientific & nonscientific community.

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Preface

Earthquakes are considered to be one of the worst natural hazards causing widespread disaster and loss of human lives. The impacts of earthquakes normally cover large areas causing deaths, injuries and destruction on a massive scale. Though they have high consequences, they have low probability. For this reason the post-disaster response takes place on ad-hoc basis without any prior preparedness. Destruction can be so swift and sudden that people have no time to escape.

Nobody can remain without being affected from such an earthshaking disaster. Every-time we confront an earthquake it leaves a host of more or less similar questions in our minds. Why earthquakes occur? Can earthquakes be predicted? Why earthquakes are confined to certain regions of the Earth's surface? Why the magnitudes vary? Can the collapsing of the buildings be prevented? When was the last earthquake? When and where there will be a next earthquake? What do we mean by focus or an epicenter of an earthquake? How the damage can be minimized?

This book contains answer of all these questions including faults and sensitive Pakistani areas regarding earthquake, seismic zones and significant earthquakes in this region. The writer's aim is to explain basic information about earthquake in simple way.

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Chapter 1

October 8

On the morning of October 8, 2005 at 8:54 hrs Azad Kashmir Northern Areas, Islamabad, Peshawar and other cities were shaken by a severe earthquake. In a few seconds the Muzafarabad city, Balakot, many small towns and hundreds of villages were razed to the ground. Thousands were buried under tons of debris. From thatched roofs of poor houses to government buildings, schools and colleges all were turned into heaps of rubble. The devastation was so extensive that rescue teams could not reach affected areas easily. The communication links with Azad Kashmir and Northern Area were destroyed and the area was totally cut off from the rest of Pakistan.

According to the US Geological Survey, 79,000 lives lost in the earthquake whereas World Bank Report given the figure of 86,000 dead. An unofficial source estimated more than 100,000 dead. After earthquake, these figures further increased because of injuries, disease and cold weather. The total number of injured were more than 100,000 while the total affected are 2,80,0000 to 3,50,0000. This earthquake is rated as one of the strongest earthquake in the last one hundred years.

Thousands of after-shocks have been recorded after October 8. Some of these measured 6 on the Richter scale. A series of after-shocks follows each major earthquake which lasts many weeks, some times months. The remaining earthquake energy continued to be released in the form of smaller shock. Many incidents of land sliding took place at Alai where people thought the cloud of dust was due to some volcano eruption.

The epicenter and magnitude of the earthquake

This earthquake occurred in the mountain tops of Himalayan range. The houses were largely double storied which were constructed with the local available material i.e. wood, clay and stones. The structure of school and official buildings were made of concrete ignoring the probable risk of the earthquake in the area. That is why most of the casualties were in schools and colleges.

The magnitude of the earthquake measured 7.6 on the Richter scale. An area of 28,000 km including some area on the other side of the L. O. C. was affected. The epicenter of the earthquake was 10 km away from Muzzaferabad. Geologically its coordinates were 34.493 East and 73.62 North and the hypocenter of earthquake was 26 km deep. This earthquake was generated due to undercutting of Indian plate in to Eurasian plate in the north. The fault on which both the plates moved is called "main boundary thrust and its orientation is north -west to south- east parallel to Himalayas. This movement is called "main boundary thrust" and its orientation is Northwest to Southeast parallel to Himalayas.

In the terms of Geology this earthquake shall be referred to as October 8, 2005 earthquake of Muzaffarabad because most of the destruction took place in Muzaffarabad. The main city is near the epicenter of the earthquake. Azad Kashmir and adjoining mountain areas are located in a geological region which is known for frequent earthquakes. In fact, these earthquakes are the result of appearance of a fault line after the collision of Indian and Eurasian plates some 55 million years ago and the affected areas are right above this fault. 8th October earthquake was also due to this fault costing thousand of lives and inflicting heavy damage to property with billions of rupees. This area shall remain under threat of the earthquake due to its peculiar underground identity. There are some possibilities of devastating floods in this region due to the movement of under ground plates, release of energy and shaking of earth in the area. According to Geologists, there are more than 3000 frozen lakes in the Himalayas Karakoram and Pir-Panjal ranges which can cause flooding in the slopes after a major earthquake.

The Destructions:

8 October earthquake is the severest earthquakes recorded at this place. As UN experts reported the destruction wise this earthquake was stronger than Tsunami. The final figure of total loss is yet to be known, however, the preliminary estimates show that -10118 km out of a total area of 15307 km of Muzzaferabad, Baramula, Kupwara, Bagh and Poonch was completely destroyed. The total number of constructed houses in the area was 535291 out of which 129075 were razed to the ground. 83694 houses were partially damaged. 2127 km long portion of roads became unserviceable 398 health units including 20 hospitals and 62 dispensaries were destroyed. 1907 educational institutions including 3 Universities 33 colleges and hundreds of primary and secondary schools were razed to the ground. Financial loss to Govt. and private offices touched the figure of 34 billion rupees while the loss to the industry was about 2 billion rupees.

The effects of this earthquake shall be felt on our socio economic life for years to come. The biggest challenge facing the developers after this catastrophe was to deal with rising trend of poverty in the earthquake hit areas.

The number of injured people was much more than the dead and many injured became incapacitated due to severe injuries and no immediate first aid was available to them. The hopes of providing treatment to the injured also vanished after the destruction of the health units. The means of living were also badly damaged. The markets were perished leaving the business activities at a standstill.

The agricultural land in the region was affected by the heavy land slides. The transport business was also hampered by destruction of the roads.

The material effects can be cured by fulfilling the basic requirements of the people, but to overcome the psychological effects after this catastrophe shall require a long time. 90% of the people in the area are suffering from psychological tension and hardly 15 to 20 percent of them would be able to live a normal life. The earthquake was so sudden that no one was prepared for it. The people were totally stunned. With the passage of time they started to recover but many of them are still suffering from the mental shock.

PHOTOS

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EARTHQUAKE 2005 LOSSES¹

*Released By Emergency Resource Centre
A project of Church World Service*

Area Affected	30,000 sq. km.
Official Casualties	73,338
Seriously Injured	69,412
Children Disabled	10,000
Pop. Affected	3.5 million people (500,000 families)
Population Lost Homes	3.3 million people (over 6,00,000 dwellings)
Health Facilities Destroyed or damaged	80%
Economic Loss	\$ 5.2 billion
Material Loss	\$ 2.8 million
Employment losses	The total loss in employment to be around 3,24,000 jobs
Total No of School Damaged	7,669 schools – 5,690 are primary and middle schools
Transport Damage	\$ 340 million
Health Facilities	\$120 million (574 health facilities)
Water Supply and Sanitation.	US\$20 million

¹ *Date collected from ERRA UN recovery plan and Asian Development Bank & World Bank Assessment Report*

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PHOTOS

(8 pages for photographs)

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Chapter 2

Earthquakes in Pakistan

Pakistan is situated in the northern border of Indian plate where it faces Eurasian plate. The Himalayas emerged out of the ground due to the collision of these two plates. The process of under cutting of Eurasian plate and moving forward of Indian is continuing for the millions of years. Indian plate advances in the north by 1.5 Inch per year on the average but it is just an average speed. What happens in fact is that the plate does not move in 50 to 100 years but the stress is continuously building upon it. When this stress reaches at a certain level, suddenly with a jerk the plates move by several feet releasing the accumulated energy. This release of energy is in the shape of waves around its center which start shaking the towns and cities in the area.

Some times the earthquake is originated from the middle of the plates instead of their boundary. At this point the plate becomes weaker due to the weight and size of the plate and a crack appear. This is the exact situation beneath the Indian state of Gujarat from where Run of Kutch fault rises toward, Karachi, passing through Southern region of Sindh including Nagarparkar, Badin and Thatta.

In the year 2001, at Bhuj and in 1819 at Kutch both the earthquakes originated as a result of cracking the plate at the same fault.

Sensitive Zones:

Pakistan is considered to be the fifth most sensitive zone in the world regarding earthquakes. China, Japan, Iran and Turkey have experienced more earthquakes than Pakistan. The land of Pakistan and adjoining areas have been centre of earthquakes before this earthquake.. Many Major earthquakes, before the recent quakes, have been recorded in Baluchistan, Kashmir and many parts of NWFP, in which thousands of people have lost their lives. The Pakistani region of Kashmir and Northern Areas are situated at the border of the Indian plate, that is why they are considered to be the most sensitive area for earthquakes. Major earthquakes have been recorded in this region before and more tremors are expected in future also. To check the probability of earthquake at a certain region we consult, a map called "Seismicity map". The region is classified according to the under ground structure of plates and the regions are called "Seismic Zones"

In other words the map shows the sensitivity of a place with respect to occurrence of earthquakes. Azad Kashmir and Northern Areas have been included in zone 4 in the seismic zone map of Pakistan which is considered as dangerous zone. On the other hand Pothohar plates is classified as zone 3 and big cities of Pakistan like Islamabad, Rawalpindi, Jhelum & Chakwal are in this zone. In the past this area has received many moderate earthquakes, and the shocks are expected in future also.

In Baluchistan, Quetta, Chaman, Loralai and Mastung are situated on the border of Indian plate and are included in the High Risk Zone or zone-4. Many moderate and major earthquakes have been experienced in the zone. The areas surrounding this zone is classified as zone -3. There are chances of moderate earthquakes in the major parts of the region. North Punjab, Upper Sindh and Kharan are included in zone-2 where the chances of moderate and mild earthquakes are always there.

Thar, Cholistan desert and adjoining areas, are include in zone-1. In this zone the Chances of earthquakes are very little.

The earthquake prone Areas of Pakistan

Zone	City	Chances of earthquake
Northern Areas	Muzaffarabad, Hazara, division, Chitral, Rawalpindi, Pothohar.	Major & Moderate Earthquakes.
Suleman and Kirthar Ranges.	Chaman, Loralai, Quetta, Mastung, Khuzdar, Lasbela	Major & Moderate Earthquakes.
Coastal belt of Southern Sindh.	Nugarparkar, Diplo, Badin, Tatta to Karachi	Moderate Earthquakes.

(Photograph)

Seismic map of Pakistan

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As mentioned before, seismologically the country has been divided into four zones, and this is called seismic zone of Pakistan. We can check the Seismic risk " of a city by consulting the maps, before constructing high rise buildings in the bigger cities, the seismic risk factor must be checked by consulting this map. The first map of seismic zone of Pakistan was prepared in 1958. This map was drawn by Meteorological Department with the collaboration of UNESCO on the basis of 100 years history of earthquakes. Another map was prepared jointly by Geological Survey and Nespak in 1980 keeping in view of both the formation of earth and presence of fault under it.

Some portions of the map were revised in 1984. This particular map is being used by LDA, CDA & KBCA for the last 25 years. Now it is necessary to further revise this map after the earthquakes of 2001 at Bhuj and 2005 at Muzzafarabad. Seismic Risk Zone map is very important document for building control authorities and is essential for preparing building designs.

As the earthquakes are regularly felt due to the motion in the fault the nearby localities also experience tremors after every 50, 100 or 500 years. That is why a map, depicting maximum felt earthquakes in the history is considered to be more authentic for calculating further chances of the earthquake.

The earthquake frequency map of Pakistan prepared by the Geophysical Centre of Pakistan Meteorological Department shows that a vast area of Pakistan has experienced moderate or major earthquakes. Those areas, which have experienced more major earthquakes demand more attention. Our big cities like Karachi and Lahore have not been hit by any major earthquake but there are chances of major earthquakes in those cities also.

Seismic Zone of Pakistan

Zone-1	Zone-2	Zone-3	Zone-4
Mir Pur khas	Skardu	Gilgit	Kalam
Nawab Shah	Sahiwal	Islamabad	Chitral
Bela	Qasur	Peshawar	Muzzaferabad
Rahim Yar Khan	Faislabad	Nowshehra	Quetta
Bahawalpur	Lahore	Thatta	Chaman
Multan	Gujranwala	Badin	
Dera Ghazi Khan	Sialkot	Gawader	

	Larkana Sukkur Jacobabad Sibi Hyderabad Karachi	Pasni	
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Major Earthquakes of Pakistan

The recent earthquake of 2005 Azad Kashmir & Northern Areas has caused devastating destruction in the area. But nobody knows that a very strong earthquake was also felt in these areas in 1555 which has been mentioned in old Persian and Sanskrit books. According to these books nearly 60,000 people died in this earthquake many of them due to landslides. This earthquake was felt during the reign of Raja Shams Shah of Kashmir, but no details are available. A major earthquake was also recorded in 1974 in these areas. The December 28th 1974 earthquake was of 6.2 magnitude. It inflicted heavy damage in Hazara, Swat and adjoining areas. Official record shows 5300 deaths whereas unofficial death toll was nearly 10,000. Seventeen thousand people were injured. "Pattan" village in the Northern area was completely destroyed, it is called Pattan earthquake.

Apart from the 2005 earthquake, the Quetta earthquake of 1935 has been the other major event in which 35000 people lost their lives. On the Richter scale that was a 7.7 magnitude earthquake, stronger than the recent earthquake of 2005. The epicenter of the earthquake was a village Alijan in Ghazabund fault located near Quetta Baluchistan. Quetta, was the populous city hence most of the deaths occurred in the city. Whole of the city except the concrete buildings were leveled to the ground causing 26,000 deaths in the city only.

There were 1736 casualties. In Mastung city, south of Quetta and 1206 in village Sariab near Quetta, 2,900 deaths were reported From Kalat and adjoining tribal areas. Unofficial sources quoted 40,260 deaths. The earthquake shocks were also felt in Sindh, Kandhar and Spin Boldak in Afghanistan as well as in Amritsar, Shimla and Agra in India. No record of any casualty in the Afghan area is available. Till 2005, this earthquake was referred to as the most devastating earthquake. According to eyewitnesses, a mysterious light was seen over the hills of Quetta before the earthquake. But Geologists says it was " Seismic light " which is generated near the epicenter at the time of the earthquake.

The region in which Pakistan is located has experienced two major earthquake in the past in which death toll it is believed has crossed 2,00,000 but no details are available. One of these was Bhanbore earthquake of 1050, in which approximately 150,000 people lost their lives. The epicenter of the earthquake was just 60 kms away from where Karachi is located today. The other earthquake was felt in Pipri, the site of today's Steel Mills, In 1668. leaving approximately 100,000 people dead, but documentary proof of this figure is also not available.

On June 16, 1819, a very strong earthquake measuring 7.5 on Richter jolted Allahband at the Indo -Pak border, resulting 3200 death and demolishing thousands of houses. The shock was so strong that a patch of 90-kms ground was raised by 4 meters. The Lahore earthquake of September 26, 1827. took over thousand lives. 350 people lost their life in Kahan earthquake in Kohlu Baluchistan on January 24, 1852. This place also experienced an earthquake few years ago in which hundreds of houses collapsed. In 1883 & 1889 the Jhalawan Baluchistan earthquake inflicted large destruction in the area, but the record is not available. The earthquake of December 20, 1892 in Chaman area near Quetta Baluchistan was so strong that railway line was uprooted in 200 kms area where the shape of the ground was changed. On October 20, 1909, an earthquake of 7.0 magnitude was recorded in Sibbi & Loralai in which at-least One hundred people died and dozens of villages were destroyed.

Buner & Hazara experienced a very strong earthquake measuring 7.9 on Richter Scale on February 1, 1929 destroying many villages. The detail of loss is not available in the record books.

A strong earthquake measuring 7.0 on Richter scale shook Shareg, a village in Baluchistan on August 25, 1931 where many houses were damaged. No considerable loss of life was reported being a less populous area. A similar earthquake was felt in Machh, Baluchistan on August 27, 1931, but no considerable loss of life was reported. On 27th November 1945 a very strong earthquake of 7.9 magnitude generated Seismic waves killing about 2000 people on the coast of Mekran Balochistan, the casualties were comparatively less because the sea tides were in reseeding phase.

