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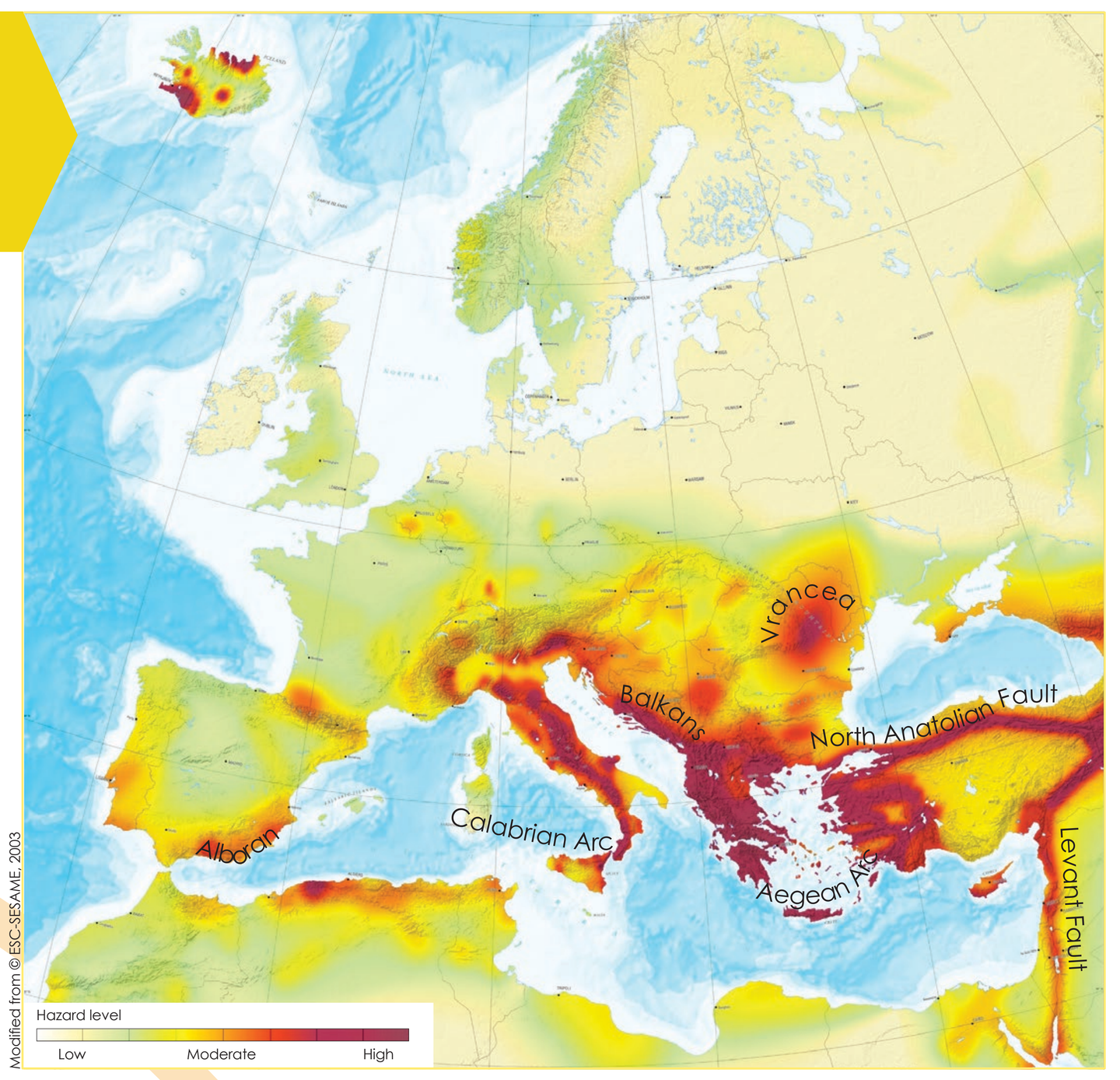
EARTHQUAKES IN THE EURO-MEDITERRANEAN REGION

INTERESTING FACTS

The hazard characterises the level of seismic activity. It takes into account the rate, the magnitude and the location of earthquakes in the given area. The higher the hazard, the more frequent the strong shaking. The hazard results from the seismic activity, and cannot be modified.

