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RACCE

Raising earthquake Awareness & Coping Children's Emotions

Theoretical *Handbook*

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The present educational Kit "Earthquakes and Volcanoes", like all other products of the project was based on the cooperation of project's staff as well as on individual specialists.

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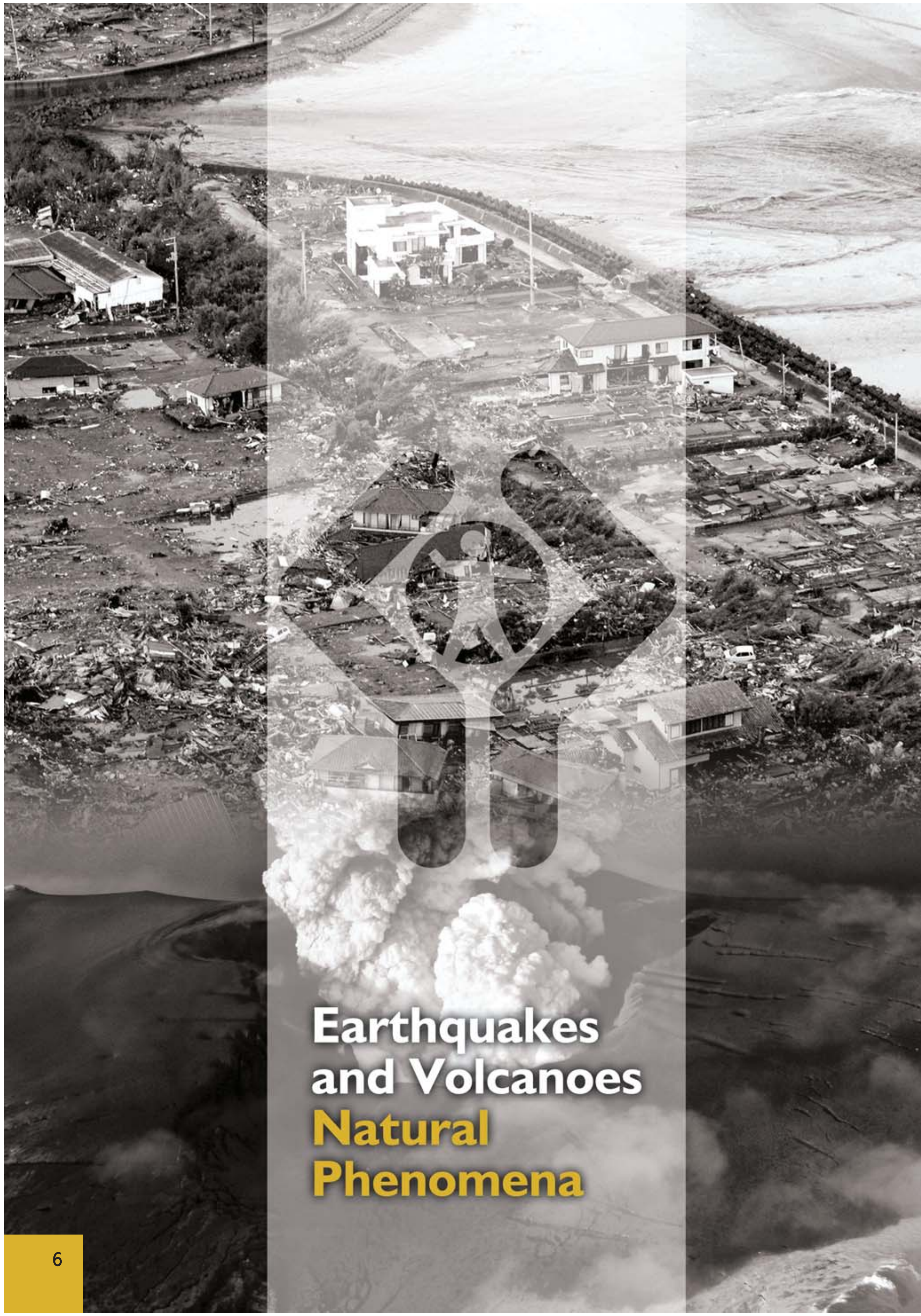
Theoretical Handbook - index

RACCE
Raising earthquake Awareness & Coping Children's Emotions

Theoretical Handbook



Earthquakes and Volcanoes Natural Phenomena

1. Natural processes, phenomena and natural hazards

Earth is a live planet, active and dangerous and its dynamics generates hazardous natural phenomena.

Natural hazards are indeed natural phenomena, such as earthquakes, land sliding, volcanic activity and flooding. They have the characteristic of posing danger to the different social entities of our planet, nevertheless, this danger is not only the result of the nature's violent forces, it is the result of the human systems and their associated vulnerabilities towards them (human vulnerability). When both types of vulnerability have the same coordinates in space and time, natural disasters can occur.

Natural disasters occur worldwide; however, their impact is greater in developing countries, where they occur very often. In most cases, the occurrence of natural disasters in these countries is due to two main factors. First, there is a relation with geographical location and geological-geomorphological settings. The second reason is linked to the economic, social, political and cultural conditions that act as factors of high vulnerability to natural disasters.

1.1 Natural phenomena

Earthquakes and Volcanic activity are natural phenomena. A natural phenomenon is a non-artificial event in the physical sense, and therefore not produced by humans, although it may affect humans. Common examples of natural phenomena include earthquake, volcanic eruptions, weather, components, erosion etc. Most natural phenomena, such as rain, are relatively harmless so far as humans are concerned, others under different conditions (i.e. stormy rain) can be hazardous both for human and natural environment.

Various types of natural phenomena occur, including (but not limited to) the following:

- Geological phenomena (volcanic activity and earthquakes)
- Meteorological phenomena (hurricanes, thunderstorms, and tornadoes)
- Oceanographic phenomena (tsunamis, ocean currents and breaking waves)

1.2 Natural disasters

The definition for natural disaster provided by the UN/ISDR (United Nations International Strategy for Disaster Reduction) is one of the most appropriate definitions:

"*A disaster is a sudden, calamitous event that causes serious disruption of the functioning of a community or a society causing widespread human, material, economic and/or environmental losses which exceed the ability of the affected community or society to cope using its own level of resources.*" (Source: UN/ISDR 2004);

Following the definitions of Natural Disaster by the UN Office for the Coordination of Humanitarian Affairs, natural disasters can be divided into three specific groups: **hydrometeorological** disasters, **geophysical** disasters and **biological** disasters

The geophysical disasters are natural earth processes or phenomena that may cause loss of life or injury, property damage, social and economic disruption or environmental degradation. These, among others, include earthquakes and its side-effects, such as, tsunamis and volcanic eruptions.

The loss of valuables or expensive construction, without human loss, may be a great negative effect on more developed and advanced countries but on the other hand in poorest countries the most expected consequence is human loss or the establishment of unfavourable conditions for survival.

In both cases the reason for the severe influence of natural disasters on humans is the lack of preparation and adequate infrastructure for such a case, in order to mitigate these effects. Additionally, a very important factor that increases the risk is the lack of integrated development plans and disaster recovery for people to be able to pursue daily life more easily.

The human weakness and vulnerability to natural disasters is often caused by ignorance, not only for the consequences of a disaster but also from the very limited extent which a given technology may have to alter a physical state.

Thus disasters are often described as a result of the combination of: the exposure to a hazard; the conditions of vulnerability that are present; and insufficient capacity or measures to reduce or cope with the potential negative consequences.

1.3 Myths and Stories

Ancient cultures have attempted to explain why certain geophysical disasters occurred like the periodically shaking of the earth. As they did not have the scientific understanding of the world that we have today, they tried to explain earthquakes and volcanoes through tales and legends.

1.3.1 Earthquake myths and other approaches

When thinking with our modern understanding and knowledge of why the earth moves, earthquake myths may seem humorous and inconsequential. But they were once standards of their various cultures, a way of trying to understand the powerful natural events that could so greatly affect the lives of ancient people.

Greece

In Greek mythology, Enceladus was one of the Giants, the enormous children of Gaia (Earth). He was disabled by a spear thrown by the goddess Athena and buried on the island of Sicily, under Mount Etna. The volcanic fires of Etna were said to be the breath of Enceladus, and its tremors to be caused by him rolling his injured side beneath the mountain. In Greece, an earthquake is still often called a "strike of Enceladus".

Southern California

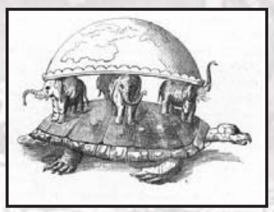
American Indians believed that when most of the world was water, Great Spirit decided to make a beautiful land with lakes and rivers that turtles carried on their backs. One day the turtles began to argue and three of the turtles began to swim east, while the other three swam west. The earth shook! It cracked with a loud noise. The turtles could not swim far, because the land on their backs was heavy. When they saw that they could not swim far away they stopped arguing and made up. But every once in a while, the turtles that hold up California argue again, and each time they do, the earth shakes.

Japan

In Japan, they believed that a wild catfish lived in the mud beneath the earth. This catfish had to constantly be restrained by the Kashima god who protected Japan from earthquakes. So long as Kashima kept a mighty rock with magical powers over the catfish, the earth was still. But when he relaxed his guard, the catfish thrashed about, causing earthquakes.