A 7.2 magnitude earthquake was also recorded in that area on August 5, 1947 but again no considerable loss of life was reported.

A strong earthquake took at least 5000 lives in Northeast of Malakand on 28th December 1974. The magnitude of this earthquake could not be calculated correctly. 220 people lost their lives in an earthquake in Gilgit on 12th September 1981. some parts of Pakistan along with Afghanistan and Central Asia states were affected by a few earthquake in the Hindukush region between the period from 1983 to 1993.

Another strong earthquake measuring 7.3 on Richter Scale shook Harnai Balochistan on 27th February 1997, killing about 50 people in Harnai, Quetta & Sibbi.. Gujarat state of India was jolted by an earthquake on 26th January 2001, which affected the adjoining Pakistan area also, killing 11000 people in Gujarat apart from 20 deaths in Pakistan area. A mild earthquake of 5.5 magnitude was recorded in Gilgit, Astore on 1st, 3rd and 21st November 2002. The death toll was

not high. Many other earthquakes of low magnitude have also been felt in Pakistan without registering heavy loss of life.

Under ground Dangerous sites in Pakistan (Faults)

Himalayan mountains emerged due to the collision of two big underground plates and the salt range along with outer portion of Himalaya slipped towards North. Consequently the underground plates changed their positions and many sensitive regions came into being. Pakistan has 9 such sites where the underground faults are believed to be existing. Following area are the locations of these faults.

1. The collision between Eurasian & Indian plates caused the emergence of Himalayan mountains along with underground fault. This fault line starts from Afghan border passing through Kohat, Taxila, Islamabad, Murree, Balakot and Muzzaferabad ends up in occupied Kashmir. An extension of this fault line also touches Bagh.
2. Indus Kohistan zone also lies on the Himalayan fault line where a strong earthquake can be experienced at any time.
3. The third big fault line is called "Panjal Fault" which is situated in vicinity of Qalandar of N. W. F. P. This fault is not considered to be an active fault.
4. A fault line starts from Mohmand Agency near Afghanistan entering Pakistan passing through Malakand, Dir and Swat terminates at Kohistan. It is not active in Pakistani area and there are no chances of any earthquake in the Pakistani area, but it is still active in Afghanistan.
5. There are many underground faults lying beneath the Hindukush and Pamir ranges on the Pak Afghan Border.
6. A fault also lies near Chaman, Baluchistan.
7. Panjab has also a fault near Hafizabad, which is an extension of a fault located in India.
8. There is a fault located in Suleman ranges on the border of NWFP and Baluchistan.
9. An Active fault exists in Runn of Kutch on the Indo-Pak border. The Gujarat earthquake of 2001 was the result of seismic activity due to this fault.

Chapter 3

Why Earthquake Occurs

An earthquake is a phenomenon that results from and is powered by the sudden release of stored energy that radiates seismic waves. At the Earth's surface, earthquakes may manifest themselves by a shaking or displacement of the ground and sometimes tsunamis, which may lead to loss of life and destruction of property.

Earthquakes may occur naturally or as a result of human activities. In its most generic sense, the word earthquake is used to describe any seismic event—whether a natural phenomenon or an event caused by humans—that generates seismic waves.

Most naturally occurring earthquakes are related to the tectonic nature of the Earth. Such earthquakes are called tectonic earthquakes. The Earth's lithosphere is a patch work of plates in slow but constant motion caused by the heat in the Earth's mantle and core. Plate boundaries glide past each other, creating frictional stress. When the frictional stress exceeds a critical value, called local strength, a sudden failure occurs. The boundary of tectonic plates along which failure occurs is called the fault plane. When the failure at the fault plane results in a violent displacement of the Earth's crust, the elastic strain energy is released and elastic waves are radiated, thus causing an earthquake. It is estimated that only 10 percent or less of an earthquake's total energy is ultimately radiated as seismic energy, while most of the earthquake's energy is used to power the earthquake fracture growth and is eventually converted into heat. Therefore, earthquakes lower the Earth's available potential energy and thermal energy, though these losses are negligible. To describe the physical process of occurrence of an earthquake, seismologists use the Elastic-rebound theory.

The majority of tectonic earthquakes originate at depths not exceeding a few tens of kilometers. Earthquakes occurring at boundaries of tectonic plates are called interplate earthquakes, while the less frequent events that occur in the interior of the lithospheric plates are called intraplate earthquakes.

Where the crust is thicker and colder, earthquakes occur at greater depths of hundreds of kilometers along subduction zones where plates descend into the

Earth's mantle. These types of earthquakes are called deep focus earthquakes. They are possibly generated when subducted lithospheric material catastrophically undergoes a phase transition (e.g., olivine to spinel), releasing stored energy—such as elastic strain, chemical energy or gravitational energy—that cannot be supported at the pressures and temperatures present at such depths.

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Earthquakes may also occur in volcanic regions and are caused by the movement of magma in volcanoes. Such quakes can be an early warning of volcanic eruptions.

A recently proposed theory suggests that some earthquakes may occur in a sort of earthquake storm, where one earthquake will trigger a series of earthquakes each triggered by the previous shifts on the fault lines, similar to aftershocks, but occurring years later, and with some of the later earthquakes as damaging as the early ones. Such a pattern was observed in the sequence of about a dozen earthquakes that struck the Anatolian Fault in Turkey in the 20th Century, the half dozen large earthquakes in New Madrid in 1811-1812, and has been inferred for older anomalous clusters of large earthquakes in the Middle East and in the Mojave Desert.

Earthquakes occur on a daily basis around the world, most detected only by seismometers and causing no damage. Large earthquakes however can cause serious destruction and massive loss of life through a variety of agents of damage, including fault rupture, vibratory ground motion (shaking), inundation (tsunami, seiche, or dam failure), various kinds of permanent ground failure (liquefaction, landslides), and fire or a release of hazardous materials, e.g. gas leaks or petrol leaks. In a particular earthquake, any of these agents of damage can dominate, and historically each has caused major damage and great loss of life; nonetheless, for most earthquakes shaking is the dominant and most widespread cause of damage.

Most large earthquakes are accompanied by other, smaller ones that can occur either before or after the main shock; these are called foreshocks and aftershocks, respectively. While almost all earthquakes have aftershocks, foreshocks occur in only about 10% of events. The power of an earthquake is always distributed over a significant area, but in large earthquakes, it can even spread over the entire planet. Ground motions caused by very distant earthquakes are called teleseisms. The Rayleigh waves from the Sumatra-Andaman Earthquake of 2004 caused ground motion of over 1 cm even at seismometers that were located far from it, although this displacement was abnormally large. Using such ground motion records from around the world, seismologists can identify a point from which the earthquake's seismic waves apparently originated. That point is called its focus or hypocenter and usually coincides with the point where the fault slip started. The location on the surface directly above the hypocenter is known as the epicenter. The total length of the section of a fault that slips, the rupture zone, can be as long as 250 km for the biggest earthquakes.

Tectonics Plates

Plate tectonics is a theory of geology which was developed to explain the observed evidence for large scale motions within the Earth's crust. The theory encompassed and superseded the older theory of continental drift from the first half of the 20th century and the concept of sea floor spreading developed during the 1960s.

The outermost part of the Earth's interior is made up of two layers: above is the lithosphere, comprising the crust and the rigid uppermost part of the mantle. Below the lithosphere lies the asthenosphere, which is a more viscous zone of the mantle. Although solid, the asthenosphere has very low shear strength and can flow like a liquid on geological time scales. The deeper mantle below the asthenosphere is more rigid again.

The lithosphere essentially floats on the asthenosphere. The lithosphere has broken up into what are called tectonic plates—in the case of Earth, there are ten major and many minor plates. These plates move in relation to one another at one of three types of plate boundaries: convergent, divergent, and transform. Earthquakes, volcanic activity, mountain-building, and oceanic trench formation occur along plate boundaries. The sideways movement of the plates is typically at a speed of several centimetres per year.

Plate tectonic theory is currently the theory accepted by the vast majority of scientists working in the geosciences. It arose out of and was preceded by early hypotheses associated with continental drift, and following the development of the mechanism of seafloor spreading, (for which the detection of magnetic anomalies distributed by a clear pattern of parallel stripes on the seafloor served as impressive evidence) plate tectonics quickly became a theory on the brink of scientific revolution. Simultaneous advances in early seismic imaging techniques in and around wadati-benioff zones collectively with numerous other geologic observations soon solidified plate tectonics as a theory with extraordinary explanatory and predictive power in subsequent decades (and continuing). Plate tectonics was developed during the late 1960s and has since been essentially universally accepted by scientists as predominant throughout all geoscientific disciplines. The theory has revolutionized the earth sciences because of its unifying and explanatory power for diverse geological phenomena.

The tectonic plates of the world were mapped in the second half of the 20th century. Rocks are also a part of Plate Tectonics because the formation of the rocks can differentiate changing. The division of the outer parts of the Earth's interior

into lithospheric and asthenospheric components is based on their mechanical differences. The lithosphere is cooler and more rigid, whilst the asthenosphere is hotter and mechanically weaker. This division should not be confused with the chemical subdivision of the Earth into (from innermost to outermost) core, mantle, and crust. The lithosphere contains both crust and some mantle. A given piece of mantle may be part of the lithosphere or the asthenosphere at different times, depending on its temperature, pressure and shear strength. The key principle of plate tectonics is that the lithosphere exists as separate and distinct tectonic plates, which float on the fluid-like (visco-elastic solid) asthenosphere. The relative fluidity of the asthenosphere allows the tectonic plates to undergo motion in different directions.

The plates are around 100 km (60 miles) thick and consist of lithospheric mantle overlain by either of two types of crustal material: oceanic crust (in older texts called sima from silicon and magnesium) and continental crust (sial from silicon and aluminium). The two types of crust differ in thickness, with continental crust considerably thicker than oceanic (50 km vs 5 km).

One plate meets another along a plate boundary, and plate boundaries are commonly associated with geological events such as earthquakes and the creation of topographic features like mountains, volcanoes and oceanic trenches. The majority of the world's active volcanoes occur along plate boundaries, with the Pacific Plate's Ring of Fire being most active and famous. These boundaries are discussed in further detail below.

Tectonic plates can include continental crust or oceanic crust, and typically, a single plate carries both. For example, the African Plate includes the continent and parts of the floor of the Atlantic and Indian Oceans. The distinction between continental crust and oceanic crust is based on the density of constituent materials; oceanic crust is denser than continental crust owing to their different proportions of various elements, particularly, silicon. Oceanic crust has less silicon and more heavier elements ("mafic") than continental crust ("felsic").

As a result, oceanic crust generally lies below sea level (for example most of the Pacific Plate), while the continental crust projects above sea.

Types of plate boundaries

Three types of plate boundaries exist, characterized by the way the plates move relative to each other. They are associated with different types of surface phenomena. The different types of plate boundaries are:

Transform boundaries occur where plates slide or, perhaps more accurately, grind past each other along transform faults. The relative motion of the two plates is either sinistral (left side toward the observer) or dextral (right side toward the observer).

Divergent boundaries occur where two plates slide apart from each other (examples of which can be seen at mid-ocean ridges and active zones of rifting (such as with the East Africa rift)).

Convergent boundaries (or active margins) occur where two plates slide towards each other commonly forming either a subduction zone (if one plate moves underneath the other) or a continental collision (if the two plates contain continental crust). Deep marine trenches are typically associated with subduction zones. Because of friction and heating of the subducting slab, volcanism is almost always closely linked. Examples of this are the Andes mountain range in South America and the Japanese island arc.

Transform (conservative) boundaries

The left- or right-lateral motion of one plate against another along transform faults can cause highly visible surface effects. Because of friction, the plates cannot simply glide past each other. Rather, stress builds up in both plates and when it reaches a level that exceeds the strain threshold of rocks on either side of the fault the accumulated potential energy is released as strain. Strain is both accumulative and instantaneous depending on the rheology of the rock; the ductile lower crust and mantle accumulates deformation gradually via shearing whereas the brittle upper crust reacts by fracture, or instantaneous stress release to cause motion along the fault. The ductile surface of the fault can also release instantaneously when the strain rate is too great. The energy released by instantaneous strain release is the cause of earthquakes, a common phenomenon along transform boundaries.

A good example of this type of plate boundary is the San Andreas Fault which is found in the western coast of North America and is one part of a highly complex system of faults in this area. At this location, the Pacific and North American plates move relative to each other such that the Pacific plate is moving northwest with respect to North America. Other examples of transform faults include the Alpine Fault in New Zealand and the North Anatolian Fault in Turkey. Transform faults are also found offsetting the crests of mid-ocean ridges (for example, the Mendocino Fracture Zone offshore northern California).

Divergent boundary

At divergent boundaries, two plates move apart from each other and the space that this creates is filled with new crustal material sourced from molten magma that forms below. The origin of new divergent boundaries at triple junctions is sometimes thought to be associated with the phenomenon known as hotspots. Here, exceedingly large convective cells bring very large quantities of hot asthenospheric material near the surface and the kinetic energy is thought to be sufficient to break apart the lithosphere. The hot spot which may have initiated the Mid-Atlantic Ridge system currently underlies Iceland which is widening at a rate of a few centimeters per century.

Divergent boundaries are typified in the oceanic lithosphere by the rifts of the oceanic ridge system, including the Mid-Atlantic Ridge and the East Pacific Rise, and in the continental lithosphere by rift valleys such as the famous East African Great Rift Valley. Divergent boundaries can create massive fault zones in the oceanic ridge system. Spreading is generally not uniform, so where spreading rates of adjacent ridge blocks are different massive transform faults occur. These are the fracture zones, many bearing names, that are a major source of submarine earthquakes. A sea floor map will show a rather strange pattern of blocky structures that are separated by linear features perpendicular to the ridge axis. If one views the sea floor between the fracture zones as conveyor belts carrying the ridge on each side of the rift away from the spreading center the action becomes clear. Crest depths of the old ridges, parallel to the current spreading center, will be older and deeper (from thermal contraction and subsidence).

It is at mid-ocean ridges that one of the key pieces of evidence forcing acceptance of the sea-floor spreading hypothesis was found. Airborne geomagnetic surveys showed a strange pattern of symmetrical magnetic reversals on opposite sides of ridge centers. The pattern was far too regular to be coincidental as the widths of the opposing bands were too closely matched. Scientists had been studying polar reversals and the link was made. The magnetic banding directly corresponds with the Earth's polar reversals. This was confirmed by measuring the ages of the rocks within each band. The banding furnishes a map in time and space of both spreading rate and polar reversals.

Convergent boundary

The nature of a convergent boundary depends on the type of lithosphere in the plates that are colliding. Where a dense oceanic plate collides with a less-dense continental plate, the oceanic plate is typically thrust underneath because of the

greater buoyancy of the continental lithosphere, forming a subduction zone. At the surface, the topographic expression is commonly an oceanic trench on the ocean side and a mountain range on the continental side. An example of a continental-oceanic subduction zone is the area along the western coast of South America where the oceanic Nazca Plate is being subducted beneath the continental South American Plate.