The hazard can be widespread, like in the Balkan region, or localised along faults such as the North Anatolian Fault in Northern Turkey or the Levant Fault in the Middle East. In these regions, large earthquakes occur along these faults and the hazard decreases when moving away from them.



How is seismic hazard determined ?

Seismic hazard is evaluated from past earthquakes. It includes recent earthquakes recorded by monitoring networks, typically since the 1970s. But forty years of observation is not representative of long-term seismicity. More ancient information extracted from historical writings, scars in ancient monuments or markers in the landscape must be added. These studies are always complex but essential especially in regions with moderate seismicity where destructive earthquakes are rare.

The offset of about 1m is due to the destructive earthquake of A.D.749 whose magnitude has been evaluated at 7 to 7.5.

Archeological site of Um el Kanatir, located within Levant Fault. ©M. Shmuel Marco (Tel Aviv University), Yehoshua Dray and Ilana Gonen, 2007

Can you give us an example of an historical earthquake in Europe?

(1) In 1356, an earthquake with a magnitude estimated at M6-M6.5 destroyed the city of Basel in Switzerland and caused destruction in France and Germany. Although the magnitude estimates based on historical writings vary, this earthquake is the largest historical earthquake in this part of Europe.

The seismic risk is the possibility of loss of life and / or economic damage by earthquakes. For example, in the desert, even if the hazard is very high, the risk is zero because there is nobody living there, nor any buildings. To reduce the risk we must build earthquake-resistant buildings. The more vulnerable the buildings, the higher the seismic risk.
This can be summarized by RISK = HAZARD X VULNERABILITY

The magnitude measures the energy released by an earthquake. When the magnitude increases by 1, the energy is multiplied by 32. So, an earthquake of magnitude 7 (denoted M7) releases 32 times more energy than M6, and, do the maths, a thousand times more than M5!

If the surface area of this circle represents the energy released by an earthquake of M5, the surface of the following circles represents the energy released by earthquakes of M6, M7 and M8.

I live in an area of moderate seismic hazard. There was a strong earthquake last year. Does this mean that nothing will happen for a long time?

Unfortunately not! There can be several earthquakes over a short period of time and then nothing for a hundred years or more!

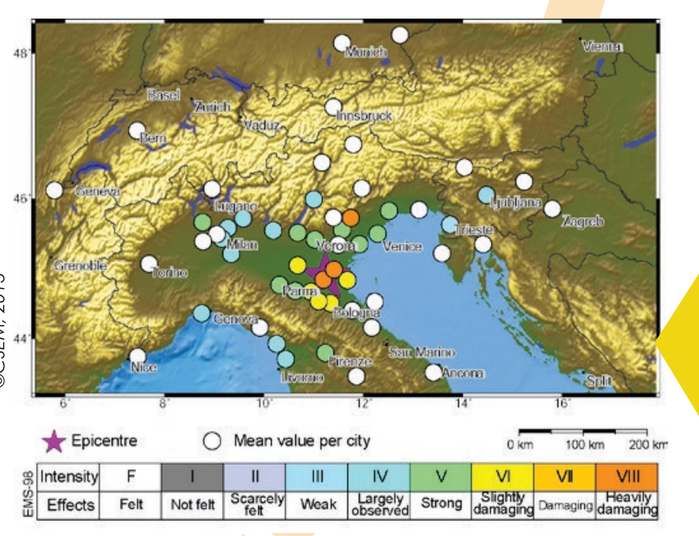
But why did this earthquake occur in my area when the hazard is higher in the neighboring region where there has not been one for over 50 years?

This is not unusual. The hazard is calculated over large periods of time, typically 500 years. Over this period, there are more earthquakes in areas where the hazard is higher, but over 50 or 100 years, the situation may be different. This is the case in your example. If you take climate for example with the climate; if it is on average warmer and drier in Tunis than in London, some days it rains in Tunis and the sun shines in London.

