Seismic Hazard

A Resilient Future: Science and Technology for Disaster Risk Reduction

Dr. João Almeida
Former Postdoctoral Researcher
Earthquake Engineering and Structural Dynamics Laboratory

example
people
technology
building
science
earthquake
data
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important
model
disaster
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level
measure
information
development
seismic hazard
disaster risk
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video
system
flood
landslide
risk reduction
early warning
vulnerability
resilience
communities
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usedtime
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ground shaking
ground motion
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region
DRR
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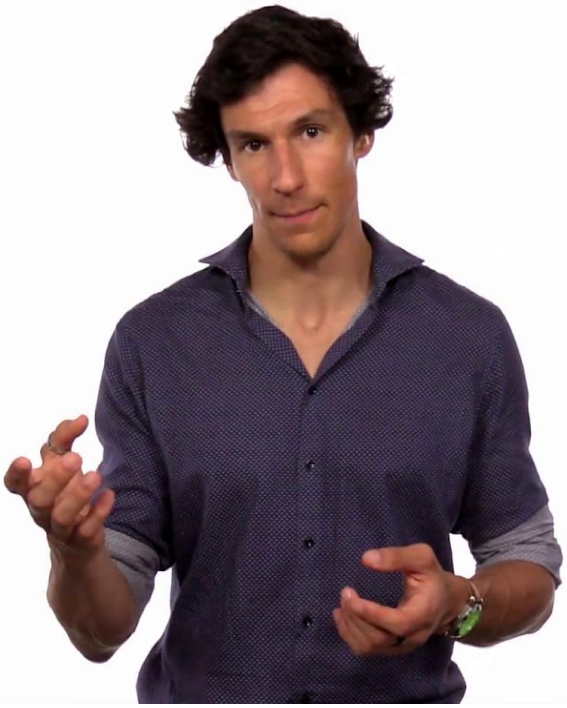
natural hazard
loss
detail
order
occur

Outline



- The origin of earthquakes
- Introduction to seismic hazard
- Expressing seismic hazard

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Hello. My name is João Almeida. I am your lecturer for this video in which I will talk about seismic hazard. I will first start by recalling how earthquakes usually occur and their waves propagate. I will then define seismic hazard and discuss how we can measure the size of an earthquake namely in terms of magnitude and intensity.

Notes

Summary

0m 04s

The origin of earthquakes

- Tectonic Earthquakes: rupture of the Earth's crust
  - Intra-plate
  - Inter-plate
- Earthquakes due to volcanic activity
- Earthquakes due to the collapse of underground cavities
  - Natural cavities
  - Artificial cavities (mining)
- Earthquakes related to dams and water basins (filling!)
- Artificial Earthquakes
  - Large blasts
  - Nuclear explosions

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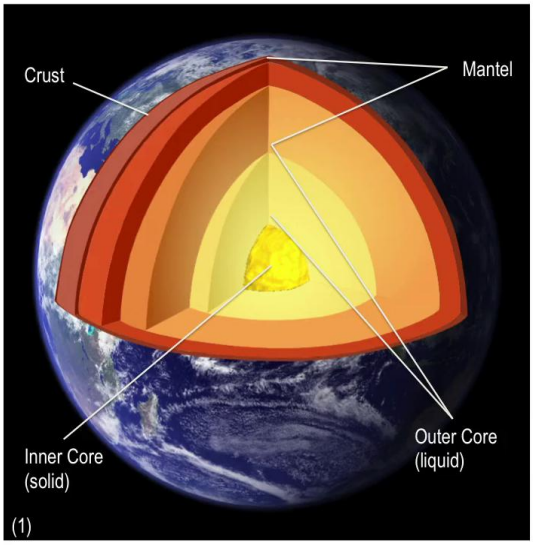
There are different types of earthquakes. They can be due to volcanic activity, collapse of underground cavities or even produced by blasts or explosions. However, the major source of large earthquakes is definitely the rupture of earth's crust namely in the so-called inter-plate earthquakes.

Notes

Summary

0m 27s

The origin of earthquakes



- The Earth has four major layers: the crust, the mantle, the outer core, and the inner core
- The crust, together with the rigid uppermost mantle, forms the lithosphere

The next few slides will bring back to memory what you most probably learn in primary school. The earth is divided in four major layers. The inner and outer core, the mantle and the crust. The skin or the hard outer layer of our planet is called the lithosphere and it is made up of the crust and the cool dense and rigid upper part of the mantle.