While the processes directly associated with the production of melts directly above downgoing plates producing surface volcanism is the subject of some debate in the geologic community, the general consensus from ongoing research suggests that the release of volatiles is the primary contributor. As the subducting plate descends, its temperature rises driving off volatiles (most importantly water) encased in the porous oceanic crust. As this water rises into the mantle of the overriding plate, it lowers the melting temperature of surrounding mantle, producing melts (magma) with large amounts of dissolved gases. These melts rise to the surface and are the source of some of the most explosive volcanism on earth because of their high volumes of extremely pressurized gases (consider Mount St. Helens). The melts rise to the surface and cool forming long chains of volcanoes inland from the continental shelf and parallel to it. The continental spine of western South America is dense with this type of volcanic mountain building from the subduction of the Nazca plate. In North America the Cascade mountain range, extending north from California's Sierra Nevada, is also of this type. Such volcanoes are characterized by alternating periods of quiet and episodic eruptions that start with explosive gas expulsion with fine particles of glassy volcanic ash and spongy cinders, followed by a rebuilding phase with hot magma. The entire Pacific Ocean boundary is surrounded by long stretches of volcanoes and is known collectively as The Ring of Fire.

Where two continental plates collide the plates either buckle and compress or one plate delves under or (in some cases) overrides the other. Either action will create extensive mountain ranges. The most dramatic effect seen is where the northern margin of the Indian Plate is being thrust under a portion of the Eurasian plate, lifting it and creating the Himalayas and the Tibetan Plateau beyond. It has also caused parts of the Asian continent to deform westward and eastward on either side of the collision.

When two plates with oceanic crust converge they typically create an island arc as one plate is subducted below the other. The arc is formed from volcanoes which erupt through the overriding plate as the descending plate melts below it. The arc shape occurs because of the spherical surface of the earth (nick the peel of an orange with a knife and note the arc formed by the straight-edge of the knife). A deep undersea trench is located in front of such arcs where the

descending slab dips downward. Good examples of this type of plate convergence would be Japan and the Aleutian Islands in Alaska.

Plates may collide at an oblique angle rather than head-on (e.g. one plate moving north, the other moving south-east), and this may cause strike-slip faulting along the collision zone, in addition to subduction.

Not all plate boundaries are easily defined. Some are broad belts whose movements are unclear to scientists. One example would be the Mediterranean-Alpine boundary, which involves two major plates and several micro plates. The boundaries of the plates do not necessarily coincide with those of the continents. For instance, the North American Plate covers not only North America, but also far eastern Siberia and northern Japan.

Driving forces of plate motion

Plates are able to move because of the relative weakness of the asthenosphere. Dissipation of heat from the mantle is acknowledged to be the original source of energy driving plate tectonics.

Two and three-dimensional imaging of the Earth's interior (seismic tomography) shows that there is a laterally heterogeneous density distribution throughout the mantle. Such density variations can be material (from rock chemistry), mineral (from variations in mineral structures), or thermal (through thermal expansion and contraction from heat energy). The manifestation of this lateral density heterogeneity is mantle convection from buoyancy forces. Tanimoto 2000. How mantle convection relates directly and indirectly to the motion of the plates is a matter of ongoing study and discussion in geodynamics. Somehow, this energy must be transferred to the lithosphere in order for tectonic plates to move. There are essentially two types of forces that are thought to influence plate motion: friction and gravity.

Friction

Basal drag

Large scale convection currents in the upper mantle are transmitted through the asthenosphere; motion is driven by friction between the asthenosphere and the lithosphere.

Slab suction

Local convection currents exert a downward frictional pull on plates in subduction zones at ocean trenches. Although, one could in effect argue that Slab-suction is actually merely a unique geodynamic setting wherein which basal tractions continue to act on the plate as it dives into the mantle (although perhaps to a greater extent -- acting on both the under and upper side of the slab).

Gravitation

Gravitational sliding

Plate motion is driven by the higher elevation of plates at ocean ridges. As oceanic lithosphere is formed at spreading ridges from hot mantle material it gradually cools and thickens with age (and thus distance from the ridge). Cool oceanic lithosphere is significantly denser than the hot mantle material from which it is derived and so with increasing thickness it gradually subsides into the mantle to compensate the greater load. The result is a slight lateral incline with distance from the ridge axis.

Casually in the geophysical community and more typically in the geological literature in lower education this process is often referred to as "ridge-push". This is, in fact, a misnomer as nothing is "pushing" and tensional features are dominant along ridges. It is more accurate to refer to this mechanism as gravitational sliding as variable topography across the totality of the plate can vary considerably and the topography of spreading ridges is only the most prominent feature. For example:

1. Flexural bulging of the lithosphere before it dives underneath an adjacent plate, for instance, produces a clear topographical feature that can offset or at least effect the influence of topographical ocean ridges.
2. Mantle plumes impinging on the underside of tectonic plates can drastically alter the topography of the ocean floor.

Plate motion is driven by the weight of cold, dense plates sinking into the mantle at trenches. There is considerable evidence that convection is occurring in the mantle at some scale. The upwelling of material at mid-ocean ridges is almost certainly part of this convection. Some early models of plate tectonics envisioned the plates riding on top of convection cells like conveyor belts. However, most scientists working today believe that the asthenosphere is not strong enough to directly cause motion by the friction of such basal forces. Slab pull is most widely

thought to be the greatest force acting on the plates. Recent models indicate that trench suction plays an important role as well. However, it should be noted that the North American Plate, for instance, is nowhere being subducted, yet it is in motion. Likewise the African, Eurasian and Antarctic Plates. The over-all driving force for plate motion and its energy source remain subjects of on-going research.

In a study published in the January-February 2006 issue of the Geological Society of America Bulletin, a team of Italian and U.S. scientists argued that the westward component of plates is from Earth's rotation and consequent tidal friction of the moon. As the Earth spins eastward beneath the moon, they say, the moon's gravity ever so slightly pulls the Earth's surface layer back westward. It has also been suggested (albeit, controversially) that this observation may also explain why Venus and Mars have no plate tectonics since Venus has no moon, and Mars' moons are too small to have significant tidal effects on Mars. [1] This is not a new argument, however.

It was originally raised by the "father" of the plate tectonics hypothesis, Alfred Wegener. It was challenged by the physicist Harold Jeffreys who calculated that the magnitude of tidal friction required would have quickly brought the Earth's rotation to a halt long ago. Many plates are moving north and eastward (not west), and the dominantly westward motion of the Pacific ocean basins is simply from the eastward bias of the Pacific spreading center (which is not a predicted manifestation of such lunar forces). It is argued, however, that relative to the lower mantle, there is a slight westward component in the motions of all the plates.

Plate motion based on Global Positioning System (GPS) satellite data from NASA JPL. Vectors show direction and magnitude of motion. Because of basic physical laws, all of these forces must be acting on the plates. However, therein remains the question of to what degree of influence each process contributes to the motion of the plates. One method of dealing with this problem is to consider the relative rate at which each plate is moving, since the diversity of geodynamic settings and properties of each plate must clearly result in differences in the degree to which such processes are actively driving the plates. For this reason geoscientists have characterized such differences of the plates in an attempt to find correlations in relative plate velocity -- and such correlations are found, indeed. One of the most significant correlations found is that lithospheric plates attached to downgoing (subducting) plates move much faster than plates not attached to subducting plates. The Pacific plate, for instance, is essentially surrounded by zones of subduction (the so-called Ring of Fire) and moves much faster than the plates of the Atlantic basin, which are attached (perhaps one could say 'welded') to adjacent continents instead of subducting plates. It is thus thought that forces associated with the downgoing plate (slab pull and slab

suction) are the big players that determine the motion of plates. The driving forces of plate motion are, nevertheless, still very active subjects of on-going discussion and research in the geophysical community.

Major plates

1. African Plate, covering Africa - Continental plate
2. Antarctic Plate, covering Antarctica - Continental plate
3. Australian Plate, covering Australia (fused with Indian Plate between 50 and 55 million years ago) - Continental plate
4. Eurasian Plate covering Asia - Continental plate
5. North American Plate covering North America and north-east Siberia - Continental plate
6. South American Plate covering South America - Continental plate
7. Pacific Plate, covering the Pacific Ocean - Oceanic plate
8. Notable minor plates include the Indian Plate, the Arabian Plate, the Caribbean Plate, the Juan de Fuca Plate and the Scotia Plate.

The movement of plates has caused the formation and break-up of continents over time, including occasional formation of a supercontinent that contains most or all of the continents. The supercontinent Rodinia is thought to have formed about 1000 million years ago and to have embodied most or all of Earth's continents, and broken up into eight continents around 600 million years ago. The eight continents later re-assembled into another supercontinent called Pangaea; Pangaea eventually broke up into Laurasia (which became North America and Eurasia) and Gondwana (which became the remaining continents).

Sensitive Areas

The Pacific Ring of Fire is a zone of frequent earthquakes and volcanic eruptions encircling the basin of the Pacific Ocean. In a 40,000 km horseshoe shape, it is associated with a nearly continuous series of oceanic trenches, island arcs, and volcanic mountain ranges and/or plate movements. It is sometimes called the circum-Pacific belt or the circum-Pacific seismic belt.

90% of the world's earthquakes and 81% of the world's largest earthquakes occur along the Ring of Fire. The next most seismic region (5–6% of earthquakes and 17% of the world's largest earthquakes) is the Alpide belt which extends from Java to Sumatra through the Himalayas, the Mediterranean, and out into the Atlantic. The Mid-Atlantic Ridge is the third most prominent earthquake belt.

The Ring of Fire is a direct consequence of plate tectonics and the movement and collisions of crustal plates. The eastern section of the ring is the result of the Nazca Plate and the Cocos Plate being subducted beneath the westward moving South American Plate. A portion of the Pacific Plate along with the small Juan de Fuca Plate are being subducted beneath the North American Plate. Along the northern portion the northwestward moving Pacific plate is being subducted beneath the Aleutian Islands arc. Further west the Pacific plate is being subducted along the Kamchatka–Kurile Islands arcs on south past Japan. The southern portion is more complex with a number of smaller tectonic plates in collision with the Pacific plate from the Mariana Islands, the Philippines, Bougainville, Tonga, and New Zealand. Indonesia lies between the Ring of Fire along the northeastern islands adjacent to and including New Guinea and the Alpide belt along the south and west from Sumatra, Java, Bali, Flores, and Timor. The famous and very active San Andreas Fault zone of California is a transform fault which offsets a portion of the East Pacific Rise under southwestern United States and Mexico. The motion of the fault generates numerous small earthquakes, at multiple times a day, most of which are too small to be felt. The December 2004 earthquake just off the coast of Sumatra was actually a part of the Alpide belt.

What Is Seismology?

Seismology is the study of earthquakes and seismic waves that move through and around the earth. A seismologist is a scientist who studies earthquakes and seismic waves.

What Are Seismic Waves?

Seismic waves are the waves of energy caused by the sudden breaking of rock within the earth or an explosion. They are the energy that travels through the earth and is recorded on seismographs.

Types of Seismic Waves

There are several different kinds of seismic waves, and they all move in different ways. The two main types of waves are body waves and surface waves. Body waves can travel through the earth's inner layers, but surface waves can only move along the surface of the planet like ripples on water. Earthquakes radiate seismic energy as both body and surface waves.

Body Waves

P Waves

The first kind of body wave is the P wave or primary wave. This is the fastest kind of seismic wave. The P wave can move through solid rock and fluids, like water or the liquid layers of the earth. It pushes and pulls the rock it moves through just like sound waves push and pull the air. Have you ever heard a big clap of thunder and heard the windows rattle at the same time? The windows rattle because the sound waves were pushing and pulling on the window glass much like P waves push and pull on rock. Sometimes animals can hear the P waves of an earthquake. Usually we only feel the bump and rattle of these waves.

S Waves

The second type of body wave is the S wave or secondary wave, which is the second wave you feel in an earthquake. An S wave is slower than a P wave and can only move through solid rock. This wave moves rock up and down, or side-to-side.

Surface Waves

Love Waves

The first kind of surface wave is called a Love wave, named after A.E.H. Love, a British mathematician who worked out the mathematical model for this kind of wave in 1911. It's the fastest surface wave and moves the ground from side-to-side.

Rayleigh Waves

The other kind of surface wave is the Rayleigh wave, named for John William Strutt, Lord Rayleigh, who mathematically predicted the existence of this kind of wave in 1885. A Rayleigh wave rolls along the ground just like a wave rolls across a lake or an ocean. Because it rolls, it moves the ground up and down, and side-to-side in the same direction that the wave is moving. Most of the shaking felt from an earthquake is due to the Rayleigh wave, which can be much larger than the other waves.

(2 PAGES FOR WAVES – GRAPHS)

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Chapter 4

Types of Earthquake

Tectonic Earthquakes

Tectonic earthquakes are triggered when the crust becomes subjected to strain, and eventually moves. The theory of plate tectonics explains how the crust of the Earth is made of several plates, large areas of crust which float on the Mantle. Since these plates are free to slowly move, they can either drift towards each other, away from each other or slide past each other. Many of the earthquakes which we feel are located in the areas where plates collide or try to slide past each other.

The process which explains these earthquakes, known as Elastic Rebound Theory can be demonstrated with a green twig or branch. Holding both ends, the twig can be slowly bent. As it is bent, energy is built up within it. A point will be reached where the twig suddenly snaps. At this moment the energy within the twig has exceeded the Elastic Limit of the twig. As it snaps the energy is released, causing the twig to vibrate and to produce sound waves.

Perhaps the most famous example of plates sliding past each other is the San Andreas Fault in California. Here, two plates, the Pacific Plate and the North American Plate, are both moving in a roughly northwesterly direction, but one is moving faster than the other. The San Francisco area is subjected to hundreds of small earthquakes every year as the two plates grind against each other. Occasionally, as in 1989, a much larger movement occurs, triggering a far more violent 'quake'.

Major earthquakes are sometimes preceded by a period of changed activity. This might take the form of more frequent minor shocks as the rocks begin to move, called foreshocks, or a period of less frequent shocks as the two rock masses temporarily 'stick' and become locked together. Detailed surveys in San Francisco have shown that railway lines, fences and other longitudinal features very slowly become deformed as the pressure builds up in the rocks, then become noticeably offset when a movement occurs along the fault. Following the

main shock, there may be further movements, called aftershocks, which occur as the rock masses 'settle down' in their new positions. Such aftershocks cause problems for rescue services, bringing down buildings already weakened by the main earthquake.

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(MAPS CONVERGeNS)

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2. Volcanic Earthquakes

Volcanic earthquakes are far less common than Tectonic ones. They are triggered by the explosive eruption of a volcano. Given that not all volcanoes are prone to violent eruption, and that most are 'quiet' for the majority of the time, it is not surprising to find that they are comparatively rare.

When a volcano explodes, it is likely that the associated earthquake effects will be confined to an area 10 to 20 miles around its base, whereas a tectonic earthquake may be felt around the globe.

The volcanoes which are most likely to explode violently are those which produce acidic lava. Acidic lava cools and sets very quickly upon contact with the air. This tends to clog the volcanic vent and block the further escape of pressure. For example, in the case of Mt Pelee, the lava solidified before it could flow down the sides of the volcano. Instead it formed a spine of solid rock within the volcano vent. The only way in which such a blockage can be removed is by the build up of pressure to the point at which the blockage is literally exploded out of the way. In reality, the weakest part of the volcano will be the part which gives way, sometimes leading to a sideways explosion as in the Mt St. Helens eruption.

When extraordinary levels of pressure develop, the resultant explosion can be devastating, producing an earthquake of considerable magnitude. When Krakatoa (Indonesia, between Java and Sumatra) exploded in 1883, the explosion was heard over 5000 km away in Australia. The shockwaves produced a series of tsunamis (large sea waves), one of which was over 36m high; that's the same as four, two story houses stacked on top of each other. These swept over the coastal areas of Java and Sumatra killing over 36,000 people.

By contrast, volcanoes producing free flowing basic lava rarely cause earthquakes. The lava flows freely out of the vent and down the sides of the volcano, releasing pressure evenly and constantly. Since pressure doesn't build up, violent explosions do not occur.

