Geologic Hazards Photos Volume 1
Earthquakes - General Topics

Earthquake Damage General Information

An earthquake is the motion or trembling of the ground produced by sudden displacement of rock in the Earth's crust. Earthquakes result from crustal strain, volcanism, landslides, and collapse of caverns. Stress accumulates in response to tectonic forces until it exceeds the strength of the rock. The rock then breaks along a preexisting or new fracture called a fault. The rupture extends outward in all directions along the fault plane from its point of origin (focus). The rupture travels in an irregular manner until the stress is relatively equalized. If the rupture disturbs the surface, it produces a visible fault.

Earthquakes can affect hundreds of thousands of square kilometers; cause damage to property measured in the tens of billions of dollars; result in loss of life and injury to hundreds of thousands of persons; and disrupt the social and economic functioning of the affected area. Although earthquakes in the United States occur most frequently in states west of the Rocky Mountains, devastating earthquakes have also occurred in the Midwest and East. All 50 states have some degree of risk from earthquakes.

Earthquakes can be measured in terms of either the amount of energy they release (magnitude) or the degree of ground shaking they cause at a particular locality (intensity). Magnitude is calculated from the record (wave amplitude) made by an earthquake on a calibrated seismograph. The magnitude scale is logarithmic. An increase of one in magnitude represents a tenfold increase in the recorded wave amplitude. However, the energy release associated with an increase of one in magnitude is not tenfold, but about thirty fold. For example, approximately 900 times more energy is released in an earthquake of magnitude 7 than in an earthquake of magnitude 5.

Intensity is determined from observations of the earthquake's effect on people, structures, and the earth's surface at a given locality. When a fault ruptures, seismic waves propagate outward in all directions and ground shaking results. Generally the severity of ground shaking increases as magnitude increases and decreases as distance from the fault rupture increases. The severity of the ground shaking can be enhanced by certain soil and subsoil types. The intensity of the earthquake is affected by the severity of the ground shaking, the duration of the shaking, the response of structures in the affected area, etc.

Hazards associated with earthquakes include ground shaking, surface faulting, earthquake-induced ground failures, tectonic uplift and subsidence, and tsunamis. Surface faulting, the offset of the earth's surface by differential movement across a fault, shears and tears structures built on the fault. Surface faulting is generally accompanied by horizontal or vertical distortion of the earth's surface that can distort or tilt structures constructed near the fault. Regional uplift and subsidence may accompany earthquakes caused by large displacements on shallow faults. Such changes can damage harbor facilities, canals, roads, railroads, and other structures.

A tsunami is a water wave or a series of waves generated by an impulsive vertical displacement of the surface of the ocean or other body of water by an earthquake or other cause. These waves can extend the damaging effects of an earthquake event thousands of kilometers from the earthquake focus.

Ground failures accompanying earthquakes include landslides, liquefaction, lateral spreads, differential settlements, and ground cracks. Earthquake shaking often dislodges rock and debris on steep slopes, triggering rock falls, avalanches, and landslides. These slides have been known to bury entire towns and may be the most damaging aspect of the earthquake event.

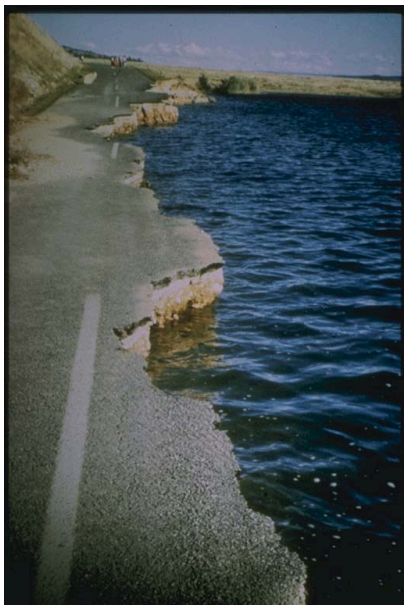
Liquefaction occurs where ground water is near the surface in soils composed of sands and silts. The soil temporarily loses strength and behaves as a viscous liquid. Structures can settle or tip in the liquefied soil or be ripped apart as the ground spreads laterally or flows. Flow failures can move over kilometers at speeds of tens of kilometers per hour. They usually develop in loose, saturated sand on slopes greater than five percent. When

subsurface sand layers lose strength because of liquefaction, lateral spreading can occur in overlying sediments allowing them to move down even the gentlest slopes. Soils may lose shear strength allowing heavy structures to settle or tip and lightweight, buried structures to rise buoyantly. Cracking may result from movement along faults, differential compaction of the soil, or slides. Strong ground shaking has compacted loose cohesionless materials and caused differential ground settlements ranging from 5 cm to more than a meter. Many of these earthquake effects are depicted in the slides included in this set.