India

In some Indian cultures they believed that the earth was a giant platform that was supported by eight mighty elephants. Earthquakes were caused by one of the elephants getting tired and lowering its head thus disrupting the balance of the earth. Other stories say that the earth was supported by four elephants who balanced on the back of turtle who balanced on a cobra. Earthquakes would happen when any of these animals would move.



Italy

According to Latin tradition the common earthquakes occurred at Ischia island (southern Italy) are due to contortions of Tifeo, a giant risen up against Jupiter and condemned to lie under the island.

New Zealand

In New Zealand they believed that Mother Earth had a child (the god Ru) inside her womb. Earthquakes were caused by the baby stretching and kicking.

Greek Philosophers

The first attempt to explain earthquakes and volcanoes without reference to mythology was made by the ancient Greek philosophers. **Aristotle** speculated that earthquakes resulted from winds within the Earth caused by the Earth's own heat and heat from the sun. Volcanoes, he thought, marked the points at which these winds finally escaped from inside the Earth into the atmosphere.

Ancient Greece **Thales from Miletus** (6th century BC) believed that an agitation of the great sea on which the earth floats, produced earthquakes. But the notion that the movement of air in sub terrestrial chambers created earthquakes formed the basis for the most elaborate theories of ancient times.

1.3.2 Volcano myths

The word "volcano" comes from the little island of Vulcano in the Mediterranean Sea offshore Sicily. Throughout history, volcanoes have frequently been identified with Vulcan and other mythological figures. Scientists now know that the "smoke" from volcanoes, once attributed by poets to be from Vulcan's forge, is actually volcanic gas naturally released from both active and many inactive volcanoes.

Vulcan, Roman god of fire

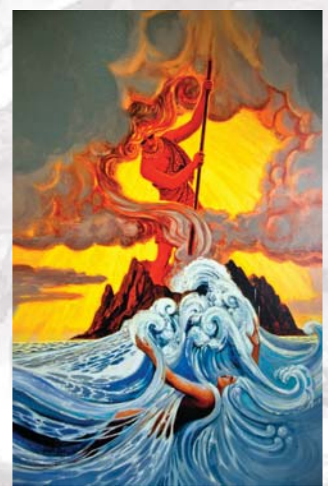
Centuries ago, the people living in this area believed that Vulcano was the chimney of the forge of Vulcan - the blacksmith of the Roman gods. They thought that the hot lava fragments and clouds of dust erupting form Vulcano came from Vulcan's forge as he beat out thunderbolts for Jupiter, king of the gods, and weapons for Mars, the god of war.

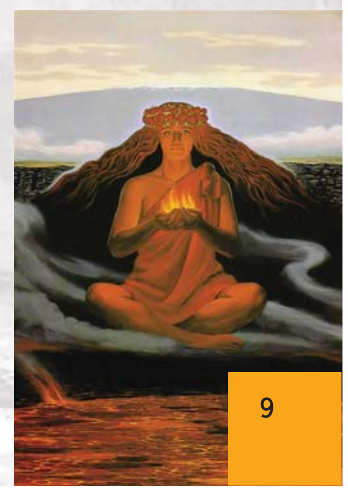
Hephaestus, Greek god of fire and forge

In Greek mythology Hephaestus son of Zeus and Hera, god of fire and forge uses a volcano as his forge, and when he works, sparks and flames fly out of the volcanoes that he works in.

Pele, Hawaiian Goddess of Volcanoes

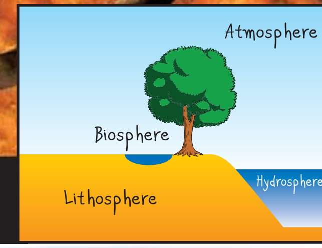
Hawaiian legends tell that eruptions were caused by Pele, the beautiful but tempestuous Goddess of Volcanoes, during her frequent moments of anger. Pele was both revered and feared; her immense power and many adventures figured prominently in ancient Hawaiian songs and chants. She could cause earthquakes by stamping her feet and volcanic eruptions and fiery devastations by digging with the Pa'oe, her magic stick. An oft-told legend describes the long and bitter quarrel between Pele and her older sister Namakaokahai that led to the creation of the chain of volcanoes that form the islands.





2. Where seismic and volcanic activities occur

2.1 Structure of the earth



Understanding earthquakes and volcanic activity need a more sharply focused picture of the Earth's internal structure.

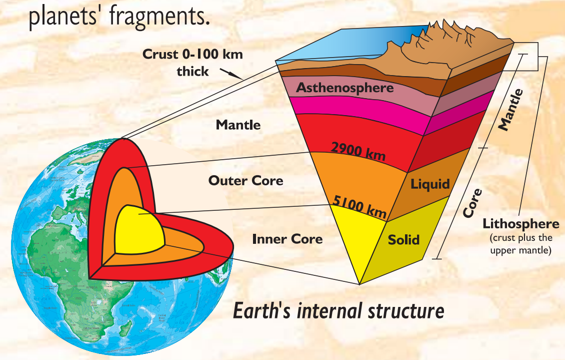
2.1.1 The Components of the Earth's System

Planet Earth is a dynamic system, constantly changing as matter and energy are transferred among its different parts. It includes the following subsystems:
The *geosphere* - the solid Earth including all the materials that comprise the crust, mantle, and core;
The *hydrosphere* - all of the water of the Earth (oceans, rivers, lakes, groundwater, etc.), including glaciers and other frozen water;
The *atmosphere* - the envelope of gases that surround the Earth (oxygen, nitrogen, carbon dioxide, etc.); and
The *biosphere* - the sum of all living matter on the Earth.

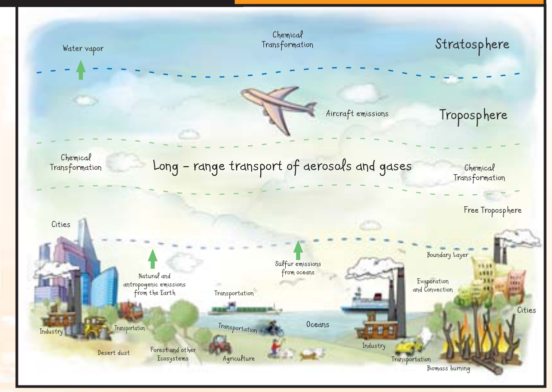
The various components of the earth system (geosphere, hydrosphere, atmosphere) interact together to create the variety of natural phenomena on our planet.

2.1.2 The interior structure of the Earth

The interior structure of the Earth, similar to the outer, is layered. These layers can be defined by either their chemical or their physical (deformation and flow of substances) properties. The Earth has an outer silicate solid crust, a highly viscous mantle, a liquid outer core that is much less viscous than the mantle, and a solid inner core. Scientific understanding of Earth's internal structure is based on observations of rock in outcrops, samples brought to the surface from greater depths by volcanic activity, analysis of the seismic waves that pass through the Earth, measurements of the gravity field of the Earth, experiments with crystalline solids at pressures and temperatures characteristic of the Earth's deep interior and of the meteorites that come from other planets' fragments.



Earth's internal structure



In geology, the crust is the outermost solid shell of a rocky planet or natural satellite, which is chemically distinct from the underlying mantle. The crust of the Earth is composed of a great variety of igneous, metamorphic, and sedimentary rocks. It consists mainly of aluminiun (Al), magnesium (Mg), silica (Si) and oxygen (O), and is subdivided into continental and oceanic crust. It has a thickness varying from few kilometres below oceans to several decades of kilometres in the continents.
The crust is underlain by the mantle. The mantle occupies about 84% of earth's volume and is composed of rocks rich in Mg and iron (Fe) like peridotite, a rock denser than rocks common in the overlying crust. The boundary between the crust and mantle is conventionally placed at the Mohorovicic discontinuity, a boundary defined by a contrast in seismic velocity. The upper part of mantle is much weaker forming a zone of about 200 kms, composed of rocks with plastic behaviour, called Asthenosphere.
The outermost, almost solid part of mantle and the overlying crust constitute the lithosphere of the Earth, which actually "floats" on the asthenosphere. Lithosphere is fragmented in parts that form the lithospheric or tectonic plates.
The core of the Earth starts from the depth of 2900 kms and is subdivided in two parts, the external and internal. The external is liquid and for this reason the S-seismic waves attenuate in it, dominated by Fe, nickel (Ni) and sulfur (S) metals. The magnetic field of the Earth is considered to be generated in the external core. The internal core is solid and is composed of Fe and Ni alloy. The maximum temperature is considered to be similar to Sun's surface, i.e. about 5.500 oC.

2.2 Plate Tectonics

In general earthquakes and volcanoes occur in specific areas. It can easily be observed that the distribution of the vast majority of both earthquakes and volcanoes around the globe show a very definite pattern, which has been proven to reflect the Earth's tectonic processes.