I've felt an earthquake of M6.5 in Japan, and it's not so impressive! I think the risk is exaggerated.

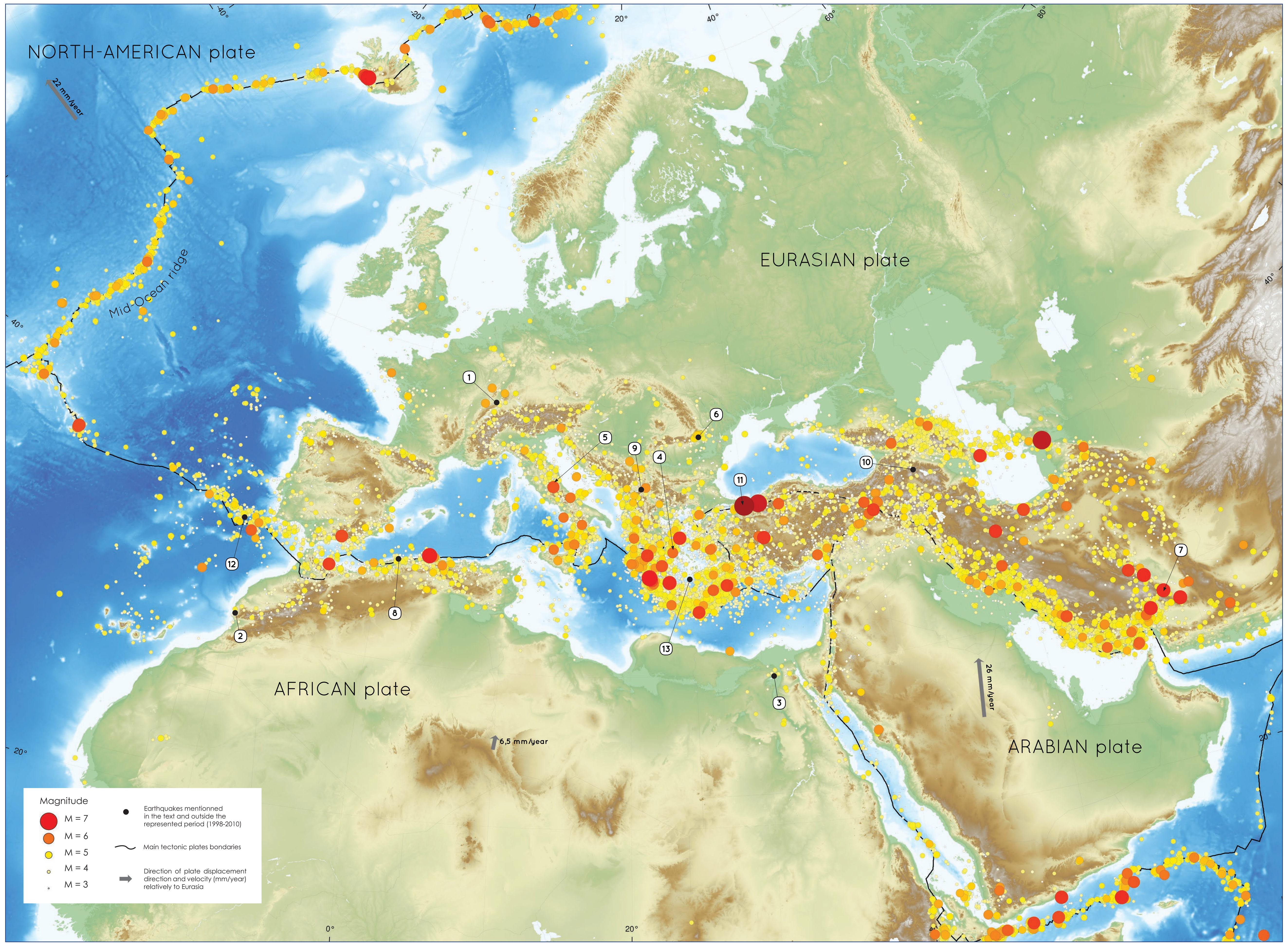
It is not the magnitude that one feels, it is the ground-shaking caused by the earthquake. Seismic waves generated by an earthquake of M6.5 are capable of damaging buildings several kilometres away. At greater distances, seismic waves are less powerful. If you weren't impressed, it was because the shaking was not really violent due to the fact you were probably far from the earthquake epicentre.

