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1. What are earthquakes and what causes them?

Earthquakes are rupturing processes in the Earth's crust that lead to vibrations on the surface layer of the planet. Most of the damaging earthquakes so far have been tectonic in origin (tectonic quakes). They are caused by a sudden displacement along a fracture face in the Earth's crust and by the resulting release of accumulated elastic energy. These fault zones are predominantly located along plate boundaries. However, there are other reasons than tectonics for the occurrence of earthquakes.

2. How many earthquakes occur annually worldwide?

Very strong earthquakes with magnitudes of 8 and higher occur once a year on a global average. On average, 15 quakes ranging in magnitude between 7 and 8 strike on an annual basis. Quakes with magnitudes greater than 7 can have devastating effects on people and the environment. Up to 1,300 moderate quakes on a scale of 5 to 6 take place worldwide every year, smaller quakes with magnitudes of 3 to 4 occur, roughly speaking, 130,000 times a year. Magnitude 3 earthquakes are usually still noticed by people if they are in the vicinity of the epicentre, but in most cases they do not cause any damage.

3. What equipment is used to record and measure earthquakes?

Earthquakes are usually measured by seismometers. Seismometers are installed on the Earth's surface around the globe in particularly „quiet places", generally in seismological observatories. These may be old tunnels, basements in remote buildings or specifically dedicated buildings on their own piece of land. The best-known seismological observatories in Germany are located in the Black Forest (BFO station near Schlitach), in Bavaria (WET station near Wetzell) and in Thuringia (MOX station near Jena). The Deutsches GeoForschungsZentrum (German Research Centre for Geosciences — GFZ) operates seismological stations in cooperation with research institutions in other countries around the world. All observatories record their data on a standardised time basis (Coordinated Universal Time, UTC), so that the data of a recorded earthquake can be collected in one place and jointly analysed. In addition to the traditional observatories, seismometers are now being operated on the sea floor, at active volcanoes, on ice floes, in glaciers, and even temporarily on the moon.

4. Where do earthquakes occur most frequently?

The uppermost layers of the earth are made up of many rigid plates (tectonic plates) that either slide towards or away from each other or over and under each other. The strongest earthquakes usually occur along the plate boundaries. Severely affected regions include, for example, the west coast of North and South America, Indonesia, Japan, Central Asia and parts of China and Turkey, and in Europe, Italy, Greece and Iceland in particular, where strong quakes are recurrent.

5. Is it possible to predict earthquakes?

No, the precise date, place and magnitude of an earthquake cannot be predicted. However, seismologists nowadays develop seismic hazard maps in which the probability of the occurrence of strong ground tremors due to tectonic quakes can be indicated for a specific period.

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6. Why are the values published on the strength of an earthquake sometimes slightly different?

One reason may be that different „strength scales“ are being cited. For example, there are several different magnitude scales for earthquakes that are based on different types of data and analyses. Other reasons could be that just after an earthquake has struck, the various services and observatories can initially only access different monitoring stations and are not yet able to share or analyse all the data completely. This may be one of the reasons for slightly different results for one and the same magnitude scale. The first early statements about the strength of an earthquake are associated with greater uncertainties due to the still small amount of data. Over the course of time, more and more data is analysed by an increasing number of monitoring stations, so that the statements about the strength of an earthquake become more accurate.

7. Where can I obtain information on current and past earthquakes?

The GFZ in Potsdam operates a global network of stations consisting of over 100 stations in which seismometers detect ground tremors. All in all, there are only a few of these global networks, but they all work closely together. The denser the monitoring network, the faster the location of the epicentre and the magnitude of the earthquake can be determined. GEOFON stands for GEOFOrschungsNetzwerk (Geosciences Research Network). You can find current global earthquake reports at www.gfz-potsdam.de/portal/gfz/Services.