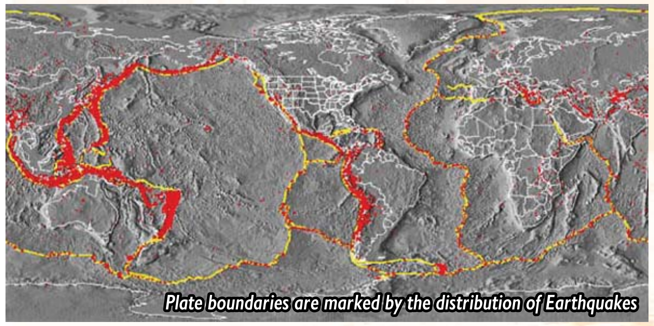


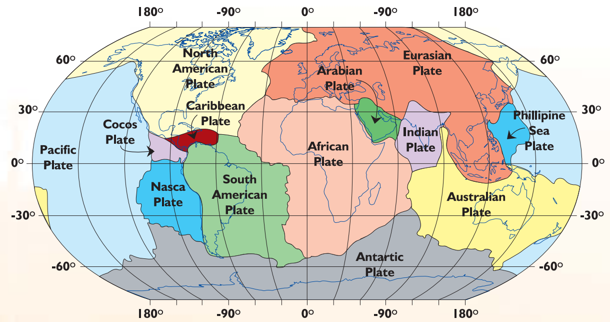
Plate boundaries are marked by the distribution of Earthquakes

In fact, earthquakes and volcanic eruptions mostly occur along the margins of the Earth's so-called **tectonic or lithospheric plates**. Due to the continuous plate motion, intense stresses are applied to their margins, breaking in parts and displacing rocks, producing thus the earthquakes. At the same time, magma rises from the cracks of the crust to the surface, giving birth to volcanoes.

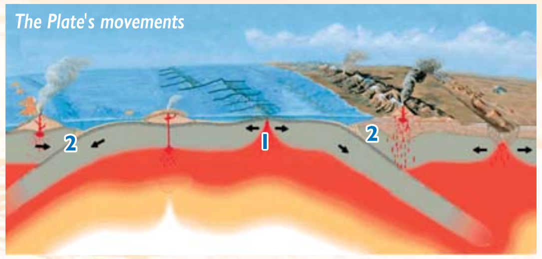
However, which is the driving force for the plate's movement? Scientists have proven that the **tectonic or lithospheric plates** constantly move in varying directions and speeds on the Earth's surface, following movements of **thermal convective currents** in their underlying asthenosphere. The high temperatures from the core are transferred to the magma of the mantle that becomes lighter and moves upwards forming these convective currents. Facing the cold crust, currents freeze, become heavier and sink back to Earth interior, transporting the overlying plates.

Plates can present mainly three types of displacements on the Earth's surface:

1.Plate divergence: as convection currents rise, the plate above them breaks into pieces which move away from each other forming a rift. As rift becomes deeper and wider magma rises and a large chain of volcanoes is formed along the breakage. Finally, sea can enter into the rift and form a new ocean which is covered at its bottom by volcanic rocks. Usually plate divergence continues submarine forming chains of marine volcanoes that are called mid-ocean ridges.

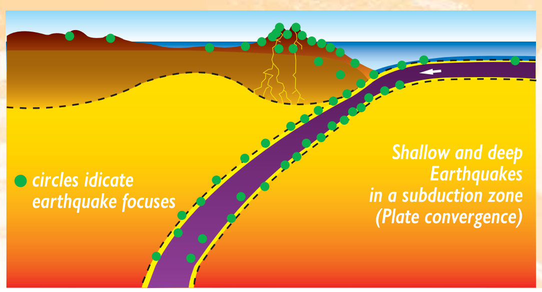


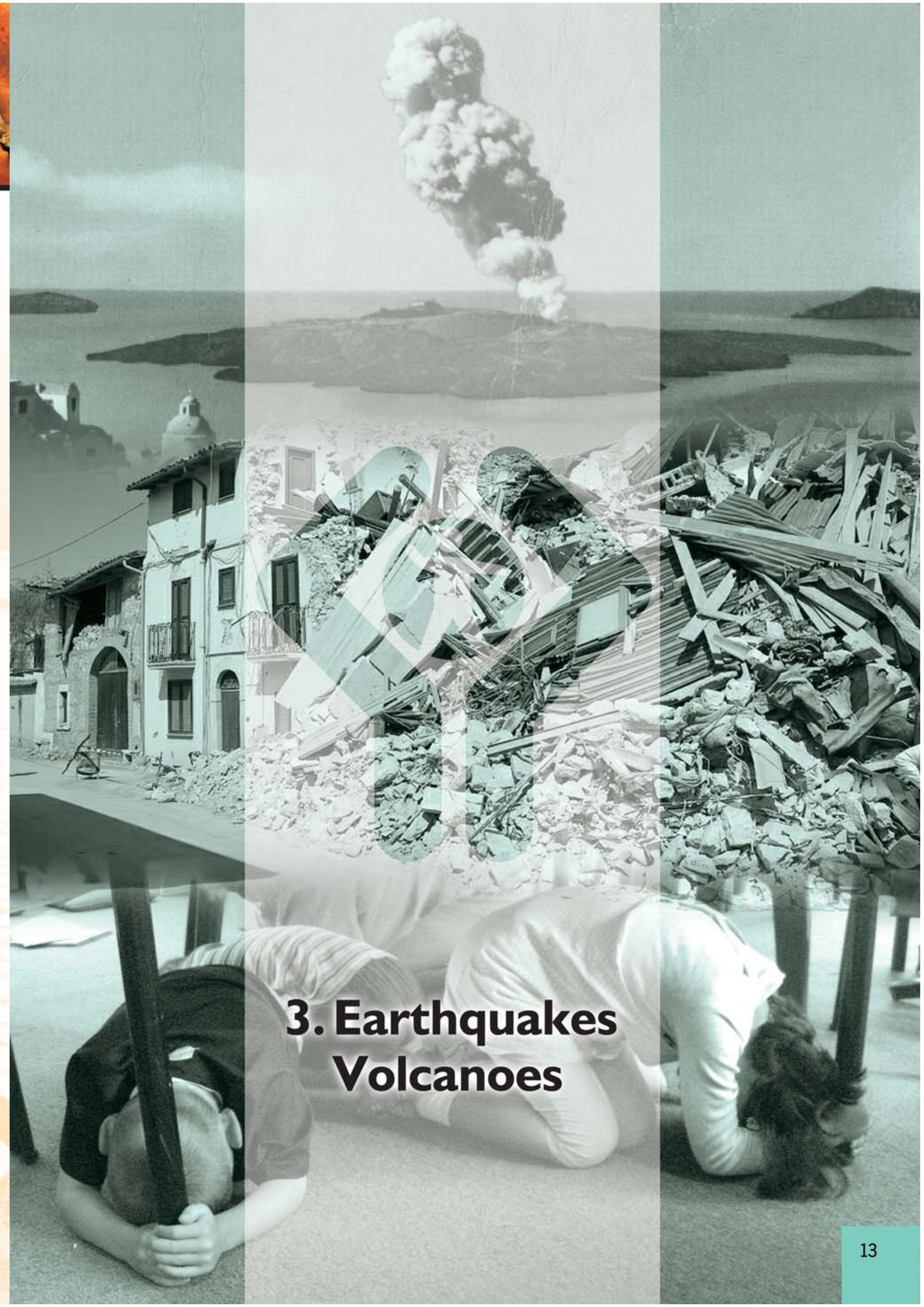
The earth's largest plates



2. Plate convergence: If two plates move against each other, then one of them, the denser, has to sink under the other, forming a subduction zone. Just at their margin a new, very deep trench is formed (the deepest areas of oceans) where some very strong earthquakes can occur due to the intense forces that are applied to rocks. As the sinking plate reaches great depths it melts and magma raises again upwards forming new volcanoes on the overriding plate in an arc-shape called volcanic arc. At the final stage of this process, oceans that separate two continents will be destroyed and continents will collide together giving birth to a new mountain chain (orogenesis) that seals them. Very strong earthquakes can happen at the plate's margins and at any time of this process.

Finally, when two plates just slide next to each other without significant vertical movement, large and long **shear (or strike slip) faults** are created, generating strong earthquakes.





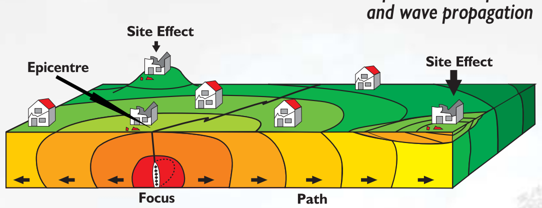
3. Earthquakes Volcanoes

3.1.1 What is an earthquake?

An earthquake is a short tremor of the earth, which owes its origin to the internal forces of our planet. More analytically is a sudden shake of the lithosphere after an energy release due to a slip on a fault or by volcanic or magmatic activity.

Types of earthquakes depending on their origin:

Earthquake's development and wave propagation



1. tectonic: they occur due to increasing stress on rocks caused by movements of the lithospheric plates (90% of earthquakes globally)
2. volcanic: they usually precede or accompany volcanic activity (7% of earthquakes globally)
3. collapse: small earthquakes that occur when underground caverns or mines collapse (3% of earthquakes globally)

Types of earthquakes depending on their focal depth:

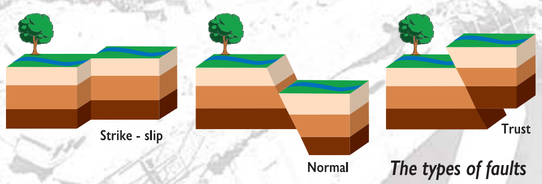
1. shallow: the focal depth measures less than 60 km, 2. intermediate: the focal depth measures between 60 and 300 km, 3. deep: the focal depth measures more than 300 km.

