EARTHQUAKES HOW AND WHY

GIUNTI Progetti Educativi

INGV

A book that describes, illustrates and explains how and why earthquakes occur. Detailed information accompanied by fascinating photos and illustrations. Questions and answers showing how, although earthquakes cannot be predicted, we can learn how to limit the damage caused and above all not to be too frightened of them.

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THE EARTH IS TREMBLING I'M NOT!

Andrea Angiolino
Francesco Fagnani

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A book to explore

This is a book of questions and answers designed to guide you through the world of earthquakes. It is a book to read and consult, a book that illustrates and explains: a starting point in a voyage of discovery.
This book was freely inspired by a fine little volume written ten years ago by Daniele Postpischl, an inquisitive and generous scientist with a complicated surname.
Daniele loved getting to the bottom of things – of caves as a speleologist and of the sea as an expert diver – heading towards new horizons, paragliding or sailing a catamaran. He was a great explorer of the old-fashioned kind. The same thirst for knowledge led him to explore fields of research that were completely new to him, since his own training was in physics and geology. Profoundly intuitive, Daniele took up the old traditional seismology and practically reinvented it, transforming it into a great modern discipline. And since research that is available only to a small number of people is never good research, Daniele always fought stubbornly to spread the results of his studies and bring exploration within the reach of everyone.
We miss Daniele dearly, and even if this book is very different from the one he had in mind, we hope that it transmits to you all that was his.

Romano Camassi, Laura Peruzza and the O3E STAFF

WHAT IS an EARTHQUAKE?

We say "as hard as rock"... but sometimes even rock isn't strong enough to resist and breaks! And when the Earth's crust gives way is when earthquakes happen.

The devastating scenario in the centre of the village of Tempera (7 km from L'Aquila, Italy). The total collapse of the church.

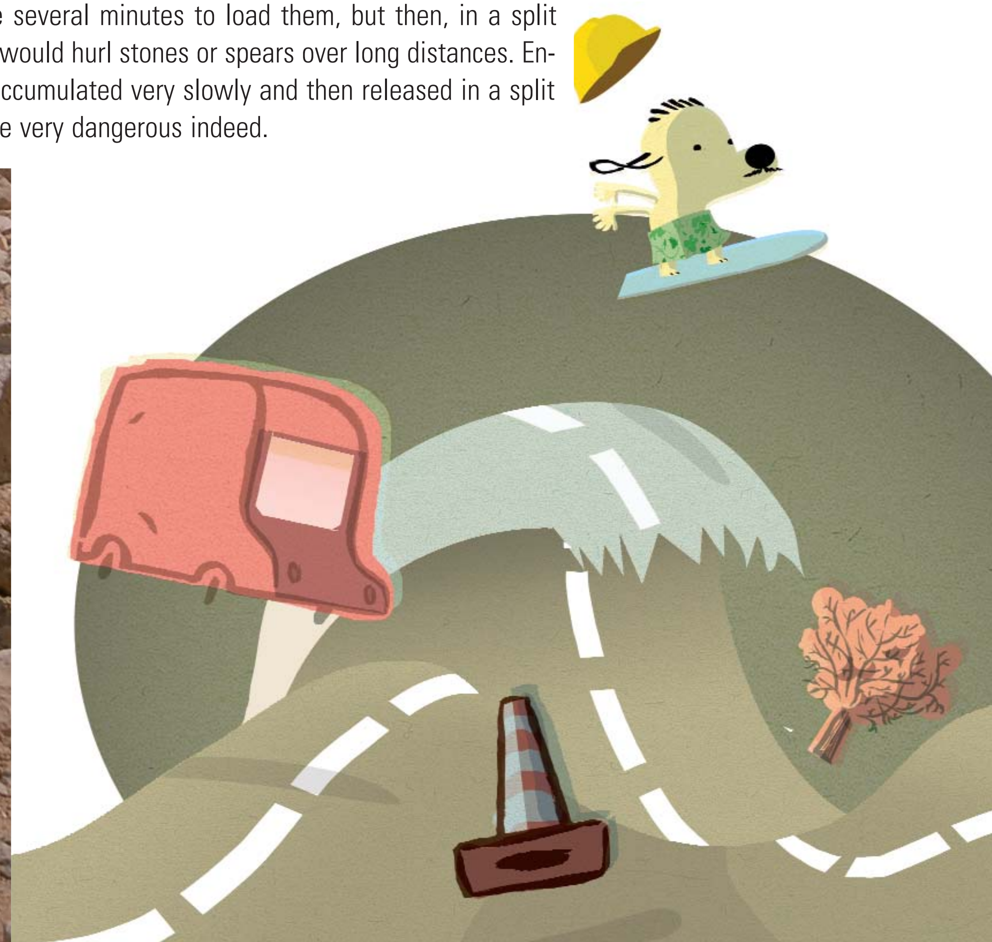
A NATURAL phenomenon

The Earth's crust is made up of rock, which sometimes, as we will see, breaks unexpectedly and unleashes huge quantities of energy. Put more simply, an earthquake! This energy expands outwards from the break point in the form of seismic waves, similar to the way rings form around the spot where a stone is thrown into water. Except that these waves make the ground shake and may cause serious damage to things, buildings and people.

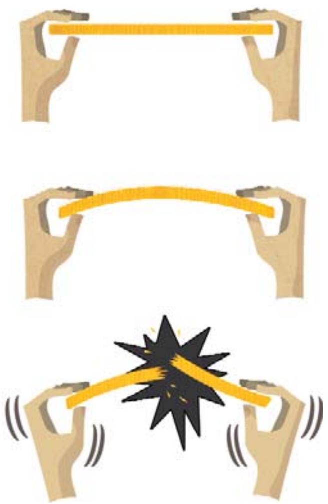
Earthquakes are natural phenomena, like floods and volcanic eruptions, but they are much faster, generally lasting no more than a few minutes. We must not, however, be misled by this speed: the conditions that generate an earthquake take centuries or millennia to build up... That's how long it takes to accumulate all that highly dangerous energy.
They could be compared to the catapults used in medieval battles: it would take several minutes to load them, but then, in a split second, they would hurl stones or spears over long distances. Energy that is accumulated very slowly and then released in a split second can be very dangerous indeed.

A major earthquake took place in the vicinity of Crete (Greece) followed by a great tsunami which devastated the eastern coasts of the Mediterranean, causing thousands of victims.

Magnitude 8.2



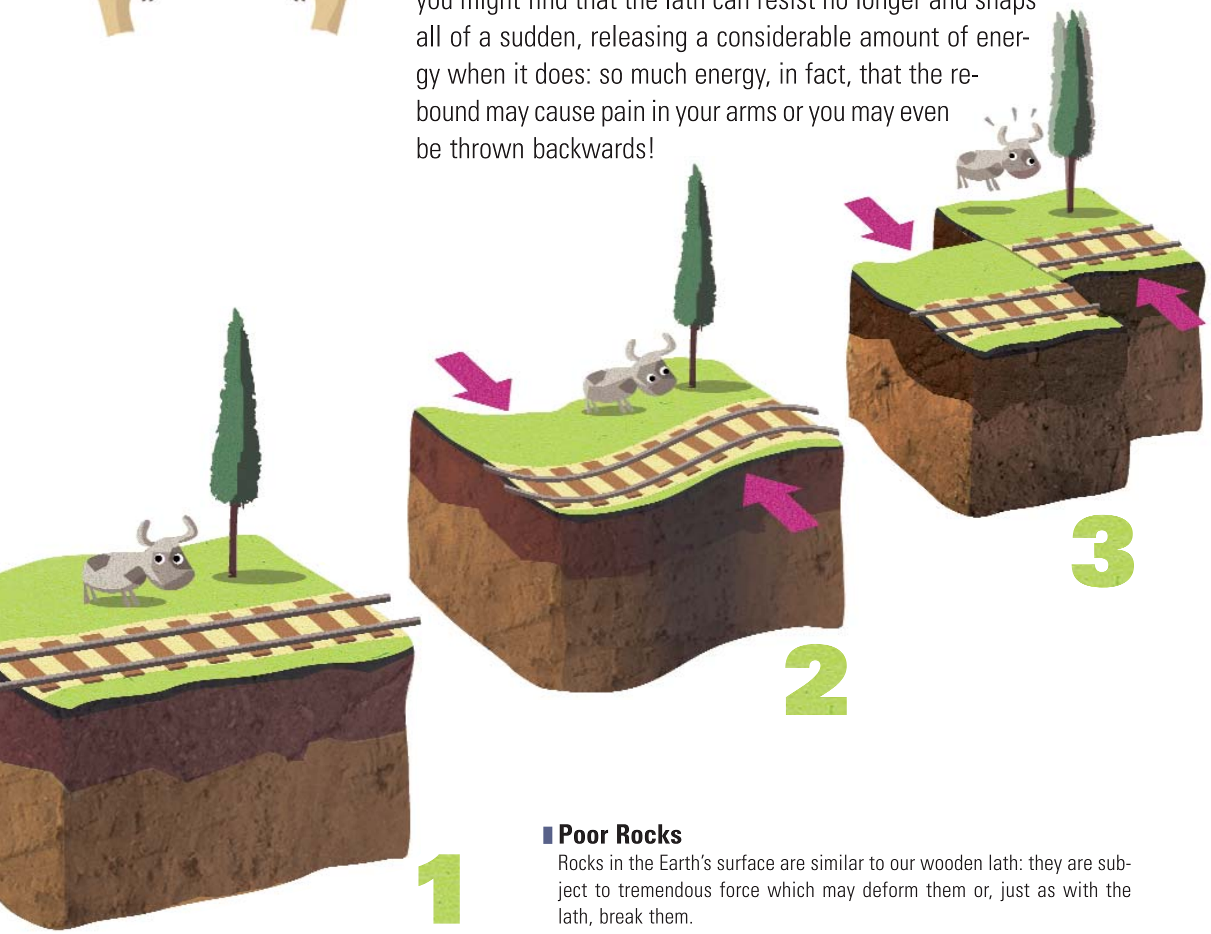
An EXPERIMENT... not to be tried!



Imagine you are holding a wooden lath. Now imagine trying to bend it with both hands. When you let go, the lath may return to its original form, depending on the kind of wood and the amount of strength you apply: this is known as "elastic behaviour". Just like a piece of elastic, no matter how hard you pull it, when you let go, it will always go back to its original length.

On the other hand, your lath may be damaged and remain in its new shape: in this case, we refer to "plastic behaviour", because the strength you used has changed its appearance.

Finally, if you bend it more and hold it for a few seconds, you might find that the lath can resist no longer and snaps all of a sudden, releasing a considerable amount of energy when it does: so much energy, in fact, that the rebound may cause pain in your arms or you may even be thrown backwards!



Poor Rocks

Rocks in the Earth's surface are similar to our wooden lath: they are subject to tremendous force which may deform them or, just as with the lath, break them.

ENOUGH is enough...

A large portion of the Earth's crust is prone to constant movement. Millions of years ago, for example, horizontal movements were responsible for separating Corsica and Sardinia from the French and Spanish mainlands until they reached the position they are in today, in the middle of the sea. Instead, "bradyseisms" are the vertical movements which have been lifting or lowering the level of the ground at Pozzuoli (Naples, Italy) for thousands of years, and are connected with a volcanic system.

As they endure the pressure of these movements, rocks can either display "elastic behaviour" and return to their original form when the pressure stops, or, if the pressure is less powerful but persists for long periods of time, layers of rock can display "plastic behaviour" and be deformed into series of folds and corrugations: spectacular examples of this can be found in mountainous areas. Alternatively, if the power is unbearably strong, the rock may suddenly snap and release all the energy that has built up inside: it is the release of this energy that sparks off earthquakes.

All the same, or are some stronger?

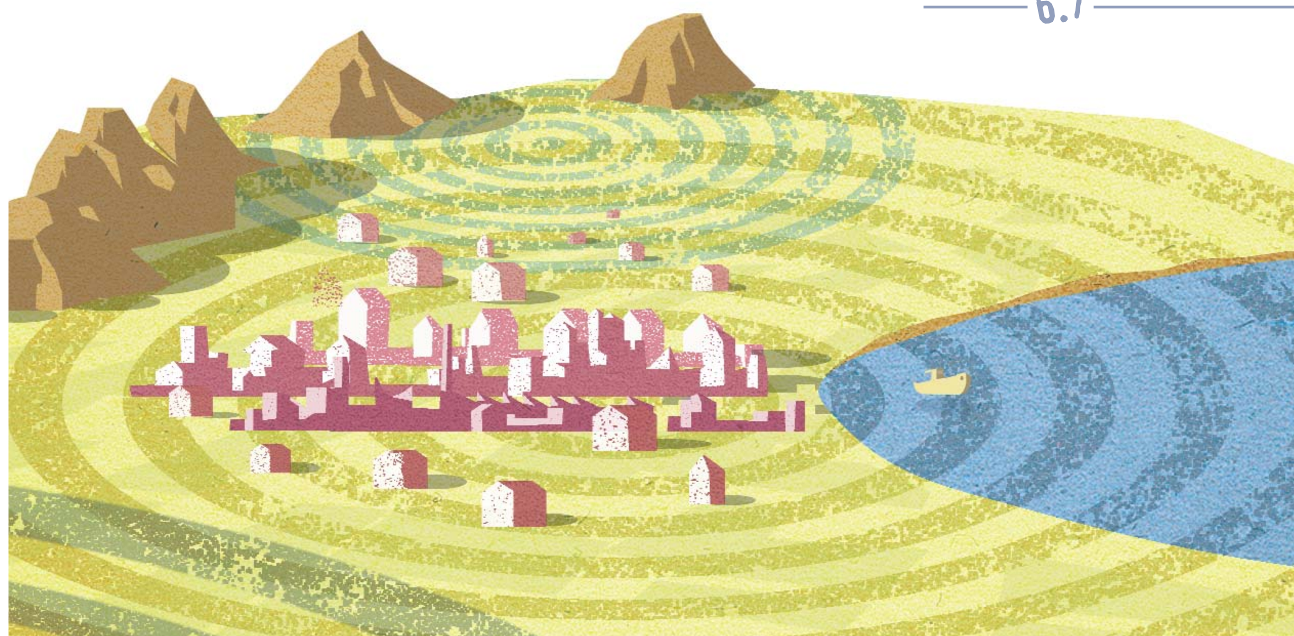
Earthquakes can be of two types.
A "seismic sequence" consisting of a mainshock, possibly preceded by a number of foreshocks and followed by aftershocks, which usually become increasingly weak and rare. In the case of a series of earthquakes of similar energy, accompanied by minor tremors, this is called an "earthquake swarm".

Earthquakes in episodes

A powerful earthquake is not usually an isolated episode.
They are sometimes preceded by small shocks and are almost always followed by a number of aftershocks that may affect an area covering several thousands of square kilometres. The kinds of aftershock and the way they follow each other depend on the characteristics of the area hit by the earthquake and the amount of energy released.
For example, in Abruzzo (Italy) in 2009 more than 15,000 aftershocks were recorded, several hundreds of which were felt by the population.

Major earthquake in the valley of the Adige in Italy, preceded by a seismic event in Germany. Serious damage in Verona. It is recorded in all the Italian, Austrian and German chronicles of the time.

Magnitude 6.7



Not always a catastrophe
A view of Bussana Vecchia (Imperia, Italy), which was struck by the earthquake of February 23, 1887.
It is estimated that approximately one million earthquakes take place on our planet each year: almost one every 90 seconds! Luckily they are very often so weak people don't even realise they have happened. Those which are strong enough to be recorded by specific instruments, called "seismographs", number about 400,000 per year.

EARTHQUAKES: cracking faults!

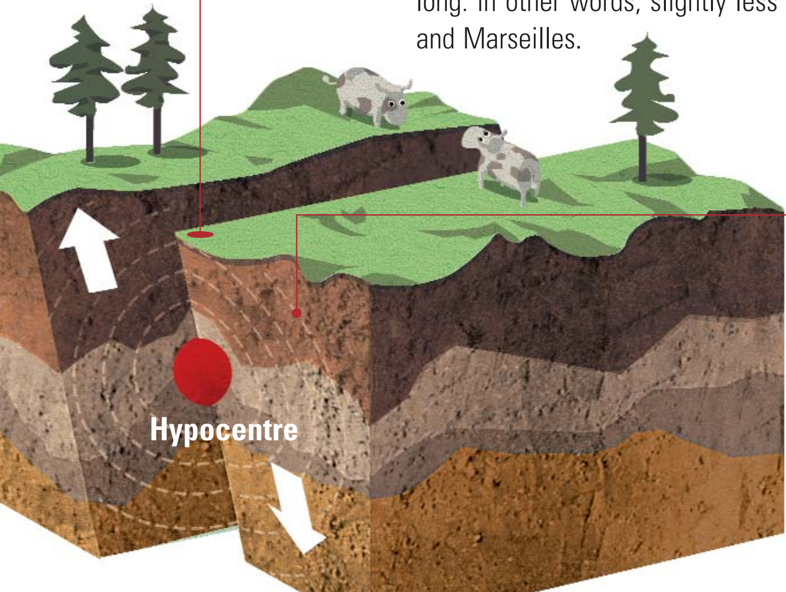
EARTHQUAKES IN HISTORY
JANUARY 25, 1348

Towards sunset a violent earthquake, which was felt in France and Germany too, destroyed numerous buildings in Villach, in Austria.
Very serious damage in Friuli too.
Several thousand victims.