8. How can I protect myself during an earthquake?

If you are inside a building:
There is no specific protection against earthquakes as they cannot yet be predicted. However, the GFZ has published a list of rules of conduct: Stay calm! Do not panic! Do not jump out of the window or from the balcony! Seek immediate protection beneath a heavy, sturdy piece of furniture (for example a table) and hold on tight to something as long as the tremors persist, even if the furniture moves. If this is not possible, take refuge under a sturdy door frame or lie down on the floor near to a load-bearing interior wall away from windows and protect your head and face with crossed arms. Stay in the building as long as the earthquake tremors persist! The most dangerous thing you can do is to try and leave the building during the quake. You can be injured by falling objects or broken glass. Exception: When the earthquake begins, you are on the ground floor and near to an exit door that leads directly to the outside (garden or open square, not a narrow street). Do not use the stairs! Do not use the elevator!

If you are outdoors:
Go as quickly as possible to an open area, far away from buildings, street lamps and utility lines. Stay there until the tremors have stopped. If you are in a car, drive immediately to the side of the road, away from buildings, trees, flyovers and utility lines. Stay in the car as long as the earthquake tremors persist! Turn on the radio. Do not drive over bridges, cross-roads or below flyovers! When the quake has subsided, continue to drive with the utmost caution (avoid bridges and ramps that could have been damaged by the event) or leave the car parked where it is. If you are at the foot of a steep slope when the tremors begin, move immediately away from it (risk of landslides or falling rocks!). If you feel earthquake tremors along a flat coastline, run as fast as you can inland to the highest point possible. An earthquake can trigger extreme (up to 30 m high) ocean waves (tsunami). These waves sometimes hit the shoreline long after the quake tremors have subsided. A second wave can also follow a lot later. For this reason, do not leave your elevated place of refuge until the official tsunami all-clear has been given.

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9. How much energy is released by an earthquake?

A magnitude 3 earthquake, which people can feel under favourable conditions, releases a seismic energy of approximately two billion joules, which corresponds to 555.6 kilowatt hours (kWh). With every added increment of magnitude, the energy increases by a factor of 30. In 2010, the average energy consumption of a private household was 66 GJ, which corresponds to 18,335 MWh and an earthquake magnitude of 4. A highly destructive magnitude 7 quake releases an energy volume of 450 gigawatt hours, which is ten per cent of the annual electrical energy volume provided by the block of a modern coal-fired power plant. In 2011, the total consumption of all private households in Germany added together came to 2194 PJ (source: Arbeitsgemeinschaft Energiebilanzen [Working Group on Energy Balances] 10/2012), which corresponds roughly to a magnitude 9 earthquake.

10. How large is the risk of earthquakes in Germany?

The risk of earthquakes in Germany is relatively low in global terms, but still not negligible. Smaller quakes occur quite frequently in particular in the area of the Rhine, the Swabian Alb, in eastern Thuringia and western Saxony, including the earthquake swarm area of Vogtland. However, clearly perceptible or even destructive quakes are rare events in Germany.

11. What was the strongest earthquake in Germany so far?

The strongest historically documented quake with an estimated magnitude of roughly 6.1 occurred on 18 February 1756 in the German region of the Lower Rhine Basin in the Cologne-Aachen-Düren area. One person was killed. If an earthquake of similar magnitude to the one in 1756 occurred today in the same location, the impact would be much more grievous due to the greater population density. In 1750, Cologne, for example, with less than 50,000 inhabitants, had almost one-twentieth of its current population. One of the strongest earthquakes in recent history hit Germany in the early morning hours of 13 April 1992 in the German-Dutch border area. The epicentre was located four kilometres to the southwest of Roermond in the Netherlands. The quake‘s hypocentre with a magnitude of 5.9 was located at a depth of 18 kilometres. In North Rhine-Westphalia, more than 30 people were injured, mainly by falling roof slates and chimneys.

12. What does epicentre mean?

The epicentre is located on the Earth‘s surface directly above an earthquake‘s hypocentre. This is the place in the Earth‘s crust where the fracture begins to spread across the fracture face.