How tectonic earthquakes are produced?

As stresses are concentrated within rocks the matter can react elastically for a certain period but very soon it will break. Whenever such a break occurs in rocks a fault develops, pieces of rocks move apart each other and the energy concentrated is realised as an earthquake. Progressive and continuous concentration of stresses on a fault tents to move rock pieces against friction. As long as friction prevails a seismic quietness occurs, but when this ends an earthquake is produced realising the seismic energy. The longer the seismic quietness is, the stronger the resulted earthquake.
The area of the fault where a rupture is initiated and the seismic waves originate is called earthquake focus and is depicted by the weight point. It's projection on earth's surface is called epicentre.

Fault types:

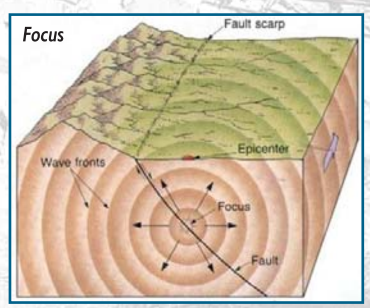
1. Strike slip fault: the fault plane is almost vertical and the two blocks slide parallel to each other, in opposite direction, without significant vertical displacement component.
2. Normal fault: the rock section above the fault plane moves downward relative to the section below the plane following gravity. It is created in areas where the crust is extended.
3. Reverse fault: the rock section above the fault plane moves upward, against gravity, relative to the section below the plane. They are indicative of shortening of the crust. Reverse are further classified in overthrust (high angle) and thrust (more horizontal) faults.



The types of faults

How is the seismic energy transferred from the focus?

The energy released during an earthquake causes deformation of the rocks in the area of the focus and produces seismic waves, which transfer the energy through the interior and the surface of the Earth. Those transferring along earth's surface are called surface waves, while those penetrating earth's interior are called body waves that hold the majority of seismic energy.



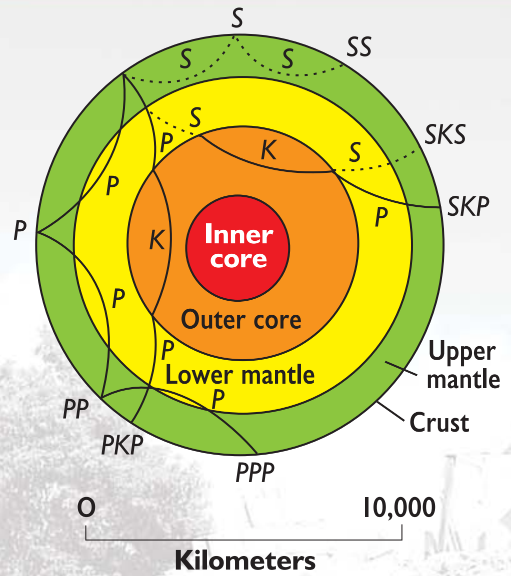
3.1.2 Seismic waves

What are the seismic waves?

When a fracture is initiated in the crust, energy is released in the form of vibrations which are called seismic waves. Seismic waves are thus the waves of energy caused by the sudden breaking of rock within the earth or an explosion. They are the energy that travels through the earth and is recorded on seismographs. The seismic waves spread out to all directions around the focus; they gradually weaken as the distance from the focus increases. There are many different types of seismic waves; some can be transmitted through all matter, some only through solid matter.
The seismic waves are distributed in two groups; those transmitted through Earth's crust that are called **surface** waves and those transmitted within Earths internal that are called **body** waves.

Surface waves are travelling only through Earth's surface and are of a lower frequency than body waves that make them to be easily distinguished on a seismogram. Though they arrive after body waves, it is surface waves that are almost entirely responsible for the damage and destruction associated with earthquakes.
Surface waves are the **Rayleigh** and **Love**. Love is the fastest surface wave and moves the ground from side-to-side. Confined to the surface of the crust, **Love** waves produce entirely horizontal motion. **Rayleigh** wave rolls along the ground just like a wave rolls across a lake or an ocean. Because it rolls, it moves the ground up and down and side-to-side in the same direction that the wave is moving. Most of the shaking felt from an earthquake is due to the Rayleigh wave, which can be much larger than the other waves.

Travelling through the interior of the earth, **body waves** arrive before the surface waves emitted by an earthquake. These waves are of a higher frequency than surface waves. Body waves are the primary (P) and secondary (S).
The **primary** waves can travel through all types of matter (solid, liquid, gas) and are faster than all other seismic waves, meaning that they arrive first at a seismic station (primary). They are longitudinal or compressional, which means that the molecules alternately compresses and dilates in the direction of the wave propagation and transformation.

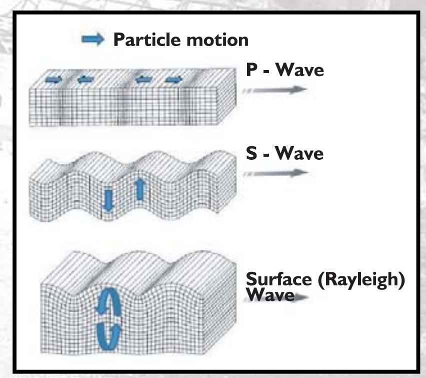


Seismic wave propagation and transformation within earth's internal.

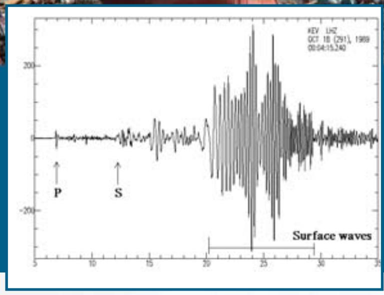
Secondary waves (S waves) can travel only through solids. They are transverse or shear waves, which mean that the molecules are displaced perpendicularly to the direction of the wave propagation. The difference in the arrival times of the P and S waves to a seismological station can be used by the seismologists to determine the distance between the station and the epicentre of an earthquake. Also can be used in Early Warning Systems.

As Body waves travel through the interior of the Earth, they create ray paths refracted by the varying density and modulus (stiffness) of the Earth's interior. The density and modulus, in turn, vary according to temperature, composition, and phase. Based on these facts body waves help scientists (geophysicists) to study Earth's interior.

The way of particle displacement during P, S and R waves



3.1.3 How to measure Earthquakes



The vibrations produced by earthquakes are detected, recorded, and measured by instruments call seismographs. The zig-zag line made by a seismograph, called a "seismogram," reflects the changing intensity of the vibrations by responding to the motion of the ground surface beneath the instrument. From the data expressed in seismograms, scientists can determine the time, the epicenter, the focal depth, and the type of faulting of an earthquake and can estimate how much energy was released.

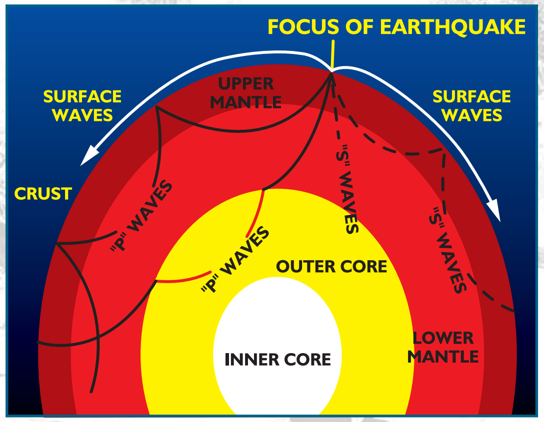
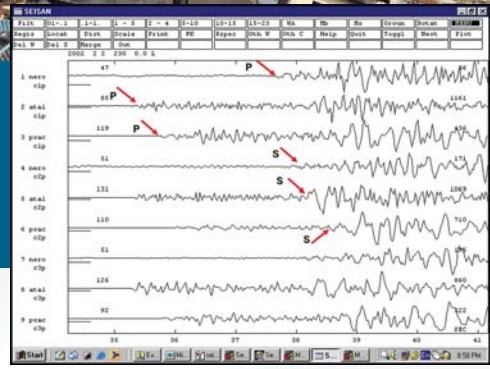


Illustration of earthquake vibration movements through the earth's layers

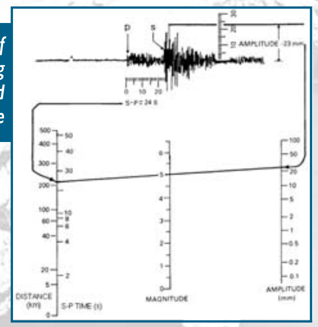
The two general types of vibrations produced by earthquakes are surface waves, which travel along the Earth's surface, and body waves, which travel through the Earth. Body waves are of two types, compressional and shear. Because compressional waves travel at great speeds and ordinarily reach the surface first, they are often called "primary waves" or simply **"P"** waves. P waves push tiny particles of Earth material directly ahead of them or displace the particles directly behind their line of travel. Shear waves do not travel as rapidly through the Earth's crust and mantle as do compressional waves, and because they ordinarily reach the surface later, they are called "secondary" or **"S"** waves. Instead of affecting material directly behind or ahead of their line of travel, shear waves displace material at right angles to their path and therefore sometimes called "transverse" waves.