Magnitude 7.0

As we have just seen, earthquakes are caused by rocks breaking: the fracture that is created is called a "fault" and can run for great distances. The 2004 earthquake in Sumatra, for example, created one that is almost 1000 km long: the same distance as from Paris to Rome. The fault caused by the earthquake that struck Irpinia and Basilicata in 1980 was almost 40 km long.
The fracture takes place underground, but sometimes it can be seen on the earth's surface too. In such cases we can see that the rocks on either side of the crack shift by several metres: in the 1964 Alaskan earthquake, one of the two blocks of rock ended up 10 metres higher than the other. In the Irpinia and Basilicata earthquake, the two blocks of rock shifted vertically by 1 metre.

This movement can sometimes be horizontal instead of vertical: in the San Francisco earthquake of 1906, for example, the two blocks moved 6 metres apart from each other. The resulting fault is 480 km long: in other words, slightly less than the distance between Bern and Marseilles.

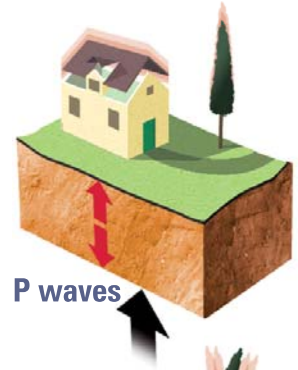


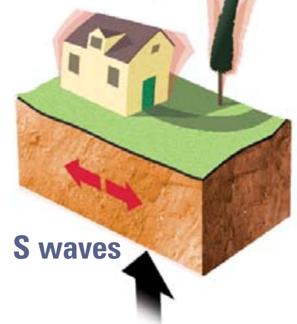
Hypocentre and epicentre
The spot where the break in the Earth's crust originates is called the "hypocentre" of the earthquake and it is in the subsurface. The point directly above that on the Earth's surface is called the "epicentre" and it is usually the place where the most serious effects take place.

Quake on the WAY

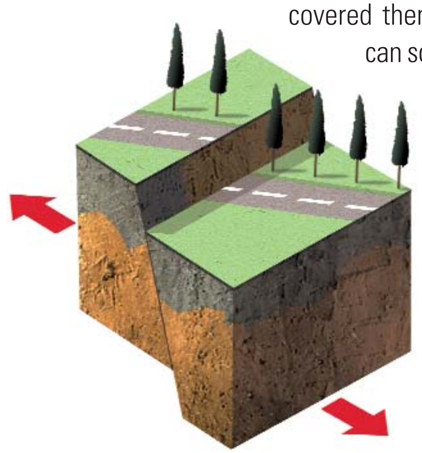
Part of the energy that is released by the breaking rocks spreads from the hypocentre in the form of waves that shake the surface of the Earth. They make it tremble, with all the people and buildings that are on top, causing varying degrees of damage: these quakes are called "seismic shocks". There are different sorts of waves, some of which are more dangerous than others. The fastest are "longitudinal" waves, which carry energy through the earth, moving matter in the same direction as the wave: rocks and liquids contract and dilate. These are the first to be felt and are therefore known as primary or "P waves".

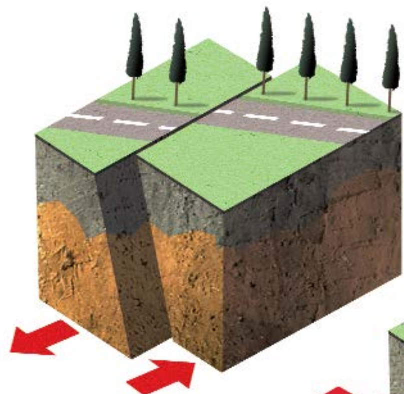
"Transverse" waves are the ones that shift the ground perpendicularly to their own direction. They are transmitted only through solids and are known as "S waves" because they are secondary, because they are slightly slower, and can do much more damage than the others. "Surface waves" spread only along the Earth's surface and not through liquids: they come last because they are the slowest. They are called "L waves" because one of the scientists who discovered them was Mr. A.E.H. Love. These too can sometimes cause significant damage.

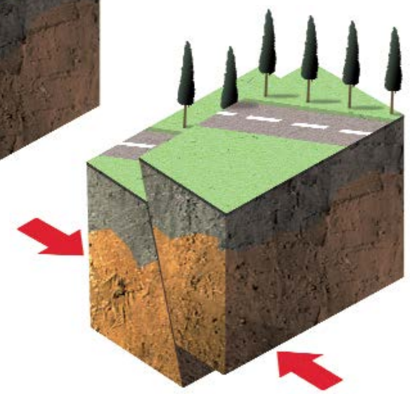




Dangerous waves
At the epicentre, the waves of an earthquake come from below; in this case the P waves, which are longitudinal, make the ground "jump" up and down. The S waves are transversal and shake the ground horizontally.







Not all faults are the same...
There are many different kinds of fault. If a fracture creates two blocks of rocks which move horizontally in opposite directions, it is called a "transcurrent" or "strike-slip" fault. The movement can, however, also be vertical. Imagine the fault is a diagonal cut in a layer of rock: one block will slightly overlap the other. If the upper block moves down, away from the other, it is known as "normal" or "dip-slip" fault. If it moves upwards against the other, then it is called a "reverse" fault or "overthrust".

WHERE do EARTHQUAKES happen?

The continents of the World are not static; they shift around on gigantic plates. Earthquakes happen mainly where these plates come together, move away or rub against one another.

A fault inside a succession of silt, sand and gravel at Piana di Sulmona (L'Aquila, Italy).

The WORLD is a scotch egg

It might sound funny to you, but our good old planet Earth has quite a lot in common with a scotch egg! Yes indeed: just like those delicious little boiled eggs wrapped in sausage meat then coated in breadcrumbs and deep-fried.
The first thing they have in common is that neither is perfectly spherical: map makers always make their Worlds round, because it's easier, but the Earth is quite irregular in shape – it is squashed at the poles. In addition to that, the Earth is made up of concentric layers. If you cut a scotch egg in half, you will see that there is a thin crusty outside, and a soft tender sausage inside and a centre made of egg.

In the same way, the Earth consists of three main layers: a hard rocky crust on the outside, whose composition is different below the oceans from the land above sea level; then there is a thick layer of softer rocks, which are rich in silica, iron and magnesium, called a "mantle"; finally, in the centre of the earth is a very dense core presumed to be composed of iron and nickel.

EARTHQUAKES IN HISTORY
OCTOBER 18, 1356

A major earthquake
destroyed many castles and all the buildings in Basle (Switzerland).
The destructions extended for a radius of between 15 and 30 kilometres. The towns of Liestal and Sissach were also damaged.

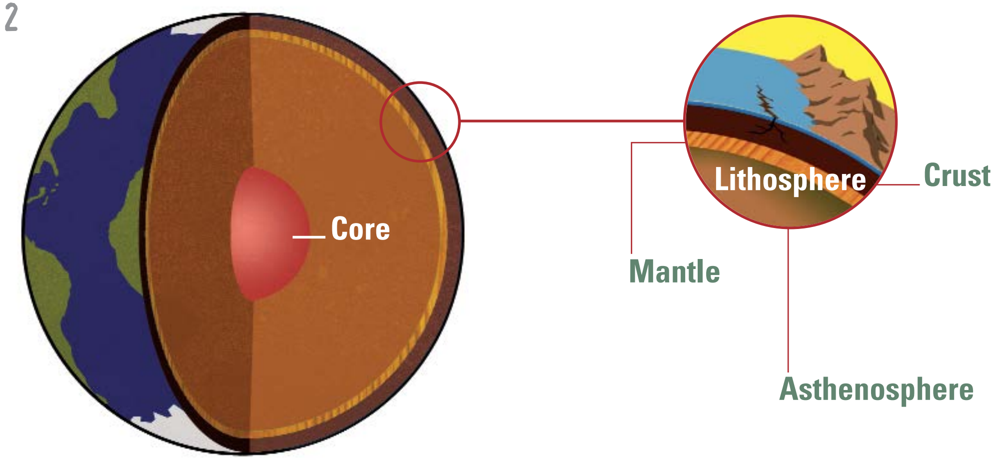
Magnitude 6.9

A planet in great shape!

In ancient times people thought that the Earth was flat or box-shaped, column-shaped or even oyster-shaped (that's what the Babylonians believed). The first sailors, however, observed that ships, as they sailed away, disappeared beyond the horizon, and as early as the VI century BC, the Pythagoreans stated that the Earth was spherical. Nonetheless, many were not entirely convinced. It was to be Ferdinand Magellan's ship, Victoria that would prove that the Earth was truly round by circumnavigating it between 1519 and 1522. Sadly, the Portuguese explorer did not live long enough to see out the journey to the end.

Pretty impressive, Eratosthenes…

As early as the III century BC Eratosthenes of Cyrene measured the circumference of the Earth by studying its shadows in different places on the same meridian: he calculated a total of 39,375 km, as against the 40,076.592 km we know today to be the precise measurement. He had practically worked out the entire circumference of the Earth despite having travelled only over a 50th of it: what a wizard! Theories about what was going on inside the Earth were much less precise. Aristotle said that earthquakes were caused by winds trapped inside underground caves; these same winds caused underground fire which ignited veins of sulphur and carbon deep inside the earth and resulted in volcanoes.



One LAYER inside another

Thanks to earthquakes...
Studying the inside of the Earth is not at all easy, because no-one has actually been there: however, some very useful information can be drawn from earthquakes.
Observing how rapidly the speed of seismic waves changes according to their depth, we can deduce how the Earth's layers differ from one another and their characteristics. Just as you can tell from the sound your fingers make tapping on a wall whether underneath there is plaster, stone, brick or just a hollow space...

To make things a little clearer we have divided the Earth into three main layers, although in actual fact these are in turn divided into other layers, each with different characteristics.
The core is formed of an inner layer and an outer layer. The inner core is solid; it is 13 times denser than water and has a radius of about 1,200 km. That makes it a little bigger than the moon. The outer core has the same characteristics as liquid and is 2,200 km thick.

The mantle is the sausage meat of our scotch-egg Earth: it is about 2,900 km thick, located between the Earth's crust and the core-egg. The mantle, which begins at a depth of between 70 and 400 km, is called the "asthenosphere" (from the Greek asthenés, which means "weak"). Although it is made of rock, the asthenosphere behaves like liquid, and is malleable like plasticine (perhaps because there are small portions of molten rock).

Further out, the upper part of the mantle and overlying crust are named "lithosphere" (from the Greek lithos, which means "stone") because they are hard… as hard as rock. The lithosphere varies in depth from place to place, just like the Earth's crust: this, which is the uppermost part of our planet, is 30-40 km thick below the continents but can be less than 10 km below the ocean beds.

On the night of 5 December
a long and very strong quake wrought destruction over a vast area of southern Italy. Thousands of victims.

Magnitude 7.2

A geoid is... a geoid!
In 1735 Charles Marie de La Condamine and Pierre Louis Moreau de Maupertuis determined that the Earth was almost round, but flattened at the poles and a little rounder at the equator. If you want to be precise, you can't say that the Earth is a sphere, you have to say that it is a "geoid". In fact, the "geoid" is a totally irregular geometric form, that more or less looks like the surface of the Earth. So, to sum up, when you use this word "geoid" to describe the Earth's shape, all you are saying is that the Earth is Earth-shaped! Now, that is what I call a real discovery!

A SIMMERING saucepan

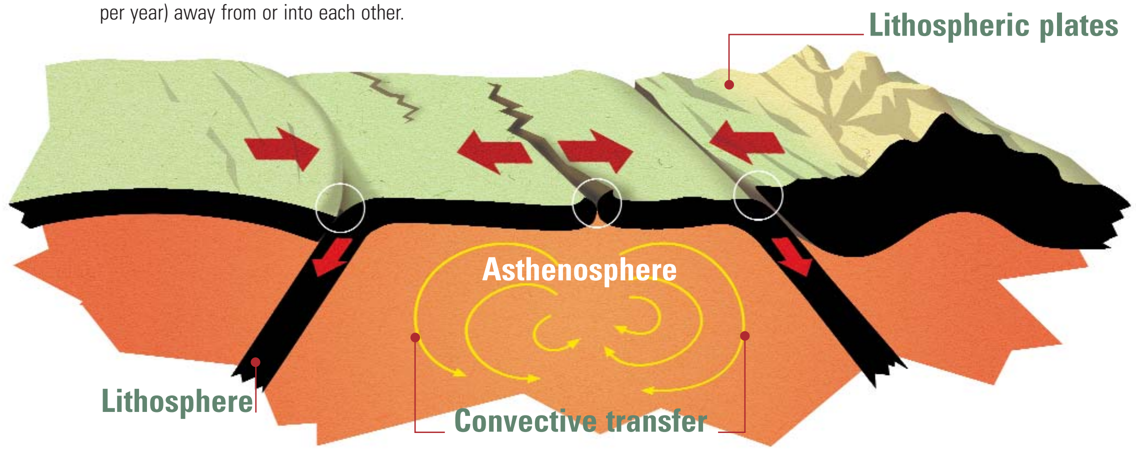
Apart from being made up of layers, there is something else that the Earth has in common with a scotch egg: sometimes, if you're not careful, the egg in the middle is so hot that is scalds your tongue! The Earth's core is also very hot: more than 6,000 °C. Just think that if your temperature goes up to 38 °C the doctor tells you to stay in bed and get some rest, and that water boils at 100 °C, imagine what hell it must be down there…!

Nobody knows exactly whether it's because of close contact with such a scorching core, or a result of the heat released by nuclear reactions occurring naturally inside the Earth, but the mantle heats up and melts in many places. The molten matter tends to climb upwards, pushing the cold stuff downwards: this creates "convective transfer". It is not at all as complicated as it sounds: think about what happens in a saucepan of boiling pasta where the water at the bottom, right next to the source of heat, boils and rises taking the pasta up with it; at the same time its thrust makes the cooler water on the top sink to the bottom.

The Earth's mantle does the same thing. These deep and very slow convective transfers are the driving force of the lithosphere; the plates it is divided into rub against each other, clash or break off and float on the fluid part of the mantle.

Geological times!
Although plate movement is imperceptible, it causes significant consequences, such as the formation of mountain ranges.
It doesn't happen straight away though: it takes a few million years...

Convective transfer
Deep convective transfers cause breaks in the lithosphere and the formation of plates which, when subjected to pushing and pulling, move extremely slowly (from less than 1 to 15 cm per year) away from or into each other.



From PANGEA to today's continents

Each of the Earth's continents sits firmly on its own plate, and moves with it, as if the plates were gigantic rafts carrying the land upon them, floating on the asthenosphere. If you look closely at the shape of continents, you realise just how they could slot into one another like puzzle pieces. For example, the large "shoulder" of South America, where Brazil is, fits into the south-west curve of Africa where Ghana, Nigeria, Cameroon, Congo and Angola are located.

The idea that continents did not remain entirely still over time was first expressed in the early 1900s, thanks to the astounding intuitions of a German called Alfred Wegener known as the theory of "continental drift". According to Wegener, 200 million years ago the continents formed a single mass of land called Pangaea, that then broke apart into a number of separate land-masses which gradually drifted away to occupy their present-day positions. But they continue to move, and in a few million years from now the Earth will look different again.

In the Sixties, the discovery of the expansion of the ocean floor, or seafloor spreading, made the mechanism of continental drift clearer. Today, most scientists believe that the "plate theory" or "global tectonics" is the most plausible explanation for many of the phenomena that take place on our planet.

Confirming evidence

Animal and vegetable fossils belonging to the same species and palaeographical environment have been found on different continents; since it is impossible that they crossed oceans, this confirms that the continents were once connected.

Other evidence are the identical rocks found along the edges of separate continents, the direction of magnetic fields, and the signs of identical glaciations found in India, South America, South Africa, Australia and Antarctica.

200 million years ago

65 million years ago

today

Continents adrift

These images illustrate the positions of continents 200 million years ago, 65 million years ago and today.

On the afternoon of 26 March,
a major earthquake struck north-eastern Italy, Slovenia and Austria; it was followed by a period of epidemics.

Magnitude 7.0

VOLCANOES and EARTHQUAKES, terrible twins

Plates in movement can drift apart, bump into each other or rub against one another. Mountain chains, such as the Alps or the Himalayas, are formed where plates collide into each other and the crust is raised. The edge of one plate can end up underneath another, and can even liquefy in areas of the asthenosphere called "subduction zones", as has happened in Japan. Sometimes the plates move rubbing against each other, like in California and in Turkey.

Both volcanoes and earthquakes are the result of these movements of separation, collision and rubbing together. In fact, almost all earthquakes occur along the edges of the plates. They usually take place within the Earth's crust, at a maximum depth of 30 km: these are known as "superficial earthquakes" and can be the most destructive. "Deep earthquakes" can occur in subduction zones, up to depths of 700 km below the Earth's surface; these cause less damage but affect much vaster areas.

Mediterranean Europe is situated along the meeting point of the African plate and the Euro Asiatic plate. This is a particularly complex position, since along the edges the lithosphere has broken up further into microplates.

When people are involved

This fresco which dates back to the XIV century illustrates the terrible effects of an earthquake. At least two billion people live in high risk seismic areas: approximately a third of the World's population.

Accurate figures on the number of victims in the past are not available; we do know, however, that in the XX century the number of victims was around one and half million, about a tenth of them in Europe.