3- Tsunami

A tsunami is a series of waves when a body of water, such as an ocean is rapidly displaced on a massive scale. Earthquakes, mass movements above or below water, volcanic eruptions and other underwater explosions, landslides and large meteorite impacts all have the potential to generate a tsunami. The effects of a tsunami can range from unnoticeable to devastating.

The term tsunami comes from the Japanese language meaning harbour and wave. Although in Japanese tsunami is used for both the singular and plural, in English tsunamis is often used as the plural. The term was created by fishermen who returned to port to find the area surrounding their harbour devastated, although they had not been aware of any wave in the open water. Tsunamis are common throughout Japanese history, as 195 events in Japan have been recorded.

A tsunami has a much smaller amplitude (wave heights) offshore, and a very long wavelength (often hundreds of kilometres long), which is why they generally pass unnoticed at sea, forming only a passing "hump" in the ocean.

Tsunamis have been historically referred to as tidal waves because as they approach land, they take on the characteristics of a violent onrushing tide rather than the sort of cresting waves that are formed by wind action upon the ocean (with which people are more familiar). Since they are not actually related to tides the term is considered misleading and its usage discouraged by oceanographers. However, since not all tsunamis occur in harbours, that term is equally misleading, although it does have the benefit of being misleading in a different language.

Tsunami History

- 6.1 1700 - Vancouver Island, Canada
- 6.2 1755 - Lisbon, Portugal
- 6.3 1868 - Hawaiian local tsunami generated by earthquake
- 6.4 1883 - Krakatoa explosive eruption
- 6.5 1917 - Halifax Explosion and Tsunami
- 6.6 1929 - Newfoundland tsunami
- 6.7 1946 - Pacific tsunami
- 6.8 1960 - Chilean tsunami
- 6.9 1963 - Vajont Dam disaster
- 6.10 1964 - Good Friday tsunami
- 6.11 1976 - Moro Gulf tsunami
- 6.12 1979 - Tumaco tsunami
- 6.13 1993 - Okushiri tsunami
- 6.14 2004 - Indian Ocean tsunami
- 6.15 2006 - South of Java Island tsunami

Causes

Generation of a tsunamiTsunamis can be generated when the sea floor abruptly deforms and vertically displaces the overlying water. Such large vertical movements of the Earth's crust can occur at plate boundaries. Subduction earthquakes are particularly effective in generating tsunamis. As an Oceanic Plate is subducted beneath a Continental Plate, it sometimes brings down the lip of the Continental with it. Eventually, too much stress is put on the lip and it snaps back, sending shockwaves through the Earth's crust, causing a tremor under the sea, known as an Undersea Earthquake.

Sub-marine landslides (which are sometimes triggered by large earthquakes) as well as collapses of volcanic edifices may also disturb the overlying water column as sediment and rocks slide downslope and are redistributed across the sea floor. Similarly, a violent submarine volcanic eruption can uplift the water column and form a tsunami.

Tsunamis are surface gravity waves that are formed as the displaced water mass moves under the influence of gravity and radiate across the ocean like ripples on a pond.

In the 1950s it was discovered that larger tsunamis than previously believed possible could be caused by landslides, explosive volcanic action and impact events. These phenomena rapidly displace large volumes of water, as energy from falling debris or expansion is transferred to the water into which the debris falls. Tsunamis caused by these mechanisms, unlike the ocean-wide tsunamis caused by some earthquakes, generally dissipate quickly and rarely affect coastlines distant from the source due to the small area of sea affected. These events can give rise to much larger local shock waves (solitons), such as the landslide at the head of Lituya Bay which produced a water wave estimated at 50 - 150 m and reached 524 m up local mountains. However, an extremely large landslide could generate a megatsunami that might have ocean-wide impacts.

Characteristics

There is a common misconception that tsunamis behave like wind-driven waves or swells (with air behind them, as in this celebrated 19th century woodcut by Hokusai). In fact, a tsunami is better understood as a new and suddenly higher sea level, which manifests as a shelf or shelves of water. The leading edge of a tsunami superficially resembles a breaking wave but behaves differently: the rapid rise in sea level, combined with the weight and pressure of the ocean behind it, has far greater force. Often referred to as "tidal waves", a tsunami does

not look like the popular impression of "a normal wave only much bigger". Instead it looks rather like an endlessly onrushing tide which forces its way around and through any obstacle. Most of the damage is caused by the huge mass of water behind the initial wave front, as the height of the sea keeps rising fast and floods powerfully into the coastal area. The sheer weight of water is enough to pulverise objects in its path, often reducing buildings to their foundations and scouring exposed ground to the bedrock. Large objects such as ships and boulders can be carried several miles inland before the tsunami subsides.

Tsunamis act very differently from typical surf swells: they contain immense energy, propagate at high speeds and can travel great trans-oceanic distances with little overall energy loss. A tsunami can cause damage thousands of kilometres from its origin, so there may be several hours between its creation and its impact on a coast, arriving long after the seismic wave generated by the originating event arrives. Although the total or overall loss of energy is small, the total energy is spread over a larger and larger circumference as the wave travels. The energy per linear metre in the wave is proportional to the inverse of the distance from the source. This is the two-dimensional equivalent of the inverse square law, which is followed by waves which propagate in three dimensions.

A single tsunami event may involve a series of waves of varying heights; so the set of waves is called a train. In open water, tsunamis have extremely long periods (the time for the next wave top to pass a point after the previous one), from minutes to hours, and long wavelengths of up to several hundred kilometres. This is very different from typical wind-generated swells on the ocean, which might have a period of about 10 seconds and a wavelength of 150 metres.

The height of a tsunami wave in open water is often less than one metre, and the height is spread over the wavelength of the tsunami which is multiple kilometres. This is unnoticeable to people on ships in deep water. Because it has such a large wavelength, the energy of a tsunami mobilizes the entire water column down to the sea bed. Typical ocean surface waves in deep water cause water motion to a depth equal to half their wavelength. This means, ocean surface wave motion will only reach down to a depth of a few 100 m or less. Tsunamis, by contrast behave as 'shallow water waves' in the deep ocean.

Because a Tsunami behaves like a 'shallow water wave,' its speed is based on the depth of the water. Typically, a tsunami wave will travel across a deep ocean at an average speed of 400 to 500 mph. As the wave approaches land, the sea shallows and the tsunami wave no longer travels as quickly, so it begins to 'pile-up'; the wave-front becomes steeper and taller, and there is less distance between

crests. While a person at the surface of deep water would probably not even notice the tsunami, the wave can increase to a height of six stories or more as it approaches the coastline and compresses. The steepening process is analogous to the cracking of a tapered whip. As a wave goes down the whip from handle to tip, the same energy is deposited in less and less material, which then moves more violently as it receives this energy.

A wave becomes a 'shallow-water wave' when the ratio between the water depth and its wavelength gets very small, and since a tsunami has an extremely large wavelength (hundreds of kilometres), tsunamis act as a shallow-water wave even in deep oceanic water. Shallow-water waves move at a speed that is equal to the square root of the product of the acceleration of gravity (9.8 m/s^2) and the water depth. For example, in the Pacific Ocean, where the typical water depth is about 4000 m, a tsunami travels at about 200 m/s (720 km/h or 450 mi/h) with little energy loss, even over long distances. At a water depth of 40 m, the speed would be 20 m/s (about 72 km/h or 45 mi/h), which is much slower than the speed in the open ocean but the wave would still be difficult to outrun.

Tsunamis propagate outward from their source, so coasts in the "shadow" of affected land masses are usually fairly safe. However, tsunami waves can diffract around land masses (as shown in this Indian Ocean tsunami animation as the waves reach southern Sri Lanka and India). It's also not necessary that they are symmetrical; tsunami waves may be much stronger in one direction than another, depending on the nature of the source and the surrounding geography.

Local geographic peculiarities can lead to seiche or standing waves forming, which can amplify the onshore damage. For instance, the tsunami that hit Hawaii on April 1, 1946 had a fifteen-minute interval between wave fronts. The natural resonant period of Hilo Bay is about thirty minutes. That meant that every second wave was in phase with the motion of Hilo Bay, creating a seiche in the bay. As a result, Hilo suffered worse damage than any other place in Hawaii, with the tsunami/seiche reaching a height of 14 m and killing 159 inhabitants.

4. Human Causes

Some earthquakes have anthropogenic sources, such as extraction of minerals and fossil fuel from the Earth's crust, the removal or injection of fluids into the crust, reservoir-induced seismicity, massive explosions, and collapse of large buildings. Seismic events caused by human activity are referred to by the term induced seismicity. They however are not strictly earthquakes and usually show a different seismogram than earthquakes that occur naturally.

A rare few earthquakes have been associated with the build-up of large masses of water behind dams, such as the Kariba Dam in Zambia, Africa, and with the injection or extraction of fluids into the Earth's crust (e.g. at certain geothermal power plants and at the Rocky Mountain Arsenal). Such earthquakes occur because the strength of the Earth's crust can be modified by fluid pressure. Earthquakes have also been known to be caused by the removal of natural gas from subsurface deposits, for instance in the northern Netherlands. The world's largest reservoir-induced earthquake occurred on December 10, 1967 in the Koyna region of western Maharashtra in India. It had a magnitude of 6.3 on the Richter scale. However, the U.S. geological survey reported the magnitude of 6.8.

The detonation of powerful explosives, such as nuclear explosions, can cause low-magnitude ground shaking. Thus, the 50-megaton nuclear bomb code-named Ivan detonated by the Soviet Union in 1961 created a seismic event comparable to a magnitude 7 earthquake, producing the seismic shock so powerful that it was measurable even on its third passage around the Earth. In an effort to promote nuclear non-proliferation, the International Atomic Energy Agency uses the tools of seismology to detect illicit activities such as nuclear weapons tests. The nuclear nations routinely monitor each other's activities through networks of interconnected seismometers, which allow to precisely locate the source of an explosion.

Sports games have been known to inadvertently produce microearthquakes. This phenomenon was first seen in 1988 with the Earthquake Game at Louisiana State University, in which fans stamped their feet and jumped up and down vigorously enough to have the effect register on the campus seismograph.

Chapter 5

How Are Earthquake Magnitudes Measured?

Seismograph

A seismograph is the device that scientists use to measure earthquakes. The goal of a seismograph is to accurately record the motion of the ground during a quake. If you live in a city, you may have noticed that buildings sometimes shake when a big truck or a subway train rolls by. Good seismographs are therefore isolated and connected to bedrock to prevent this sort of "data pollution."

The main problem that must be solved in creating a seismograph is that when the ground shakes, so does the instrument. Therefore, most seismographs involve a large mass of some sort. You could make a very simple seismograph by hanging a large weight from a rope over a table. By attaching a pen to the weight and taping a piece of paper to the table so that the pen can draw on the paper, you could record tremors in the Earth's crust (earthquakes). If you used a roll of paper and a motor that slowly pulled the paper across the table, you would be able to record tremors over time. However, it would take a pretty large tremor for you to see anything. In a real seismograph, levers or electronics are used to magnify the signal so that very small tremors are detectable. A big mechanical seismograph may have a weight attached that weighs 1,000 pounds (450 kg) or more, and it drives a set of levers that significantly magnify the pen's motion.

The Richter Scale

The magnitude of most earthquakes is measured on the Richter scale, invented by Charles F. Richter in 1934. The Richter magnitude is calculated from the amplitude of the largest seismic wave recorded for the earthquake, no matter what type of wave was the strongest.

The Richter magnitudes are based on a logarithmic scale (base 10). What this means is that for each whole number you go up on the Richter scale, the amplitude of the ground motion recorded by a seismograph goes up ten times. Using this scale, a magnitude 5 earthquake would result in ten times the level of ground shaking as a magnitude 4 earthquake (and 32 times as much energy

would be released). To give you an idea how these numbers can add up, think of it in terms of the energy released by explosives: a magnitude 1 seismic wave releases as much energy as blowing up 6 ounces of TNT. A magnitude 8 earthquake releases as much energy as detonating 6 million tons of TNT. Pretty impressive, huh? Fortunately, most of the earthquakes that occur each year are magnitude 2.5 or less, too small to be felt by most people.

Although Richter originally proposed this way of measuring an earthquake's "size," he only used a certain type of seismograph and measured shallow earthquakes in Southern California. Scientists have now made other "magnitude" scales, all calibrated to Richter's original method, to use a variety of seismographs and measure the depths of earthquakes of all sizes.

Here's a table describing the magnitudes of earthquakes, their effects, and the estimated number of those earthquakes that occur each year.

Earthquake Magnitude Scale

Magnitude Number	Earthquake Effects	Estimated Each Year
2.5 or less	Usually not felt, but can be recorded by seismograph.	900,000
2.5 to 5.4	Often felt, but only causes minor damage.	30,000
5.5 to 6.0	Slight damage to buildings and other structures.	500
6.1 to 6.9	May cause a lot of damage in very populated areas.	100
7.0 to 7.9	Major earthquake. Serious damage.	20
8.0 or greater	Great earthquake. Can totally destroy communities near the epicenter. One every 5 to 10 years	

Earthquake Magnitude Classes

Earthquakes are also classified in categories ranging from minor to great, depending on their magnitude.

Class	Magnitude
Great	8 or more
Major	7 - 7.9
Strong	6 - 6.9
Moderate	5 - 5.9
Light	4 - 4.9
Minor	3 - 3.9

The Mercalli Scale

Giuseppe Mercalli (From Walker, 1982) Another way to measure the strength of an earthquake is to use the Mercalli scale. Invented by Giuseppe Mercalli in 1902, this scale uses the observations of the people who experienced the earthquake to estimate its intensity.

The Mercalli scale isn't considered as scientific as the Richter scale, though. Some witnesses of the earthquake might exaggerate just how bad things were during the earthquake and you may not find two witnesses who agree on what happened; everybody will say something different. The amount of damage caused by the earthquake may not accurately record how strong it was either.

Some things that affect the amount of damage that occurs are

- * the building designs,
- * the distance from the epicenter,
- * and the type of surface material (rock or dirt) the buildings rest on.

Different building designs hold up differently in an earthquake and the further you are from the earthquake, the less damage you'll usually see. Whether a building is built on solid rock or sand makes a big difference in how much damage it takes. Solid rock usually shakes less than sand, so a building built on top of solid rock shouldn't be as damaged as it might if it was sitting on a sandy lot.

Modified Mercalli Intensity Scale

Mercalli Intensity Magnitude Witness Observations
(at epicenter)

I	1 to 2	Felt by very few people; barely noticeable.
II	2 to 3	Felt by a few people, especially on upper floors.
III	3 to 4	Noticeable indoors, especially on upperfloors, but may not be recognized as an earthquake.
IV	4	Felt by many indoors, few outdoors. May feel like heavy truck passing by.
V	4 to 5	Felt by almost everyone, some people awakened. Small objects moved. Trees and poles may shake.
VI	5 to 6	Felt by everyone. Difficult to stand. Some heavy furniture moved, some plaster falls. Chimneys may be slightly damaged.
VII	6	Slight to moderate damage in well built, ordinary structures. Considerable damage to poorly built structures. Some walls may fall.

VIII	6 to 7	Little damage in specially built structures. Considerable damage to ordinary buildings, severe damage to poorly built structures. Some walls collapse.
IX	7	Considerable damage to specially built structures, buildings shifted off foundations. Ground cracked noticeably. Wholesale destruction. Landslides.
X	7 to 8	Most masonry and frame structures and their foundations destroyed. Ground badly cracked. Landslides. Wholesale destruction.
XI	8	Total damage. Few, if any, structures standing. Bridges destroyed. Wide cracks in ground. Waves seen on ground.
XII	8 or greater	Total damage. Waves seen on ground. Objects thrown up into air.