Identification of P & S waves on a seismogram of a Greek earthquake

The magnitude of an earthquake, usually expressed by the Richter Scale, is a measure of the amplitude of the seismic waves. The scale is logarithmic so that a recording of 7, for example, indicates a disturbance with ground motion 10 times as large as a recording of 6. A quake of magnitude 2 is the smallest quake normally felt by people. Earthquakes with a Richter value of 6 or more are commonly considered major; great earthquakes have magnitude of 8 or more on the Richter scale.

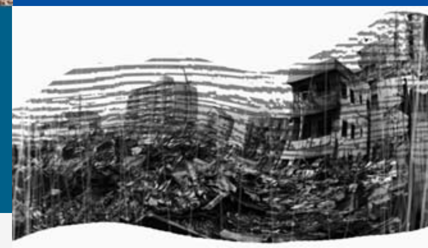
The graphic estimation of earthquake magnitude using the S-P arrival difference and the seismogram amplitude



An earthquake's destructiveness depends on many factors. In addition to magnitude and the local geologic conditions, these factors include the focal depth, the distance from the epicenter, and the design of buildings and other structures. The extent of damage also depends on the density of population and construction in the area shaken by the quake.

- Magnitude describes the amount of energy released during an earthquake and is measured with Richter scale. It runs from 0 upwards and, theoretically, there is no maximum value but practically the maximum value is around 8.5 degrees. Each earthquake is expressed through a unique value on the Richter scale. Magnitude of an earthquake is the same everywhere observed.
- " Intensity refers mainly to the effects of an earthquake and is commonly measured by Mercalli scale. It runs from 0 to 12. The intensity depends on the distance from the focus, the bedrock type, the magnitude and other facts. Intensity is also used to study historical earthquakes because the effects are those that can be found in records.

3.1.4 Seismic risk

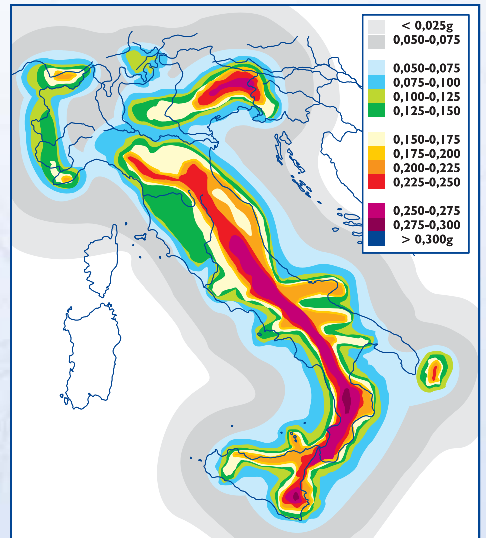


According to USA/FEMA (Federal Emergence Management Agency), **Seismic hazards** are sources of potential harm or loss during earthquakes. They can be natural phenomena, such as landslides or tsunamis that are generated by earthquake ground shaking. They can also be elements of the built environment, such as vulnerable buildings, brittle piping, or loose equipment, which can become hazards when exposed to earthquake shaking.

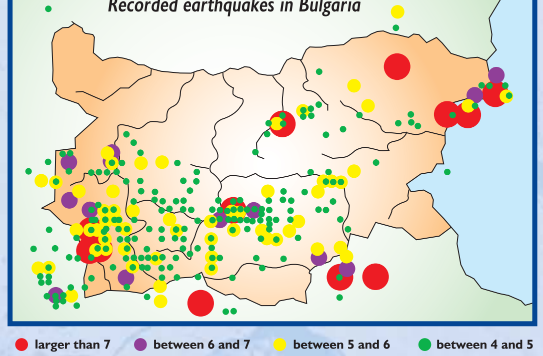
The level of seismic hazard in a region is measured as the likelihood that ground shaking exceeding a specified strength will occur in the region during a specified period. The probability of such shaking is estimated by analyzing past earthquake activity in the region, evidence of stress building up within area faults, and how seismic waves are likely to move through the Earth's crust and overlying soils in the area.

Seismic risks are the harm or losses that are likely to result from exposure to seismic hazards. They are usually measured in terms of expected casualties (fatalities and injuries), direct economic losses (repair and replacement costs), and indirect economic losses (income lost during downtime resulting from damage to private property or public infrastructure). Other, more specific measures of risk are also used for disaster planning, such as probable volumes and durations of utility outages and displaced households, and amounts of debris likely to be generated.

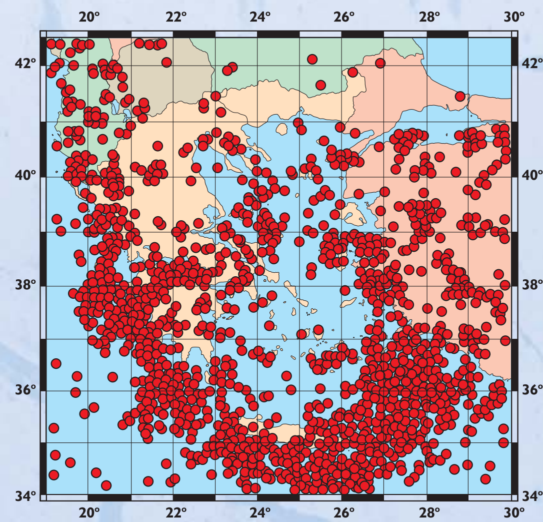
In any geographic area, three main factors together determine seismic risks: the level of seismic hazard, the number of people and amount of property that are exposed to seismic hazards, and how vulnerable these people and property are to the hazards.



Seismic risk in Italy



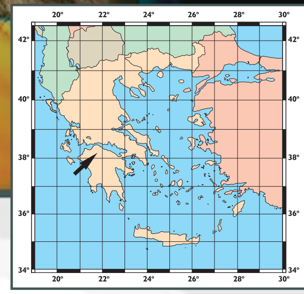
Recorded earthquakes in Bulgaria



Recorded earthquakes in Greece for the period 1992-2010

3.1.5 Seismic surveillance:

the tools that we use in order to identify seismic activity and predict, if possible, earthquakes



Epicentre of Eliki earthquake (373BC, M=7)

a. Can we prevent earthquake?

The answer is no. Earthquakes, as several other natural phenomena are the result of global systems and processes that we cannot manage or even affect. Thus, much effort is put in order to predict if possible if an earthquake might happen. The goal of earthquake prediction is to give warning of potentially damaging earthquakes early enough to allow appropriate response to the disaster, enabling people to minimize loss of life and property. A primary goal of earthquake research is to increase the reliability of earthquake probability estimates. Ultimately, scientists would like to be able to specify a high probability for a specific earthquake on a particular fault within a particular year. Scientists estimate earthquake probabilities in two ways: by studying the history of large earthquakes in a specific area and the rate at which strain accumulates in the rock.

b. Can scientists predict earthquakes?

There's currently no organization or government or scientist capable of successfully predicting the time, place, and magnitude of the future earthquake. Scientists have tried many different ways over the decades of predicting earthquakes, but none have been successful. On any particular fault, scientists know there will be another earthquake sometime in the future, but they have no way of telling when it will happen.

However, scientists are very good at saying things more general about earthquake hazards and earthquake risks. For example they can look at faults and patterns of earthquakes over many years and they can do a pretty good job of saying where on the landscape it's likely to have earthquakes on which faults, how big those earthquakes are likely to be and about how heavy the shaking is likely to be from those earthquakes.

Using that information, we can improve building codes, we can do land use planning, we can avoid buildings next to faults that are hazardous. So we can forecast in the long term where the earthquake hazard is likely to be.

c. Animals & Earthquakes

The earliest reference we have to unusual animal behavior prior to a significant earthquake is from Greece in 373 BC. Rats, weasels, snakes, and centipedes reportedly left their homes and headed for safety several days before the Eliki earthquake (estimated magnitude 7) that caused the total destruction of the ancient cities of Eliki and Voura (Gulf of Corinth).

The story of the unique successful prediction in the last decades: Haicheng earthquake, China (1975 February, 04 11:36 UTC, Magnitude 7.0)

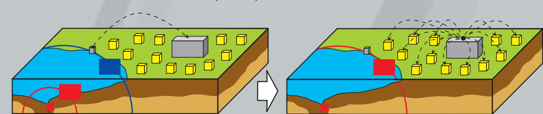
The earthquake caused more than 2,000 fatalities and many injuries. Chinese officials ordered the evacuation of Haicheng (population about 1 million) the day before the earthquake. In the preceding months, changes in land elevation and in ground water levels, and widespread reports of peculiar animal behavior had been reported. The increase in foreshock activity triggered the evacuation warning. It was estimated that the number of fatalities and injuries would have exceeded 150,000 if no earthquake prediction and evacuation had been made. The evacuation, along with the local style of housing construction and the time of the main shock, 7:36 p.m., saved thousands of lives.

d. Early warning system

With this system the instant a large earthquake is recorded sensors in the ground transmit a signal to receiving stations throughout the area. You're taking advantage of the idea that once an earthquake occurs and it's detected, you can essentially out-race the seismic waves that are propagating through the ground by sending a radio signal ahead, and so the farther away you are, the more time of warning that you have.