If the earthquake is strong enough to be felt

As we have already said, of those million earthquakes that take place each year, only a few of them can be felt. At least 120 of them are as strong as the ones that struck Irpinia and Basilicata in 1980 and at least 20 or so are as serious as the Messina earthquake in 1908 which was responsible for 80,000 deaths. Fortunately, earthquakes happen mainly at sea or in sparsely inhabited areas, as illustrated in the map of the principal plates.

WHAT IS a TSUNAMI?

70% of our planet is under the sea: submarine landslides, volcanic eruptions and underwater earthquakes are very frequent and can create imperceptible waves that in some cases, once they reach the coastline, become gigantic and catastrophic.

A photo of damage caused by the tsunami which struck South East Asia in December 2004.

Little WAVES grow

When something big, like an earthquake, a landslide or a volcanic eruption happens under the sea or near the coast, it can provoke a series of waves; this is called a tsunami.

Waves such as these spread out in rings like the ones you can see when you drop a stone into a puddle of water. Great quantities of water are moved, but very deep down, so hardly anything can actually be noticed on the surface. Waves made by seaquakes are in fact very small, even as small as 30/60 cm with a space of 100 to 200 km between each one: frequency can vary from one every 5 minutes up to one an hour. For these reasons, they cannot be felt in the open sea as they are lost amongst other normal waves: but the deeper the water the higher the speed they can reach: up to 800 km/h, and once they reach shallow areas they can become monsters of up to 50 m and have devastating effects.

EARTHQUAKES IN HISTORY
JULY 20, 1564

This Nice earthquake
destroyed numerous French villages, including La Bollène, Roquebillière, Belvédère and Clans.

Magnitude 5.9

Terrifying records

On August 27, 1883, the eruption of the Krakatau volcano between Sumatra and Java provoked a 30 m wave which crashed onto the coasts of the two islands killing 36,500 people. The earthquake that took place in the Indian Ocean on December 26, 2004 is also tragically famous; the tidal waves following the seaquake struck the coastlines of many Asian countries, including Sri Lanka, India, Malaysia, Thailand and Indonesia, and even reached the coast of Africa. In the Aeolian archipelago in Italy a small seaquake occurred on December 30, 2002 following an underwater landslide beneath the Stromboli volcano. Among the largest waves ever generated by a seaquake are those that struck Valdez, in Alaska, on March 27, 1964 (all of 52 metres high). This seaquake, caused by an earthquake with its epicentre in Alaska, affected the entire Pacific.

A fatal error
Tsunami waves are a danger if the earthquake occurs at sea and there are built-up areas along the coast.
On February 5, 1783 the first wave of a tsunami that struck Messina and the Calabrian coast in Italy (illustrated here in a period print), caused over a thousand deaths amongst those who ran to the coast to seek refuge from the effects of the earthquake.

Watch out for the WATER!

EARTHQUAKES IN HISTORY
JANUARY 9-11, 1693

Two very strong tremors
destroyed Catania (Italy) and 70 other Sicilian sites. Some, such as Noto, were later rebuilt elsewhere.

Magnitude 7.4

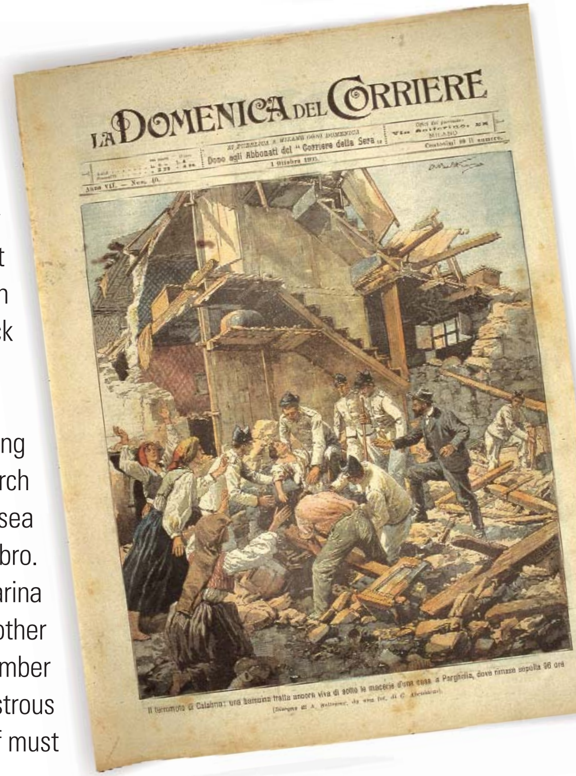
Luckily, tsunami only happen in very particular conditions: they are always sparked off by earthquakes that unleash vast quantities of energy, in territories with faults of a certain kind and coastlines where the depth of the water diminishes particularly rapidly.

For this reason, only a limited number of areas on the Earth are prone to the risks of highly destructive tsunami. Most of them take place in the Pacific Ocean: particularly along the coasts of Japan, Kamchatka and Hawaii. In fact, Honolulu is precisely where an extremely advanced tsunami alarm network is located: it relies on a large number of registration bases (seismometers and mareographs) which monitor the whole Pacific area. This makes it possible to pinpoint tsunami-generated waves immediately following the earthquake that has provoked them. The estimated arrival time of the wave on the coast can then be calculated and populations in danger can be alerted with a few hours' notice.

TSUNAMI closer TO home

Sometimes, the sea disappears immediately before a giant wave arrives. This is what happened at Lisbon (Portugal) on November 1, 1755: the sea receded to such a degree that the bay was completely drained. This cost the lives of numerous people who ventured out onto the newly-revealed sea floor only to be washed away by the huge wall of water that crashed in just a few minutes later. That day, Lisbon was destroyed by the earthquake and the waves struck the coasts of Portugal, Spain and Morocco.

Similar events have also occurred in the past along some coastal areas of the Italian peninsula. On March 27, 1638 following an earthquake in Calabria, the sea withdrew by 2,000 feet (about 600 m) at Pizzo Calabro. On February 23, 1887, a violent earthquake at Diano Marina (Imperia) caused the sea to recede by 4 m. In many other places the recession was of about one metre and a number of boats felt a slight quake. Fortunately, however, disastrous tsunami are rare: the earthquake that sparks them off must be very strong and take place in very deep water.



Earthquakes that shake the sea
The Pacific is on the other side of the world, but dangerous tsunami have happened in the Mediterranean, too: especially in the Aegean Sea and in southern Italy. Examples of the latter include that caused by the Messina earthquake of December 28, 1908, which struck western Sicily and Calabria, generating 13 m waves (photo: the front page of a newspaper of the time, illustrating rescue operations).

Tsunami at Stromboli
The effects of the tsunami at Stromboli (Aeolian Islands, Italy) on December 30, 2002.

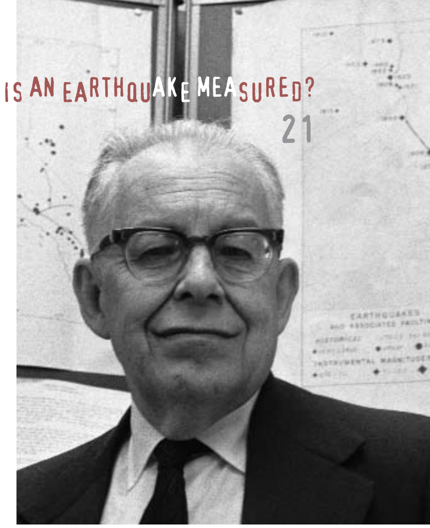
HOW is an EARTHQUAKE MEASURED?

There is more than one approach to measuring an earthquake: the Richter magnitude tells us how much energy has been unleashed by an earthquake, whereas the Mercalli scale classifies its effects on the territory.

The world's oldest Seismometer was invented by the Chinese philosopher, Chang Eng in 132 AD.

From stars to earthquakes

Charles Richter (1900-1985), a brilliant physics graduate and a "Star Trek" aficionado, was convinced that his future lay in astronomy and the study of stars. But after he accepted a job in a geophysics lab he had a lightning conversion to seismology. In 1935, at the debut of his prestigious academic career at the California Institute of Technology, he developed a system for measuring the energy released by earthquakes through the definition of the concept of magnitude.

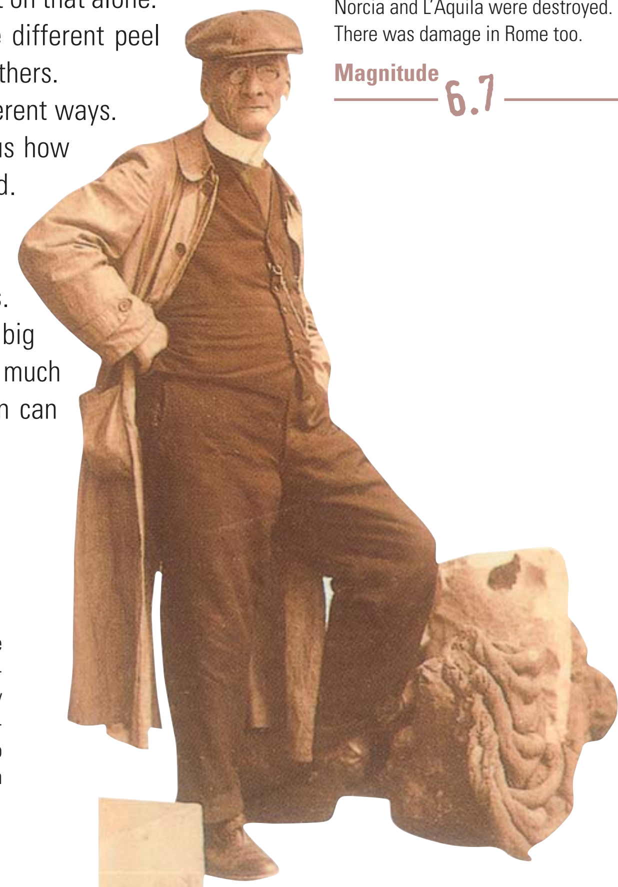


As sharp as a LEMON

Have you noticed how some lemons are very small, and others are absolutely huge? You can measure them in different ways: with a ruler, for example, you can measure size; or you can weigh them, just like the grocer when you go to buy some. Once you have squeezed a lemon, you can check the amount of juice it contained: a small glassful? A quarter of a glass? Half? The quantity of juice will depend on the size of the lemon, but not on that alone.
Lemons of the same dimensions may have different peel thicknesses; some are simply juicier than others.
An earthquake too can be measured in different ways. The Richter magnitude, for example, tells us how much elastic energy has been released. Differently, other systems such as the Mercalli scale represent the earthquake's effects on the land, objects and buildings.
It's a bit like saying that one measures how big the lemon is and the other measures how much juice it produces. Both kinds of information can be very useful.

Between January and February 1703 a series of major earthquakes struck central Italy and many towns and villages between Norcia and L'Aquila were destroyed. There was damage in Rome too.

Magnitude 6.7



The geologist priest

After being ordained to priesthood, Giuseppe Mercalli (1850-1914) decided to study for a degree in Natural Science and focus on geology and the study of earthquakes. In 1902 he invented the scale which is still used today to measure the intensity of earthquakes based on observation of their effects.

A PENDULUM in reverse

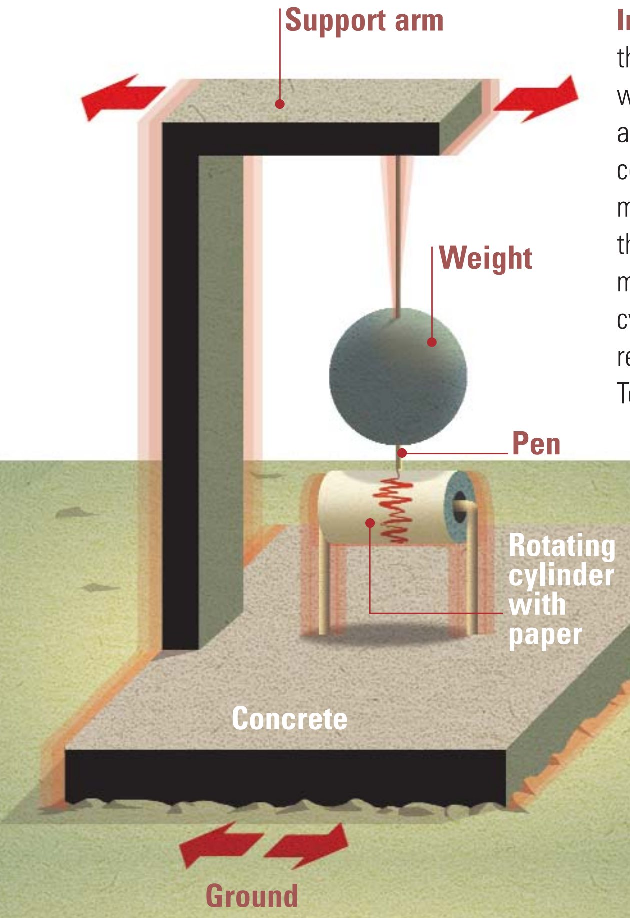
EARTHQUAKES IN HISTORY
AUGUST 14, 1708

Between March and October 1708 a strong sequence of earthquakes struck the south of France. The main earthquake, on August 14, caused serious damage in the town of Manosque.

Magnitude 5.5

The main device used to study earthquakes is the seismograph. It is effectively a pendulum which records movements in the particular part of the earth in which it is located.

You may have watched a pendulum in motion. The largest ones are hung from the ceiling and have a tip that traces their movements, every swing, in a layer of sand on the ground below. Well, the seismograph works in exactly the opposite way: the pendulum stays absolutely still, while the rest of the world shakes with the earthquake...including you as you watch it! The seismograph pendulum is very heavy and tends to stay still as a result of the same "principle of inertia" that explains why passengers fall backwards if a bus sets off unexpectedly... what is really happening is that you are staying still instead of moving with the bus!



In other words, as the earth quakes, so does the supporting arm that the pendulum hangs from, whereas the pendulum itself and the pen that is attached to it stay quite still. The rotating paper-covered cylinder that the needle and ink make marks on, however, shakes in the same way as the ground. Thus a recording of the movement is made, called a "seismogram". The paper-covered cylinder rotates as the earthquake happens and a reading is given for the duration of the tremor.

Technological progress has led to the design of much smaller and much more sophisticated electronic seismometers, which have now replaced all the old instruments.

An incredibly sensitive device...

There are various types of seismograph: vertical or horizontal. Each earthquake observation centre usually has three: one to measure north-south oscillations, one for east-west oscillations, and another for vertical oscillations. This makes it possible to record earthquake movements in all directions.

What does a SEISMOGRAM tell us?

Lots of information can be read in a seismogram: it is possible to determine, for instance, how much time elapses between the arrival of P waves and S waves.

The broadest oscillation recorded by the seismogram indicates the energy of an earthquake, which is measured in "magnitude". To be precise, this has to be compared to the distance from the hypocentre: clearly, if two earthquakes cause the same oscillation, the one that is further away must be the stronger!

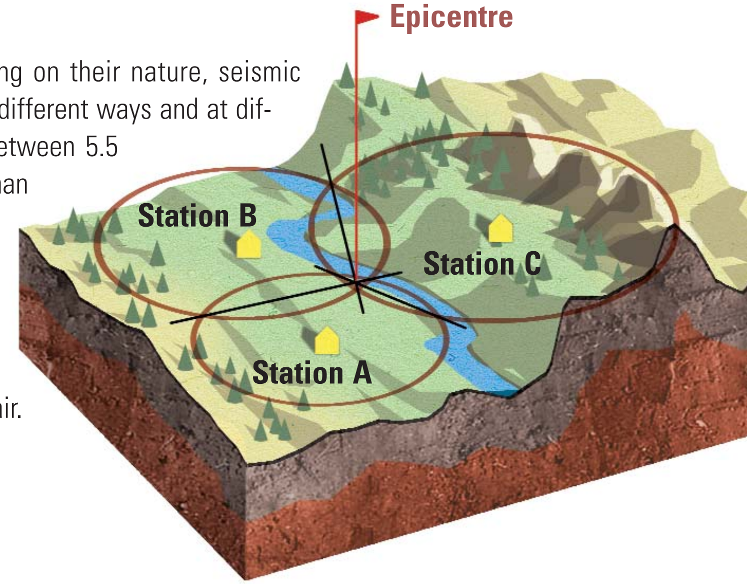
If we know the speed of the P waves and S waves, and the seismograph tells us, in terms of seconds, the distance between them, we can calculate how long it took them in total and, therefore, how far away the hypocentre is.

Another useful device

The accelerometer is used to record changes in the speed at which the ground trembles. This information is extremely important to understand the extent of damage buildings may have suffered: in fact this does not depend only on the strength of the earthquake, but more on how rapidly it is unleashed.

Above, view of the accelerometer station at Sant'Agata di Puglia (Foggia, Italy).

We already know that, depending on their nature, seismic waves travel through the ground in different ways and at different speeds. P waves travel at between 5.5 and 14 km/second: 24 times faster than a supersonic plane such as Concorde, just imagine that! S waves travel at between 3 and 7 km/second, whilst L waves move at around 3.5 km/second: more than 10 times the speed at which sound travels through the air.



Let's come to the point...