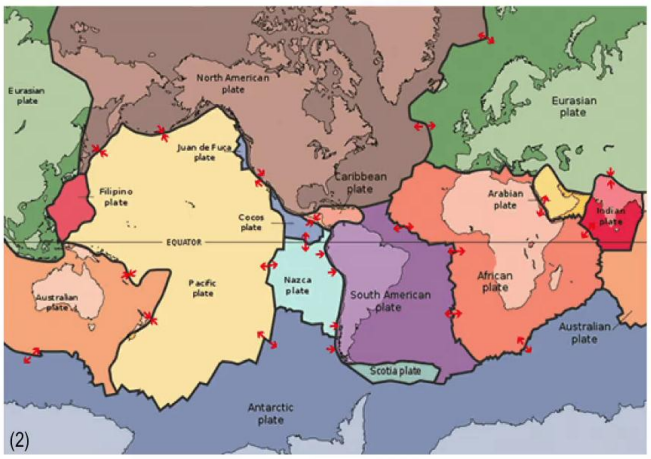
Notes

Summary

0m 46s

The origin of earthquakes

The lithosphere is divided into seven major continental tectonic plates



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However, our planet's skin is not all in one piece. It is composed of many pieces covering the surface of the earth called tectonic plates.

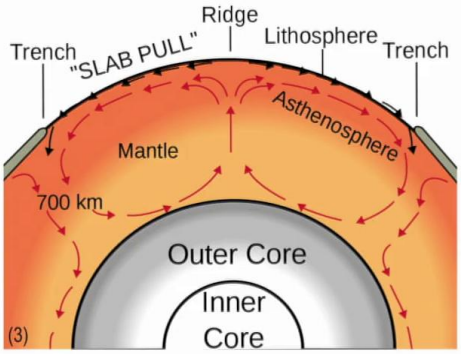
Notes

Summary

1m 09s

The origin of earthquakes

Because of the difference in temperature between the core and the crust, convection currents generate in the mantle



These tectonic plates are not immobile. In fact, the difference in temperature between the core and the crust creates convection currents that force these plates to keep slowly moving around in different directions at different speeds sliding past one another and bumping into each other.

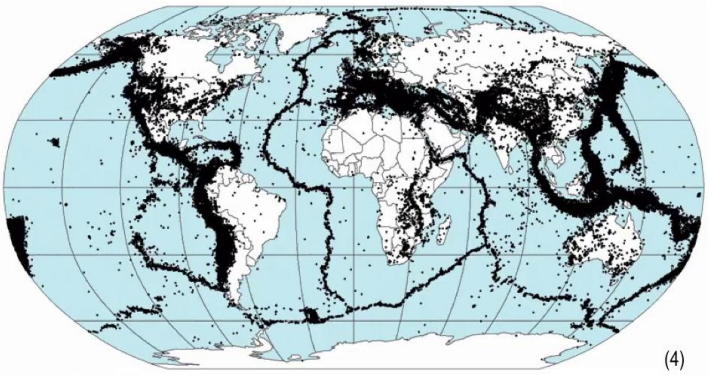
Notes

Summary

1m 20s

The origin of earthquakes

Approximately 80,000 earthquakes with magnitude (M) > 5 since 1960



(4)

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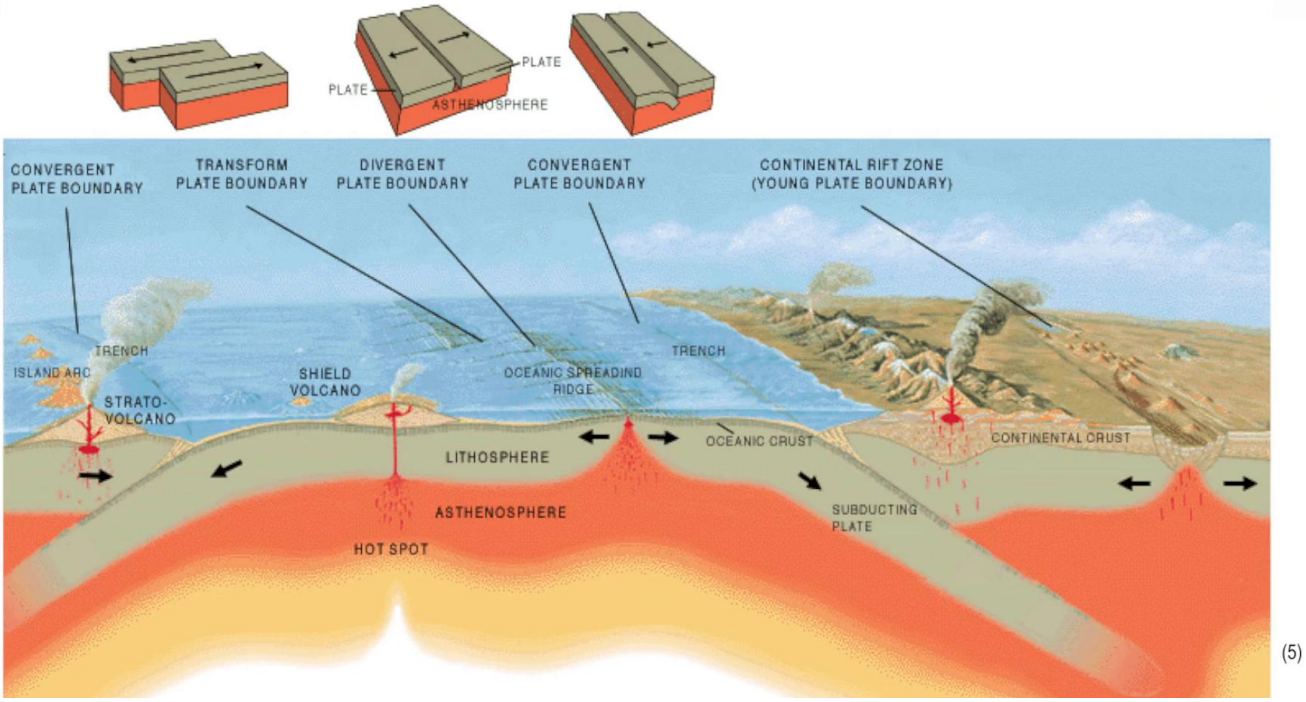
The edges of these plates are called plate boundaries. The boundaries are made up of many faults and most of the largest earthquakes around the world occur on these faults. Since the edges of the plates are rough they get stuck while the rest of the plate keeps moving.