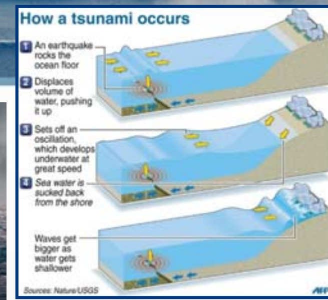
The actual time saved by such a system might only amount to 10 or 20 seconds, but this could be long enough to divert or temporarily immobilize public transportation systems or to simply warn people to take cover and possibly save their lives.

Figure 2. Earthquake Early Warning in Japan: When two or more Seismometers detect P-waves (upper), the Japan Meteorological Agency immediately analyzes the readings and distributes the warning information to advanced users, such as broadcasting stations and mobile phone companies, before the arrival of S-waves (lower).



In our days, modern mobile phone or tablet industry offers many opportunities through the various applications developed, to use our new generation devices either as seismometers that could record earthquakes or as early warning systems that can receive instantaneous warning messages.

3.1.6. What a is a Tsunami



Earthquake triggered tsunami

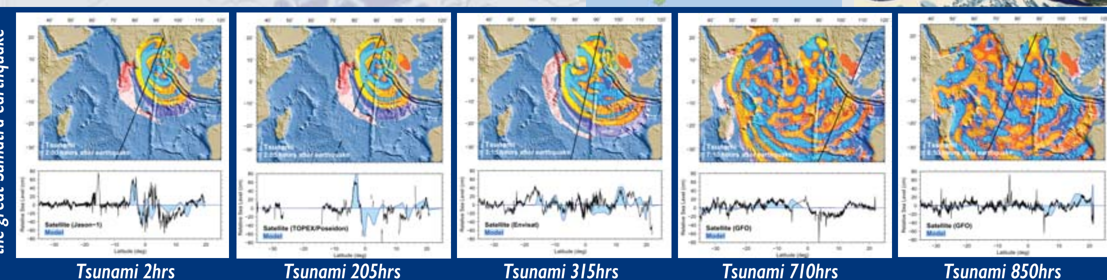
Tsunami: is a series of sea waves with very long wavelengths (typically hundreds of kilometers) caused by large-scale disturbances of the ocean, such as: earthquakes, landslide volcanic eruptions. When reaching a shore, it develops a destructive force and can cause enormous damage and many casualties. Tsunami arises from a significant shift of water masses in the ocean, the seas or even a lake. Main reason for this, are earthquakes, but tsunami can also be caused by volcanic eruptions, landslides close to a shore or underwater, or even a meteorite crash.

On one hand, tsunami causes disaster by sheer impact force, which depends more on the length and speed of the waves than on their height. On the other hand, retreating water masses can cause great damage by dragging along everything on their way. A tsunami develops a speed between 50 and 800 km/h. Even at minimal speed, the impact of one cubic meter of water equals the force of a car crashing at 50 km/h. If the wave is 100 meters in length, this would mean 100 consecutive car crashes.

Despite more than 80% of tsunamis originating in the Pacific Ocean, in 1755 in the Atlantic Ocean a 15 meters high wave, resulting from an earthquake rated 9 on the Richter magnitude scale, hits Portugal's capital Lisbon. This "megatsunami" causes 60000 deaths, and the remnants of the wave can be traced all the way till Ireland!

Another tsunami, caused by a marine earthquake rated 9 on the Richter scale, swallowed the coastline of Natori, Honshu Island, Japan, on March 11th, 2011. The waves reached more than 15 meters in height, with many human looses and damages, among them and the nuclear accident at Fucushima station.

Prior to that another tsunami with a maximum height of 11 meters flooded Tokyo. This tsunami was caused by a huge earthquake in Kanto, Japan, in September 1923. It had disastrous consequences on Tokyo and Yokohama, where more than 100000 people died.

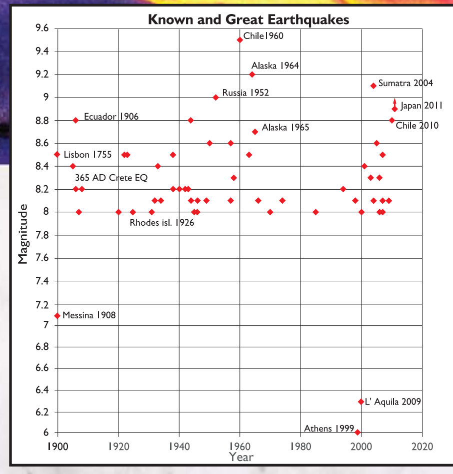


Tsunami propagation following the great Sumatra earthquake

A 1945 painting by W. Molino about the great 1923 Tokyo EQ and tsunami.

Ten percent of all tsunamis worldwide occur in the Mediterranean due to earthquakes caused by the African Plate drifting northwards underneath the Eurasian Plate. On average, one disastrous tsunami takes place in the Mediterranean region every century. Geological research and historical records report of many powerful tsunamis that have taken the lives of thousands over the ages. Greece and southern Italy are mostly affected.

3.1.7 Famous Earthquakes and Tsunami



In recent years humanity has experienced a series of very strong and disastrous earthquakes as well as some minor volcanic eruptions that remind us the power of the Earth and the influence of those phenomena in modern societies. Some characteristic examples of past disasters are not only a ringing bell but also a treasure of knowledge to improve our behaviors, policies and priorities.

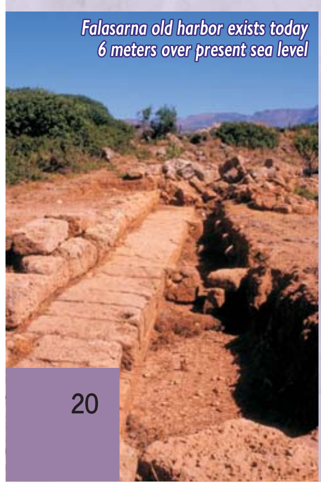
a. Famous earthquakes

Phalassarna Earthquake

On the 21st of July 365 AD a very strong earthquake stroke eastern Mediterranean that was recorded by the majority of the historians and travelers of the era. A strong tsunami was also produced that travelled all over eastern Mediterranean.

Initiated south-west of Crete island the earthquake resulted in the instantaneous uplift of the half part of the island ranging from 9 meters in the area of Paleochora in the southwest, to 1 meter in central Crete. More than 100 towns in Crete changed to ruins, Alexandria in Egypt, Sicily and Cyprus were also heavily damaged, whereas the coastal town of Phalassarna at the northwestern Crete was devastated. Excavations of the harbor facilities of the town, that at present are located 6 meters over sea level, revealed the remnants of the tsunami and the effects of the earthquake.

The earthquake is related to the subduction of the African plate underneath Europe that takes place south of Crete. Such strong earthquakes in southern Greece take place approximately every 5-6 centuries. Based on the ground observations, the swallow focal depth and the reported damages the magnitude of the Phalassarna earthquake was estimated at the 8,3 Richter scale, which place the event at the top of the Mediterranean seismicity.


Falasarna old harbor exists today 6 meters over present sea level


The 365 AD sea level occurs in central Crete one meter over present sea level

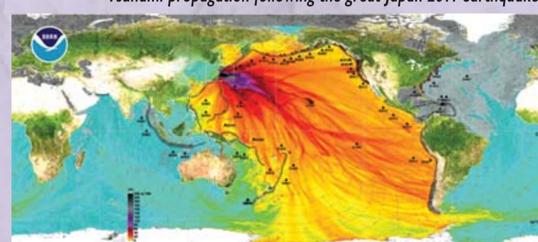
The Honshu, Japan Earthquake

The memories of Honshu earthquake and tsunami that took place on the 11th of March 2011 are very fresh to all of us as modern media brought to our home images that even scientists could only imagine in past times. The 9 Richter scale earthquake, the 4th stronger event since 1900, was hazardous for all Japan. At least 15703 people were killed, 4647 are missing, 5314 were injured, 130927 displaced and at least 332395 buildings, 56 bridges and 26 railways destroyed or damaged by the earthquake and the tsunami along the entire east coast of Honshu. The most serious effect was the Fukushima nuclear station's destroy. The total economic loss in Japan was estimated at 309 billion US dollars.

The earthquake was produced by the subduction of the Pacific plate beneath Japan. At that area Pacific plate is approaching North American plate at a rate of 8 cm per year which is of the highest existing in Earth. During the earthquake a rupture area on the existing fault of about 300 kms long and 150 kms wide moved at about 30-40 meters! The ground acceleration reached values of about 2,9 gal (1 gal=Earth gravity acceleration), whereas the tremor lasted over 5 minutes! A great number of fore- and after-shocks were also recorded.

The large displacement of the ocean bottom caused the creation of the disastrous tsunami which in some places in Honshu reached a height of 38 meters! It travelled all over Pacific sweeping out coastal areas in all Japan, Indonesia, Peru, California and Canada, even causing some massive slabs of ice to calve from the Sulzberger Ice Shelf, Antarctica!

Tsunami propagation following the great Japan 2011 earthquake



b. Famous Tsunamis in Mediterranean

The most important tsunamis recorded in Mediterranean sea are the following:

May 2003: After a quake near the coast of Algeria, a tsunami was generated which destroyed over 100 boats on Mallorca and flooded Palmas Paseo Maritimo.