Slide Set Images

Compression of Fence, Hebgen Lake, Montana Earthquake of August 18, 1959, Hebgen Lake, Montana. The magnitude 7.1 earthquake killed 28 people and caused $11 million property damage.

GROUND DEFORMATION-COMPRESSION This snake-like fence at Culligan's ranch (about 1 km east of Red Canyon entrance and less than 20 km from the Montana epicenter) is a result of compression as soils moved downhill during the quake. Movement along a fault running through the Culligan's property damaged practically all the buildings. Photograph Credit: U.S. Geological Survey (J.R. Stacy).



Slumping of Highway into Hebgen Lake, Montana Earthquake of August 18, 1959, Hebgen Lake, Montana. The magnitude 7.1 earthquake killed 28 people and caused $11 million property damage.

GROUND DEFORMATION-SLUMPING A section of Highway 287 has crumbled into Hebgen Lake. Landslides, submersion, cracking, and shifting of the roadway made the road impassable for a distance of nearly 58 km. Over 200 vacationers were trapped in Madison Canyon when the earthquake destroyed whole sections of highway. Timber and road damage were estimated at $11 million. Photograph Credit: University of California, Berkeley.

Government Hill School

Earthquake of March 28, 1964, Prince William Sound, Alaska. The magnitude 8.5 earthquake killed 131 people and caused $538 million in property damage. An area consisting of 120,700 km2 was shaken with damaging intensity. GROUND DEFORMATION-SLUMPING Photo shows extent of subsidence at Government Hill School in Anchorage. Soils failed and moved down slope. The soil failure left a part of the school on unmoved ground and dropped the remainder into a wide trough or graben. Photograph Credit: National Geophysical Data Center.

Slumping of Turnagain Heights Subdivision, Anchorage, Alaska Earthquake of March 28, 1964, Prince William Sound, Alaska. The magnitude 8.5 earthquake killed 131 people and caused $538 million in property damage. An area consisting of 120,700 km2 was shaken with damaging intensity.

GROUND DEFORMATION-SLUMPING Slumping of the entire Turnagain Heights subdivision in Anchorage occurred when soil liquefied during the earthquake. The subdivision was located on a bluff above Cook Inlet. A section of earth 2,576 m long and 273 m wide broke loose and slid 21 m toward Cook Inlet. At least 75 houses were destroyed. The most probable explanation of the landslide was a loss of strength in underlying soils from the ground shaking. Sand lenses liquefied and clay soils weakened and moved down slope in a complicated motion. Slope failure began 1.5 to 2.0 minutes after the start of the earthquake. Photograph Credit: National Geophysical Data Center.

Leaning Apartment Houses in Niigata, Japan Earthquake of June 16, 1964, Niigata, Japan. The magnitude 7.4 earthquake killed 26 and destroyed 3,018 houses and moderately or severely damaged 9,750 in Niigata prefecture.

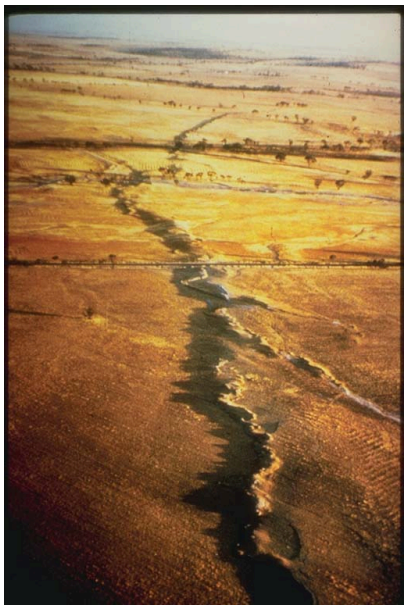
LIQUEFACTION-DIFFERENTIAL SETTLEMENTS Aerial view of leaning apartment houses in Niigata produced by soil liquefaction and the behavior of poor foundations. Most of the damage was caused by cracking and unequal settlement of the ground such as is shown here. About 1/3 of the city subsided by as much as 2 meters as a result of sand compaction. Photograph Credit: National Geophysical Data Center.