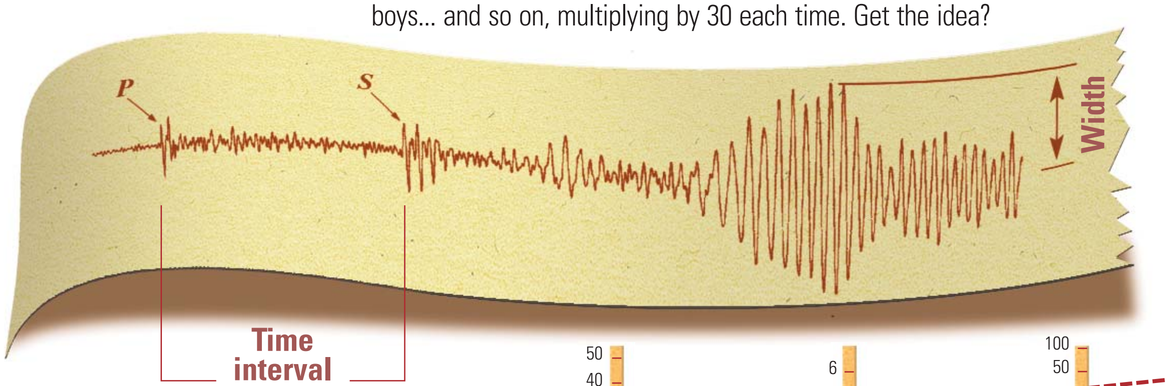
The earthquake can be located by measuring the distance between three different stations and the hypocentre: all you need is a compass and a map. Stick the compass needle into one of the stations on the map, open the compass points to the distance that you have calculated on the arrival times of the P and S waves, then draw your circle. Now do the same thing with the other two stations. Then draw three straight lines which join the intersecting points of the circles; the point where these three lines meet is the epicentre.

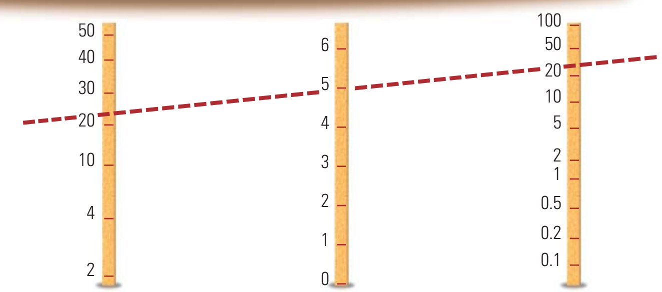
A REALLY powerful EARTHQUAKE!

Tracing an earthquake
The seismogram is the line reading made by seismograph during the earthquake. From analysis of the seismogram, seismologists are able to establish the magnitude of a seismic event. In fact, the values taken into consideration are the maximum amplitude reading on the seismogram and the time interval between the arrival of longitudinal P waves (which are the first to arrive) and transverse S waves (which arrive second).

Magnitude was defined in 1935 by the seismologists Beno Gutenberg and Charles Francis Richter. The latter gave his name to "Richter magnitude" also known, incorrectly, as the "Richter scale". A bit hard on Beno Gutenberg!

Zero magnitude was given to earthquakes that were barely picked up by seismographs of the time. That means the ones that provoked a maximum oscillation of a thousandth of a millimetre of the needle of a seismograph situated 100 km away. A really tiny movement! Then they defined the various magnitudes of their scale based on the increasing amplitude of the needle movement.
At that point, Gutenberg and Richter discovered a correlation between the magnitude they had established and the energy released by the earthquake: they realised that for each level, the energy was approximately 30 times greater than the previous level. Thirty times is a huge difference: imagine what a difference it would make if you were playing tug-of-war and at the other end of the rope there were thirty boys instead of just one! At magnitude 2 the effect is like having 900 boys at the other end of the rope, magnitude 3 is equivalent to 27,000 boys... and so on, multiplying by 30 each time. Get the idea?

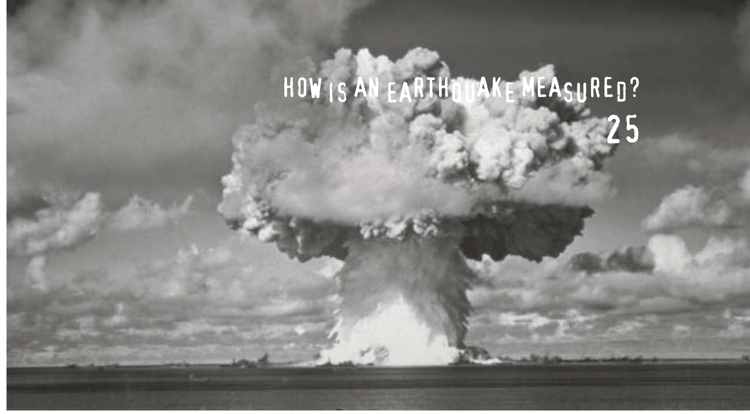




How to calculate magnitude
Calculating the magnitude of an earthquake involves marking in the right-hand column the maximum amplitude in millimetres recorded by the seismograph, and in the left-hand column the difference in arrival times between the S and P waves, which indicate the distance from the hypocentre. Then, by connecting the two points with a straight line, the central column will give us the earthquake's magnitude. As you can see from the graph, the magnitude reading is directly proportional to the amplitude of the broadest oscillation and the distance between the S and P wave arrival times.

The earthquake that took place on November 1, 1755, one of the strongest in the history of Europe, destroyed Lisbon (Portugal) and was felt in most of Europe. There was serious damage in North Africa too.

Magnitude 8.7

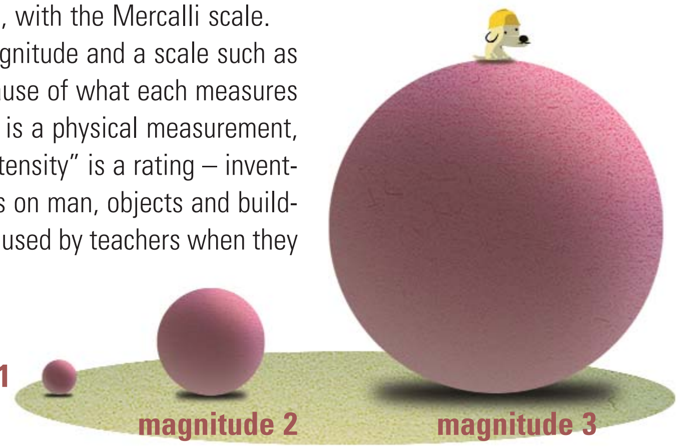


MUCH more than an ATOMIC bomb

We have already seen what 0 on the Richter magnitude corresponds to. In theory there is no limit but, fortunately, earthquakes have never gone over magnitude 9. A superficial earthquake has to reach at least magnitude 5 before causing substantial damage in the area of the epicentre: the energy released is equivalent to the atomic bomb which was exploded experimentally on Bikini Atoll in 1946. An earthquake of magnitude 9, as we now know, is 30 times 30 times 30 times 30 times 30... 810,000 times more powerful than that atomic bomb. Mind-boggling!
More modern seismographs than those available to Richter can measure earthquakes that are even weaker than magnitude 0: this is the reason why today we can even indicate magnitude with negative numbers.

However, it is often useful to assess the effects that an earthquake has on land, buildings and people, rather than the energy that it releases; sadly, we could even say that this is ultimately what interests us most. This measurement is called "macroseismic intensity" and it can be obtained, for example, with the Mercalli scale.
The difference between the Richter magnitude and a scale such as Mercalli's is fundamental, not just because of what each measures but also of how they do so. Magnitude is a physical measurement, given by instruments; the "degree of intensity" is a rating – invented by man – of the earthquake's effects on man, objects and buildings: it is similar to the marking system used by teachers when they "classify" their pupil's achievements...

Ml and Mw
Seismologists use different types of magnitude: the main ones are the Richter Magnitude (ML, also called "local magnitude") and moment magnitude (MW). The ML is calculated from the maximum amplitude on the seismogram, while MW is calculated on the entire seismogram and it is more representative of the size of the earthquake.
The ML can be calculated in a few minutes, while the MW takes several hours. The two estimates 'measure' the same thing differently.



To put it another way
To get an idea of the proportions of different levels of energy in earthquakes, we can imagine each magnitude as a different-sized sphere. The volume of each sphere is proportional to the quantity of energy released.
In relation to this drawing, the energy released by the 1908 Messina earthquake, which reached magnitude 7.3, would be represented by a sphere of over 9 metres in diameter!

The seismograph and magnitude
Once they had established magnitude 0, Richter and Gutenberg defined the various other levels of magnitude passing from one level to another each time an oscillation of the seismograph needle was 10 times greater than the previous one: magnitude 1, therefore, is reached when the oscillation is one hundredth of a millimetre, magnitude 2 when it is a tenth of a millimetre and 3 when it is a millimetre and so on.

An EARTHQUAKE with great EFFECTS

This earthquake, one of the most significant that ever took place in Switzerland, was also felt in southern Germany, Austria and northern Italy. It caused serious damage in Brig, with slighter effects on Berne, Zurich and Milan.

Magnitude 6.1

"Macroseismic intensity" is calculated by bringing together all possible information describing the effects produced by the earthquake in the various areas struck. This is then compared with the descriptions corresponding to each level on the scale and the level that best matches the description is identified.

There are a number of different scales that serve this purpose. The simplest of those used in Europe is the Mercalli Cancani Sieberg (MCS): but the Medvedev Sponheuer Karnik (MSK) and the European Macroseismic Scale (EMS), devised in 1992 and updated in 1998, are also used. They have complicated names, but the idea behind them is quite straightforward. All these scales are divided into 12 levels: on the next page you will see an example of a very simplified description of the levels on the MCS scale (otherwise known more simply as the "Mercalli scale"). Let's imagine there is an earthquake (fingers crossed there isn't!). You hear the bookcase groan, feel the floor shake and see the light swing, but nothing more serious than that happens: your aunty continues to snore in the next room and your little sister playing in the garden doesn't realise anything has happened at all... Let's have a look over here for a similar description: these are clearly the effects of the 4th grade on the Mercalli scale.

Past evidence
The MCS scale is also useful for classifying the effects of past earthquakes on the basis of descriptions which were recorded at the time. More sophisticated scales, such as the EMS, cannot be used for this purpose because in addition to information concerning damage inflicted on buildings they also require details of how they were built, how vulnerable they were to begin with, etc. Things that are difficult to find out: often the only evidence remaining of certain events is limited to a few words, such as the epigraph on the facade of the Polla castle (Salerno, Italy) damaged by the earthquake of 1561 («oppido motu terrae concusso»), and rebuilt by Giovanni Villano in 1590.

The degrees of the MERCALLI scale (MCS)

I Earthquake usually not felt, but can be recorded by instruments.

II Felt only by a few people, in quiet environments, on upper floors of buildings.

III Light tremor felt only by a few people indoors; suspended light fittings may swing slightly.

IV Objects rattle and creak; suspended light fittings swing.

V Felt by most people, even outdoors; almost everyone will run outside and those who are asleep will wake up. Doors and windows bang, some windows will break, liquids spill out of their containers, pictures move and unstable objects fall over.

VI Plaster may fall, cracks appear in walls, objects fall; people are frightened.

VII Considerable damage; elements from upper parts of buildings such as chimneys may fall.

VIII Collapse of old and dilapidated buildings; serious damage to a quarter of buildings.

IX Half the buildings made in brick will collapse; almost all others are rendered uninhabitable.

X Total collapse and serious damage to three quarters of the buildings; effects on land too (landslides and cracks).

XI Almost all brick buildings and bridges collapse; dramatic effects on the territory.

XII Destruction of all man-made constructions, major changes to the natural environment.

Point by POINT

You know the annoying sound of your neighbour's radio first thing on a Sunday morning? All it takes to wake you up is for him to turn it on in the room next to yours even if the volume is right down... But if this inconsiderate person lived on the other side of your garden, he would have to turn the volume up much higher to irritate you in the same way!
The same applies to earthquakes: they have different effects on the different places they strike. Correct analysis requires complete "macro-seismic monitoring", assigning the correct intensity to each of the places that experienced the earthquake. The same effects may derive from an earthquake of average intensity that was very close, or from a more powerful earthquake that was much further away.
Each piece of information that is gathered is put onto a map called the "intensity map" that, once complete, gives an overview of the entire situation. The barycentre of the area of highest intensity can then be pinpointed, which is called the "macroseismic epicentre".

The intensity map is an essential instrument for comparing two earthquakes from the point of view of their effects: it is not enough to look at the maximum level, the extent of the affected areas must also be taken into consideration.

EARTHQUAKES IN HISTORY
JULY 22, 1767

This earthquake struck the Ionian Islands (Greece), seriously damaging many villages on the island of Kefalonia. Damage was also recorded on Zante.

Magnitude 7.2

EUROPE is under CONTROL

To keep our territory under constant observation, various national seismic networks, scattered over different parts of the continent have been created over the last few decades. Among the main seismic networks in southern Europe are those of the Swiss Seismological Service (SED), the French Network (ReNaSS – Réseau National de Surveillance Sismique) and the National Institute of Geophysics and Volcanology (INGV). National networks cooperate with each other through various structures and initiatives, such as the EMSC (European-Mediterranean Seismological Center) and Orfeus (Observatories and Research Facilities for European Seismology).

For map, see page 62.

In the event of an earthquake, data is immediately transmitted from all stations to computers at the various national centres, which process it and furnish the results to qualified personnel on duty around the clock. In this way, in the space of just a few minutes, the Civil Defence organisations can be provided with all the preliminary information concerning the earthquake: when it happened, its epicentre, the energy it released and the area that is likely to have suffered damage. Any necessary rescue and aid operations can then be organised. With a minimal margin of error, the seismic networks guarantee localisation of all earthquakes occurring in any part of Europe, even the most remote. Remember, though, that damage becomes an issue only from magnitudes of around 4.5.

An earthquake with no frontiers
This period photo shows the terrible consequences of the earthquake that struck Diano Marina (Imperia, Italy) on February 23, 1887. Of a magnitude of 7.0, the earthquake produced serious damage in eastern Liguria and slighter effects in France (even in Menton and Nice) and was also felt in Switzerland.

Can EARTHQUAKES BE FORESEEN?

If earthquakes were foreseeable, would this change the fate of millions of people who live in seismic areas? Perhaps not, or perhaps not completely. In any case, at present we cannot yet speak of forecasts.

Sant'Emidio is worshipped as the patron saint of earthquakes.

Where, WHEN and how big

Some things can't be avoided: like your crummy cousin coming to stay. You can't stop him coming, but if you know he is going to come, you can take precautions, like putting a password on your computer and faking a dose of yellow fever... better to overdo it! Unfortunately, on the subject of unpleasant visits, the location of the next earthquake, how strong it will be and, most importantly of all, when it will be, still can't be forecasted. What we can know with a certain degree of precision is where earthquakes may occur in the future and the maximum level of energy they may be expected to release. It is impossible, however, to know when they will strike.

Long-term forecasts can be made which classify dangerous areas according to the probability that strong earthquakes might occur, and the frequency that can be expected of them. The geological characteristics of the area need to be examined and former seismic activity has to be analysed. Medium-term forecasts can also be attempted by trying to identify the period in which an earthquake might be expected.

To do this, we need to understand how much energy has accumulated that could provoke an earthquake in that area, and also the way in which it will be released: whether a little at a time, with many low magnitude shocks, through a few very strong shocks. Just like that cousin of yours: does he drop in frequently just for tea? Or at Easter and Christmas for days at a time? You need to know so you can plan your next attack of yellow fever.

EARTHQUAKES IN HISTORY
FEBRUARY 5, 1783

On February 5, 1783 a long and devastating seismic sequence produced serious damage throughout central-southern Calabria (Italia). Approximately 200 towns and villages were destroyed.

Magnitude 7.0

Fruitless research... so far

In Monaco and other cities in the Mediterranean, buildings that have been constructed on the basis of anti-seismic criteria are not rare. Although Japan and the United States have invested a great deal to keep high seismic risk areas under control, so far no-one has managed to discover how earthquakes might be predicted.

A more precise SIGN

EARTHQUAKES IN HISTORY
JULY 5, 1855

Damage in Visp, Törbel,
Visperterminen, St. Niklaus, Grächen and Stalden (Switzerland).
200 houses damaged, one victim and numerous wounded.

Magnitude 6.4

The systems that we have mentioned give us an idea of which areas are high risk. Further investigation in such areas may well lead to a breakthrough in forecasting, in the short term and with a certain amount of precision, when the awaited earthquake will strike.
This would seem possible because, according to some scientists, the stress to which rocks are subjected can modify some of their characteristics, before they eventually break. If this were true, these would be the only values that would have to be checked: any unusual readings could be considered as forewarnings, or clear signs of an imminent earthquake. Systematic surveillance of these warnings would finally make it possible to pinpoint the initial moment of an earthquake. However, we have to be aware of the fact that, hand in hand with the benefits of forewarnings come the negative effects of false alarms.

Many people also believe that seismic events are preceded by peculiar "earthquake weather", characterised by warm winds or fog. People also say that animals begin to behave strangely before an earthquake. No scientific studies have been able to prove anything of the sort. Just as there is no proof that if you dream that your cousin is bitten by a dog, you can play numbers 21 and 70 and expect to win the national lottery: in fact, you might as well throw your money down the drain. And yet there are people who believe it!

And yet there are people who believe it!
Despite popular belief, it has never been proved that strong winds and odd animal behaviour indicate the arrival of an earthquake.
Below: an illustration of the earthquake in Aigle (Switzerland) of 1584.