July 9th, 1956: The best documented and most recent tsunamigenic earthquake in the Aegean Sea between Greece and Turkey is the one that occurred near the south-west coast of the island of Amorgos, killing 53 people, injuring 100 and destroying hundreds of houses. The waves were particularly high on the south coast of Amorgos and on the north coast of the island of Astypalaea. At these two places, the reported heights of the tsunami were 25 and 20 m, respectively.

December 28th, 1908: Due to an earthquake and the ensuing tsunami, the city of Messina in Italy was almost completely destroyed. More than 75000 people were killed.

November the 1st, 1755: The Portuguese capital of Lisbon and its inhabitants were particularly badly hit by an earthquake that occurred in the eastern Atlantic Ocean. Two thirds of the city were destroyed from resulting fires. The people seeking refuge from the flames at the banks of the Tejo River were surprised by huge flood waves produced by the earthquake. Approximately 60.000 people lost their lives. The waves were even observed in Ireland and on the other side of the Atlantic on the Lesser Antilles. On the coastline of the Madeira Islands the waves still had a height of 15 metres.

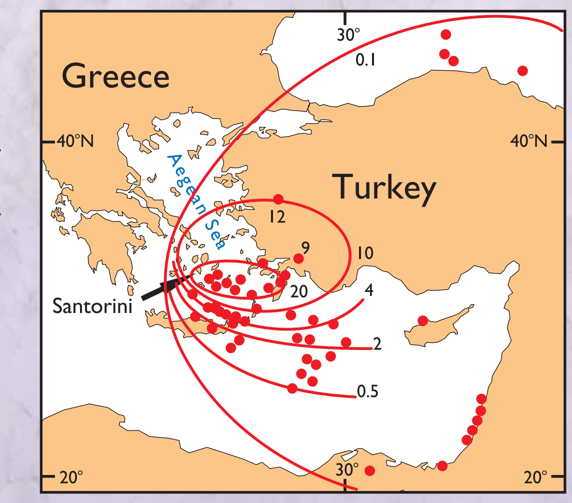
September 26th, 1650: A destructive earthquake was accompanied by a submarine explosion from the Columbo Volcano, which crater lies in the sea to the northeast of the island of Santorini. There was a devastating tsunami observed on the island of Ios, north of Santorini and waves of up to 16 m were reported.

1303: The quake with an estimated strength of 8 in Richter scale destroyed the island of Rhodos and the eastern part of Crete. It caused a tsunami which reached the Egyptian coast.


Volcanic deposits in Santorini

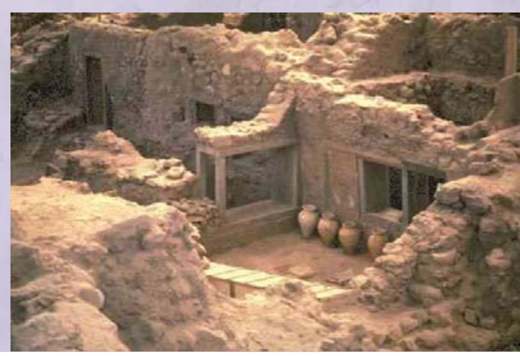
365: The quake of 8.2 in Richter scale in the year 365 caused heavy destruction on the whole of Crete island. The tsunami that developed as a result of the quake destroyed completely coastal regions as far as Egypt and eastern Sicily. Records indicate that 50000 people lost their lives in Alexandria.

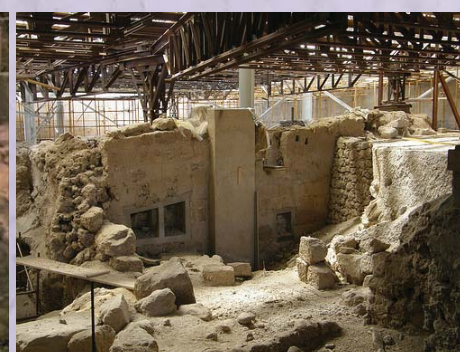
1628 BC: The coasts of the entire eastern Mediterranean were submerged by flood waves of up to 20 metres high. The waves were caused by the volcanic eruption of Santorini in the Aegean Sea, and is believed to be responsible for the destruction of the Minoan culture.

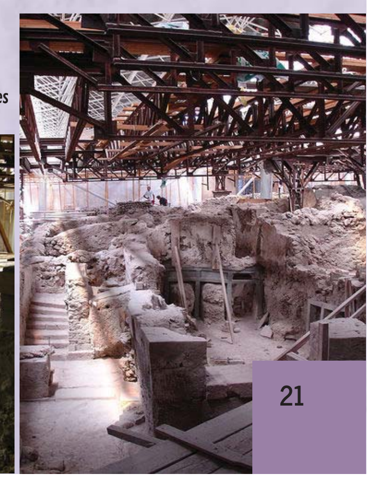


Ash deposits from Minoan eruption (in cm)

The Akrotiri antiquities





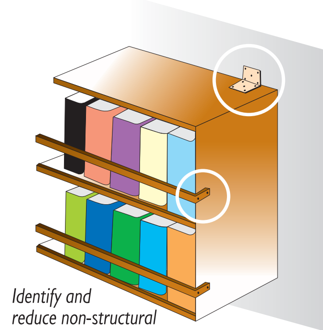


3.1.8 Preparedness Measures

Earthquakes strike suddenly and without warning. It is globally accepted that no direct prediction of forthcoming earthquake, in terms of specific time, place and magnitude, can be made. Many people think the destruction caused by earthquakes is unavoidable, and that the only option is to pick up the pieces after the shaking stops. Actually, almost all earthquake damages and losses can be reduced by measures everybody should take **before**, **during**, and **after**.
Many also think that all the damage and injuries from earthquakes comes from collapsing buildings. Again, this isn't the case. As buildings are designed better, more of the losses in earthquakes are from objects that break or fall on people causing injury. By planning and practicing what to do if an earthquake strikes, everybody can learn to react correctly and automatically when the shaking begins.
"*Disasters can be substantially reduced if people are well informed and motivated towards a culture of disaster prevention and resilience, which in turn requires the collection, compilation and dissemination of relevant knowledge and information on hazards, vulnerabilities and capacities*" *(UN/ISDR, 2005)*. Earthquake injuries and damages can be mitigated or prevented if appropriate measures are taken.

Develop family emergency procedures and make plans for reuniting family.

Build an emergency kit



Identify and reduce non-structural hazards

a. Preparedness measures at Home

Before an earthquake

The members of each family can take several measures to protect themselves and their property in case of an earthquake, such as to:
- Be informed about the earthquake phenomenon. Knowing what to expect can reduce panic.
- Be informed about the municipality emergency plan.
- Develop family emergency procedures and make plans for reuniting your family in a safe open - air place in the neighborhood.
- Make a family communication plan in case the members of the family are not together when an earthquake occurs. Identify an appropriate out - of town contact that can act as a central point of contact in an emergency.
- Organize a Personal Support Network, in case there is a family member with disabilities. That Support Network is a group of people (family members, friends, neighbors) that will help the person with disabilities to take actions before and right after an earthquake.
- Build an emergency kit. A disaster supplies kit is simply a collection of basic items a household may need in the event of an emergency.
- Keep a list of emergency phone numbers.
- Identify and reduce non-structural hazards.

Earthquake safety is more than minimizing damage to buildings. The contents of the buildings must be secured to reduce the risk for life and property. Anything heavy enough that can cause injury or fragile and/or expensive enough to be a significant loss if it falls, should be secured. For example:
- Fasten shelves securely to walls.
- Place large or heavy objects on lower shelves.
- Store breakable items such as bottled foods, glass, and china in low, closed cabinets with latches.
- Fasten heavy items such as pictures and mirrors securely to walls and away from beds, couches and anywhere people sit.
- Brace overhead light fixtures and top heavy objects
- Repair defective electrical wiring and leaky gas connections. These are potential fire risks. Get appropriate professional help. Do not work with gas or electrical lines yourself.

In addition to contents within living space, also items in other areas, such as your garage must be secured.
- Be aware of how to turn off gas, water and electricity in case the lines are damaged.
- Hold earthquake drills at home with family members: Drop, cover and hold on
- Locate safe spots in each room and reinforce this information by moving to these places during each drill.

During an earthquake

If inside all members of the family should remember to:
- Stay inside and calm until the shaking stops. Do not exit a building during the shaking. Research has shown that most injuries occur when people inside buildings attempt to move to a different location inside the building or try to leave
- Drop to the ground, take cover by getting under a steady table and hold on to it until the shaking stops. If there isn't a suitable furniture, drop to the ground and cover the head and the neck with the arms.
- Stay away from glass, windows, and anything that could fall, such as lighting fixtures or furniture.

Drop to the ground, take cover by getting under a study table and hold on to it.

- Do not stand in a doorway. In reinforced concrete buildings, doorways are no stronger than any other part of the house. Stand in a doorway only in case of masonry building.
- If you use a wheelchair, lock the break on the wheels and cover your head and neck with your arms, crouching towards your knees as much as possible.

If outside everyone should remember to:
- Stay outside, away from hazards (buildings, streetlights, utility wires, exterior walls etc. The greatest danger from falling debris is just outside doorways and close to outer walls.