Union Pacific Railway Damage from Ground Deformation, Seattle, Washington Earthquake of April 29, 1965, Seattle, Washington. The magnitude 6.5 earthquake killed 7 and caused 12.5 million in property damage.

GROUND DEFORMATION-LANDSLIDE Damage to the Union Pacific Railway occurred when hillside fill slid away from beneath a 121 m section of the branch line just outside Olympia, more than 60 km from the epicenter. Photograph Credit: University of California, Berkeley.

Tipped Residence Due to Differential Settling, Caracas, Venezuela Earthquake of July 29, 1967, Caracas, Venezuela. The magnitude 6.6 earthquake killed 240 and caused $50 million in property damage.

GROUND DEFORMATION-DIFFERENTIAL SETTLING The ground collapsed beneath this structure in Caracas. A house in foreground has been removed. A number of houses with one or two floors showed great damage in Caracas and in the surrounding area. In addition, a number of high-rise buildings were partially or totally destroyed. This destruction was concentrated in two small areas, one in Caracas and one in Caraballeda, north of Caracas. Soil failures such as the one shown here were blamed for much of the damage. Photograph Credit: National Geophysical Data Center.

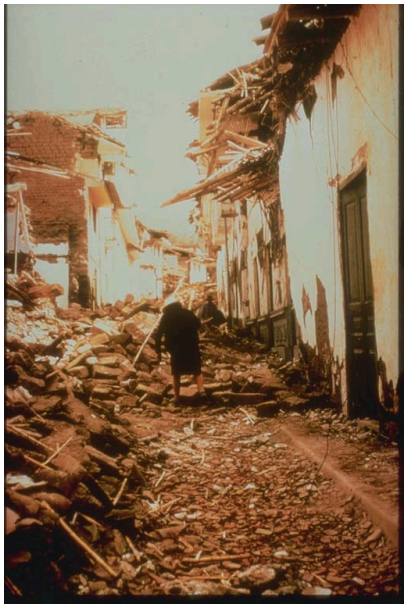


Surface Rupture, Meckering, Australia Earthquake of October 14, 1968, Meckering, Australia. The magnitude 6.8 earthquake caused $2.2 million in property damage. This earthquake was particularly efficient in the generation of surface waves.

GROUND DEFORMATION-SURFACE RUPTURE Aerial view shows a railroad crossing surface rupture near Meckering. The fresh surface rupture was about 30 km long. Photograph Credit: University of California, Berkeley (Dr. Bruce Bolt).

Before View of City Street, Huaraz, Peru Earthquake of May 31, 1970, Huaraz, Peru. The magnitude 7.8 earthquake killed 66,794 and caused $250 million in property damage. Several towns were almost totally destroyed. This earthquake, with complicating factors of landslides and floods, was one of the largest disasters ever to occur in the Southern Hemisphere.

GROUND SHAKING Photo shows a city street in Huaraz before the earthquake. This adobe construction is typical of much of the housing that underwent complete collapse in the Andean townships. Photograph Credit: University of Colorado.



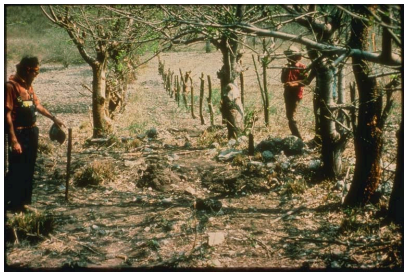
After View of City Street, Huaraz, Peru Earthquake of May 31, 1970, Huaraz, Peru. The magnitude 7.8 earthquake killed 66,794 and caused $250 million in property damage. Several towns were almost totally destroyed. This earthquake, with complicating factors of landslides and floods, was one of the largest disasters ever to occur in the Southern Hemisphere.