Notes

Summary

1m 40s

The origin of earthquakes



(5)

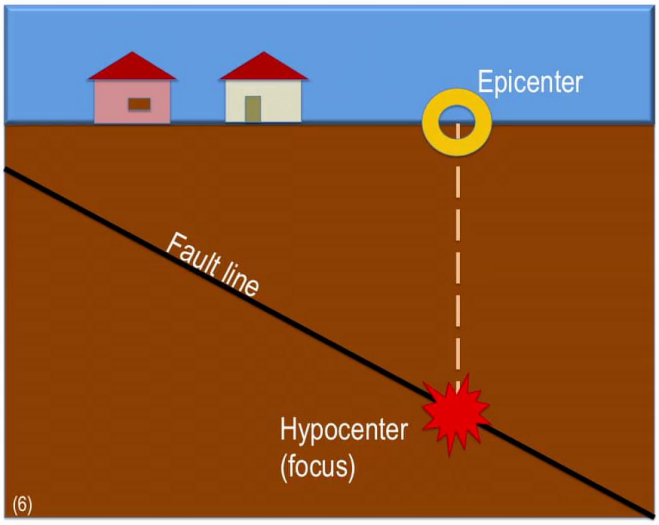
When the plate has moved far enough a rupture stress is reached at the point, the two mass blocks on either side of the fault unstick and slide along the surface of the fault with an instantaneous release of elastic strain energy.

Notes

Summary

1m 58s

The origin of earthquakes



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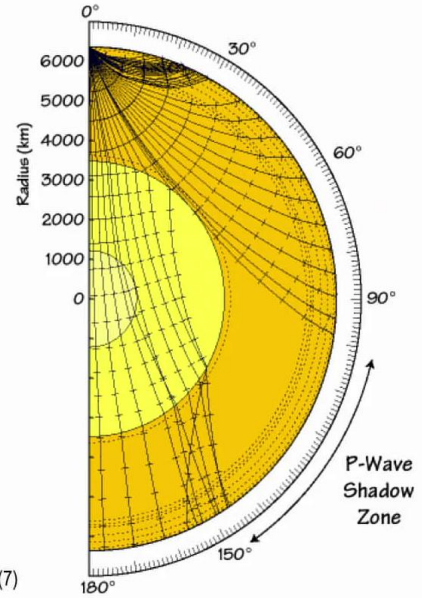

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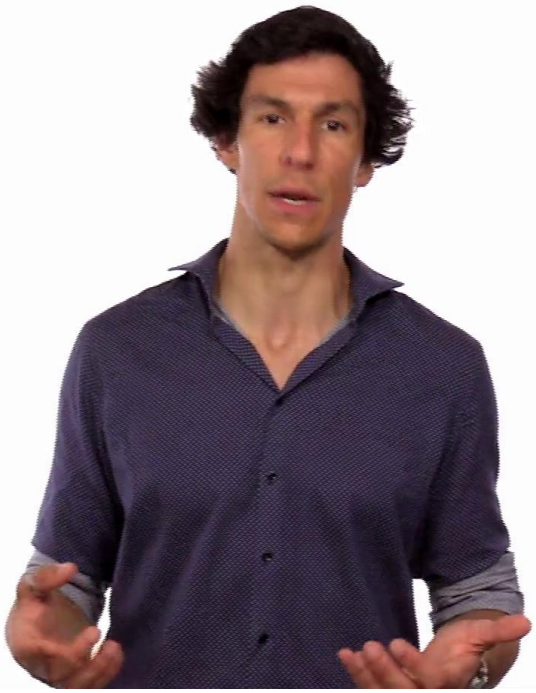
The point within the earth where an earthquake rupture starts is called Hypocenter or Focus. If it's depth is up-to 60 kilometers, we say that it is a superficial earthquake while deep ones have hypocenters between 300 to 700 kilometers. The epicenter is the point directly above the hypocenter at the surface of the earth. The energy released in an earthquake is transmitted in the form of seismic waves, such as the faster compressional waves P and the slower transverse waves S which propagate inside the earth in the radial direction undergoing phenomena of reflection and refraction.