Earthquake prediction

An earthquake prediction is a prediction that an earthquake in a specific magnitude range will occur in a specific region and time window. Seismologists are not currently able to predict earthquakes with such accuracy, though the early results of the Demeter satellite suggest that this could become possible; instead they focus on calculating the seismic hazards of a region by estimating the probabilities that a given earthquake or suite of earthquakes will occur.

Controversy in trying to predict earthquakes

With regard to earthquake prediction, people have tried to associate an impending earthquake with such potential precursors as seismicity patterns, electromagnetic fields, weather conditions and unusual clouds, radon or hydrogen gas content of soil or ground water, water level in wells, animal behavior, and so on - thereby hoping that the observed seismicity foreshadows its destruction by such observable phenomena.

Thus far, controversy has arisen because most conclusions have been made from a small data set, sometimes without well-understood physical phenomenon in mind to explain the claims. This is particularly a problem when the data set is noisy or there are questions regarding how it is gathered. A meaningful earthquake prediction must have all the following elements:

Specific area

Specific magnitude or magnitude range

Specific time window

Estimate of probability compared to random chance

A physical basis

Earthquake Prediction in China

Chinese earthquake prediction research is largely based on unusual events before earthquakes, such as change of ground water levels, strange animal behavior and foreshocks. They successfully predicted the February 4, 1975 M7.3 Haicheng Earthquake and the China State Seismological Bureau ordered an evacuation of 1 million people the day before the earthquake, but failed to predict the July 28, 1976 M7.8 Tangshan earthquake. This failure put Chinese earthquake prediction research in doubt for several years.

Chinese research has now merged with western research, but traditional techniques are still common. Another successful prediction of the November 29, 1999, M5.4 Gushan-Pianling Earthquake in Haicheng city and Xiuyan city, Liaoning Province, China was made a week before the earthquake. No fatalities or injuries were reported.

Demeter microsatellite

The CNES satellite has made observations which show strong correlations between certain types of low frequency electromagnetic activity and the seismically most active zones on the Earth, and have shown a sharp signal in the ionospheric electron density and temperature near southern Japan seven days before a 7.1 magnitude occurred there (on August 29 and September 5, 2004, respectively).

Animal behavior

Animals can detect the P-wave or ultrasonic wave generated by a big underground explosion or the rupture of an earthquake, even if the waves are too small for humans' senses. These waves travel faster than the S-wave earthquake wave that most strongly shakes the ground and causes the most damage. When this happens, animals can detect the incoming earthquake wave, and start behaving agitatedly or nervously, the same way a human would behave if they heard a loud explosion right outside their house.

Others postulate that the animal behavior is simply their response to an increase in low-frequency electromagnetic signals. The University of Colorado has demonstrated that electromagnetic activity can be generated by the fracturing of crystalline rock. Such activity occurs in fault lines before earthquakes. According to recent research, electromagnetic sensors yield statistically valid results in

predicting earthquakes - modern science's answer to centuries of human observation of animals.

Some people believe that in these ways, animals sense the immediate onset of earthquakes. In support of this claim, instances are cited when people have witnessed flight of animals just before an earthquake disaster. In fact, according to the Chief conservator of forests for the Indian state of Tamil Nadu, a few minutes before the killer tsunami waves generated by an underwater earthquake hit the Indian coastline in December 2004, a 500-strong herd of blackbucks rushed away from the coastal areas to the safety of a nearby hilltop. Since the beginning of recorded history, observations of unusual animal behavior before earthquakes have been recorded by people from almost all civilizations. The Chinese began a systematic study of this unusual animal behavior and in December 1974 predicted a major earthquake that did, in fact, occur in February 1975. But skeptics claim to debunk nearly all such observations. In fact, the 1975 prediction relied most heavily on a series of strong foreshocks. The animal behavior reports are often ambiguous and not consistently observed. There is little evidence for animals being able to sense impending earthquakes, although it is likely they can sense the initial, weaker P-waves before people. Seismometers remain much more sensitive than even the animals, however.

In folklore, some animals have had more reports of being able to predict quakes than others. Likely: Dogs, cats, chickens and other smaller animals. There have been reports with elephants, too. Unlikely: Goats, horses, cows, and larger animals.

Japan has a long tradition associating catfish with earthquake prediction. From this idea emerged a long university research programme concluding in 2004 in which it was proposed that the (established) high sensitivity of catfish to electric fields was involved in detecting fields of a few hertz because of piezoelectric effects on deeply buried quartz crystals. Actual monitoring of catfish and correlation with earthquakes gave results that are not promising.

Other predictions

In early 2004, a group of scientists at the University of California, Los Angeles, lead by Dr. Vladimir Keilis-Borok, predicted that a quake similar in strength to the San Simeon earthquake would occur in a 12,000 square mile (31,100 km) area of Southern California by September of that year. The odds were given as 50/50.

In April 2004, the California Earthquake Prediction Evaluation Council (CEPEC) evaluated Keilis-Borok's prediction and reported to the California State Office of Emergency Services. CEPEC concluded that the "uncertainty along with the large

geographic area included in the prediction (about 12,400 square miles) leads (us) to conclude that the results do not at this time warrant any special policy actions in California." The predicted time window came and went with no significant earthquake.

Based on the historic record of the various published efforts to predict a quake, one might conclude that earthquake prediction is usually imprecise, but remains an art that is scientifically and socially useful.

According to new research to be published by Prof. Shlomo Havlin, of Bar-Ilan University's Department of Physics, earthquakes form patterns which can improve the ability to predict the timing of their recurrence. In November 2005 (Nov 11 issue) the journal *Physical Review Letters*, published by the American Physical Society, published an article by researchers from Israel and Germany that say that there is a way to predict when the next earthquake will hit.

Prof. Shlomi Havlin's from Bar-Ilan University in Israel, in collaboration with Prof. Armin Bunde, of the Justus-Liebig University in Giessen, Germany, and Bar-Ilan University graduate student Valerie Livina used the "scaling" approach from physics to develop a mathematical function to characterize earthquakes of a wide range of magnitudes in order to learn from smaller magnitude earthquakes about larger magnitude earthquakes. The team's findings reveal that the recurrence of earthquakes is strongly dependent on the recurrence times of previous earthquakes.

This memory effect not only provides a clue to understanding the observed clustering of earthquakes, but also suggests that delays in earthquake occurrences, as seen today in Tokyo and in San Francisco, are a natural phenomenon.

In another paper in the journal *Nature*, Richard Allen of the University of California claims that the distinction between small and large earthquakes can be made from the very first seconds of seismic energy recorded by seismometers, though other scientists are not convinced.[8] If correct this may make earthquake early warning (as distinct from prediction) possible.

Loma Prieta, California

From 1968 to 1988 scientists in California mapped seismic activity on a cross section of the fault lines. They identified a big "seismic gap" in the Loma Prieta area where no earth shaking had occurred during the study. They therefore concluded that Loma Prieta was due for an earthquake. On 17 October 1989 the

Loma Prieta earthquake occurred, measuring 7.1 and causing 63 deaths. This prediction, however was not very useful as it could not predict the exact date.

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Chapter 6

Earthquake Precautionary Measures Before the Quake

Develop a family earthquake plan. Prepare yourself, your family and your home by completing the activities on this checklist. Decide how and where your family will reunite if separate. Choose an out-of-state friend or relative that separated family members can call after the quake to report their whereabouts and condition. Conduct practice drills. Physically place yourself in safe locations. Keep a list of emergency phone numbers.

Learn first aid and CPR (cardiopulmonary resuscitation) from your local Red Cross chapter or other community organization.

Know the safe spots in each room: under sturdy tables, desks, or against inside walls.

Know the danger spots: windows, mirrors, hanging objects, fireplaces and tall, unsecured furniture, hanging plants.

Learn how to shut off gas, water and electricity in case the lines are damaged. Consider automatic gas shut off valves.

Check chimneys, roofs, walls foundations for stability. Make sure your house is bolted to its foundation. Secure water heater and appliances that could move enough to rupture utility lines. Keep breakables and heavy objects on bottom shelves. Secure hanging plants and heavy picture frames or mirrors (especially over beds). Put latches on cabinet doors to keep them closed during shaking.

Keep flammable or hazardous liquids such as paints, pest sprays or cleaning products in cabinets or secure on lower shelves.

Maintain emergency food, water and other supplies, including a flashlight, a portable battery-operated radio, extra batteries, medicines, first aid kit and clothing.

Family Earthquake Plan

Plan Responsibilities

There will be many things to take care of after a severe earthquake. Make plans with family, friends, and neighbors, assigning specific responsibilities to each person. Talk about the possibilities that may occur and develop plans for assisting those in greater need. Remember that it may be difficult to get around after an earthquake, so each person's task needs to be related to where he or she may be and what they are capable of doing.

Plan to meet

Make a plan on where and how to reunite family members. Choose a person outside the immediate area to contact if family members are separated. Telephone service may be down, however, long distance service may be restored sooner than local service. Remember, use the phone only for emergency purposes.

Plan for children

Know the policies of the schools or daycare centers your children attend in the event of a damaging earthquake. Have a plan to have someone pick them up if you are unable to do so. Inquire into the shelters and emergency provisions in those areas.

Know Your Environment:

The safest place in the home:

During a large earthquake, stay away from large panes of windows, shelves with heavy objects, masonry veneer (such as the fireplace), heavy furniture, or large appliances. These items tend to fall, break or move around and can injure you or your children. The hallway is usually one of the safest places in the home. Kitchens and garages tend to be the most dangerous. Also know the safest place in each room. In a very large earthquake, it will be difficult to move from one place to another.

Exits and alternative exits:

Always know the possible ways to exit your home and work place in case of an emergency. If the main exits are blocked or unavailable, work out a plan for alternative exits. Practice with your children where these exits are and how to use them.

Location of shut-off valves:

Know the location of the water, gas and electricity and how to operate the valves. If you are unsure, contact the utility company for a demonstration.

Make Special Provisions:

Elderly, disabled or persons under medications:

These persons may have difficulty moving around after an earthquake. Plan to have someone check on them after the shock. They may need help in retrieving items from blocked passage ways or, in case of a severe quake, need assistance evacuating a building. Also, they may need special foods or medications. A good plan would include a supply for a few days to a week.

Pets and animals:

Along with being concerned with your safety, you will need to be provide special care for your pets and animals. They often become distressed and disoriented, running about and sometimes bolting in fear. Reassure them with praise and security statements. Include extra food and water in your emergency food supplies. If you need to evacuate, make a plan that will include care for your pets. Remember, emergency shelters do not allow pets.

Know Community Resources

Police and Fire:

Know the location of the nearest Police and Fire Stations. Following a damaging earthquake these persons will be quite busy and may be unable to respond with expected speed.

Shelter and medical care:

After an earthquake disaster, emergency shelters and temporary medical centers will be set up in your community. Contact your local Office of Emergency Services before the earthquake and find out the plans for you area.

Community plans

Know your neighborhood. You may be able to help others or others may be able to help you. Also know where to go to help your community after a disaster. It may be days before outside emergency assistance arrives. It is important to help each other!

Emergency Food Supplies

In an major disaster such as a large earthquake, food suppliers, grocery stores and quick marts will probably sustain heavy damage and will be unavailable for

several days. Roads may be blocked and extended power outages could occur. Your source for food may be cut off.

WHAT SHOULD YOU DO FOR FOOD SUPPLIES?

Prepare an emergency food supply that will last each individual several days or as much as a week. Use foods that your family likes. Canned foods, dry mixes, dehydrated fruit, etc. that are normally used will do just fine. Try for a balance meal approach. Don't forget a manual can opener in the event of a power outage. Foods stored in dark, cool areas last longer. Rotate food items from storage at least once or twice a year to avoid spoilage and keep freshness. It may be helpful to write the date on the items the day they were stored.

WHAT ABOUT FOODS IN REFRIGERATORS OR FREEZERS?

Perishable foods such as milk, meats, etc. that are normally stored under refrigeration will spoil quickly without it. If still cold, these foods should be used first. Foods in freezers can last several days without power if the door is not opened frequently.

WHAT NOT TO DO...

If perishable foods lose refrigeration and become warm, DO NOT USE

If canned foods have been damaged and are bulging or leaking, DO NOT USE.

DO NOT USE food from open containers where broken glass is present, or where household chemicals have spilled.

Unsealed containers and those that have been punctured by rodents or have rodent droppings should NOT be used.

There are several reputable suppliers of prepared emergency food supplies for individuals, families and business. Check your Yellow Pages for a distributor nearest you.

During the Quake

Remain calm! Think through any action before you proceed.

Protect your head and neck with your arms. If possible, grab a book, a pillow or any other item to shield yourself from falling glass and debris.

If you are indoors, you must immediately **LOOK, DUCK, COVER, HOLD**. Duck under a sturdy furniture or into a strong doorway. If you are in a rural area and near an exit, move outside.

Do not turn on lights. Do not strike a match because it could be explosive while natural gas is leaking.

If you are outdoors and the ground starts shaking from a large earthquake, move to an open area away from trees, buildings, walls and power poles. Move away from beaches, waterfronts and saturated soggy ground. In a narrow valley, move to the center of narrow valleys and look up slope for tumbling rocks. Keep your eyes open for dangerous things and watch the effects caused by the earthquake.

Because of their relatively safe condition, people outside often see more of the effects of earthquakes. If it is a very strong earthquake, watch for surface waves, listen for sounds, at night, look for flashing lights. Grab a video or still-shot camera and take pictures.

If you are in the car, move to the side of the road and stop the car. Do not stop near buildings, power lines and on or under overpasses or bridges. Stay in your car until the shaking stops. Keep your safety belt on until the shaking stops.

Look Duck Cover Hold

When you feel an earthquake, the first thing to do is **LOOK**. Look around! Look above! See what could hurt you, what could save you from injury. Get your bearings on your next move. Find cover and **DUCK** under a desk or sturdy table. Stay away from windows, bookcases, file cabinets, heavy mirrors, hanging plants, and other heavy objects that could fall. Watch out for falling plaster or ceiling tiles. Stay under **COVER** until the shaking stops. **HOLD** onto the desk or table. If it moves, move with it.

Here are some additional tips for specific locations:

If you're in a **HIGH-RISE BUILDING**, and you are not near a desk or table, move against an interior wall, and protect your head with your arms. Do not use the elevators. Do not be surprised if the fire alarm or sprinkler systems come on.

If you're **OUTDOORS**, move to a clear area away from trees, signs, buildings, or downed electrical wires and poles.

If you're on a **SIDEWALK NEAR BUILDINGS**, duck into a doorway to protect yourself from falling bricks, glass, plaster, and other debris.

If you're DRIVING, pull over to the side of the road and stop. Avoid overpasses, power lines, and other hazards. Stay inside the vehicle until the shaking is over. Always carry emergency supplies.

If you're in a CROWDED STORE OR OTHER PUBLIC PLACE, do not rush for exits. Move away from display shelves containing objects that could fall. If items begin to fall, Duck under shelves.

If you're in a WHEELCHAIR, stay in it. Move to cover, if possible, lock your wheels, and protect your head with your arms.

If you're in the KITCHEN, move away from the refrigerator, stove, and overhead cupboards. (Take the time NOW to anchor appliances and install security latches on cupboard doors to reduce hazards.)

If you're in a STADIUM OR THEATER, stay in your seat and protect your head with your arms. Don't try to leave until the shaking is over. Then leave in a calm, orderly manner.

After the Quake

Check for injuries. Apply first aid. Do not move seriously injured individuals unless they are in immediate danger. Do not use the telephone immediately unless there is a serious injury or fire.