Four possible SIGNALS

In recent years, research into the precursors of an earthquake has focused on four main categories of signals which could provide prior warning.
Firstly, there are the seismologic forewarnings: prior to a significant seismic event, a series of microquakes can be picked up on instruments. So, it is useful to study events that occur before a strong earthquake: how strong they are, how often they happen and where, in such a way as to recognise the same behaviour in the future. Like an elderly teacher who always starts muttering in the same way before he loses his temper completely: as soon as he starts, you know what's coming!
Geophysical forewarnings of an earthquake are even more complicated to assess, like anomalies in the speed of the P and S waves, and particular variations in the magnetic and electric characteristics of the rock.

The geochemical forewarnings consist of variations in certain chemical elements in underground water, particularly radon (radioactive gas).
Lastly, the geodetic forewarnings relate to various changes in the level and inclination of the ground surface.

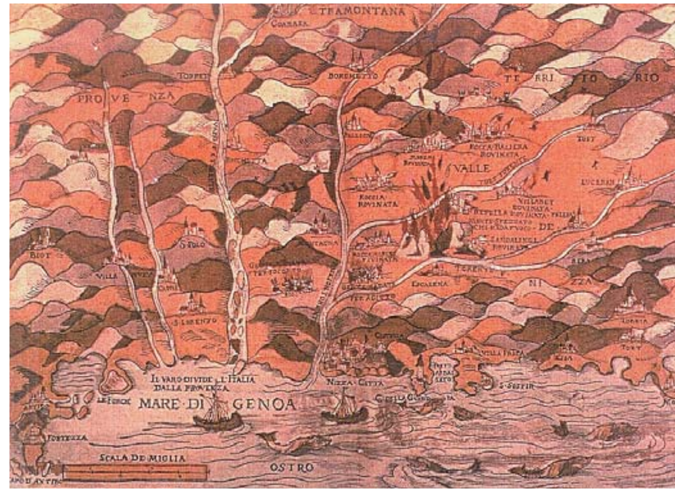
No one of these happens every time...
None of the premonitory signs always occurs before every important earthquake. This is the reason why research is moving towards simultaneous observation of a number of phenomena.

HOW SEISMIC is EUROPE?

Understanding Europe's seismicity is fundamental to identify the places that are most at risk. Seismicity is studied through information collected from instruments, analysing the effects produced by past earthquakes, backed by geological knowledge of the characteristics of the various areas.

Expect the THIRD...

We have said that it is not easy to foresee where, when and how strong an earthquake will be. Luckily, earthquakes don't happen for no reason: they tend to always recur in the same areas. It is possible to study past events, through information that has already been collected by instruments and the evidence that they have left in rocks and buildings, to understand at least where the next ones are going to happen. Studying the past permits us to assess the "seismicity" of places and take precautions so that the effects of future earthquakes can be reduced.



The oldest sismic map
This extraordinary wood engraving illustrates the effects of the earthquake in the Maritime Alps on July 20, 1564.

We can refer to data from seismographs for more recent earthquakes, but specific instrumental networks for earthquake surveillance have existed in Europe only since the second half of the XIX century, and a modern and efficient observation network only for thirty years or so. For events that happened before that, all we can do is study the historical documents or the traces that have survived in man-made works, and the landscape.

From historical and instrumental information the essential parameters of the earthquakes can be obtained: time of origin, coordinates of the epicentre, intensity and – when recorded by instruments – magnitude and depth.

This was the strongest earthquake ever recorded in Liguria (Italy), and was felt in a vast area. Approximately 640 victims and hundreds of people wounded. The epicentre was in the sea off the coast of Imperia.

Magnitude 7.0

A shattering century!
Over the last hundred years, the Euro-Mediterranean area has been struck by numerous significant seismic events. Of these 18 have exceeded magnitude 7 and caused almost 200,000 victims. It is reasonable to assume that others will take place in the future with similar frequency...

A voice from the PAST

Historical but also very contemporary!
The objective of Historical Seismology is to study earthquakes that it has not been possible to observe using instruments and questionnaires. Not just those of the distant past, but also more recent ones for which there are no scientific observations, but there are newspaper articles, TV reports and cine films... All this evidence has to be analysed in precisely the same way as the historic documents.

Historians base their studies of the past mainly on written and visual evidence: chronicles, letters, paintings, contracts, frescoes, documents and so on. This is a good system for studying earthquakes too. In effect, over the last thirty years and principally in Europe, "Historical Seismology" has emerged as a scientific discipline. This is the study of earthquakes using the sources and methods of historical research. In practice, the effects produced by the earthquakes are analysed through historical evidence. These are highly complex studies because the availability, the language, the type and quality of historical sources vary a great deal in different times and in different places.

Additionally, the sources used were rarely intended as evidence: they were not recorded with future seismologists' needs in mind, but for a million other different reasons. That is why Historical Seismology requires the intervention of historians who understand earthquakes, seismologists who understand historical sources and even perhaps the occasional engineer: it is what is called an "interdisciplinary subject".

Evidence from other eras
When information has been gathered from many different places and is reasonably precise, key points of the earthquake can be deduced: time of origin, coordinates of the epicentre… In this way "catalogues of earthquakes" can be compiled: Europe boasts a long-standing tradition in this field. Many have been created in the past, often in the wake of the emotions provoked by some major event. Among the most famous are the repertoires published by M. Bonito (1691) and M. Baratta (1901) for Italy, by A. Perrey (1845) for France, by O. Volger (1857) for Switzerland and by J. Schorn (1902) for Austria.

Even further BACK in time

Archaeologists study the past mainly by examining man-made artefacts: buildings and objects and various other items. This type of analysis can be applied to earthquakes, too. Thus we have Archaeoseismology, another very recent discipline, developed by archaeologists and seismologists working primarily in the Mediterranean basin (Greece, the Middle East, and North Africa). This is effectively the study of earthquakes that occurred in periods for which we have no written documentation or very limited evidence describing the effects of the earthquake explicitly or in detail.

Archaeoseismology, therefore, observes the damage caused by earthquakes to ancient constructions. Imagine what it means to have to discover, from a pile of ruins, whether its collapse was provoked by an earthquake, or by other natural events such as landslides, floods and subsidence, or by historical events such as battles or revolutions.

When there are no written documents recording the seismic origin of the damage, other proof has to be discovered through a variety of analytical methods. These call for the involvement of experts from different fields, so that here too we talk about interdisciplinary studies, as in the case of Historical Seismology.

EARTHQUAKES IN HISTORY
APRIL 18, 1906

On the morning of April 18, a violent earthquake located to the south-east of the city of San Francisco (USA) generated serious damage. It was followed by a devastating fire.

Magnitude 7.8

Paleoseismology, a subject with a complicated name
And what does a Paleoseismologist do, huh? Well, he tries to get the earthquake to confess by, so to speak, pinning it to the ground! To extend our knowledge of earthquakes right back to prehistoric times, that is to the quakes that have left no trace in artefacts or writings, this scientist will examine geological layers in areas of "seismogenetic" faults. No, that is not a new swear word: it means "able to generate earthquakes". The Paleoseismologist can, therefore, discover when earthquakes happened in past millennia and how strong they were.

WHERE to be extra CAREFUL

Messina, Reggio Calabria (Italy) and around 40 other towns along the Strait were destroyed. Major damage in Calabria and Sicily as far as Etna. The quake was felt in Malta and Albania too.

Magnitude 7.1

Chronological lists of past and recent earthquakes form catalogues that are used to draw seismicity maps and provide fundamental information for assessing seismic risk in different places. To these we can add all the information yielded by the geological characteristics of the soil: this twofold analysis enables us to identify "seismogenetic zones", namely the places where we can expect future earthquakes of more or less devastating consequences.

In Europe there are many high risk areas. Those in which we can expect the strongest earthquakes are the countries bordering the Mediterranean Sea: Turkey (where the strongest earthquakes occur), Greece and southern Italy. Some areas of the Iberian peninsula, south-east France, the Alps and Central Europe also feature a fairly significant seismic activity, while moderate earthquakes can occur almost anywhere.

It must be said that European earthquakes, whilst potentially able to cause considerable damage, are less powerful than those which strike in other zones, such as Japan or California. The terrible quakes of the early 1900s, such as those in central Calabria (1905), Messina (1908) and Avezzano (1915) were just over magnitude 7, whereas those of San Francisco (1906) and Tokyo (1923) released 20/30 times more energy, exceeding magnitude 8.

Not the most relaxing of places

The fault line of San Andreas, in California, is hundreds of kilometres in length. Many earthquakes have occurred along it, including the 1906 disaster that destroyed San Francisco.

More POWERFUL and more frequent

Seismogenetic zones can be classified on the basis of the maximum energy released or the frequency of the earthquakes. In Europe, for example, we have areas where minor earthquakes occur frequently, as in the Po valley in Italy or in Switzerland. This also applies to certain volcanic areas, although here earthquakes can be more destructive because the hypocentre is closer to the surface.

In most areas, the situation is worse because, along with a number of weak but frequent earthquakes, there are also more violent earthquakes of an energy that can reach or exceed magnitude 5. This is the case in the western and eastern Alps, along the Pyrenees and in south-eastern Spain, southern France and central Italy.

There are some areas that produce much stronger earthquakes, such as southern Italy and certain countries that were previously part of Yugoslavia. Less frequent but very strong earthquakes can occur in the Atlantic off the coast of Portugal and North Africa (with severe effects in Spain too). The strongest earthquakes occur along the Hellenic and Calabrian arcs. These are the areas in which the most serious earthquakes of all take place, since the energy accumulated over lengthy periods is then released all at once.

For map, see page 62.

Can BUILDINGS BE made SAFE?

It can and must be done! Old buildings have to be brought up to standard to make them withstand collapse, and new projects must be designed intelligently. It's not even expensive, if you consider what's at stake.

Detail of a construction using seismic isolation in Bazzano (L'Aquila, Italy).

Seismic STANDARDS for higher RESISTANCE

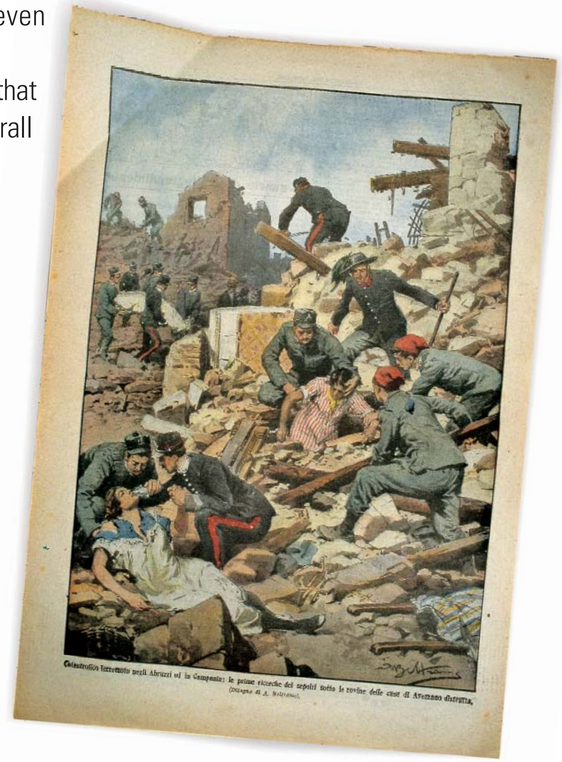
Buildings are constructed to withstand normal conditions: to bear their own weight, the weight of the people who live in them, and the weight of the occupants' belongings, and to withstand the most frequent weather conditions, such as strong winds and snow. In short, they are designed mainly to stand up to vertical pressure. But earthquakes are exceptional events that shake horizontally. Houses are like powerful heavyweights, ready to confront their opponents with their fists... but the earthquake is a treacherous opponent who unexpectedly whips out the mat from under the boxer's feet, making him fall to the ground!

This is the reason why, to protect their citizens, all self-respecting governments make rules about how buildings are to be constructed in order to withstand the effects of earthquakes; these laws are called "antiseismic regulations". The "seismic classification" specifies in which parts of the country these regulations must be applied. So, antiseismic regulations establish that, in certain areas, buildings must be able to withstand even horizontal tremors of the ground.
Examination of damage observed to date suggests that the problem with the buildings is often not their overall strength, but rather a series of details

EARTHQUAKES IN HISTORY
JUNE 11, 1909

With a terrifying rumble, the quake devastated the countryside of Provence (France) and towns and villages such as Rognes, Saint-Cannat, Lambesc, Vernègues and Pélissanne were destroyed.

Magnitude 6.2



Minimising damage
A period illustration showing people being rescued from underneath the rubble in the aftermath of an earthquake. Almost all the damage caused to people and things during earthquakes is due to the collapse of buildings and other man-made constructions; making these quake-resistant would mean greatly reducing the catastrophic impact of earthquakes.

There is STILL time to improve

EARTHQUAKES IN HISTORY
JANUARY 13, 1915

Catastrophic earthquake
that razed to the soil the town of Avezzano in Abruzzo (Italy).
The earthquake was felt in a huge area and even caused slight damage in Rome.

Magnitude 7.0

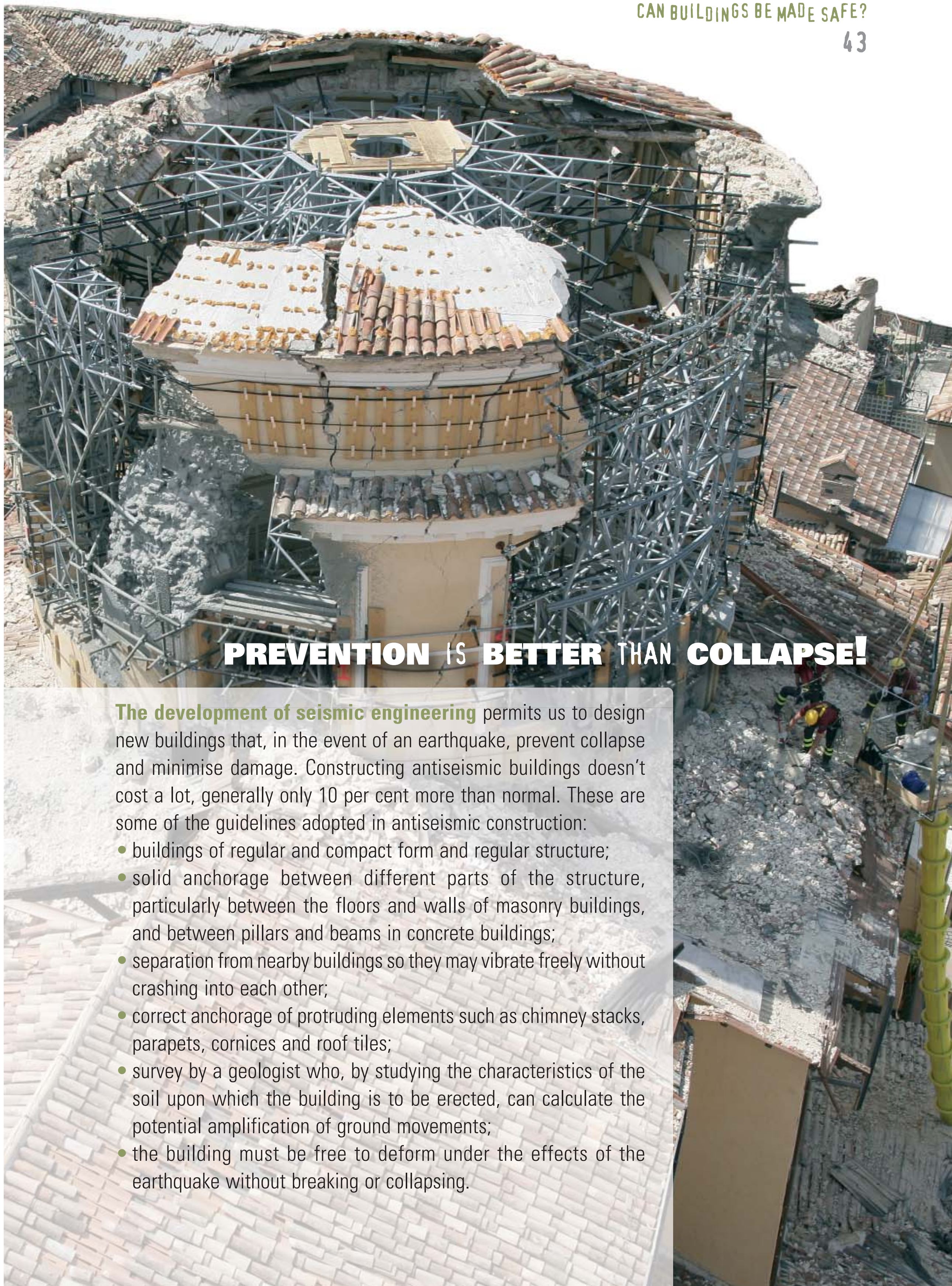
Particularly vulnerable buildings can still have work done to them before the next earthquake. In fact that is exactly what must be done! And once the genuine weak points have been identified, it is not even a particularly expensive operation.

Some of the improvements that are most frequently recommended for brick buildings are the insertion of chains, belt-courses and crowns to anchor walls to each other and to the floors; the use of tension rods to eliminate horizontal thrust against the walls from roofs and ceilings; the recourse to localised reinforcement for the weakest points and the maintenance of walls which have already suffered crack and fracture damage.