Notes

Summary

2m 15s

Introduction to seismic hazard



Seismic Hazard is “a potentially damaging physical phenomenon induced by an earthquake that may cause loss of life or injury, property damage, social and economic disruption or environmental degradation.”

(Modified from UNISDR, 2009)

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Until now I recalled how earthquakes originate and their waves propagate. Seismic hazard refers to all the physical phenomena caused by earthquakes that may be potentially damaging either directly for human life, for physical assets or in any other social, economic or even environmental dimension.

Notes

Summary

2m 59s

Introduction to seismic hazard: Recording

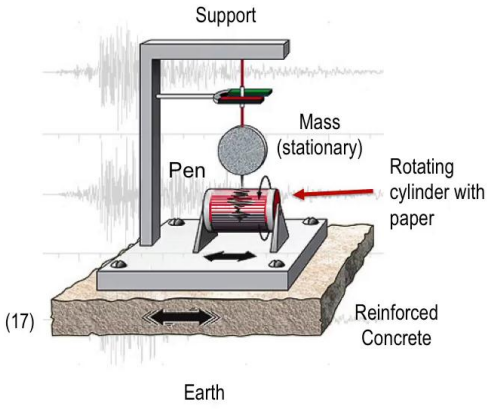
They include ground shaking which can make it difficult for us to stay on our feet or more importantly makes structures collapse but also surface rupture for those cases where the fault does not remain buried or hidden under the uppermost layers of rock in the crust. Tsunamis and you may recall that in the Indian Ocean in 2004, as shown in this picture or after the recent Japanese earthquake of 2011. Liquefaction, when a water saturated soil temporarily loses it's strength and behaves as a fluid or even landslides and rockfalls. Instruments that characterize the ground motion have been developed since ancient times, as Zhang's seismoscope, where a bronze ball drops from one of the eight dragon heads to the toad's mouth to indicate the earthquake direction.

Notes

Summary

3m 21s

Ground shaking: How to record it?



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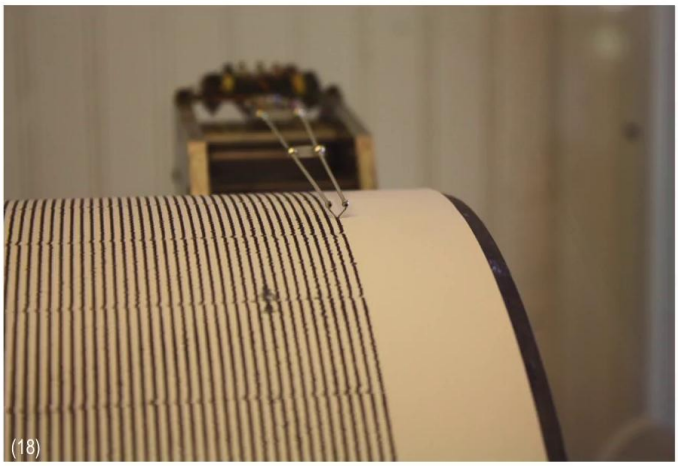
(18)

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In more classical seismographs, as represented in this sketch when an earthquake causes the ground to shake the base of device shakes too but hanging weight does not. The relative displacement between the shaking part of the seismograph and the motionless part is what is recorded.

Notes

Summary

4m 17s

Introduction to seismic hazard: Recording

Modern seismometers are based on analog and digital technologies

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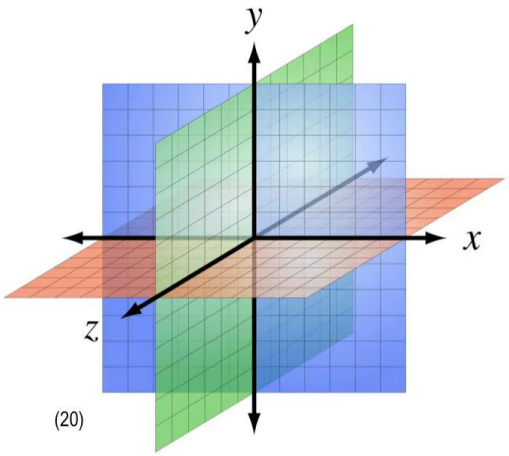
Modern seismometers based on analog and digital technologies allow not only to register the displacements associated to ground shaking but also ground motion records of acceleration and velocity.