The intensity describes the effects of an earthquake. For a given earthquake, intensity varies from one locality to another.



Macroseismic intensity map obtained from 350 web questionnaires.

For example the M6.1 earthquake, May 20, 2012, in Northern Italy caused damage near the epicentre, and was weakly felt in cities like Bern, Nice, Zagreb and Munich.



Period covered by this map of seismicity: 1998-2010. Earthquakes from non-tectonic sources (quarry blasts, rock bursts, landslides, chemical explosions ...) were excluded when sufficient information was available to identify them. This map is intended to present seismicity on a Euro-Mediterranean scale and not the details on a national scale. For more detailed information in your own country, please contact its national earthquake monitoring institute. Resources are also available at http://www.preventionweb.net
Seismicity map generated with the GMT software (©Wessel & Smith, 1991),projection Mercator Transverse. Topographic and bathymetric data: ©GEBCO Digital Atlas. Reference for the plate boundaries : Bird, P. [2003] An updated digital model of plate boundaries, Geochemistry Geophysics Geosystems, 4(3), 1027, doi:10.1029/2001GC000252. Reference for plate motion: Nuvel 1A (DeMets et al., 1994). Référence GMT : Wessel, P., and W. H. F. Smith, Free software helps map and display data, Eos Trans., AGU, 72, 441, 1991.

EARTHQUAKE STORIES

Near cities, near monuments

(2) On February 29, 1960, an earthquake hit the city of Agadir (Morocco). The death toll was estimated at 12,000 people, a third of the population. However, a magnitude at 5.7 can be considered as "moderate''. In this range of magnitude, significant damage is concentrated around the epicentre, typically in the first ten kilometers. In Agadir, the earthquake occurred directly below the city which explains the catastrophe.

(3) In 1992 in Cairo (Egypt), there were more than 500 deaths following a M5.8 earthquake located near the Pyramids of Giza. It flattened 350 vulnerable buildings of the old town.

(4) Another example, in Athens (Greece) in 1999, 143 people were killed following a M5.9 earthquake which struck near the city.

(5) In 2009, the medieval city of L'Aquila (Italy) was partially destroyed by an earthquake of M6.3, killing about 300 people.

These earthquakes raise complex questions: How can we reduce the vulnerability of old buildings and monuments? How can we ensure their transmission to future generations while preserving their architectural and cultural value?

Santa Maria Paganica's church (L'Aquila, Italy) - *Courtesy of Golder Associates. All rights reserved.*

Beyond borders

(6) In 1977, an earthquake of M7.2 located in the region of Vrancea (Romania) knew no borders: it caused damage in Romania, including Bucharest, and also in Bulgaria. Thirty-five thousand buildings were destroyed, and more than 1,500 people lost their lives.

Devastating impact

The Upper citadel of Arg-e Bam before and after the destructive earthquake of 2003. ©M. James Conlon, 2003 - ©M. Randolph Langenbach, 2004

(7) Earthquakes can have terrifying dimensions on the scale of a city or a country. In 2003, in Bam (Iran), half of the 70,000 inhabitants of the city perished in a M6.6 earthquake. Of course, the shock was violent but it rapidly became clear that new buildings did not comply with the building regulations in force in the country. The death toll should have been much less. The 2000 year old Citadel, the emblem of the city, did not resist.

(8) El Asnam (Algeria) was 80% destroyed in 1980 by a M7.3 earthquake only 26 years after a precedent earthquake which had caused the loss of 1,300 lives. (9) Skopje, capital city of FYRO Macedonia, underwent the same fate in 1963.

(10) In 1988, 1% of the total population of Armenia, more than 30,000 people, disappeared after the M6.8 Spitak earthquake.
On January 12, 2010, 300,000 people died in Haiti after a violent earthquake. Port-au-Prince was devastated... How does a city or a country recover from such a disaster without outside help?