GROUND SHAKING Photo shows a city street in Huaraz after the earthquake. Photograph Credit: University of Colorado.

Compression of Freeway, San Fernando, California Earthquake of February 9, 1971, San Fernando, California. The magnitude 6.7 earthquake killed 66 and caused $0.5-1.0 billion property damage.

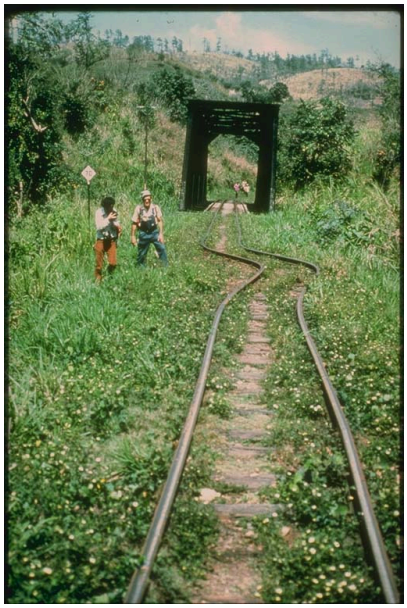
SURFACE FAULTING The photograph shows freeway compression of about 69 cm that occurred south of the interchanges of Routes 5/210 near San Fernando. The dip of the fault plane on Freeway 210 was inferred to be 12 degrees. Structural damage to highways and bridges from this earthquake centered in an area north of the city, which included the Route 5/210

Interchange and the Route 5/14 Interchange. Most of the major structural damage to highways was within 10 km of the earthquake epicenter. Photograph Credit: National Geophysical Data Center.



Offset of Trees along Fault, Motagua, Guatemala Earthquake of February 4, 1976, Guatemala. The magnitude 7.5 earthquake killed 23,000, injured 76,000, and caused $1,100 million in property damage. It was felt over 100,000 square km and was accompanied by extensive surface faulting.

SURFACE FAULTING View southward along a row of trees offset about 3.25 m by strike-slip motion along the Motagua fault in Guatemala. The amount of offset is indicated by the distance between the row of trees on the right and the stake at which the man points. The stake is aligned with the row of trees in the background. Photograph Credit: U.S. Geological Survey.

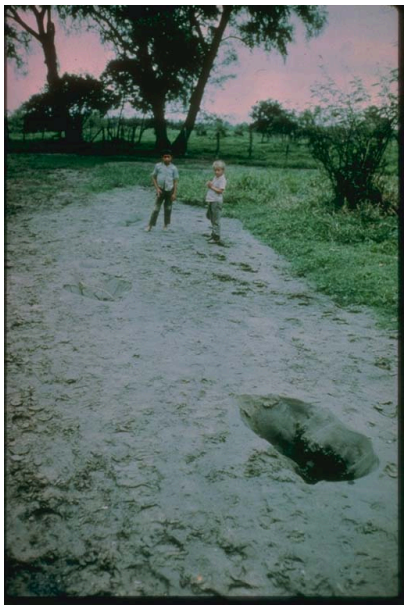


Twisted Railroad Tracks across Fault, Guatemala Earthquake of February 4, 1976, Guatemala. The magnitude 7.5 earthquake killed 23,000, injured 76,000, and caused $1,100 million in property damage. It was felt over 100,000 square km and was accompanied by extensive surface faulting.

SURFACE FAULTING The view is looking north along railroad tracks that were twisted and offset 1.07 m by the Motagua fault, which is perpendicular to the tracks. This is one of numerous localities at which the main railroad line between the coastal port of Puerto Barrios and Guatemala City was disrupted by the faulting. Photograph Credit: U.S. Geological Survey.

Landslide near Guatemala City, Guatemala Earthquake of February 4, 1976, Guatemala. The magnitude 7.5 earthquake killed 23,000, injured 76,000, and caused $1,100 million in property damage. It was felt over 100,000 square km and was accompanied by extensive surface faulting.

LANDSLIDES Landslides occurred in the steep roadcut of stratified pumice and ash deposits at the San Cristobal subdivision west of Guatemala City. The materials exposed in this roadcut are typical of much of the Pleistocene tephra deposits that underlie inhabited parts of the Guatemalan highlands. Photograph Credit: U.S. Geological Survey.