Notes

Summary

4m 37s

Earthquake records



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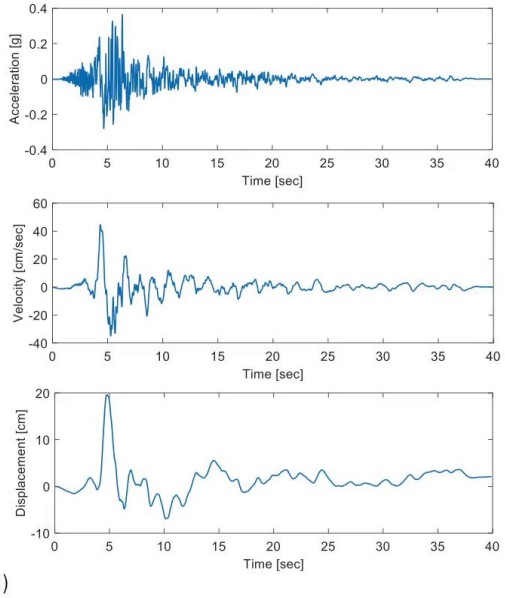

(21)

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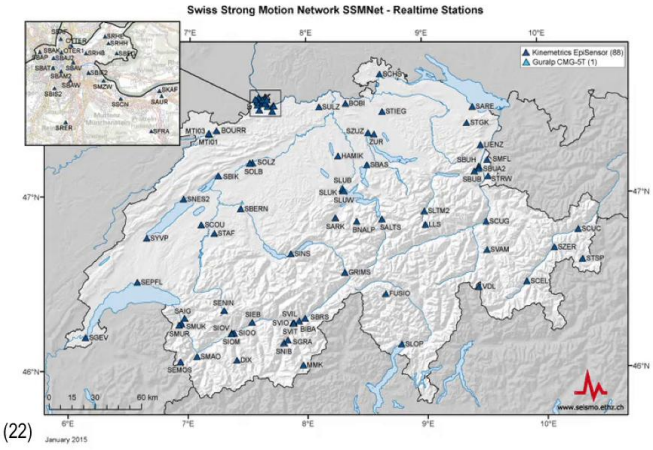
Besides, these records can be measured along any two perpendicular horizontal directions or even along the vertical axis.

Notes

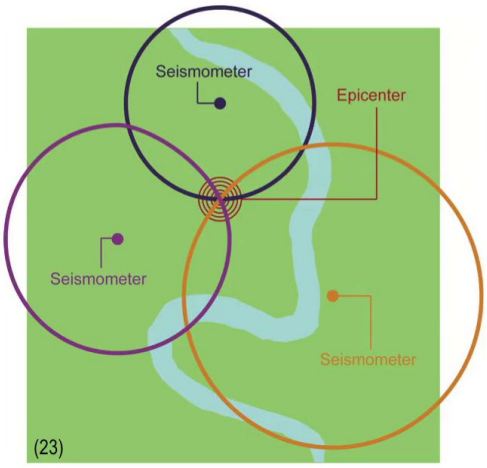
Summary

4m 50s

How to find the epicenter of an earthquake?



Network of seismographs in Switzerland



Different speed of P and S waves + Triangulation

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Using the existing networks of seismometers scientists can then determine exactly where the earthquake was based on the speed difference between the P and S waves and by using a method called triangulation.

Notes

Summary

4m 58s

Introduction to seismic hazard: Measuring

How to measure the earthquake's size?

- Magnitude
  - It quantifies the energy released by an earthquake
  - For each earthquake, there is only one magnitude (for each magnitude scale)
- Intensity
  - It measures the effect of the earthquake at a specific site
  - For each earthquake, many intensities can be determined

When it comes to measuring the size of an earthquake there are basically two measures that can be employed. Magnitude and intensity. Magnitude quantifies the global energy released by an earthquake while intensity expresses the local earthquake effects, disease at a specific site. It is therefore easy to understand that for each earthquake there is only one magnitude value.

Notes

Summary

5m 12s

Quantifying the energy released: Magnitude

- Several magnitude scales (e.g. Richter scale, M_L)
- Most common one: moment magnitude M_W, which is proportional to the average amount of slip on the fault and the size of the area that slipped