13. What is the intensity of an earthquake?

Earthquake research uses two scales to classify earthquakes and earthquake tremors. They are often confused. The magnitude scale is a measure of the energy released during the fracture process at the quake‘s hypocentre. In contrast to this, the intensity scale classifies the shocks/vibrations at any given location on the Earth‘s surface according to the type of vibration as perceived by people and the degree of earthquake damage. This intensity scale (sometimes also abbreviated according to its authors‘ names to MSK or MM or - in the latest version for Europe - to EMS98) divides earthquakes into 12 classes. An intensity of 12 on this scale corresponds to total destruction. If the corresponding maximum vibrations do not apply for an indefinite distance from the quake‘s hypocentre but rather for the area directly above the hypocentre, at the so-called epicentre, then one speaks of the so-called I0 epicentral intensity. As a rule, it is the greatest intensity observed in an earthquake. Because of its spatial nature, the earthquake intensity scale is comparable to the Beaufort wind force scale, which

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also consists of 12 classes - from „Calm“ to „Hurricane force“.

14. What is „earthquake magnitude“?

Magnitude is the logarithmic measure of the seismic energy released by an earthquake at its hypocentre. To determine the magnitude, the ground movements must be recorded as seismograms using seismometers. An increase in magnitude of one unit corresponds to an increase in ground movement by a factor of 10 and increase in energy roughly to the power of thirty. Whereas the magnitude is a measure of the energy released in the earthquake‘s hypocentre, the intensity classifies the vibrations at any given location on the Earth‘s surface.

15. What is a Richter scale?

It is a magnitude scale designed by the American seismologist Charles Francis Richter in 1935 for California. It ranks the ground motion of the primary waves measured with a special seismograph (Wood Anderson seismograph) on a logarithmic scale. The Richter scale was originally defined for stations at a distance of a few hundred kilometres. In the following years further magnitude scales were developed to include stations at greater distances and sometimes analyse other wave types.

16. What was the strongest earthquake ever recorded?

The Shaanxi earthquake in China in 1556 is considered the most devastating quake in human history, with a death toll of approximately 830,000 and an estimated magnitude of 8. The strongest quake in the last hundred years took place in Chile on 22 May 1960 with a (moment) magnitude of 9.5. On 28 March 1964, a magnitude 9.1 quake shook the Prince William Sound in Alaska. Further strong quakes occurred on 26 December 2004 off the north-eastern coast of Indonesia in the Indian Ocean with a magnitude of 9.2, and on 11 March 2010 in the Pacific Ocean off the east coast of Japan with a magnitude of 9.0. All four events took place below the sea and triggered devastating tsunamis.

17. Which magnitude values can be distinguished from each other?

Local earthquake magnitude (ML) is determined on the basis of the primary waves from only relatively close stations. Normally this magnitude scale applies to distances of up to several hundred kilometres between the earthquake and the station. In contrast to this, the body wave magnitude (mb) uses seismic waves travelling through the deep interior of the Earth that are recorded by stations at distances of over 2,000 km. This magnitude is always determined very quickly. However, for strong earthquakes (> 6 mb), the bodywave magnitude is considered to be saturated, so that the magnitude hardly increases, even though the quake was a great deal stronger. Surface waves travel relatively slowly across the surface of the earth (velocities of some 3-4 km/s compared with 8-14 km/s for the body waves in the Earth‘s interior), but they can still be measured well at large distances from the hypocentre. The surface-wave magnitude (MS) determined from these waves only saturates during stronger events and was used for a long time to characterise strong quakes. However, the slow propagation speed means that the MS only becomes available some time after the event. Nowadays, earthquakes and stronger quakes are characterised primarily by the moment magnitude (Mw) that no longer saturates and can be linked directly with the physical parameters of the hypocentre. To determine this magnitude, theoretical seismograms are usually computed for the Earth and compared with observations. In the case of strong quakes, surface waves are mostly compared with each other, which is why the Mw value also cannot be made available immediately after the event.