(11) In 1999, the North Anatolian Fault ruptured over 120 km in the industrial area of Izmit (Turkey). There were 17,000 deaths and 600,000 made homeless by this M7.4 earthquake. Today, a similar earthquake threatens Istanbul.

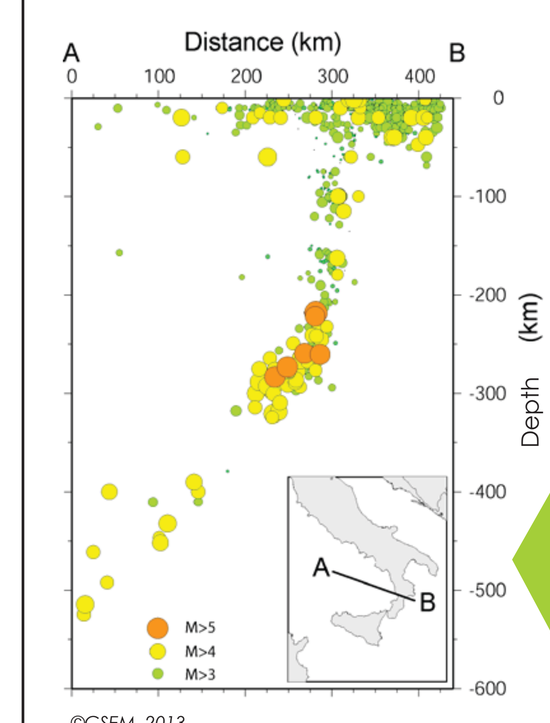
Railway's deformation (shifted of 2.7 m) caused by the earthquake of 1999. ©M. Okan Tüysüz, 1999

How can we prepare? How can we limit the human, cultural and economic impacts of future earthquakes? By investing in prevention and educating the population and decision makers, and by improving enforcement of building codes.

ORIGINS

An earthquake is a rupture, two rock masses that move abruptly one against the other along a fault. This rupture generates seismic waves which propagate through the Earth.

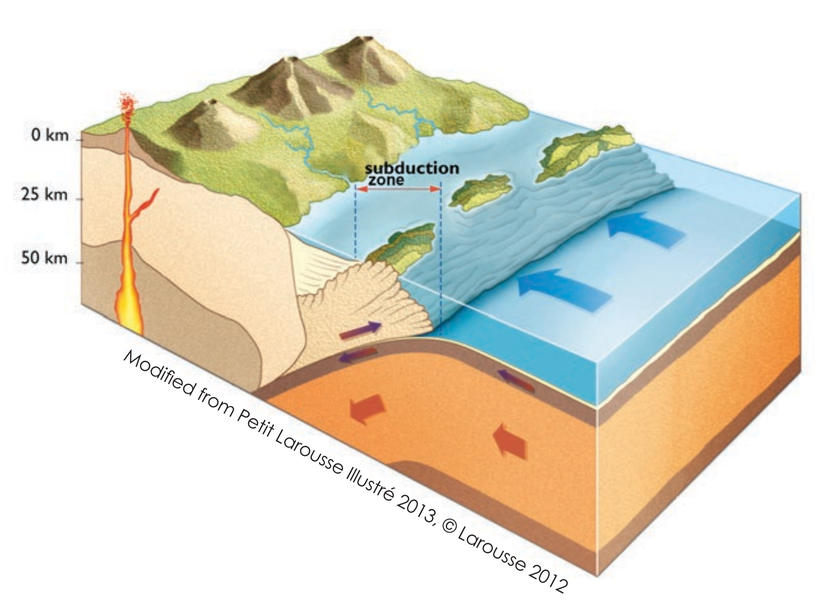
The main cause of earthquakes is related to **plate tectonics**, ie the stresses generated by plate motions.
In the Euro-Mediterranean region, the tectonics are controlled by the slow motion of the African plate at a velocity of about 6.5 mm / year and the motion of the Arabian plate at 26 mm / year coming into collision with the Eurasian plate.
These motions are very slow. In comparison, fingernails grow at 40 mm a year!