Hunt for Hazards:

Check for gas and water leaks, broken electrical wiring or sewage lines. If there is damage, turn utility off at the source.

Check building for cracks and damage, including roof, chimneys and foundation.

Check food and water supplies. Emergency water may be obtained from water heaters, melted ice cubes, toilet tanks and canned vegetables.

Turn on your portable radio for instructions and news reports. Cooperate fully with public safety officials.

Do not use your vehicle unless there is an emergency. Keep the streets clear for emergency vehicles.

Be prepared for aftershocks.

Stay calm and lend a hand to others.

If you evacuate, post a message inside your home telling family members where you can be found.

EARTHQUAKE RESCUE ARRANGEMENTS IN PAKISTAN.

Effective arrangements to overcome earthquakes and other natural disasters do not exist in Pakistan. Numerous casualties in the recent earthquake in Kashmir and NWFP are living proof that none of our institution had any plan to overcome such earthquakes. There was no effective arrangement to alert the people before an earthquake. Thank God this earthquake occurred in remote hilly areas where multistory buildings are not constructed. God forbid, had this occurred in Lahore, Karachi or any populated city then the damage would have been manifold. In our big cities the construction of multistory buildings is on the rise without proper planning. In populated cities there are numerous buildings where the earthquake risk factor was not considered in their construction. According to law, in the construction of high raised buildings, the earthquake-proof designs are mandatory.

In developed countries small concrete blasters are commonly used to pull out the people safely from the earthquake effected areas. By making holes in the layers of concrete with the help of these blasters the people pressed under the debris are pulled out easily. Unfortunately this technology is not available in Pakistan. In recent earthquake at Muzaffarabad, Balakot and other places, people tried to pull out the entrapped persons from rubble in conventional way and large number of people were died waiting for rescue teams.

Now there is a great need for Scientific analysis of all the earthquakes occurred in the country so far. Huge building should be constructed under the supervision of geo-technical engineers. The engineers know about the earth structure and they have the knowledge of how much weight the earth can bear and which kind of cement should be used. The land having excessive quantity of salt spoils the cement after some time. In such cases the special cement should be used which fights against sulphate.

International laws are not followed in our buildings. Earthquake waves moving in the crust of the earth, enter in the foundation of the building and effect the upper stories. As a result the weak walls cannot stand and roofs shake. Some buildings collapse at once. These are called non-framed buildings. After observing the recent earthquake it reveals that framed as well as non-framed buildings were damaged in Kashmir. The basic reason was the use of bad quality construction material and these buildings were not earthquake proof.

Earthquakes are continuous phenomenon in Japan. Therefore, the buildings are being constructed to bear the earthquake of magnitude 10. In our country, we do not consider the air pressure while constructing the multistory buildings. Building should be designed in such a way that it may not collapse suddenly, and people have time to evacuate the building. In the effected areas of 8 October earthquake none of the big building was safe.

Now, we should have a department for the coordination between the people and the concerned departments in earthquake prone areas.. This department will be responsible for long term planning about earthquakes, watching system and helping machinery and also the preparation of volunteers. Seismic survey of the buildings of populated cities in high-risk zone may be conducted and these may be graded according to the earthquake. On the basis of these analysis the map of the area should be prepared.

Geophysical Center

Under the geophysics divisions of Meteorological department a geophysical centre is already functioning in Quetta where arrangement for recording and research on earthquakes is available.

Five other observatories are working in Peshawar, Saidpur (Islamabad), Lahore, Karachi and Khuzdar. Latest instruments are available in Quetta and Peshawar. There exist analog recording, and time is recorded in GMT. These observatories issue seismic bulletins regularly. There are facilities for recording nuclear explosions also. Geologists, civil engineers and students of universities get seismic data from the center.

Geomagnetic observatories are also working in Quetta and Gilgit. These observatories established in 1953 and 1964 respectively. Geomagnetic data is prepared in these observatories on monthly three monthly, and annual basis and sent to world geomagnetic centres of United States of America, Russia, United Kingdome, Denmark and Japan. The data is provided to national and international agencies on exchange basis.

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Some Additional Measures (Church World Service – Pakistan/Afghanistan)

Earthquake is shaking of earth, movement or the shock created deep in the earth. The energy released in case of a big earthquake is equal to 200 million TNT explosive materials and its severity can be gauged through the Richter Scale. Movement of present layer in the earth is the reason for an earthquake. It has not yet become possible to predict the occurrence of an earthquake. Following measures could be helpful to minimize the losses that are followed by earthquakes:

Keep the telephone numbers of Edhi Centre, Red Crescent, Civil Defence and Emergency Centers set up by the Government in case of any Emergency.

You should identify what type of calamities could possibly hit the neighborhood, village, city or area where you live that could create an emergency situation for you.

Besides yourself, also keep other members of your family informed about the organization/institution you would contact in case of emergency.

Identify the exit routes well in advance in case of emergency.

Contact the helping organizations/institutions before hand, if you have elderly and disabled persons at your home.

You should ask whether the place you serve or the school or institution where your children study, are prepared in advance to meet any emergency situations or not.

Those living in the calamity prone area may select any of their friend or relative and give their telephone numbers to all members of the family so that a person who has separated from the family in emergency situation could be contacted. Train your children in making long distance calls.

Fix a place e.g. outside your own home or in your neighborhood to gather at one place in case you are separated from each other during any emergency situation.

Prepare a small first aid box. Keep the necessary articles that you plan to take along during the emergency situation, separately with care. Keep the necessary documents of members of your family in a water-proof envelope.

A gallon per day water should be taken for one person. Water should be taken in unbreakable utensil(s).

Clothes, shoes, and other arrangements should be made in accordance with summer, winter and rainy season. Blanket and other material required for sleeping purposes should be kept in a manner that it could be carried easily when required. Keep the preventive tablets and medicines with utmost care.

Additional battery should also be kept along with radio battery. Keep cash, ornaments, and additional keys of the house, car and office at a proper place from where these could be taken easily when required.

Keep the telephone numbers of the family doctor and friends, and necessary articles of children and elderly people along.

What should be done if fire breaks out owing to earthquake?

If windows and door-frames catch fire, then all members of the family should sit down or lay down on the floor.

Family members should also be told not to touch or open hot doors and windows because there is an utmost possibility of fire outside these doors and windows or these have caught fire itself. You can identify it by touching the lower parts of these doors and windows yourself. Find out any other exit point if doors and windows are hot.

What should be done if power breaks down?

There should at least be two exit routes in the house so that it is easy to come out in emergency situation.

The family members should know the whereabouts of particular connections of electricity, gas and water and how to close the same in emergency situations. Some exercises should be carried out in this connection so as to train them all.

Keep the telephone numbers of those organizations/institutions, persons and emergency centers besides the telephone set. These numbers should be written in bold letters.

Children should know the numbers they should call in emergency situations and what information should be given.

All family members should be apprised of the timings of local radio stations for special broadcasts, news updates on the calamity.

Sketch the internal drawing of your house with a black color pen and then identify windows, doors, window-panes, stairs, heavy furniture i.e. cupboards, sofa set and dining table, with a blue color pen. In the end, identify two places on this paper where to meet after exit from the house in emergency situation. If your house comprises of two floors then make exit arrangements for every floor, separately. All family members should practice to exit from house in emergency situation, twice a year.

You should know through radio, newspaper, and other government or non-governmental sources where to take refuge in emergency situation.

What type of houses are the most vulnerable?

Those houses that are situated in uneven areas, and are constructed on garages and houses that are constructed on pillars.

Presence of such dangerous articles in the house that may cause injuries or death to any member(s) of the family if they break, fall or catch fire.

How to avoid such dangers?

Electricity wiring should be checked again and fixed if required. If there is leakage in gas then it should be fixed.

Close the table drawers tightly and keep the heavy articles in the lower drawer of the table.

Pictures should not be affixed near the bed or where you sleep.

Geysers and heaters should be affixed in the wall tightly.

Cracks in the roof or walls should be repaired immediately.

Burners and articles that may be inflammable should be kept away from insecticides, and chemical substances.

What plan should be made to face emergency situations?

The family members should be warned in advance what losses they can suffer by this calamity.

Chapter - 7

Deadliest Earthquakes On Record

1) SHAANXI, CHINA January 23, 1556

The **Shaanxi earthquake** or **Hua County Earthquake** is the deadliest earthquake on record, killing approximately 830,000 people. It occurred on the morning of 23 January 1556 in Shaanxi, China. A 520 mile-wide area was destroyed and in some counties, seventy-five percent of the population was killed. Most of the population at the time lived in artificial caves in *loess* (1) cliffs, many of which collapsed during the disaster. Modern estimates, based on geological data, give the earthquake a magnitude of approximately 8 on the moment magnitude scale. Aftershocks continued several times a month for half a year.

In the annals of China it was described thus:

In the winter of 1556 AD, an earthquake catastrophe occurred in the Shaanxi and Shanxi Provinces. In our Hua County, various misfortunes took place. Mountains and rivers changed places and roads were destroyed. In some places, the ground suddenly rose up and formed new hills, or it sank in abruptly and became new valleys. In other areas, a stream burst out in an instant, or the ground broke and new gullies appeared. Huts, official houses, temples and city walls collapsed all of a sudden.

The shaking reduced the height of the Small Wild Goose Pagoda in Xi'an from 45 meters to 43.4 meters

(1) *Loess caves*:

Millions of people at the time lived in artificial Loess caves on high cliffs in the area of the Loess Plateau. Loess is the name for the silty soil that windstorms deposited on the plateau over the ages. The soft loess clay had formed in millions of years due to wind blowing silt to the area from the Gobi Desert. Loess is a highly erosion-prone soil that is susceptible to the forces of wind and water. Much of the population lived in dwellings called Yaodongs in these cliffs. This

was the major contributing factor to the huge death toll. The earthquake caused landslides, which destroyed the caves.

2) SUMATRA TSUNAMI, INDONESIA, December 26, 2004

The 2004 Indian Ocean earthquake, known by the scientific community as the **Sumatra-Andaman earthquake**, was an undersea earthquake that occurred at 07:58:53 local time on December 26, 2004 with an epicentre off the west coast of Sumatra, Indonesia. The earthquake triggered a series of devastating tsunamis that spread throughout the Indian Ocean, killing 283,000 people and inundating coastal communities across South and Southeast Asia, including parts of Indonesia, Sri Lanka, India, and Thailand. The catastrophe is one of the deadliest disasters in modern history. The magnitude of the earthquake was originally recorded as 9.0 on the Richter scale, but has been upgraded to between 9.1 and 9.3.. At this magnitude, it is the second largest earthquake ever recorded on a seismograph

This earthquake was also reported to be the longest duration of faulting ever observed, lasting between 500 and 600 seconds, and it was large enough that it caused the entire planet to vibrate at least half an inch, or over a centimetre. It also triggered earthquakes in other locations as far away as Alaska.

The earthquake originated in the Indian Ocean just north of Simeulue island, off the western coast of northern Sumatra. The resulting tsunami devastated the shores of Indonesia, Sri Lanka, India, Thailand and other countries with waves up to 30 m (100 ft). It caused serious damage and deaths as far as the east coast of Africa, with the furthest recorded death due to the tsunami occurring at Port Elizabeth in South Africa, 8,000 km (5,000 mi) away from the epicentre.

The shift of mass and the massive release of energy very slightly altered the Earth's rotation. The exact amount is yet undetermined, but theoretical models suggest the earthquake shortened the length of a day by 2.68 microseconds. The Andaman and Nicobar Islands appear to have shifted south-west by around 1.25 m (4.1 ft) and to have sunk by 1 m (3.28 ft).

3) TANGSHAN, CHINA July 27, 1976

The **Tangshan earthquake** is one of the largest earthquakes to hit the modern world, in terms of the loss of life. The epicentre of the earthquake was near Tangshan in Hebei, China, an industrial city with approximately one million inhabitants. The earthquake left 242,419 people dead, according to official figures, though some sources offer much higher estimates. A further 164,581 people were recorded as being severely injured.

The earthquake hit in the early morning, at 03:42:53.8 local time and lasted for around 15 seconds. Many sources list it as 8.2 on the Richter scale, but Chinese Government's official sources state 7.8. It was followed by a major 7.1 magnitude aftershock some 15 hours later, increasing the death toll. Many people in Tangshan reported seeing strange lights – so-called "earthquake lights" – the night before the earthquake. Well water in a village outside of Tangshan reportedly rose and fell three times the day before the earthquake. Gas began to spout out of a well in another village on July 12 and then increased on July 25 and July 26. Other wells throughout the area showed signs of cracking. It has been reported that animals in the area sensed the earthquake before it struck. A thousand chickens reportedly refused to eat and acted wildly. There were also reports that dogs would not stop barking and goldfish jumped out of their bowls. Most animals in the city did in fact survive.

Tangshan was thought to be in a region with a relatively low risk of earthquakes. Very few buildings had been built to withstand an earthquake, and the city lies on unstable alluvial soil. The earthquake devastated the city over an area roughly 4 miles by 5 miles. Many of the people who survived the initial earthquake were trapped under collapsed buildings and killed by a 7.1 magnitude aftershock 15 hours after the initial tremor.

The seismic waves spread far, with damage in cities such as Qinhuangdao and Tianjin, and a few buildings as far away as Beijing, 140 km from the epicenter, were damaged. Many people of the Tangshan city were disabled in this earthquake.

The large loss of life caused by the earthquake can be attributed to the time it struck and how suddenly it struck. The earthquake lacked foreshocks that usually come with earthquakes of this magnitude. It also struck at just before 4 AM leaving many people unprepared as they lay asleep.

4) ALEPPO, SYRIA August 9, 1138

The **1138 Aleppo earthquake** was an earthquake that was located near the town of Aleppo in northern Syria. At that time it was the rule of Imadudin Zangi in the city. The United States Geological Service lists it as the fourth deadliest earthquake in history. However, the figure of 230,000 dead is based on a historical conflation of this earthquake with earthquakes in November 1137 on the Jazira plain and the large seismic event of 30 September 1139 in the Persian city of Ganja. The first mention of a 230,000 death toll was by Ibn Taghribirdi in the fifteenth century.

5) DAMGHAN, IRAN December 22, 856

On Tuesday, 22 December 856 there was a catastrophic earthquake in the eastern Alburz which devastated the district of Qumis and the region of western Khurasan dependent on Nishapur. Along a fertile tract of land running for 350 kilometres between the Alburz and the Dasht-i-Kavir, from Khuvar to beyond

Bustam and in parts of Tabaristan and Gurgan, 200000 people were killed and practically all villages were ruined. In the district of Qumis, the earthquake was worst at Damghan, which was half destroyed with 45096 casualties. In the mountain regions there were extensive ground deformations, including probably surface faulting. The old city of Shahr-i-Qumis, former capital of the province, was also destroyed and was probably finally abandoned after the earthquake. One third of Bustam collapsed and the region between this town and Damghan still showed the effects of the earthquake two generations later. Tabaristan and Gurgan were also affected by the shock, which had a disastrous effect on the water supplies of the district of Qumis, either causing the drying up of springs and qanats, or triggering landslides which dammed the streams flowing down to the plain. Outside the meizoseismal region, Nishapur to the east and the Jibal province to the west and southwest of Qumis were also strongly shaken, the earthquake being felt in Ray, Qum, and as far as Isfahan, where it caused great concern. Aftershocks continued for some year, probably causing damage in western Khurasan.