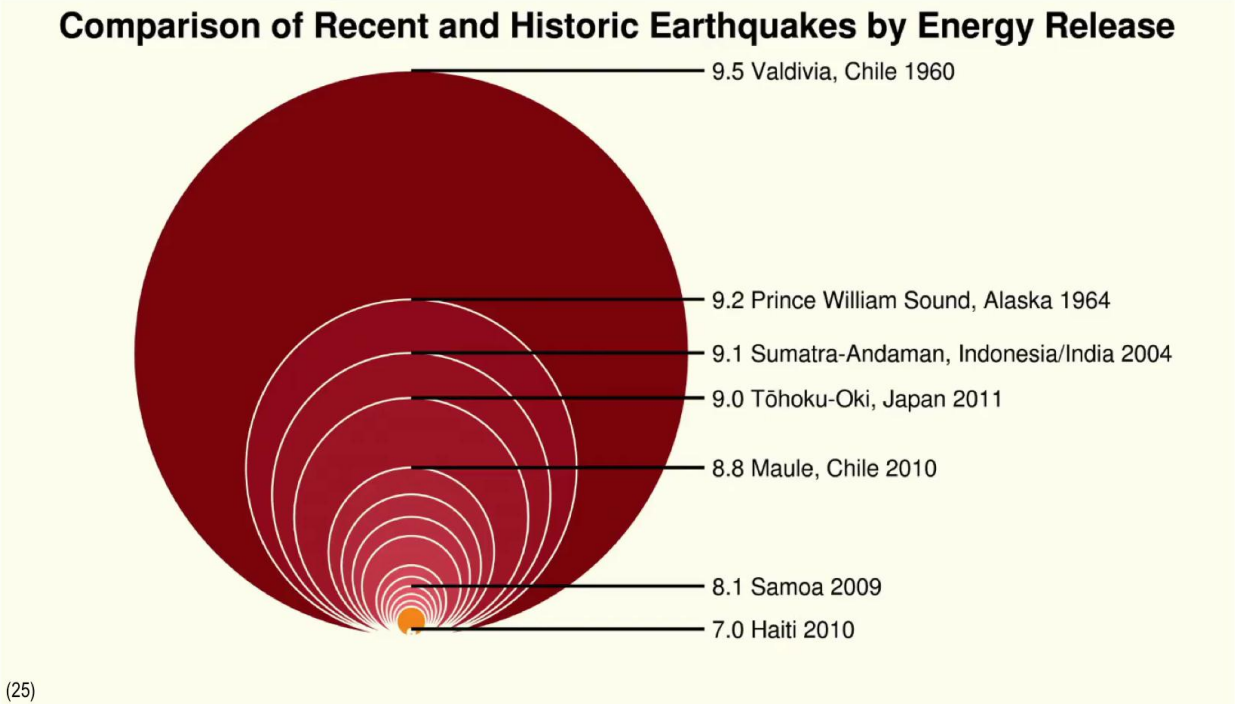
Instead, many parameters can be used to measure the intensity. With respect to magnitude there are several scales. Although the Richter scale developed in 1930's is perhaps the most famous, the one which is commonly used for official purposes is the Moment Magnitudes developed in the 1970's. It is based on the seismic moment of the earthquake which is proportional to the average displacement along the fault and the size of the area that slipped.

Notes

Summary

5m 40s

Quantifying the energy released: Magnitude



(25)

Just to give you a rough estimate of the amount of released energy, consider that the magnitude 4 earthquake is approximately similar to the explosion of a small atomic bomb within a radius of a 100 kilometers. An increase of one step on this logarithmic scale corresponds to approximately 32 times increase in terms of the amount of energy which means that, for instance, a magnitude 7 earthquake is around a 100 times bigger than a magnitude 5 earthquake. This should put things in perspective if I tell you that a few earthquakes with magnitude larger than 9 have been measured over the past 70 years. The maximum magnitude registered until today was approximately of 9.5 in Chile in 1960.

Notes

Summary

6m 13s

Expressing seismic hazard: Intensity

- Observational: Intensity that is assigned based on observations (also known as macroseismic intensity)
- Instrumental: Intensity that is measured from instruments, such as accelerographs (more commonly known as ground motion parameters)

→ Conversion between observational and instrumental intensity involves lots of uncertainty

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Seismic hazard is, however typically expressed through the intensity of ground shaking from an earthquake at a given site which can be measured using a number of parameters as stated before. This can be categorized into two types. Intensity that is assigned based on observations, also known as micro-seismic intensity and intensity that is measured from instruments such as accelerographs, commonly known as ground motion parameters. The conversion between observational and instrumental intensity involves much uncertainty. Let's see why by looking in more detail into each of this categories.

Notes

Summary

7m 00s

Expressing seismic hazard: Observational intensity

- "A measure of ground shaking obtained from damage done to structures built by humans, changes in the Earth's surface, and felt reports." (Bolt, 2004)
- Indirect measure of ground shaking. It is used in particular to estimate the ground movement in a region
- Some of the most famous scales:
  - Modified Mercalli Intensity (MMI)
  - Medvedev-Sponheuer-Karnik (MSK)
  - Mercalli-Cancani-Sieberg (MCS)
  - European Macroseismic Scale (EMS-98)

Following the definition of Bolt, observational intensity is a measure of ground shaking obtained from damage done to structures built by humans, changes in the earth's surface and felt reports. It is an indirect measure for the ground shaking being particularly useful for historical earthquakes. This is where no records of the ground motions are available or for recent earthquakes in regions where no accelerometers were installed. The most famous scale is probably the Modified Mercalli Intensity (MMI). However, there are others.