Some plate boundaries are well marked and blocks slide horizontally alongside to each other, such as along the Levant Fault (eastern Mediterranean) and the North Anatolian Fault (Turkey).

This **depth view** of the seismicity of the Calabrian arc (Sicily) shows the African plate dipping north west under the Eurasian plate with earthquakes of up to a depth of 300 km.

In the Aegean arc (Greece), or Calabrian arc, a plate slides and slowly sinks beneath another plate. This phenomenon is called **subduction**. By dipping, the plate also deforms, generating earthquakes which mimic the geometry of the plate.



The Vrancea (Romania) and Alboran regions (southern Spain) are ancient subduction zones where the current interaction is complex.

The origin of earthquakes can also be **volcanic**. They are then located near volcanoes.

In Scandinavia and Scotland, the melting of the thick ice layer which started about 15,000 years ago towards the end of the last ice age, decompressed rock masses. Freed from the weight of the ice, these masses have risen slowly generating low seismic activity. This process is called **post-glacial rebound**.

Finally, some **human activities** can cause earthquakes, usually of low magnitude. We observe such earthquakes around some mines in North West England or Poland, or around gas extractions in the Netherlands. The causal link between a given earthquake and human activities is often difficult to prove.

Plates disappear in subduction zones, but where are they created?

They are created at seamounts called mid-ocean ridges, where two tectonic plates move apart to reveal new materials. The further away from the ridge, the older the plate. This phenomenon appears in the Red Sea where Africa and Saudi Arabia are gradually separating.

Aerial view of the Almannagjá fault (Iceland) ©M. Oddur Sigurðsson, 2004

Located on the North Atlantic ridge between the North American and Eurasian plates, Iceland is, from a tectonic point of view, straddling America and Europe!

Can earthquakes be predicted ?

To date, there is no way to predict when and where an earthquake will occur. There are, however, a few special cases. Seismologists estimate that a M7.5 earthquake or so should occur in the coming fifty years in the Marmara Sea south of Istanbul. But no one knows if that will be next week or in 50 years time.

Can animals feel when an earthquake will occur?

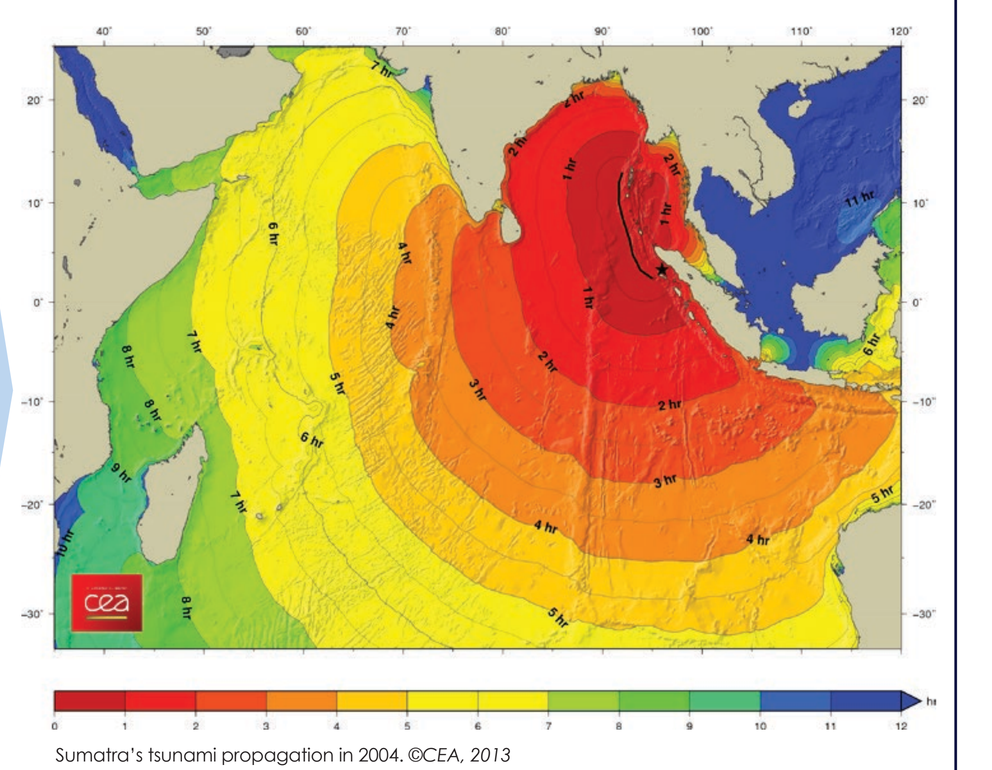
Several cases of strange animal behaviour have been reported before earthquakes. In one example, swarms of toads were observed in the streets of Taizhou (China), two days before the devastating earthquake in Sichuan in 2008. But swarms of toads are also observed without any earthquake occurring. Coincidences? We do not know. Nevertheless, such behaviour is not systematic before an earthquake and scientific studies on animals have yielded no positive results so far.