6) NINGXIA, GANSU, CHINA December 16, 1920

At 8pm on December 16, 1920, an earthquake took place in Haiyuan District. The epicenter was in LiuPan Mountain area on the borders of Gansu and Ningxia. The epicenter magnitude was 12. Haiyuan and Xiji counties were damaged most seriously. Gansu, Ningxia, Shaanxi and even Qinghai, Hennan, and part of Shanxi also suffered from the earthquake. When the earthquake took place, the lights swayed in Beijing. Even the people far away in Shanghai could feel it. Such a wide spread earthquake was not only rarely seen in China but also in the whole world in terms of its intensity and its wide range.

The ground surface became high hills and deep valleys. The mountain exploded and the ground was split. Dark water flooded anywhere. The four cities including Haiyuan and Guyuan were completely destroyed. More than 70,000 people died in the earthquake in Haiyuan only. The total casualty was no less than 200,000. Walls and buildings of Guyuan collapsed. The rural areas were hit more severely. Two villages of the northwest were leveled completely. 30,000 people were killed and 60,000 domestic animals were buried in soil."

It was extremely cold that day when the earthquake happened. Because the residents stayed indoors, many people died in the earthquake. Some people suffocated to death. Some died of the pains in serious wounds or were even tore up by wolves. Many people died of hunger or coldness. The spread of the diseases in the next years also resulted in numerous death.

7) TSINGHAI, CHINA May 22, 1927

A horrible earthquake killed 200,000 peoples in China in 1927. It was the seventh great earthquake on earth. Its magnitude was 7.9. Due to this quake underground water resources were destroyed and new lakes formed in various parts of the region

8) ARDABIL, IRAN March 23, 893

An earthquake killed about 150,000 people in Iran in 893AD. In those days there was not any equipment to measure the magnitude of earthquake but history confirms the death toll.

9) KANTO, JAPAN September 1, 1923

The **1923 Great Kanto earthquake** struck the Kanto plain on the Japanese main island of Honshu on the morning of September 1, 1923. The quake was later estimated to have had a magnitude between 7.9 and 8.4 on the Richter scale.

According to most reliable sources, at least 105,385 lost their lives and over 37,000 went missing, presumed dead. Over 570,000 homes were destroyed, leaving an estimated 1.9 million homeless.

Because the earthquake struck at lunchtime when many people were using fire to cook food, the damage and the number of fatalities were amplified due to fires which broke out in numerous locations. The fires spread rapidly due to high winds from a typhoon and some developed into firestorms which swept across cities. As the earthquake had caused water mains to break, putting out the fires took nearly two full days. The fires were the biggest cause of death.

Tsunami reached the coast within minutes in some areas, the port of Yokohama was badly affected.

On top of this violence, opponents were abducted and killed by members of the police who claimed the victims had intended to use the crisis as an opportunity to overthrow the Japanese government.

10) AZAD KASHMIR, PAKISTAN October 8, 2005

The **Kashmir earthquake** (also known as the **South Asia earthquake** or **Pakistan earthquake**) of 2005 was a major earthquake whose epicenter was Azad Kashmir. The earthquake occurred at 08:50:38 Pakistan Standard Time (03:50:38 UTC) on October 8, 2005. It registered a minimum magnitude of 7.6 on the moment magnitude scale making it a major earthquake similar in intensity to the

1935 Quetta earthquake, the 2001 Gujarat Earthquake, and the 1906 San Francisco earthquake. As of November 8, 2005 the Pakistani government's official death toll was 73,276, while officials say nearly 1,400 people died in Indian-administered Kashmir and three people in Afghanistan.

11) LISBON, PORTUGAL November 1, 1755

Lisbon earthquake took place on November 1, 1755, at 9:40 in the morning. It was one of the most destructive and deadly earthquakes in history, killing between 60,000 and 100,000 people. Geologists today estimate the Lisbon earthquake approached magnitude 9 on the Richter scale with an epicenter in the Atlantic Ocean about 200 km (120 mi) west-southwest of Cape St. Vincent. The quake was followed by a tsunami and fire, resulting in the near-total destruction of Lisbon.

The earthquake lasted six minutes, causing gigantic fissures five metres (16 ft) wide to appear in the city center. Several tens of minutes after the earthquake, an enormous tsunami engulfed the harbor and downtown, rushing up the Tagus river. It was followed by two more waves. In the areas unaffected by the tsunami, fire quickly broke out, and flames raged for five days. The shockwaves of the earthquake were felt throughout Europe as far as Finland and North Africa. Tsunamis up to 20 metres (66 ft) in height swept the coast of North Africa, and struck Martinique and Barbados across the Atlantic.

This was the first earthquake studied scientifically for its effects over a large area, it signalled the birth of modern seismology.

Eighty-five percent of Lisbon's buildings were destroyed, including famous palaces and libraries, several buildings that had suffered little earthquake damage were destroyed by the subsequent fire. The earthquake accentuated political tensions in Portugal and profoundly disrupted the country's eighteenth-century colonial ambitions.

12) MESSINA, ITALY DECEMBER 28, 1908

On December 28, 1908, Europe's most powerful earthquake shook southern Italy. Centered in the Messina Strait, which separates Sicily from Calabria, the quake's magnitude equaled a 7.2 on the Richter scale. It is considered the twelfth deadliest earthquake. Moments after the quake's first jolt, a devastating tsunami formed, causing forty-foot waves to crash down on dozens of coastal cities.

The Messina quake was undeniably the most destructive to ever hit Europe. Most of southern Italy's cities lost as many as half their residents that morning.

The population of the city of Messina alone -- 150,000 -- was reduced to only hundreds; the total death toll throughout Italy was estimated at nearly 200,000. Accounts of shaking and aftershocks were reported throughout Sicily.

13) GANSU, CHINA December 25, 1932

A Magnitude-7.6 earthquake rattled China, killing approximately 70,000 in 1932. It was 13th deadliest earthquake of known history.

14) ANCASH, PERU May 31, 1970

The **1970 Ancash earthquake** was an undersea earthquake that occurred on May 31, 1970, affecting the Peruvian regions of Ancash and La Libertad, and that combined with a subsequent landslide, was the most catastrophic natural disaster ever recorded in the history of Peru.

The epicenter of the earthquake was located 30 km off the coast of Casma and Chimbote on the Pacific Ocean. It had an intensity of 7.9 on the Richter scale and up to VIII on the Mercalli scale.

The earthquake lasted 45 seconds and destabilized the northern wall of Mount Huascarán, inducing a rock and snow avalanche and burying the towns. The reported death toll from the earthquake and avalanche totalled as high as 66,000. About 19,600 went missing and 143,331 were injured. Over 500,000 people were left homeless. The earthquake affected an area of about 83,000 kms. Economic losses surpassed half a billion dollars U.S.D.

15) QUETTA, PAKISTAN May 30, 1935

1935 Balochistan Earthquake occurred on May 30, 1935 at Quetta, Balochistan. The earthquake had a magnitude of 7.7 on the Richter scale. Total deaths were anywhere from 30,000 to 60,000 people. This is one of the deadliest known earthquakes in South Asia. The quake was centered 4.0 kilometres South West of Ali Jaan, Balochistan, Pakistan.

16) MANJIL-RUDBAR, IRAN June 21, 1990

A magnitude 7.7 earthquake occurred in the Gilan Province between the towns of Rudbar and Manjil in northwest Iran on Thursday, June 21, 1990 (June 20 at 21:00 GMT). The event, the largest ever to be recorded in that part of the Caspian Sea region, may have been composed of two or more closely-spaced earthquakes occurring in rapid succession. These quakes, exceptionally close to the surface for this region, were also unusually destructive. More than 35,000 people lost their lives, more than 500,000 became homeless, nearly 100,000 buildings were

destroyed, three cities and 700 villages were razed to the ground. Such great disaster occurred not only because of a large magnitude earthquake but also because of poor construction and preparation in vulnerable areas. Reconstruction of the region was estimated to cost at least 2.8 billion dollars. The long-term effects of this catastrophic event included the disruption of the economies of at least three large provinces, and the human resettlement of at least three large cities and 700 villages; reconstruction to modern standards has taken decades to accomplish and absorbed a considerable part of the country's budget.

17) ERZINCAN, TURKEY December 27, 1939

On December 27, 1939, an earthquake of seven violent shocks measuring 7.9 on the Richter scale hit Erzincan. It was the most powerful earthquake to hit Turkey and still is.

The first stage killed about 8000 people. The next day, it was reported that the death toll had risen to 20,000. An emergency relief operation began. By the end of the year, 30,000 had died due to more earthquakes and several floods.

18) BAM, IRAN December 26, 2003

A earthquake with a magnitude 6.6 struck the southeastern city of Bam on December 26, 2003 at 5:26 AM local time killing an estimated 43,000 people and destroying a 2,000 year-old fortress near the city. About 60 percent of the buildings in Bam were destroyed. The high death toll occurred because very few people who were trapped when their mud-brick homes collapsed managed to survive. Rescue workers reported that the collapsing mud-brick structures had completely disintegrated and buried people in piles of earth, rather than trapping them in voids or air pockets between building slabs, as would happen in a concrete building collapse. Those few who did survive being trapped were generally rescued within the first few hours, after being dug out by local survivors, or were trapped in ventilated air pockets.

19) SPITAK, ARMENIA December 7, 1988

The **Spitak Earthquake** was a tremor with a moment magnitude of 7.2, that took place on December 7, 1988 at 11:41 local time in the Spitak region of Armenia, then part of the Soviet Union.

Local housing infrastructure (particularly schools and hospitals) performed poorly in the earthquake and this resulted in 25,000 lost lives. It has been estimated that if the earthquake had occurred 5 minutes later, children would have left their schools' unstable buildings. This short time delay could have

saved many lives. The entire city of Spitak was destroyed. The tremor also caused damage to many surrounding villages.

Since most of the hospitals in the area were destroyed, and due to freezing winter temperatures, officials at all levels were not ready for a disaster of this scale and the relief effort was therefore not launched properly. The Armenian government let in foreign aid workers to help with the recovery in the earthquake's aftermath, and this was one of the first cases when rescue and relief workers from other countries were allowed to take part in relief works in the Soviet Union.

Contributions poured in from around the world to help the earthquake victims through the winter and to rebuild much of the housing. Spitak was rebuilt from scratch in a location next to the previous town, with many neighborhoods having very distinct architecture reflecting the country which donated/built the homes there. A monument expressing the appreciation of the Armenian people for assistance from the U.S. was erected in Washington D.C. in 1990.

Tables

List of significant earthquakes

This is a list of significant earthquakes as listed by the United States Geological Survey (USGS)

<u>Date</u>	<u>Place</u>	<u>Fatalities</u>	<u>Magnitude</u>
January 23, 1556	Shaanxi, China	830,000	~8
August 17, 1668	Anatolia, Turkey	8,000	~8
January 26, 1700	Northern California to Vancouver Island		~9
November 1, 1755	Lisbon, Portugal	C. 80,000	~8.7
December 16, 1811	New Madrid, Missouri		~8.1
January 23, 1812	New Madrid, Missouri		~7.8
February 7, 1812	New Madrid, Missouri		~8
June 2, 1823	Kilauea, Hawaii		~7
June 10, 1836	South San Francisco Bay region		~6.5
June, 1838	San Francisco Peninsula, California		~6.8
January 5, 1843	Marked Tree, Arkansas		~6.3
January 9, 1857	Fort Tejon, California	1	~7.9
December 16, 1857	Naples, Italy	11,000	~6.9
October 8, 1865	San Jose, California		~6.5
April 3, 1868	Hilea, Southeast Hawaii	77	~7.9
October 21, 1868	Hayward, California	30	~6.8
February 20, 1871	Molokai, Hawaii		~6.8
March 26, 1872	Owen's Valley, California	27	~7.6
December 15, 1872	Cascades, Washington		~7.3

November 23, 1873	California-Oregon coast		~7.3
August 31, 1886	Charleston, South Carolina	60	~7.3
April 24, 1890	Corralitos, California		~6.3
October 27, 1891	Mino-Owari, Japan	7,223	~8
April 19, 1892	Vacaville, California	1	~6.4
April 21, 1892	Winters, California		~6.4
October 21, 1895	Charleston, Missouri		~6.6
June 15, 1896	Sanriku, Japan		~8.5
June 12, 1897	Assam, India	1,500	~8.3
June 20, 1897	Calaveras, California		6.3
March 31, 1898	Mare Island, California		~6.3
April 15, 1898	Mendocino County, California,		~6.8
September 4, 1899	Cape Yakataga, Alaska		7.9
September 10, 1899	Yakutat Bay, Alaska		8
October 9, 1900	Kodiak Island, Alaska		7.7
March 3, 1901	Parkfield, California		6.4
August 27, 1904	Fairbanks, Alaska		7.3
July 9, 1905	Mongolia		8.4
January 31, 1906	Colombia-Ecuador	1,000	8.8
April 18, 1906	Cape Mendocino to San Juan Bautista, California	3,000	7.8
August 17, 1906	Valparaiso, Chile	20,000	8.2
December 28, 1908	Messina, Italy	70,000	7.2
July 1, 1911	Calaveras, California		6.5
October 3, 1915	Pleasant Valley, Nevada		7.1
October 11, 1918	Puerto Rico	116	7.5
December 6, 1918	Vancouver, Canada		7
December 16, 1920	Ningxia-Gansu, China	200,000	8.6
January 31, 1922	Mendocino, California		7.3
March 10, 1922	Parkfield, California		6.1
January 22, 1923	Mendocino,		7.2

	California		
September 1, 1923	Kanto, Japan	143,000	7.9
March 1, 1925	Quebec, Canada		6.3
June 28, 1925	Clarkston Valley, Montana		6.6
June 29, 1925	Santa Barbara, California	13	6.8
October 22, 1926	Monterey Bay, California		6.1
March 7, 1927	Tango, Japan	3,020	7.6
May 22, 1927	Tsinghai, China	200,000	7.9
November 4, 1927	offshore Lompoc, California		7.1
November 18, 1929	Newfoundland, Canada		7.3
December 21, 1932	Cedar Mountain, Nevada		7.2
March 2, 1933	Sanriku, Japan	2,990	8.4
March 11, 1933	Long Beach, California	115	6.4
November 20, 1933	Baffin Bay, Canada		7.4
January 15, 1934	Bihar, India	10,700	8.1
June 8, 1934	Parkfield, California		6.1
November 1, 1935	Quebec, Canada		6.2
July 22, 1937	Salcha, Alaska		7.3
January 23, 1938	Maui, Hawaii		6.8
November 10, 1938	Shumagin Islands, Alaska		8.2
December 26, 1939	Erzincan, Turkey	32,700	7.8
May 19, 1940	Imperial Valley, California		7.1
December 7, 1944	Tonankai, Japan	1,223	8.1
April 1, 1946	Unimak, Alaska	165	7.3
June 23, 1946	Vancouver Island		7.3
August 4, 1946	Dominican Republic	100	8
December 20, 1946	Nankaido, Japan	1,330	8.1
October 16, 1947	Fairbanks, Alaska		7.2
April 13, 1949	Olympia, Washington		7.1
August 22, 1949	Queen Charlotte		8.1