This type of intervention makes building collapse less likely and any damage easier to repair. There are however also a number of crucial buildings which are very important in the emergency situations that follow every earthquake: hospitals, for example, fire stations, power stations. It is not sufficient simply to prevent them collapsing: they must stay intact and fully functional even directly following an earthquake! This is why antiseismic work on these, or antiseismic design of new buildings, must be much more rigorous than for any other building.

What if the building already exists?

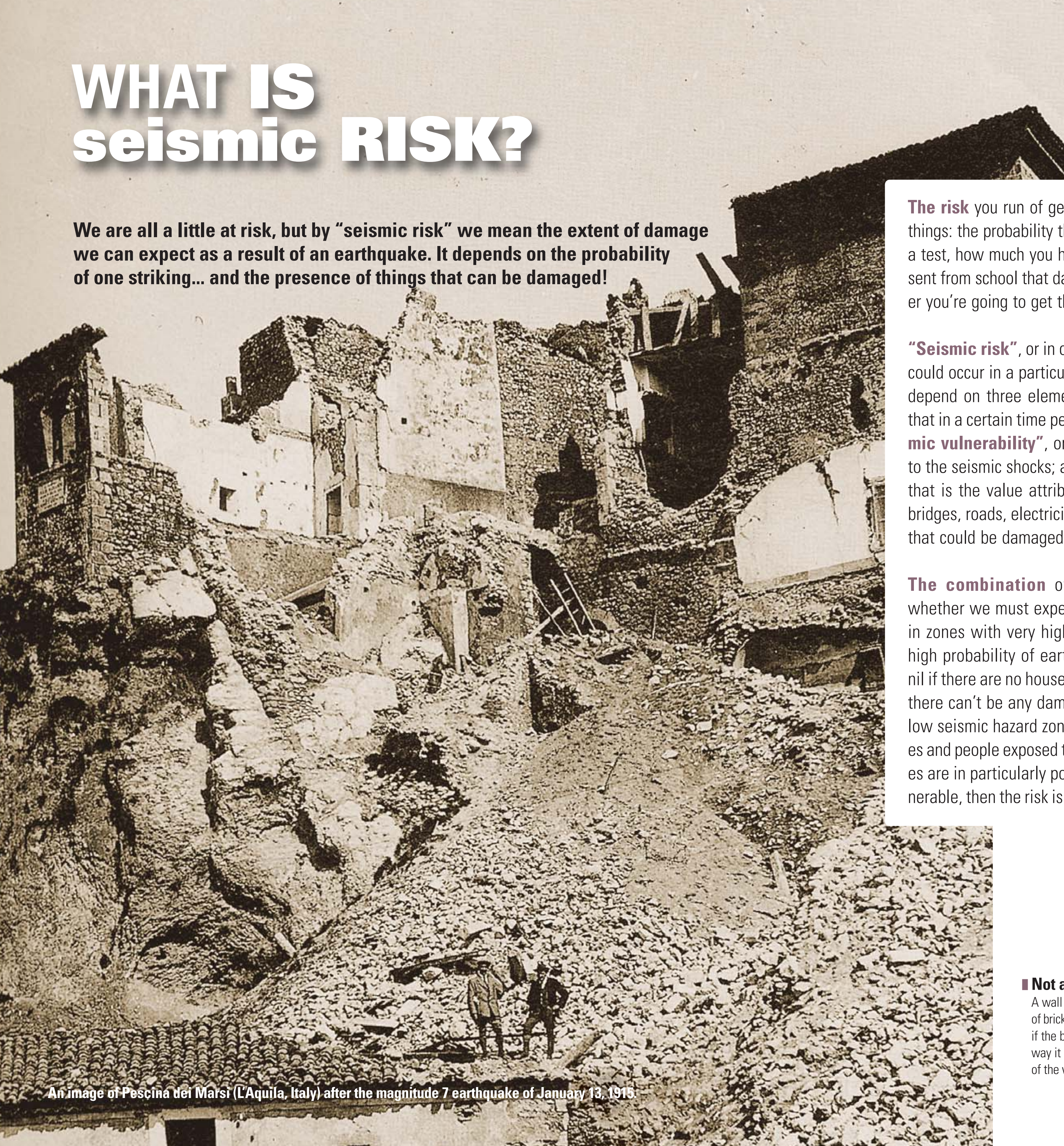
Antiseismic regulations also include standards for building renovation and extension, the strictness of which increases in proportion to the importance of the work. Making existing buildings antiseismic is more difficult. This is because they were built in the past, when knowledge of construction techniques was less evolved, and also because buildings can conceal design defects or flaws that are hard to identify. On the left is an example of the reinforcement of an existing building using chains. This is a low cost solution.



PREVENTION IS BETTER THAN COLLAPSE!

The development of seismic engineering permits us to design new buildings that, in the event of an earthquake, prevent collapse and minimise damage. Constructing antiseismic buildings doesn't cost a lot, generally only 10 per cent more than normal. These are some of the guidelines adopted in antiseismic construction:

- buildings of regular and compact form and regular structure;
- solid anchorage between different parts of the structure, particularly between the floors and walls of masonry buildings, and between pillars and beams in concrete buildings;
- separation from nearby buildings so they may vibrate freely without crashing into each other;
- correct anchorage of protruding elements such as chimney stacks, parapets, cornices and roof tiles;
- survey by a geologist who, by studying the characteristics of the soil upon which the building is to be erected, can calculate the potential amplification of ground movements;
- the building must be free to deform under the effects of the earthquake without breaking or collapsing.



WHAT IS seismic RISK?

We are all a little at risk, but by "seismic risk" we mean the extent of damage we can expect as a result of an earthquake. It depends on the probability of one striking... and the presence of things that can be damaged!

An image of Pescina dei Marsi (L'Aquila, Italy) after the magnitude 7 earthquake of January 13, 1915.

What MUST we EXPECT?

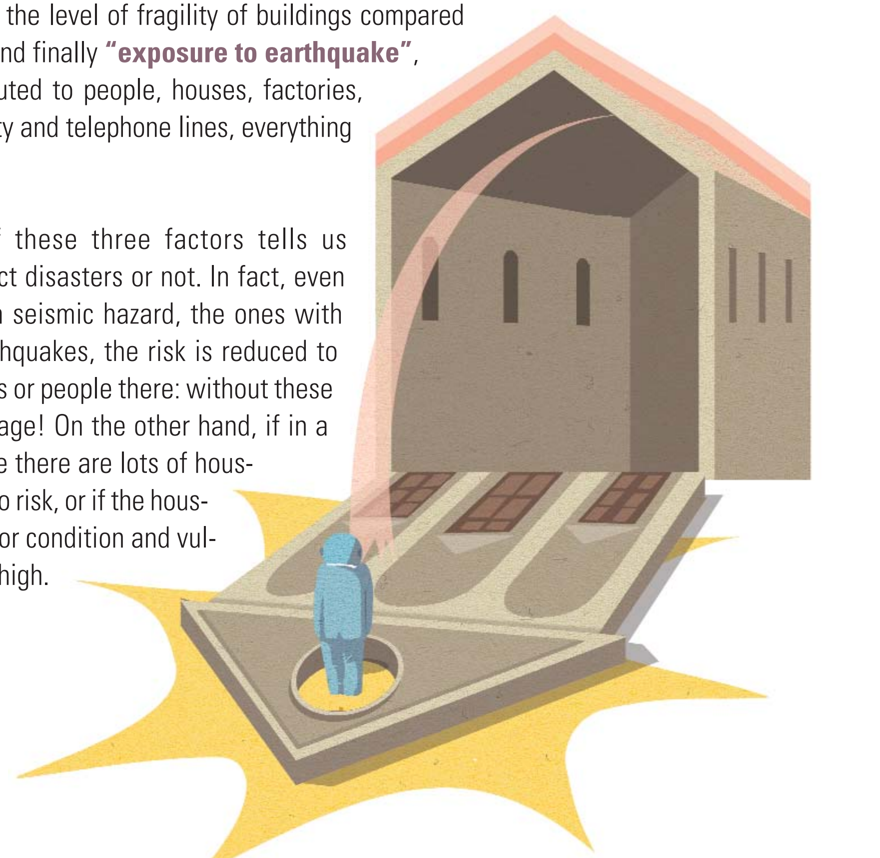
The risk you run of getting a bad mark in maths depends on three things: the probability that one day your teacher decides to give you a test, how much you have studied, and whether or not you are absent from school that day. But don't get your hopes up, sooner or later you're going to get that test... so get working!

"Seismic risk", or in other words, the estimate of the damage that could occur in a particular area affected by an earthquake, can also depend on three elements: **"seismic hazard"**, or the probability that in a certain time period powerful earthquakes can occur; **"seismic vulnerability"**, or the level of fragility of buildings compared to the seismic shocks; and finally **"exposure to earthquake"**, that is the value attributed to people, houses, factories, bridges, roads, electricity and telephone lines, everything that could be damaged.

The combination of these three factors tells us whether we must expect disasters or not. In fact, even in zones with very high seismic hazard, the ones with high probability of earthquakes, the risk is reduced to nil if there are no houses or people there: without these there can't be any damage! On the other hand, if in a low seismic hazard zone there are lots of houses and people exposed to risk, or if the houses are in particularly poor condition and vulnerable, then the risk is high.

On 25 January 1946,
towards 6.30 p.m., the strongest earthquake in Switzerland of the XX century struck the region of Sierre, causing particularly serious damage to the municipality of the same name.

Magnitude 6.1



Not all walls are the same

A wall can be more or less resistant to earthquake shocks depending on the material it is made from. Walls made of bricks or concrete blocks are more robust than those made of stones, especially if the stones are round. Better still if the bricks or blocks are not too hollow inside. The kind of cement that seals them together, the quantity and the way it has been applied are other factors that influence the resistance of the wall. But the most important feature of the wall is that must be firmly anchored to other elements of the house (the other walls, the floor).

SEISMIC hazard

They can recur
In high risk seismic zones, more care is necessary. One shock may be the sign of another one, which might even be bigger. The problem is that the second may arrive after minutes, hours, days or months... Don't take any notice of improvised experts; just listen to official information.

EARTHQUAKES IN HISTORY
MAY 6, 1976

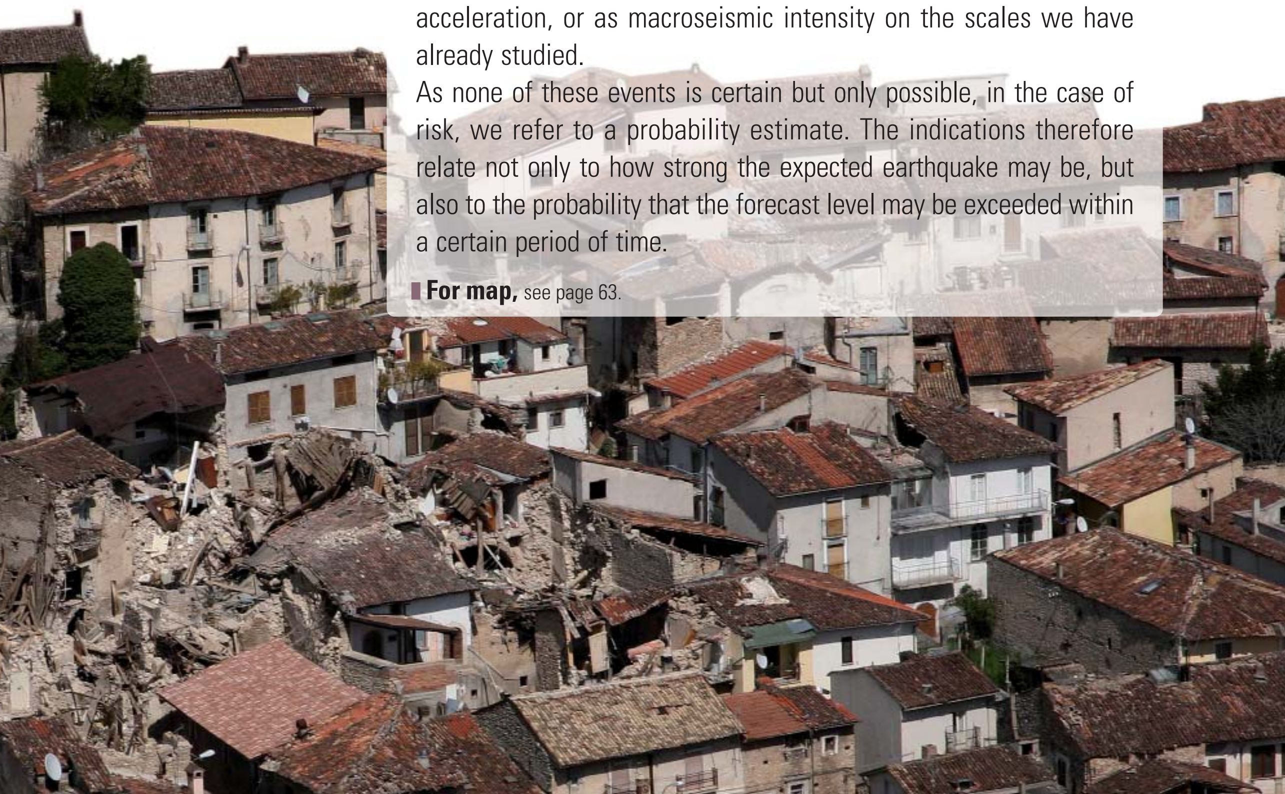
A very strong earthquake
in north-eastern Italy, felt all over Europe, causing moderate damage in Slovenia and Austria too.

Magnitude 6.5

Judging an area's seismic hazard, the probability that it will be struck by an earthquake in the future, requires careful examination of all available information.

Firstly, we must understand the "seismic history" of that place, or at least have a list of past earthquakes as complete as possible. After this, the past earthquakes need to be linked to all available geological information. This is generally done by seismogenetic zoning, which we spoke about earlier, and consists of creating a map of the seismogenetic sources in our area, rather like the diagram of pipes and radiators a plumber prepares before installing central heating in a house. Finally, a simulation is created of how an earthquake spreads, the way its energy radiates from the seismogenetic sources. Again this is similar to the way the plumber studies how the heat progressively diminishes in proportion to the distance from the boiler. On the basis of this data, measurements can be obtained about the tremors in the ground caused by potential earthquakes occurring nearby or far away, but strong enough to be felt in the place under examination. These values are usually expressed in terms of ground acceleration, or as macroseismic intensity on the scales we have already studied.
As none of these events is certain but only possible, in the case of risk, we refer to a probability estimate. The indications therefore relate not only to how strong the expected earthquake may be, but also to the probability that the forecast level may be exceeded within a certain period of time.

For map, see page 63.



Reduce the RISK

We have explained that seismic risk is not influenced only by the seismic hazard of the place, but also by exposure to the earthquake and the seismic vulnerability of man-made objects. In order to reduce this risk, one or more of these factors must be downsized.

Seismic hazard depends on the probability of an earthquake happening and on local geological characteristics: clearly these cannot be reduced.

So, we can work on exposure, which depends on the economic value and the number of people in the buildings. Risk is an assessment of damage, and hence the greater the number of people in the buildings (hospitals, schools, churches, stadiums and so on) the greater the damage. It is also very serious when the damaged buildings are expensive to rebuild (like dams and power stations), when they are located in crowded areas and their collapse can cause serious economic damage (flooding, black outs etc). In short, the more expensive or crowded the buildings are, the higher the risk when they are located in high-risk areas. Where possible, it is a much better idea to build these in lower risk areas.

To sum up, the factor that is easiest to act on is construction vulnerability. We have already seen that we can reduce it by renovating existing buildings following specific criteria, and designing new ones more intelligently. There are even laws – called antiseismic regulations – that oblige people to do this.

Looking to the PAST

In theory you can leave your bicycle parked in front of your house and no one will steal it, because it is against the law to take other people's things. If you're unlucky, someone might take your bike anyway, and then you can just hope that the police find it again and punish whoever is guilty.

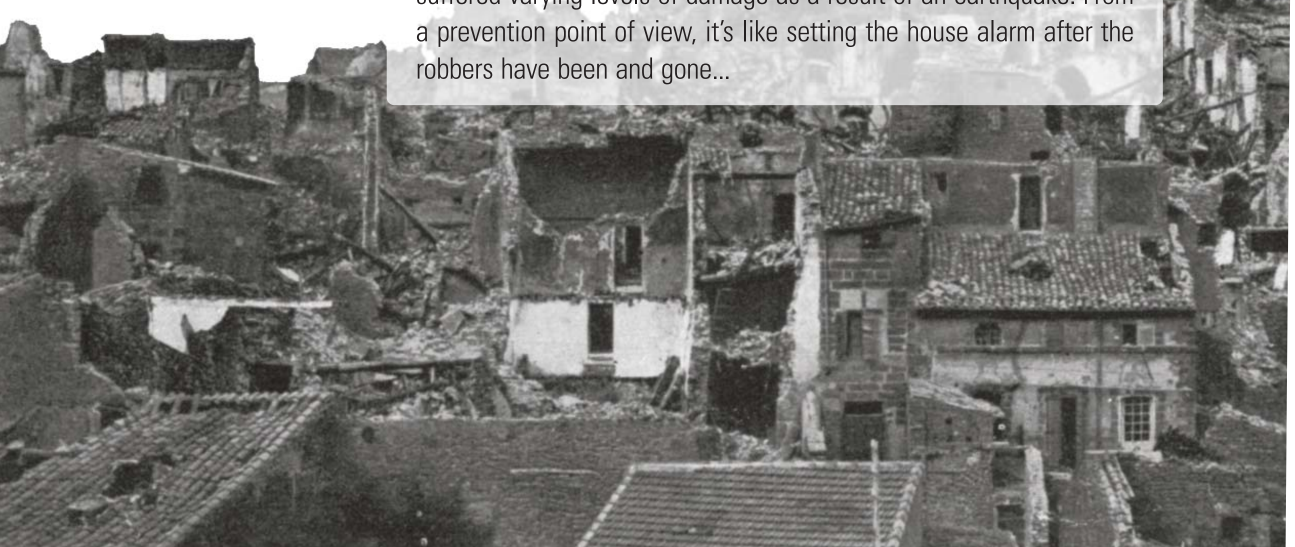
EARTHQUAKES IN HISTORY
JULY 27, 1976

One of the most devastating earthquakes in history, which caused serious damage in the city of Tangshan (China). The victims, officially 255,000, may have numbered three times as many.