EFFECTS

Earthquakes cause the ground to shake and shake the buildings through their foundations. When the ground shaking is violent and/or the buildings are vulnerable, they collapse. This usually explains most of the **damage** and **casualties**.

Earthquakes also produce **indirect damage** such as fires, landslides and tsunamis.
After the M7.9 earthquake September 1, 1923 in Japan, fires spread over Tokyo. They caused considerable damage as all access to water had been cut off.
Landslides are a significant risk in mountainous and wet areas such as tropical regions. In 2001, in El Salvador (Central America), they were the cause of nearly half of the victims of the earthquake of M 7.9 that hit the country.
Unlike earthquakes, tsunamis can cause serious damage thousands of kilometers away. In this case, the origin of the tsunami is usually a strong undersea earthquake.

In 2004, in Indonesia, the rupture of the M9.3 earthquake spread over 1200 km. Displacement reached locally 25 m. This earthquake alone released twice the average energy released each year by all earthquakes that occur across the globe! The tsunami devastated the Indonesian coasts. But it also struck the coastline in Somalia 6000 km away.

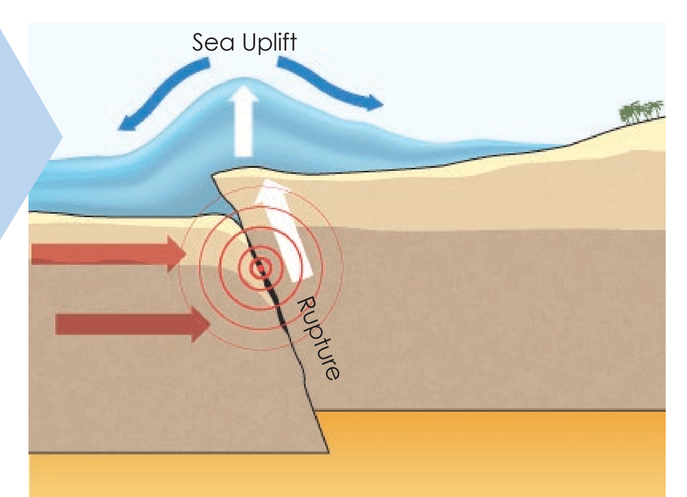


Sumatra's tsunami propagation in 2004. ©CEA, 2013

(12) In 1755, a tsunami was generated 300 km off the coast of Portugal which not only affected its coastline but also that of Morocco. Lisbon was destroyed by the earthquake and fire. This disaster shocked the whole of Europe.

How can an earthquake cause a tsunami?

During an earthquake, two walls of rock move suddenly against each other. When this movement is vertical and distorts the bottom of the ocean, a body of water is suddenly raised (or lowered), generating a wave that propagates in the ocean.



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When submarine landslides or volcano flanks collapse into the sea they also generate tsunamis, generally smaller and more localised. In 2002, a landslide on the slopes of the Mount Stromboli (Aeolian Islands north of Sicily) ended up in the sea. The tsunami injured several people on the island.