	Islands, British Columbia, Canada		
August 15, 1950	Assam-Tibet	1,526	8.6
August 21, 1951	Kona, Hawaii		6.9
July 21, 1952	Kern County, California	12	7.3
November 1952	Kamchatka, Russia		9
March 29, 1954	Spain		7.9
July 6, 1954	Rainbow Mountain, Nevada		6.6
August 24, 1954	Stillwater, Nevada		6.8
December 16, 1954	Fairview Peak, Nevada		7.1
December 16, 1954	Dixie Valley, Nevada		6.8
October 24, 1955	Concord, California	1	5.4
March 9, 1957	Andreanof Islands, Alaska		9.1
December 4, 1957	Mangolia	30	8.1
April 7, 1958	Huslia, Alaska		7.3
July 10, 1958	Fairweather, Alaska	5	7.7
August 18, 1959	Hebgen Lake, Montana	28	7.3
February 29, 1960	Agadir, Morocco	10,000	5.7
May 22, 1960	Chile	5,700	9.5
March 28, 1964	Prince William Sound, Alaska	125	9.2
June 16, 1964	Niigata, Japan	26	7.5
February 4, 1965	Rat Islands, Alaska		8.7
April 29, 1965	Seattle-Tacoma, Washington, USA.	7	6.5
June 28, 1966	Parkfield, California		6.1
September 12, 1966	Truckee, California		5.9
December 10, 1967	Koyna, India		6.3
October 2, 1969	Santa Rosa, California		5.7
May 31, 1970	Peru	66,000	7.9
July 31, 1970	Colombia	-	8
February 9, 1971	Sylmar, California	65	6.7
February 4, 1975	Haicheng, China	10,000	7

August 1, 1975	Oroville, California		5.8
November 29, 1975	Kilauea, Hawaii	2	7.2
February 4, 1976	Guatemala	23,000	7.5
July 27, 1976	Tangshan, China	242,419*	7.6
August 6, 1979	Coyote Lake, California		5.7
October 15, 1979	Imperial Valley, California		6.4
January 24, 1980	Livermore, California		5.8
May 25, 1980	Mammoth Lakes, California		6.1
May 27, 1980	Mammoth Lakes, California		6
November 8, 1980	Gorda Plate, California		7.2
May 2, 1983	Coalinga, California		6.5
October 28, 1983	Borah Peak, Idaho	2	7
November 16, 1983	Kaoiki, Hawaii		6.7
April 24, 1984	Morgan Hill, California		6.2
November 23, 1984	Round Valley, California		5.7
September 19, 1985	Michoacan, Mexico	9,500	8
December 23, 1985	Nahanni, Canada		6.8
May 7, 1986	Andreanof Islands, Alaska		8
July 8, 1986	Palm Springs, California		6.1
July 21, 1986	Chalfant Valley, California		6.2
October 1, 1987	Whittier Narrows, California	8	5.9
November 30, 1987	Gulf of Alaska		7.9
January 22, 1988	Tennant Creek, Australia		6.3
March 6, 1988	Gulf of Alaska		7.8
November 25,	Quebec, Canada		5.9

1988			
December 7, 1988	Spitak, Armenia	25,000	6.8
October 17, 1989	Loma Prieta, California	63	6.9
December 25, 1989	Quebec, Canada		6
June 28, 1991	Sierra Madre, California	2	5.6
August 17, 1991	Honeydew, California		7.1
April 23, 1992	Joshua Tree, California		6.1
April 25, 1992	Cape Mendocino, California		7.2
April 26, 1992	Cape Mendocino, California		6.7
June 28, 1992	Landers, California	3	7.3
June 29, 1992	Little Skull Mountain, Nevada		5.7
September 2, 1992	Nicaragua	116	7.7
September 29, 1993	Latur-Killari, India	9,748	6.2
January 17, 1994	Northridge, California	60	6.7
June 9, 1994	Bolivia	5	8.2
September 1, 1994	Cape Mendocino, California		7.1
January 17, 1995	Kobe, Japan	5,502	6.9
May 21, 1997	Jabalpur, India	38	5.8
July 17, 1998	New Guinea	2,183	7
January 25, 1999	Colombia	1,185	6.2
August 17, 1999	Izmit, Turkey	17,118	7.6
September 20, 1999	Chi-Chi, Taiwan	2,400	7.7
October 16, 1999	Hector Mine, California		7.2
November 12, 1999	Duzce, Turkey	894	7.2
September 3, 2000	Napa, California		5
November 16, 2000	Papua, New Guinea		8
January 13, 2001	El Salvador	844	7.7
January 26, 2001	Gujrat, India	20,085	7.7

February 28, 2001	Olympia, Washington, USA		6.8
June 23, 2001	Peru	75	8.4
March 25, 2002	Hindu Kush Region, Afghanistan	1,000	6.1
April 20, 2002	Au Sable Forks, New York		5.2
November 3, 2002	Denali National Park, Alaska		7.9
May 21, 2003	Boumerdes, Algeria	2,266	6.8
September 25, 2003	Hokkaido, Japan		8.3
November 17, 2003	Rat Islands, Alaska		7.8
December 22, 2003	San Simeon, California	2	6.6
December 26, 2003	Southeastern Iran (Bam)	31,000	6.6
September 28, 2004	Parkfield, California		6
December 26, 2004	Northern Sumatra (Indian Ocean Earthquake)	283,106	9
March 28, 2005	Northern Sumatra	1,313	8.7

Other earthquakes not listed by the USGS

Date	Site	Deaths	Magnitude
464 BC	Sparta, Greece	?	-
226 BC	Rhodes, Greece	?	-
365	Knossos, Crete, (Greece)	50,000	XI
365	Cyrene, Libya	?	-
May 20, 526	Antiochia, Syria	250,000	-
844	Damascus, Syria	50,000	VIII
847	Mosul, Iraq	50,000	-
847	Damascus, Syria	70,000	X
856	Qumis, Damghan, Iran	200,000	-
856	Corinth, Greece	45,000	-

893	Caucasus	82,000	-
893	Daipur, India	180,000	-
893	Ardabil, Iran	150,000	-
1036	Shanxi, China	23,000	-
1042	Palmyra, Baalbek, Syria	50,000	X
1057	Chihli (Hopeh), China	25,000	
1138	Ganzah, Aleppo, Syria	230,000	XI
1156-1157	Syria	?	-
1170	Sicily	15,000	-
July 5, 1201	Upper Egypt or Syria	1,100,000	IX
1268	Cilicia, Anatolia Turkey	60,000	-
September 27, 1290	Chihli (Hopeh), China	100,000	6.7
May 26, 1293	Kamakura, Japan	30,000	-
October 18, 1356	Basel, Switzerland	1,000	6.5
January 26, 1531	Lisbon, Portugal	30,000	-
November 25, 1667	Shemakha, Azerbaijan	80,000	XII
June 7, 1692	Port Royal, Jamaica	30,000	-
January 11, 1693	Catania Province, Sicily	60,000	-
1693	Naples, Italy	93,000	-
1707	Japan (seismic wave)	30,000	-
December 30, 1730	Hokkaido, Japan	137,000	-
1731	Beijing, China	100,000	-
October 11, 1737	Calcutta, India	300,000	-
October 16, 1737	Kamchatka, Russia		9.3
June 7, 1755	Northern Persia	40,000	-
November 18, 1755	Boston, Massachusetts	0	-
February 28, 1780	Iran	200,000	-
February 4-5, March 28, 1783	Calabria, Italy	35,000	-
February 4, 1797	Quito, Ecuador &	41,000	-

	Cuzco, Peru		
February 10, 1797	Sumatra, East Indies (now Indonesia)	300	8.4
December 8, 1812	Wrightwood, California, USA	40	~7
November 24, 1833	Sumatra, East Indies (now Indonesia)		8.7
January 23, 1855	Wairarapa, New Zealand	4	~8
February 16, 1861	Sumatra, East Indies (now Indonesia)		8.5
February 3, 1931	Napier, New Zealand	258	7.9
December 25, 1932	Gansu, China	70,000	7.6
April 21, 1935	Hsinchu-Taichung, Taiwan	3,279	7.1
December 20, 1942	Turkey		6.9
November 26, 1943	Turkey		7.7
January 15, 1944	San Juan, Argentina	8,000 ~ 10,000	IX (7.8)
February 1, 1944	Turkey		7.5
August 17, 1949	Turkey		7.1
August 13, 1951	Turkey		6.8
August 8- 12, 1953	Kefalonia, Greece	476	7.2
May 26, 1957	Turkey		6.8
August 19, 1966	Turkey		6.6
July 22, 1967	Turkey		7
May 22, 1971	Turkey		6.8
December 23, 1972	Managua, Nicaragua	5,000 - 20,000	6.3
June 30, 1975	Norris Junction, Yellowstone National Park, Wyoming, USA	0	6.1
March 4, 1977	Bucharest, Romania	1,500	7.5
June 21, 1990	Northwestern Iran (Manjil-Rudbar earthquake)	35,000	7.7

March 13, 1992	Turkey		6.5
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Largest earthquakes by magnitude

Pos.	Date	Location	Magnitude
1	May 22, 1960	Valdivia, Chile	9.5
2	December 26, 2004	Off west coast northern Sumatra, Indonesia	9.31
3	October 16, 1737	Kamchatka, Russia	~9.3
4	March 27, 1964	Prince William Sound, Alaska, USA	9.2
5	March 9, 1957	Andreanof Island, Alaska, USA	9.1
6	November 4, 1952	Kamchatka, Russia	9
7	January 26, 1700	Cascadia subduction zone from Northern California to Vancouver Island	~9
8	January 31, 1906	Colombia-Ecuador	8.8
9	February 4, 1965	Rat Islands, Alaska, USA	8.7
10	November 24, 1833	Sumatra, Indonesia	8.7
11	November 1, 1755	Lisbon, Portugal	~8.7
12	March 28, 2005	Sumatra, Indonesia	8.5 - 8.7*
13	December 16, 1920	Ningxia-Gansu, China	8.6
14	August 15, 1950	Assam-Tibet	8.6
15	December 16, 1575	Valdivia, Chile	8.5

* Scientists have not yet agreed on an official magnitude.

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Chapter -8

Some common terms that one may encounter while studying about earthquakes.

Active fault: a fault that is likely to have another earthquake some time in future.

aseismic: the term refers to a fault on which no earthquake has been observed.

benioff zone: a zone of earthquake epicenters distributed on well defined planes that dips from a shallow depths to as great as 700 kilometers.

Body wave: seismic waves that travel either along or near the earth's surface.

crust: it is the uppermost part of the earth. It consists of two distinct parts, the oceanic crust and the continental crust.

core: the innermost part of the earth, which is divided into an inner core, the upper boundary of which is 1,700 km from the centre and an outer core, 1820 km thick. Both parts are thought to consist of iron-nickel alloy. The temperature may be 30000C.

dip: the angle that a stratum or fault plane makes with the horizontal.

earthquake: a shaking or trembling of the crust of the earth caused by breaking and shifting of rock beneath the surface or by underground volcanic process.

epicenter: the point on the surface of the earth directly above the focus of an earthquake.

fault: a fracture in the earth's crust along which there has been displacement of rock on one side relative to the other. The displacement ranges from a few centimeters to a few kilometers and may occur in horizontal, oblique or vertical direction.

fault system: two or more fault sets which interconnect

fault scarp: a steep cliff formed by movement along one side of a fault.

fault trace or fault line: intersection of the fault surface with the surface of the earth or any other horizontal surface of reference.

Fault throw: The amount of vertical displacement of rocks due to faulting.

Fault Zone: A fault expressed as an area of numerous fractures.

First motion: On a seismogram, the direction of ground motion as the p-wave arrives at the seismometer.

Forseocks: A tremor which precedes a larger earthquake or mainshock

Fault terrace: A step on slope, produced by displacement of two parallel faults.

Geodesy: The branch of science concerned with surveying and mapping the earth's surface.

Geology: The branch of science concerned with the origin, structure and composition of the earth.

Geophysics: The branch of science in which the principles of mathematics and physics are applied to the study of the earth's crust and interior.

Ground failure: A general reference to land slides, liquefaction, lateral spreads and any other consequence of ground shaking.

Ground motion: The movement of the earth's surface caused by seismic waves and travel through the earth and along its surface.

Interplate coupling: It means a fault between two plates is locked and capable of accumulating stress.

Isoseismal: A contour or line on a map bounding points of equal intensity for a particular earthquake.

Lithosphere: The topmost layer of the earth's structure forming the of plates that take part in the movement of plate tectonics.

Locked fault: A fault that is not slipping because of frictional resistance on the fault is greater than the shear stress across the fault. A locked fault is expected to

store strain for extended periods. The frictional resistance is eventually overcome in an earthquake.

Love wave: A type of seismic surface wave having a horizontal motion that is transverse or perpendicular to the direction of the propagation of the wave.

Mainshock: The largest earthquake in a cluster of earthquake. The mainshock is sometimes preceded by one or more foreshocks but almost always followed by many aftershocks.

Mantle: The immediate zone of the earth between the crust and the core, accounting for 82 percent of the earth's volume. The mantle is separated from the crust by the Mohorovicic discontinuity and from the core by the Gutenberg discontinuity. It is thought to consist of silicate Minerals Such as Olivine.

P-wave: The primary or the fastest seismic waves traveling away from an earthquake, consisting of a series of compressions and dilatations parallel to the direction of travel of the wave.

Paleoseismic: The history of seismic events which is determined by examining the layers of rock beneath the surface and how they have been displaced by earthquake in the past.

Plate tectonics: The theory that the earth's surface consists of a number of plates or large crustal slabs whose slow but constant motion explain continental drift, mountain formation, etc.

Rayleigh wave: A surface seismic wave with retrograde, elliptical motion at the free surface. It is also known as r-wave.

Strike-slip fault: A fault on which the two blocks of rocks slide past one another.

Rupture front: The instantaneous boundary between the slipping and locked parts of fault during an earthquake.

S-wave: A seismic body wave that shakes the ground back and forth perpendicular to the direction of propagation of the wave. It is also called shear wave.

Seismicity: The degree to which a region of the earth is subject to earthquake.

Seismic movement: A measure of the size of an earthquake derived from the area of fault rupture, the average amount of slip and the force required to overcome the stress generated by the faulting.

Seismic wave: Generated by an earthquake, seismic waves are elastic waves and they travel either along or near the Earth's surface (surface seismic waves) or through the earth's interior (body seismic waves)

Seismic zone: An area of seismicity probably sharing a common.

Seismogenic: Capable of generating earthquake.

Seismogram: The chart of an earthquake as recorded by a seismograph

Seismology: The branch of geology concerned with the study of earthquakes.

Seismometer: An instrument that records the intensity and duration of earthquakes and similar tremors. Strictly speaking seismograph is a term that refers to the seismometer and its recording device as a single unit.

Seismoscope: An instrument indicating only the occurrence and time of an earthquake.

Seismic constant: In building codes dealing with earthquake hazards, an arbitrarily set quantity of steady acceleration in units of acceleration of gravity, that a building must withstand.

Seismic discontinuity: A surface at which velocities of seismic waves changes abruptly.

Shearing stress: A stress in which the material by one side of a surface such as a fault plane, pushes on the material on the other side of the surface with a force parallel to the surface.

Slip rate: The rate at which two sides of a fault are slipping relative to one another.

Slip: The relative displacement of formerly adjacent points on opposite sides of a fault measured on the fault surface.

Subduction: The process by which one crustal block descends beneath another.

Subduction zone: The place where two crustal blocks come together, one riding over the other.

Surface faulting: Displacement that reaches the Earth's surface during slip along a fault. Surface faulting normally occurs with shallow earthquakes.

Surface wave: Seismic waves that travel along the Earth's surface for example, Rayleigh and Love waves.

Tectonic: Designing of, or pertaining to changes in the structure of the Earth's crust, the forces responsible for such deformation or the external forms produced.

Teleseismic: Pertaining to earthquake at distances greater than 1,000 km from the site of measurement.

Thrust fault: A dip-slip fault in which the upper block above the fault plane moves up and over the lower block.

Isunami: A huge sea wave caused by a great disturbance under an ocean, as a strong earthquake or volcanic eruption.

Tectonics: A branch of geology that deals with the Earth's crustal structure and the forces that produce changes in it.

Tsunamigenic: Referring to those earthquakes, that can generate tsunamis.

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3. To acquire and extract knowledge from the ground experiences and deductions are made for dialogue.
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