Magnitude 7.5

All this happens thanks to laws: regulations that every nation invents so that life for its citizens can run as smoothly as possible and they are as protected as much as they can be from danger. Laws do not only stop people from hurting others, but also from hurting themselves: this is the reason why you have to wear a helmet when you drive a motor scooter. This regulation is quite recent: it was passed a few years ago. Laws can in fact be changed and continually updated. To defend citizens from earthquakes, all self-respecting countries prescribe how buildings must be built, by way of "antiseismic regulations", and specify in which parts of the country these must be applied by way of "seismic classification".

Even in the past, immediately after the great earthquakes laws were passed in many European countries with indications of how to build more safely. These regulations, however, were eventually abandoned. In Italy, for example, seismic classification of the Italian territory was begun after the earthquake of 1908 (in France after the 1960 Agadir earthquake, in Switzerland in 1989). However, in practice, up until 1980, an Italian municipality would be declared seismic only after it had suffered varying levels of damage as a result of an earthquake. From a prevention point of view, it's like setting the house alarm after the robbers have been and gone...



A hundred years later
A view of Rognes (France) after the earthquake of June 11, 1909, which caused very serious damage.

A MORE useful classification

Over recent years several European countries have updated their seismic codes. For a long time the seismic codes of different countries were defined only after the occurrence of strong earthquakes. In recent decades, however, laws are no longer based on past earthquakes, but on the foreseeable effects of future ones. Many countries, therefore, have defined the different seismic zones depending on hazard.

France, for example,has defined 4 seismic zones, from 0 (negligible seismicity), without special rules, to zone 3 (high seismicity).

Switzerland has a code that divides the territory into 3 seismic zones (and so does Greece, for example), with different values for the expected quakes. Italy (like Germany), has a seismic zoning map, which identifies four zones with different values of expected acceleration, and so do the majority of European countries (Austria, Spain, etc.), although the number of zones and the acceleration values vary greatly.

So why only afterwards?
Once, only areas that had already experienced earthquakes would be classified as seismic: the purpose of classification was not to evaluate future risks but to receive funds to pay for reconstruction.
That was why we used to look to the past rather than to the future! If the entire building stock were renovated in compliance with antiseismic regulations, we could avoid experiencing in the future catastrophes like those of the past.

The work of the Firefighters
Truly commendable work was done by the tireless firefighters in Abruzzo (Italy) in the aftermath of the earthquake of April 6, 2009.

Latest NEWS!

Experience shows that almost everywhere minor ground shaking may happen, perhaps caused by non-local earthquakes. It is, therefore, fundamental, to guarantee at least a minimum quality of public building everywhere. Consequently there are specific technical regulations for each zone which must be applied in the design of buildings or infrastructures, such as bridges or viaducts, so that they will be able to withstand the expected tremors. Seismic zoning is also destined to undergo further updating as scientific advances are made in the field of earthquakes or as the result of decisions made by individual countries.
Likewise the technical standards should be updated and improved, and above all local authorities must be in a position to ensure that such standards are actually applied.

As regards the safety of buildings, to give an example, the new Italian technical standards indicate how to design and build safe constructions (buildings, bridges, warehouses etc.) that can withstand the tremors of an earthquake. These standards lay down that the entity of the seismic action to be taken into consideration in the design of the structures must be defined in each part of the country, no longer on the basis of the seismic zone; this is, therefore, a more accurate estimate. The new standards contain modern criteria and new rules for the reinforcement of existing structures, which is a fundamental aspect in the reduction of seismic risk.

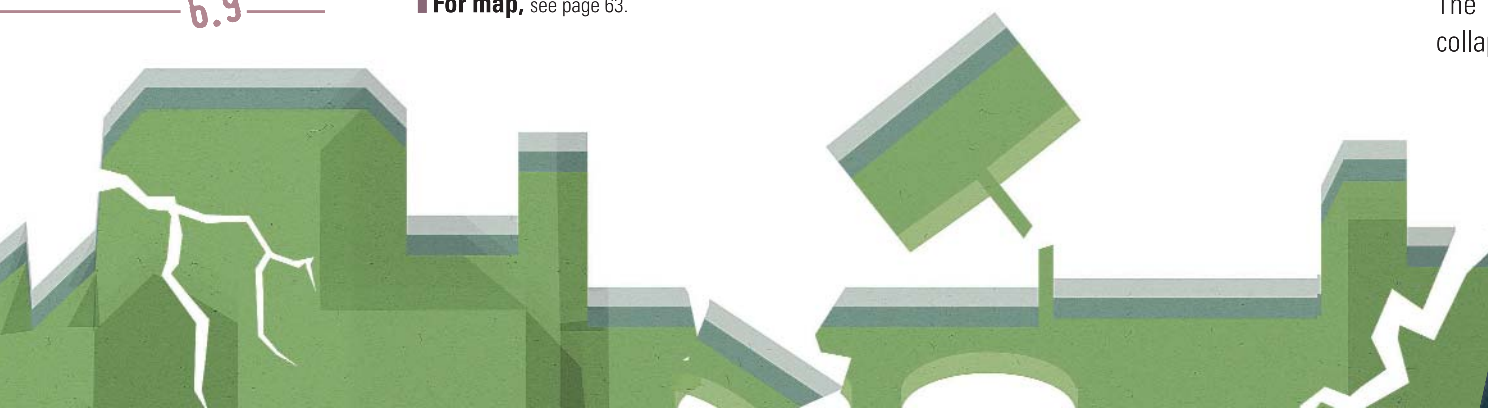
Earthquakes on the front page
Above, the front page of the daily paper "La Sicilia" devoted entirely to the earthquake in the Belice valley (Italy) in 1968, which caused around 300 victims.

EARTHQUAKES IN HISTORY
NOVEMBER 23, 1980

Approximately 860 towns
and villages struck in Irpinia and Basilicata (Italy). Terrible damage. 10,000 wounded. Felt all over Italy.

Magnitude 6.9

For map, see page 63.



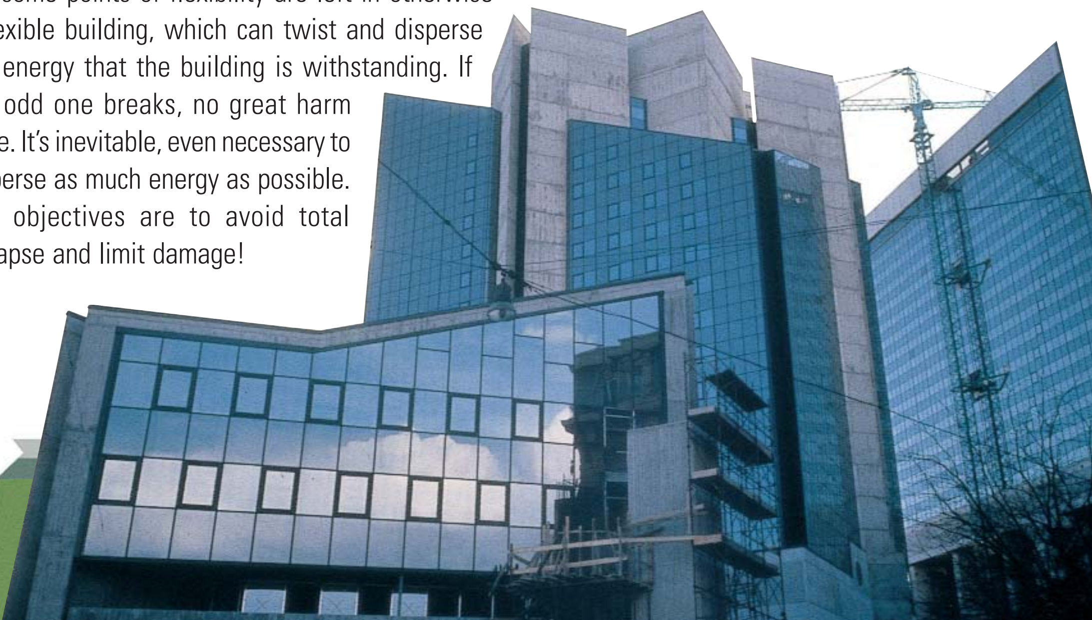
Small BREAKS, great ELASTICITY

If you are a football player or a fan, you will know how important it is not to let your opponent score a goal. However, it is not the most important thing, if you want to win a match or even the championships! Ending a match without letting the opposing team get even one point is greatly satisfying, but what really counts is scoring more goals than them. And in some situations, a draw can be the wisest option.

Understanding your objectives is very important in earthquake prevention, too. The objective of Italian law, for example, in accordance with European regulations (Eurocode 8) is primarily to defend human life in the event of an earthquake, secondly to limit damage, and lastly to guarantee that structures which are vital to Civil Defence continue to be efficient.

To achieve all this, clearly the main concern is that buildings don't collapse. Eurocode 8, however, also focuses attention on all the other components that might fall and wound or kill a person, or destroy the main structure of a building: from windows to balconies, from aerials to railings. In addition to that, it accepts that constructions will suffer a little damage: building houses that remain completely intact would be very difficult indeed, impossible even, just like winning all the matches in the championship without the opponent getting even one single goal!
So, some points of flexibility are left in otherwise inflexible building, which can twist and disperse the energy that the building is withstanding. If the odd one breaks, no great harm done. It's inevitable, even necessary to disperse as much energy as possible. The objectives are to avoid total collapse and limit damage!

The important thing is to think about it
For each seismic zone, the law prescribes the horizontal force which houses must be able to withstand. Differences in robustness from one category to another are substantially modest, but constructions that adhere to standards are much more resistant than those which don't. Futuristic buildings, in particular, have to be designed so they can stand up to very strong shocks.



What happens during an EARTHQUAKE?

Many things can happen. Some effects of the earthquake cause permanent damage, others cease immediately.

Atrocious scenes of destruction? Don't worry this is just a film...

The FURTHER away, the MORE PEACEFUL...

Some effects of the rude family picnic are permanent, others are temporary. The permanent ones include plastic bags, cigarette butts and other rubbish spread around the place, twigs snapped from trees and burnt grass where the fire was. Temporary damage includes the smell of fried food, the blare of the radio and sounds of screaming; the closer you are the more obvious these become: unbearable at 10 m, more tolerable as you move away.

The consequences of an earthquake are also partly permanent and partly temporary, and they are always less serious the further away from the epicentre you are. The area that has been struck can be divided into two parts: the "damaged" area, and the "affected" area, where effects are limited to a swinging light, small objects sliding around, pictures moving and similar events.

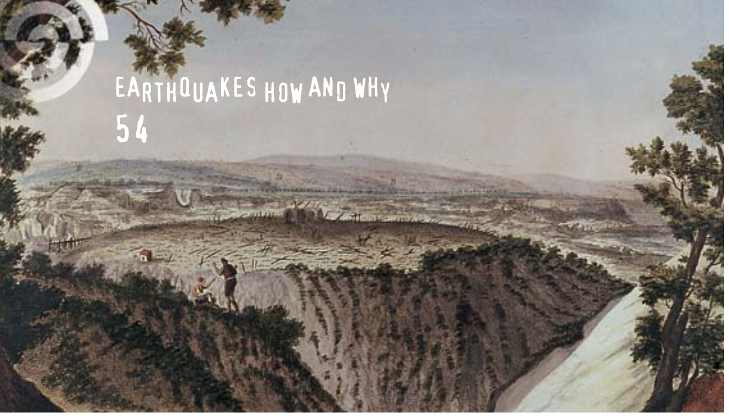
The seriousness of the effects depends a great deal on the kind of ground: if it is hard rock the earth trembles less, but if the earth is less compact, oscillations amplify and cause more damage. Amplifications also happen where different qualities of earth (clay and rock, for instance) meet, or in areas where buildings have been built on crests, slopes and ridges.

EARTHQUAKES IN HISTORY
JANUARY 16, 1995

This earthquake caused very serious damage in the area of Kobe (Japan), with victims, thousands of wounded and serious damage to the infrastructures.

Magnitude 6.9

Concentration!
Sometimes seismic waves are influenced by the shape of layers beneath the ground: in some cases they can concentrate energy. A bit like a magnifying glass which, thanks to its shape, will concentrate the rays of the sun. Even the shape of a ridge or hills or steep slopes can focus seismic rays on the summit, where damage often concentrates.



During an earthquake...
Soils that are rich in water can sprout fountains, while springs sometimes increase their output or dry up completely.
In lakes "seiches" can occur: rapid oscillations of water that generally leave a characteristic mark on the muddy deposits on the lake bed; occasionally the lakes break their banks.

In the AREA of damage

EARTHQUAKES IN HISTORY
AUGUST 17, 1999

This earthquake,
which took place in the northern section of the North Anatolic fault (Turkey) caused over 17,000 victims, tens of thousands of wounded and enormous economic damage in the region of İzmit.

Magnitude 7.6

When seismic waves reach the Earth's surface, a series of events takes place: some permanent, others temporary.
One of the most serious permanent effects of an earthquake is the collapse of buildings, which is the most common cause of victims. There can also be damage to roads, railways, aqueducts, gas pipes and other similar things: these are all rigid structures that have trouble adapting to the distortion in the earth, overwhelmed with tremors, and end up breaking.

Other permanent effects are landslides and subsidence that can reach disproportionate dimensions and have devastating effects on people. The earthquake of Chimbote in 1970, in Peru, for example, caused a piece of rock and snow to detach from Mount Huascarán, fall for a distance of 1000 m, and kill almost 20,000 people in its path.

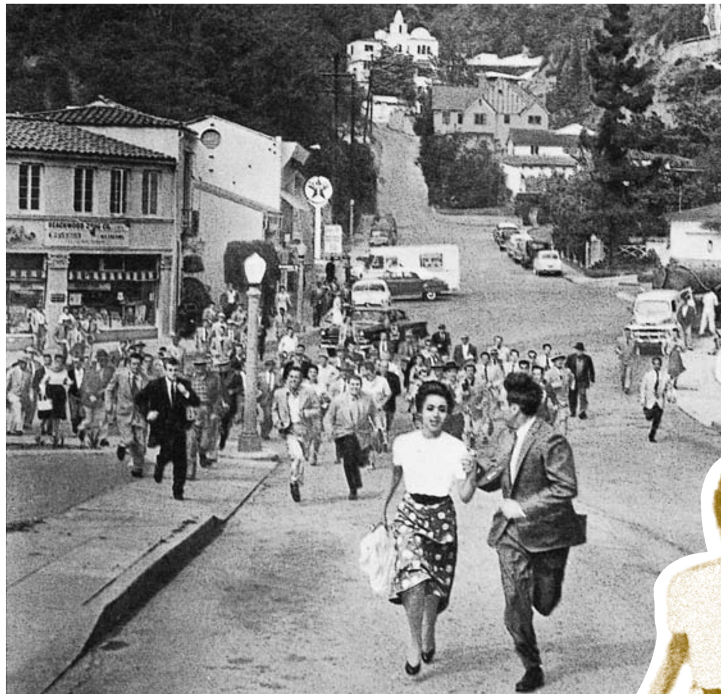
The Earth can fracture, for many kilometres; sometimes it is the fault line itself that provokes the earthquake and then appears on the surface. A rarer effect that occurs in very specific conditions with earthquakes of magnitudes in excess of 6 is "ground liquefaction". If a granular consistency such as sand contains a lot of water it can lose compactness and become liquid: try jumping ten times on the seashore, and you will feel how suddenly the ground turns squidgy. In situations like this, buildings fall down. This is what happened, for example, at Adapazari, in Turkey, during the earthquake of August 17, 1999.

The power of an earthquake
The city of Adapazari photographed after the earthquake that struck Turkey in 1999.

GET UP and run, THIRTY-ONE

Temporary effects of an earthquake include thunder and lighting. Sometimes you might see flashes that look as if they are coming out of the ground. When P waves reach the surface of the ground, we can usually hear a kind of muffled bang, almost out of our range of hearing. This can happen even before the quake itself: the shaking can usually be felt afterwards, when the S waves arrive, the ones that cause the most violent tremors.

Fear is ingrained
Fear is a very ancient emotion, which animals also very clearly share. Just think: what do animals do when they are frightened by a fire? They flee from peril as fast and as far as possible until they reach safety. It is quite natural to experience fear in certain situations: if we didn't, we would be machines! The important thing is not to let your reactions get out of control.