© M. Tom Pfeiffer, 2011

(13) In 1550 BC, a major tsunami swept the Eastern Mediterranean shores after the explosion of the Santorini volcano in the Aegean sea. One can imagine the enormous volume of rock expelled by looking at what remains today of the volcano! This disaster is allegedly the origin of the myth of Atlantis.

How can I protect myself from earthquakes?

The main threat during an earthquake is from falling objects. Protection is primarily to prevent items falling and to protect yourself from them.
Building regulations, which depend on the hazard level, are designed to prevent the collapse of buildings during the earthquake. Inside the house, you should check that all items are properly secured (shelves, lamps ...).

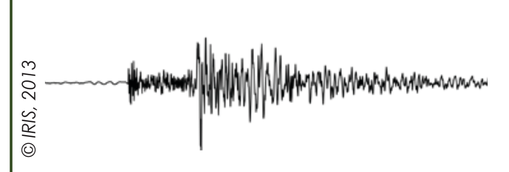
During the shaking, do not try to leave buildings because objects can fall from facades, roofs or balconies. Protect yourself from falling objects by placing yourself under a table, for example. If you are outside, stay away from buildings.

Once the shaking stops and before leaving the building, turn off the gas and electricity. Take the necessary items for a night outdoors (water, food, clothing, radio, flashlamp, etc..). Stay away from buildings as an aftershock is likely to occur. Only use your phone in case of emergency to give priority to rescue operations.

For more details, contact your national authorities. For example, resources are available at: www.wikihow.com/Prepare-for-an-Earthquake or www.ready.gov/earthquakes

MONITORING

Detecting earthquakes



© IRIS, 2013

The monitoring is based on the recording by seismic stations of waves generated by earthquakes. The earthquake's location is determined upon the time the waves arrive at different stations and their propagation speed. The magnitude is estimated from the amplitude of the recorded waves.

How many earthquakes are there a year?

Their number depends on the magnitude considered. The strongest earthquakes are the most rare. Across the globe, over a year, there are on average 1,500 earthquakes greater than M5 (about 4 per day), 150 earthquakes greater than M6, and about fifteen M7 or more. Five earthquakes reached or exceeded M9 between 1950 and 2012.

The existing monitoring networks locate all earthquakes above magnitude 5 in the world. Smaller earthquakes cannot be detected if they are far from seismic stations. That is why their numbers can only be estimated. Globally, there are about 15,000 earthquakes greater than M4, and 150,000 greater than M3 per year.

Tsunami early warning

Seismic waves travel much faster than a tsunami. It is possible to warn people before a tsunami hits by locating earthquakes capable of generating a tsunami very quickly (within 10 – 15 minutes), and by predicting the arrival times of the tsunami along the coast. The greater the distance between the earthquake and the coast, the more time the population will have to get to safety.

Tsunami warning centre (CENALT). ©CEA/CADAM, 2012.

We hear more and more about earthquakes and their destruction. Has their number increased?

The average number of earthquakes is not increasing, but their impact (destruction, victims) does increase over time, unfortunately. Indeed, the world population has mutiplied by 7 in two centuries. Earthquakes, which were not felt 150 years ago, can now affect newly-built urban areas and cause damage. In fact, the seismic hazard has not changed but the risk has increased and keeps increasing with growing world population.

Will the number of earthquakes increase with climate change?

Not on a global scale because climate change has no effect on the slow motion of tectonic plates which is the main cause of earthquakes.
However, if ice melting were to continue, the seismicity in areas like Greenland could slightly increase in the long run because of the phenomenon of post-glacial rebound. (see" origins").

Are there any tsunami warning centres in the Euro-Mediterranean region?

Tsunami warning centres cover the Mediterranean sea, North East Atlantic ocean, and the Black Sea.
Public education is nevertheless essential. The population within a short distance of the earthquake cannot be informed of the arrival of the tsunami in time. The mere feeling of an earthquake near the coast, or seeing the sea receding or an unusual whirlpool must encourage people to move to safety to higher ground further inland.

Have a look at our website: www.emsc-csem.org

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