Liquefaction, Motagua Valley, Guatemala Earthquake of February 4, 1976, Guatemala. The magnitude 7.5 earthquake killed 23,000, injured 76,000, and caused $1,100 million in property damage. It was felt over 100,000 square km and was accompanied by extensive surface faulting.

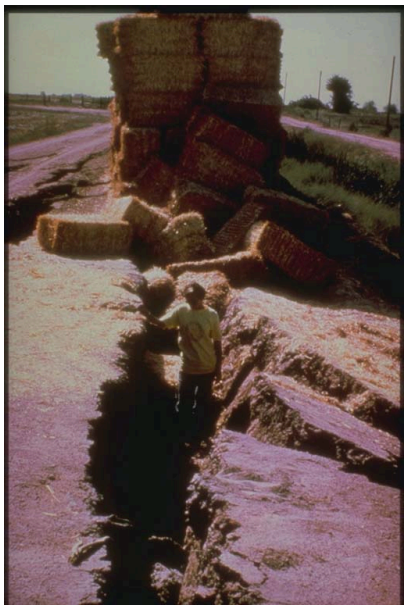
LIQUEFACTION Sand mounds deposited by spouting from the row of crater-like vents in the lower Motagua Valley, Guatemala. Increased pressure due to the earthquake forced the liquefied sands to the surface. Photograph Credit: U.S. Geological Survey.

Support Pillar Failure, Imperial County Services Building, El Centro Earthquake of October 15, 1979, El Centro, California. The magnitude 6.9 earthquake caused $30 million property damage and injured 91 people.

GROUND SHAKING The support pillar failed at the east end of the Imperial County Services Building in El Centro. This 6-story reinforced concrete frame and shear wall structure completed in 1971 at a construction cost of $1.87 million, was designed to be earthquake resistant. The concrete at the base of the columns was shattered and the vertical reinforced bars were severely bent, allowing the building to sag about 30 cm. The building was later destroyed and rebuilt. Photograph Credit: U.S. Geological Survey.

Offset of Lettuce Rows across Fault, El Centro, California Earthquake of October 15, 1979, El Centro, California. The magnitude 6.9 earthquake caused $30 million property damage and injured 91 people.

SURFACE FAULTING Here earthquake faulting has caused an offset of rows in a lettuce field near El Centro. Such a fault with purely horizontal displacement to the right as one looks across the fault is known as a right lateral strike slip fault. The agriculture industry suffered heavy losses due to damage to canals, irrigation ditches, and subsurface drain tiles disturbed by the movement along the Imperial Fault. Photograph Credit: University of Colorado.



Slumping near El Centro, California Earthquake of October 15, 1979, El Centro, California. The magnitude 6.9 earthquake caused $30 million property damage and injured 91 people.

GROUND DEFORMATION-SLUMPING This slumping resulted from the earth shaking near El Centro. The earthquake produced extensive lateral slope failure along many irrigation canals. Photograph Credit: University of Colorado.

Sand Boil produced by Liquefaction, El Centro, California Earthquake of October 15, 1979, El Centro, California. The magnitude 6.9 earthquake caused $30 million property damage and injured 91 people.

LIQUEFACTION The photo shows one of many sand boils that formed near El Centro. At localities where the water table is close to the surface, compaction of saturated unconsolidated materials is often accompanied by ejection of water or water-sediment mixtures forming sand boils. Photograph Credit: University of Colorado.

Collapsed Unit of Pallante Factory, Campania, Italy Earthquake of November 23, 1980, Campania, Italy. The magnitude 6.8 earthquake killed over 3,000, injured 7,750, and caused severe property damage. An additional 1,575 were reported missing and presumed dead. Two hundred fifty thousand were reported to be homeless. Twenty five thousand square kilometers of southern Italy were devastated.

GROUND SHAKING Collapsed unit of the Pallante factory at Campania, caused by failure at a construction joint. Some infill walls of the remaining structure have also failed. The large death toll from a magnitude 6.9 earthquake resulted from poor construction practices such as the infill masonry wall shown here. Photograph Credit: National Academy Press.

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