Notes

Summary

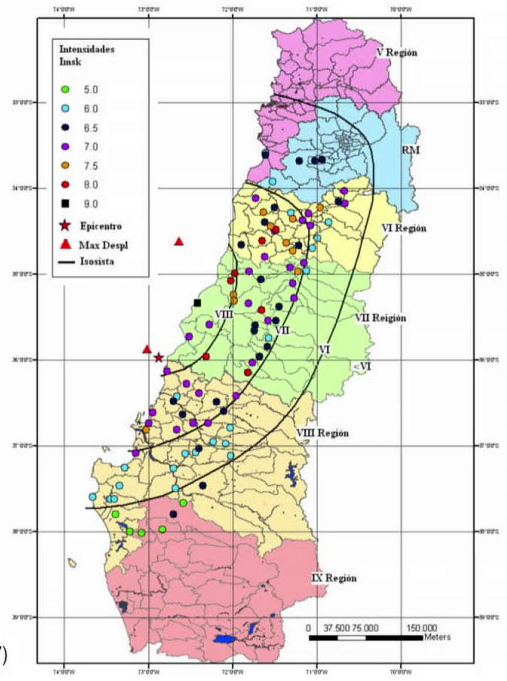
7m 42s

Expressing seismic hazard: Observational intensity

EMS intensity	Definition	Description of typical observed effects (abstracted)
I	Not felt	Not felt.
II	Scarcely felt	Felt only by very few individual people at rest in houses.
III	Weak	Felt indoors by a few people. People at rest feel a swaying or light trembling.
IV	Largely observed	Felt indoors by many people, outdoors by very few. A few people are awakened. Windows, doors and dishes rattle.
V	Strong	Felt indoors by most, outdoors by few. Many sleeping people awake. A few are frightened. Buildings tremble throughout. Hanging objects swing considerably. Small objects are shifted. Doors and windows swing open or shut.
VI	Slightly damaging	Many people are frightened and run outdoors. Some objects fall. Many houses suffer slight non-structural damage like hair-line cracks and fall of small pieces of plaster.
VII	Damaging	Most people are frightened and run outdoors. Furniture is shifted and objects fall from shelves in large numbers. Many well built ordinary buildings suffer moderate damage: small cracks in walls, fall of plaster, parts of chimneys fall down; older buildings may show large cracks in walls and failure of fill-in walls.
VIII	Heavily damaging	Many people find it difficult to stand. Many houses have large cracks in walls. A few well built ordinary buildings show serious failure of walls, while weak older structures may collapse.
IX	Destructive	General panic. Many weak constructions collapse. Even well built ordinary buildings show very heavy damage: serious failure of walls and partial structural failure.
X	Very destructive	Many ordinary well built buildings collapse.
XI	Devastating	Most ordinary well built buildings collapse, even some with good earthquake resistant design are destroyed.
XII	Completely devastating	Almost all buildings are destroyed.

(26)

Grünthal, G. (ed.): European Macroseismic Scale 1998 (EMS-98). Cahiers du Centre Européen de Géodynamique et de Séismologie 15, Centre Européen de Géodynamique et de Séismologie, Luxembourg, 99 pp., 1998. http://www.gfz-potsdam.de/EMS98



(27)

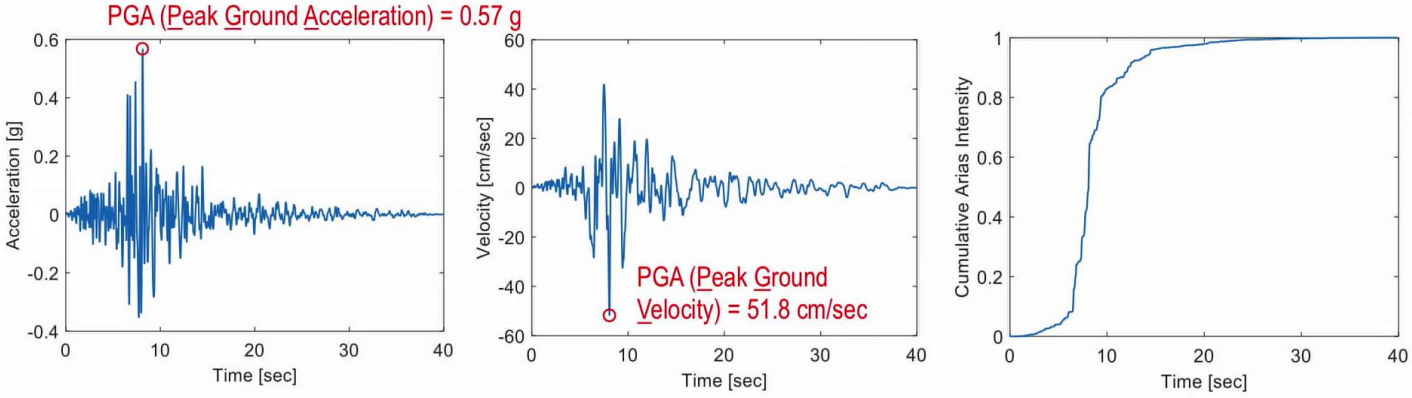
For example, this table presents the short form of the European Microseismic Scale (EMS) 98 which is a 12-point scale. Roman numerals are used to emphasize the fact that this scales are neither continuous nor linear. The level 3 corresponds to the level of human perceivability while damaging structures initiate in level 7. The top two degrees are rarely attained, if ever. This figure on the right shows the application of a micro-seismic intensity scale to the Chile earthquake of 2010. Note that due to local side effects the maximum intensity does not necessarily occur at the epicenter. Further, one can also observe the eyes of intensity lines which bound in an approximate manner a region with one predominant intensity.