They also have differing effects on man. Sometimes we don't realise there has been an earthquake until a short time after. Sometimes, you might not actually feel the quake, but you could suddenly feel nauseous and dizzy. If the earthquake is stronger, the shocks are quite clearly felt: enough to wake those in the land of Nod.
But what effects do earthquakes have on our emotions? If they are strong enough to be felt, they are certainly powerful enough to upset us! Fear is the first strong emotion we experience during an earthquake. But don't panic: we'll see how we can control that…

WHAT SHOULD we do if there is an EARTHQUAKE?

Now we understand all about the phenomenon, we have reached the most important part: what is the best thing to do if there is an earthquake.

Anti-earthquake drills in a school.

How to BEHAVE

There are a number of occasions when people must know how to behave. When you are riding your bike out on the roads, you have to learn to stay on the right side of the road, like all conscientious drivers. But you must also learn to indicate with your arm when you want to turn left or right, and ring your bell when you come to a blind bend... so you don't end up on the ground with grazed knees and elbows, or worse still, plastered from head to toe in a hospital bed! It is even more important to know how to react before, during and after an earthquake: doing the right thing can help us save ourselves and others.

Unfortunately, the risks associated with earthquakes cannot be entirely eliminated. But by following a few simple instructions, damage to people and objects can be quite drastically reduced. Behaviour varies depending on the most serious kinds of damage that could occur in the place where you are. Clearly the situation is different if you know that buildings will only suffer slight damage, or instead that the tremors could be so strong that they will make the oldest houses fall down, or even that brick buildings will collapse and possibly some of the concrete ones too.

EARTHQUAKES IN HISTORY
MAY 21, 2003

This strong earthquake, which was felt in Spain and Morocco too, struck northern Algeria making nearly 150,000 people homeless. It was followed by a moderate tsunami.

Magnitude 6.8

Generally speaking
The perils of an earthquake are numerous and can vary from place to place. This is why it is so complicated to give advice that applies to all areas and situations: all we would like to do in this book is outline the most general points to remember.

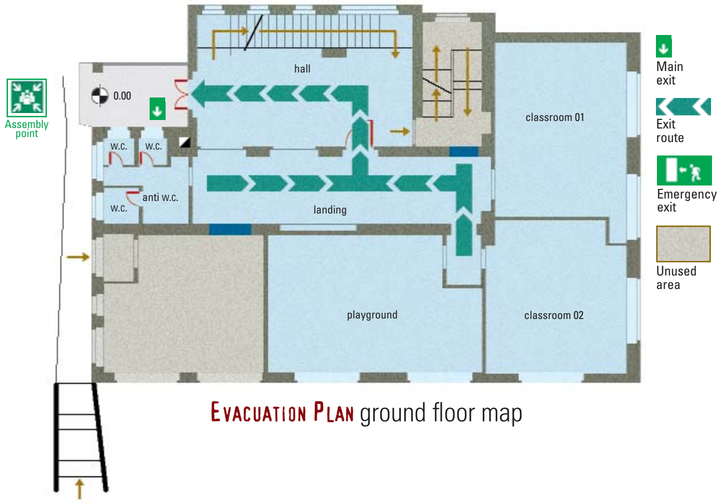
Before an EARTHQUAKE

The first thing to do is find out as much as you can: straight away, no time to lose. If you're reading this book then you are already doing this: great!
By now you have picked up lots of information about earthquakes and their risks, but what you don't have, but need, is specific information about where you live. To begin with, try to find out which seismic zone your town or village is in. If it is a high risk area, be careful! Whether your family already has a house or is about to buy or rent one, encourage your parents to check that it has been built in conformity with antiseismic criteria. Otherwise it will have to be readapted, so as to make it more resistant to earthquakes.

Civil Defence is the organisation that looks after us in the event of natural calamities. You need to get information about their plans: what have they organised to limit damage, who should you turn to and what should you do in the event of an earthquake. The local head of Civil Defence is the mayor: the Civil Defence programme should be on display in the relevant office in the town hall, which, in small towns is part of the Engineering Department. Local authorities too play a role in the Civil Defence system, and we can apply to them for information and details.
With your family, check where the closest hospital is and which are the most open, least dangerous routes to reach it. Always keep handy some important telephone numbers: fire brigade, emergency doctor, ambulance service. If you have a mobile phone, save them in your phone book!

Prepare the house
You and your parents should make sure that bookcases, heavy furniture, gas ovens and water heaters are tightly secured to walls. Find out where the water and gas taps are, and the electricity master switch; learn how to turn them off: this is also useful should you ever be caught in a house fire or flood.

Escape where?
An "evacuation plan" is a diagram of how to organise leaving a building in the event of an emergency. Discover if there is one for the building where you live, it is a good idea to know it off by heart and be ready to follow it at any moment.



EVACUATION PLAN ground floor map

The HOUSE is shaking

If you are in your house during an earthquake, your initial instinct is to run outside. But a quake will last, at the very most, 10 seconds or so... although it will feel like ages! Between one tremor and another as little as a few seconds can pass. If you are not near a door that leads directly out onto a wide open space, attempting to escape can be extremely dangerous and pointless: the earthquake would be over before you managed to get outside. Better to stay calm and seek the safest place where you are, protecting yourself from collapsing parts of the building, from pieces of furniture and the heaviest objects. Try to stay next to the strongest parts: near weight-bearing walls (the thickest and most resistant ones), under archways, in doorways and near corners in general.

Pay attention to lights, wall cupboards and other large hanging objects, which might drop, and to glass which could shatter and cut you. Seek shelter under a bed, or under a strong table. Beware of electric wires, which could break free and create live ends, which may then give off sparks and start fires.

The earthquake in Sumatra
(Indonesia), one of the largest in the world history, was followed by a tsunami that caused damage in many countries of southern Asia and eastern Africa.
Magnitude 9.1

Do not go down those stairs!
Stay well away from stair wells and lift shafts! Staircases can be the most fragile structure in the whole house and are likely to cave in. Lifts can get stuck very easily because of power cuts or because the shaft twists.

Not all houses are the same...
Advice to stay indoors refers to zones where buildings are not expected to be destroyed and to antiseismic constructions. If you are in a risk area, and inside a building that does not comply with antiseismic standards, your behaviour will be different depending on the situation.

Seen from the OUTSIDE

Think before it happens

When an earthquake strikes you don't have time to "get your wits about you": try to identify, before it happens, which are the safest places inside and outside the house. Keep in mind that buildings, parts of them and pieces of furniture may collapse or fall; tanks of liquid may overflow; gas leaks may cause explosions and fires.
And if you are out in the open, stay away from bridges and viaducts: they might fall, with disastrous consequences.

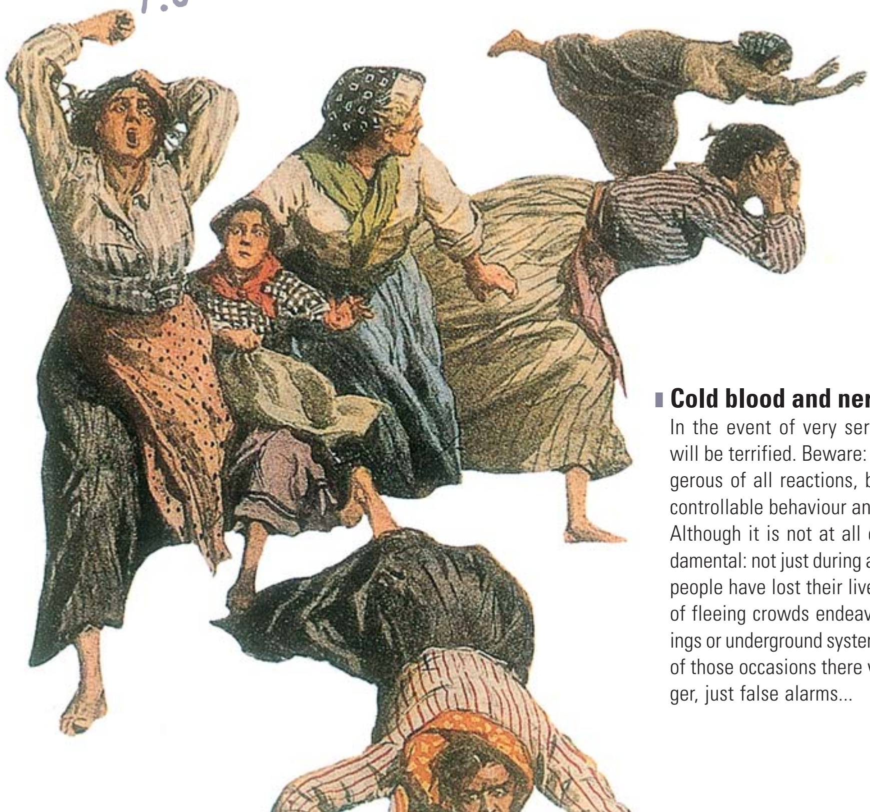
EARTHQUAKES IN HISTORY
OCTOBER 8, 2005

This earthquake struck
the region of Kashmir (Pakistan) in particular, where numerous villages were razed to the ground. It was also felt in India, Afghanistan and other Asian countries.

Magnitude 7.6

People generally think that it is safer to be caught in an earthquake while you're outside the house. That is not entirely true: even if you are outside, a number of basic rules must be followed.

The first is to move away from walls: you could be hit by a flying roof tile, chimney pot, cornice or gutter. If you cannot distance yourself from buildings, perhaps because you are in a narrow street that is not very close to an open square, it is advisable to stand under an archway or in a doorway.
Whatever the case may be, stay away from trees that might topple onto you, and electricity pylons: the cables could snap and whip across you! In some areas, if you are on the beach, it is a good idea to move away from the water's edge, as there could be a tidal wave.
The same advice applies if you are in the car. Don't park under bridges or viaducts... or on top either!
Finally, one last piece of advice: don't park in places where landslides might occur.



Cold blood and nerves of steel

In the event of very serious earthquakes, people will be terrified. Beware: panicking is the most dangerous of all reactions, because it can lead to uncontrollable behaviour and cause terrible accidents. Although it is not at all easy, keeping calm is fundamental: not just during an earthquake either! Many people have lost their lives, trampled by stampedes of fleeing crowds endeavouring to get out of buildings or underground systems. And, ironically, on some of those occasions there was not even any real danger, just false alarms...

An unexpected GUEST... what to do?

Although it's natural to be in a bit of a funk at the beginning, once the initial shivers have worn off there's something you must remember: the danger is not the earth shaking, but the buildings that can come tumbling down on top of you.
And so you have to think clearly about what to do to protect yourself, and avoid behaviour that can jeopardise your safety. In short, everything we've just been telling you. And as soon you start using your head again, you're practically home and dry!

Once the quake is over, do everything you can to help others and not obstruct the rescue operations. If you're already outdoors, stay there, choosing a safe place in line with the instructions we have given you.
If you're indoors, go outside without rushing. Put out any fires that may have broken out, and don't use matches, candles or lighters, even if you're in the dark. Before leaving, make sure you switch off the gas, electricity and water, so as to avoid further damage caused by broken pipes and above all by possible fires. If you smell gas, open the doors and windows, and inform the people in charge that there's probably a gas leak. Leave the building, taking care not to hurt yourself on sharp objects, and watching out for things that could still fall. Don't use the lift, since it could get blocked or even plunge down the shaft: better to use the stairs.
Don't use the telephone, except for serious and urgent cases, so as to leave the lines free for those who are in real need.
In the event of serious damage, help those who are hurt and wounded and inform the people in charge that you wish to help in the rescue operations. Earthquakes are inevitable, but we can all do our very best to protect ourselves, before, during and after!

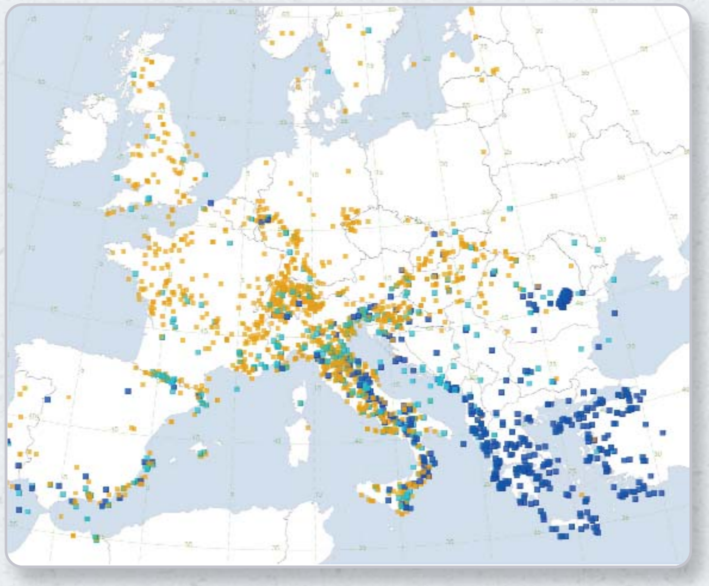
EARTHQUAKES IN HISTORY
APRIL 6, 2009

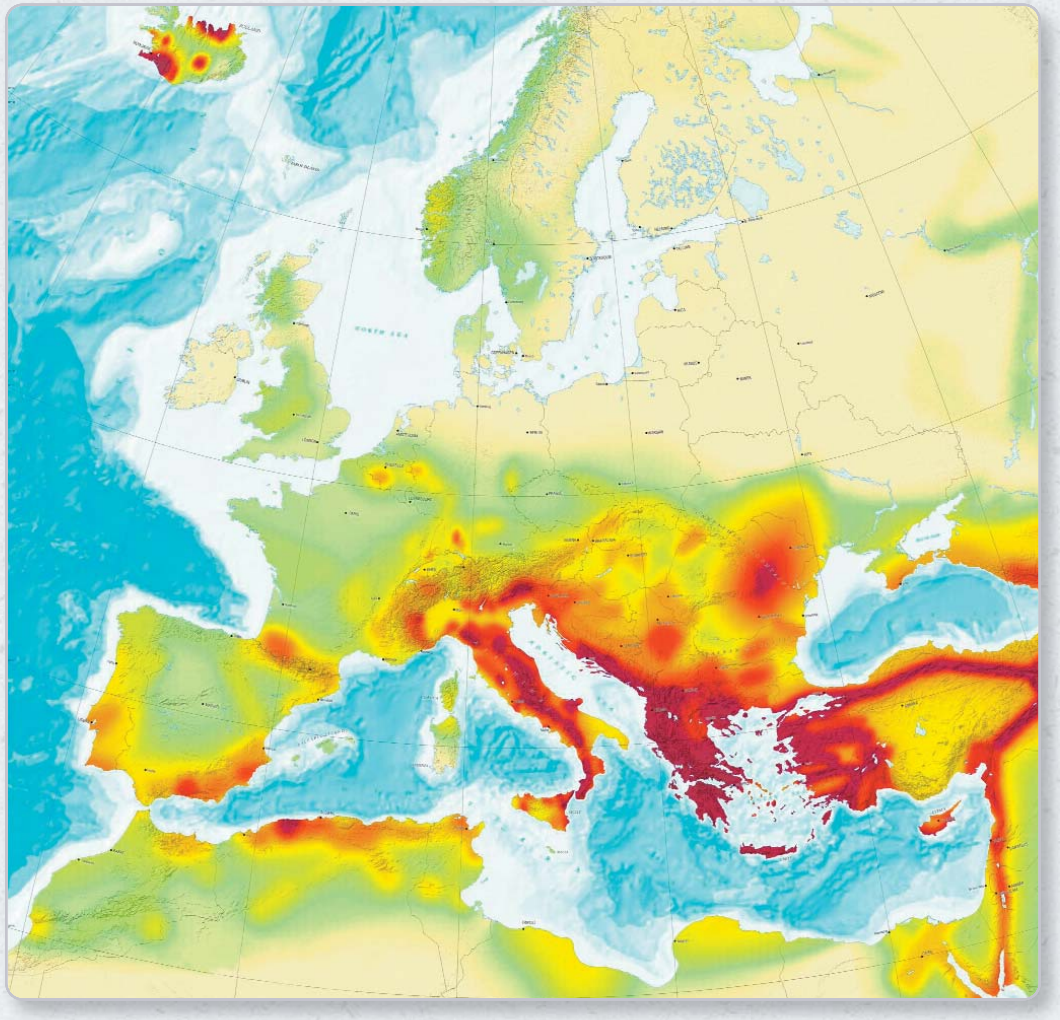
Major earthquake in
Abruzzo, followed by a long sequence. The old city centre of L'Aquila (Italy) and numerous towns and villages in the vicinity were seriously damaged.

Magnitude 6.3

Who keeps watch over us
This map shows the current European Seismic Network (Station Map Virtual European Broadband Seismograph Station Network – VEBSN).

Disasters of the past
Would you like to know where the most destructive earthquakes have taken place in the past? Here they are, marked on this map of Europe, classified by magnitude. The most peaceful geographical areas are western France, central Spain and most of northern Europe. However, almost all the earthquakes of greater energy (in blue) occur in the countries of the Mediterranean area, where the stresses generated by the collision between the African and Eurasian plates are focused (NERIES, AHEAD - European Archive of Historical Earthquake data, www.emidius.eu/AHEAD/).





Euro-Mediterranean seismic hazard map
The colours represent the different levels of seismic risk: from the highest (purple) to the lowest (green and beige) (ESC_SESAME hazard map).

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EDURISK means education in risk. Seismic and volcanic risk in particular.
EDURISK is a project promoted by the Dipartimento della Protezione Civile, which offers educational tools and educational programmes for schools, with the objective of reducing risks.
Earthquakes how and why is one of the tools for secondary schools.
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