Notes

Summary

8m 17s

Expressing seismic hazard: Instrumental intensity



(28)

(Northridge earthquake)

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For what concerns ground shaking as recorded by seismic instruments, a large number of parameters can be considered. One can, for instance, take the maximum absolute value of the ground acceleration during an entire earthquake record, the so-called Peak Ground Acceleration or PGA or any other ground motion parameter such as the peak ground velocity or the area's intensity which measures the energy within the record.

Notes

Summary

9m 12s

Expressing seismic hazard

- Seismic hazard is characterized by location, intensity, and frequency/ probability
- Return period T of an earthquake = Average time between two earthquakes of $M_W \geq m$

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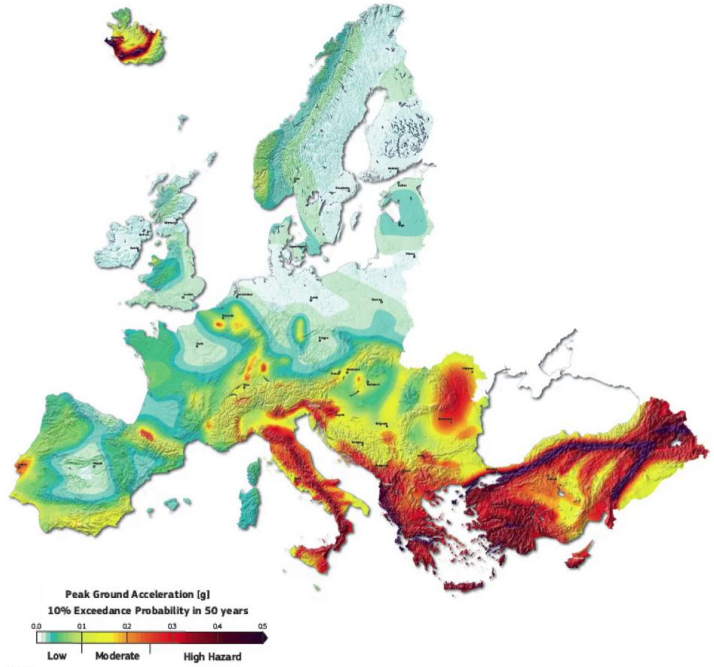
Seismic hazard, however, is not only characterized by location and intensity. It's frequency or probability of occurrence is also required. This can be expressed by the return period T of an earthquake which is the mean time between the occurrence of two earthquakes with the magnitude equal or larger than the specified value.

Notes

Summary

9m 42s

Expressing seismic hazard



(29)

Seismic hazard can be expressed in hazard maps: levels of ground motion with a given probability of exceedance in a given number of years

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Finally, seismic hazard can be expressed in the form of hazard maps which show the levels of ground motion with a given probability of exceedance over a period of time. This example, for instance, displays the peak ground acceleration for a 10% exceedance probability in 50 years as obtained for Europe by the program Share.

Notes

Summary

10m 06s

Main points

- Seismic hazard is expressed by a certain intensity measured at a given site or region
- Seismic hazard is approximately constant in time

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In a nut shell, in this video we have seen how earthquakes generate and their waves propagate. How we can record them and how we can measure their size namely in terms of magnitude and intensity. Many different intensity measures can be used to express seismic hazard due to ground shaking at a given site or region. Besides, seismic hazard due to natural earthquakes can be characterized probabilistically and it is approximately constant in time.

Notes

Summary

10m 30s

Acknowledgements

Dr. João Almeida and the Cooperation & Development Center (CODEV) would like to thank, Dr. Helen Crowley and Prof. Rui Pinho, for providing the technical and educational input for this video

In other words, the seismic hazard here in Lausanne, where I live, is expected to be approximately the same today or in 100 years time. Does this mean that the seismic risk of this region or any other region will also be the same in 100 years? The answer is no and the reason is that seismic hazard is only one of the components that influence seismic risk. I will explain this in more detail in video of week 2. See you there.

Notes

Summary

10m 59s

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(27) Astroza, M. and Ruiz, S. in Astroza, M., Cabezas, F., Moroni, M.O., Massone, L., Ruiz, S., Parra, E., Cordero, F. and Mottadelli, A (2010) Intensidades Sísmicas en el Área de Daños del Terremoto del 27 de Febrero de 2010, Departamento de Ingeniería Civil, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile, 23 pp.

Notes

Summary

11m 34s

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Summary

11m 44s

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Notes

Summary

11m 47s