If outside in a vehicle should remember to:
- Stop as quickly as safety permits in a safe area
- Avoid stopping near or under buildings, trees, overpasses, and utility wires

After an earthquake

After the shaking stops all members of the family should remember to:
- Check for injuries among the family and neighbors, provide first aid as needed and if you are aware of this, and call for emergency medical assistance.
- Turn off water and electric services to avoid further damage.
- Extinguish small fires or report larger blazes.
- Wear shoes and proper clothes.
- Evacuate the building without using elevator.

Go to a predefined safe open space and stay away from damage areas

- Go to a predefined safe open space and stay away from damage areas. Avoid waterfront areas because of the threat of tsunamis.
- Keep in mind that aftershocks may strike at any time, exacerbating hazards and requiring you to immediately drop, cover, and hold on.
- Listen for instructions from the competent authority.
- Use telephone for emergencies, only.

Regardless of the severity of this earthquake, learn from the experience. If there are things that could have been done better in preparing for this earthquake, do them better now in preparation for the next earthquake.

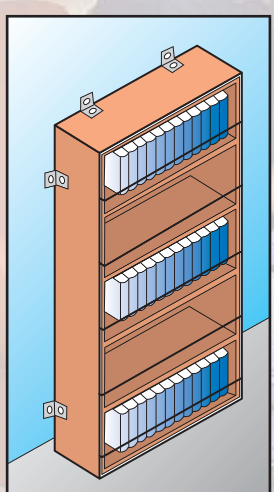
b. Preparedness measures at school

The school earthquake safety is urgent and of primary importance. So it is very crucial for every school community to implement the proper safety measures in order to be prepared in a case of an earthquake.
While each disaster earthquake and school community is unique, every school faces similar challenges in order to manage effectively the earthquake situation. Those responsible for school safety must understand and been prepared because earthquakes threat the lives of students, teachers, and staff. Taking an active role in preparedness will help teachers and students to deal with their natural and reasonable fear of earthquakes.

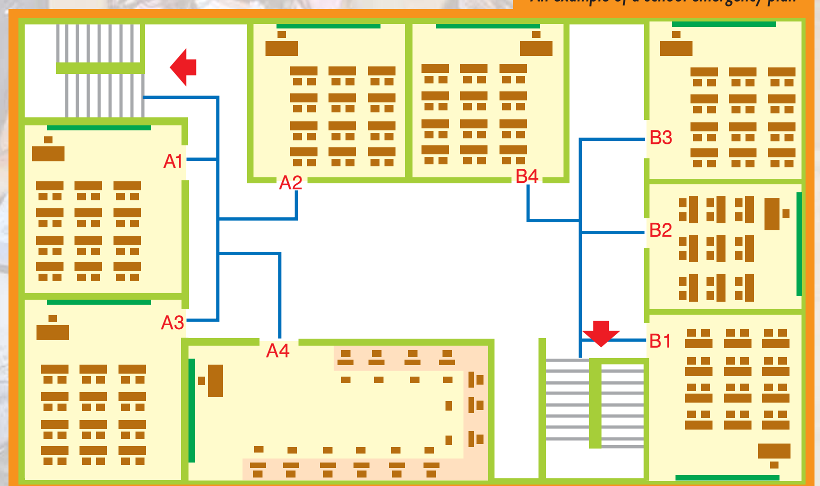
Before an earthquake

Since earthquake shaking is possible almost everywhere, earthquake safety should be practiced by everyone. The Director of each school is responsible to provide the following procedure of actions:

- Information and education of the students, teachers and parents, in order to learn what happens during an earthquake, how to prepare for earthquake shaking, and how to stay safe during and after an earthquake at school. The educational procedure used should be mainly based on lectures, seminars, educational material and projects on earthquake protection provided by the official country authorities. Recently, emphasis is also given on the application of virtual reality systems and earthquake simulators for school seismic risk preparedness. Additionally, the teachers' ongoing training programs in emergency procedures, first aid, evacuation, and use of fire extinguishers are necessary.
- Identification and reduction of nonstructural hazards in offices, classrooms, laboratories, corridors and other school areas, that may cause damage or injury during an earthquake. In this framework there are a lot of actions to be undertaken by teachers before an earthquake, to prevent serious injuries resulting from damage to non-structural materials and items of equipment. These actions include: securing and anchoring of glass panels, anchoring of furniture, securing of books and other items on bookshelves, storage of dangerous and fragile objects in safe locations, securing of lighting fixtures - ceiling fans - notice boards - frames and hangers, securing of reagents in the school's chemistry lab, arrangement of desks in classrooms and removal of unnecessary furniture and maintenance and securing of roof tiles, fencing or metal railings.
- Development and regularly update of School Earthquake Emergency Plan. To be operational, the plan should be clear and straightforward and should contain the following:
  - description of priorities, procedures and actions to be taken before, during and after an earthquake
  - preparation of emergency supplies kit or proper equipment, such as radios, flashlights, batteries etc.
  - assignment of specific duties to teachers
  - determination of primary and alternate routes for emergency evacuation of the school
  - definition of the open safe gathering place, such as a courtyard, that will be gathered by the students after the evacuation of the building. Determination of an alternative open safe area that will be used in the case of damaged primary predefined open area. The parents of the students should be informed about these areas, because after a strong earthquake event they should come to take them home.
  - definition of a team of at least two people that will be responsible to help students or teachers with disabilities to be prepared for the seismic event and to evacuate the building..
- Hold periodic earthquake school drills. Earthquake drills should take place at least three times during the year. Only through regular practice the emergency plans are improved and preparedness will be achieved. The teachers and the students should practice to Drop, Cover, and Hold on, the way out of the building, and in as many other settings as possible, until the drill becomes second nature to them. Earthquake drills have to be taken place in order to everyone at school be educated to act correctly in case of a real earthquake, to identify gaps and challenges in the school emergency plan, and to build a culture of earthquake behaviour to the school community.



An example of a school emergency plan



During the earthquake

Most people caught in earthquakes have a feeling of helplessness. Especially if they have never experienced a quake before, they have no idea how long it is going to last or what will happen next. During an earthquake, it is essential to begin the safe action: Drop, Cover, and Hold on, at the first sign of a quake. More specifically:
If inside (classrooms, staff rooms and corridors), the students and teachers should remember:

- to remain calm, do not run and stay inside.
- to Drop, Cover and Hold on. If the students are in the classroom they should drop to the floor, take cover under the desk, and hold on to it firmly. If the students are in the corridors or other areas of the school building, they should drop to the floor, cover and protect head and neck with their arms.
- to remain covered in the safe position away from hazards, until the shaking stops.
- it may not be possible for children with impaired mobility to get under a desk, so they should tuck your head down and use their arms or whatever is handy to protect their heads and necks. If they are using a wheelchair they have to lock the brake of the wheels first and then to cover their head and neck with their hands.

If outside in the courtyard, the students should remember to:

- stay outside away from the buildings
- avoid power lines, signs and other hazards
- obey to the orders given by the School Director or the teachers.

After an earthquake

After the shaking has stopped:

- each teacher of the class should ask for the students to leave the classroom and follow the evacuation route according to the school emergency plan, walking quickly, but not running.
- nobody use elevators. The electricity may shut off suddenly.
- students or school staffs should help the injured or disabled students to evacuate the school building.
- students should be gathered in the courtyard or other safe outdoor area in an orderly way, following the school emergency plan.
- students should stay calm, away from buildings.
- teachers who are responsible should check for injuries and provide first aid for injured
- teachers who are responsible should search the missing students or teachers.
- the School Director informs and obeys the orders given by the school authorities.
- students stay in the courtyard or any other open air safe area until the parents come to take them home (if there is the relevant announcement of the competent authority, according the national legal framework). It may take a long time for parents to get to school. The teacher of every class is responsible for this procedure.
- teachers and students should be prepared for aftershocks. These may be strong.
- students can cope with the disturbed environment and their own emotional reactions.

3.1.9 Earthquake Vocabulary

Active fault: A fault that has had sufficiently recent displacements so that, in the opinion of the use of the term, further displacements in the foreseeable future are considered likely.

Body waves: A seismic wave that travels through the interior of the Earth and is not restricted to any boundary surface.

Earthquake: The violent motion of the ground caused by the passage of seismic waves radiating commonly from a fault along which sudden movement has taken place.

Elastic energy: The energy stored within the Earth during elastic deformation.

Epicenter: That point on the Earth's surface which is directly above the focus of an earthquake.

Fault: A surface or zone of rock fracture along which there has been displacement.

Focus: The place within the earth where an earthquake commences and from which the first P-waves arrive.

Foreshock: An earthquake that immediately precedes the mainshock of a series and originates within the region of hypocenter of the mainshock. Currently recognised as such, only after the occurrence of the mainshock.

Plates: Large, nearly rigid, but still mobile segments of blocks involved in plate tectonics that include both crust and some part of the upper mantle.

Plate tectonics: A global theory of tectonics in which an outermost sphere (the lithosphere) is divided into a number of relative rigid plates that collide with, separate from, and translate past on another at their boundaries.

P-waves: The primary or fastest wave travelling away from an earthquake source, consisting of a train of compressions and dilatations parallel to the direction of travel of the wave.

Seismic hazard: The physical effects such as ground shaking, faulting, landsliding, and liquefaction that underlie the earthquake's potential danger.

Seismic risk: The likelihood of human and property loss that can result from the hazards of an earthquake.

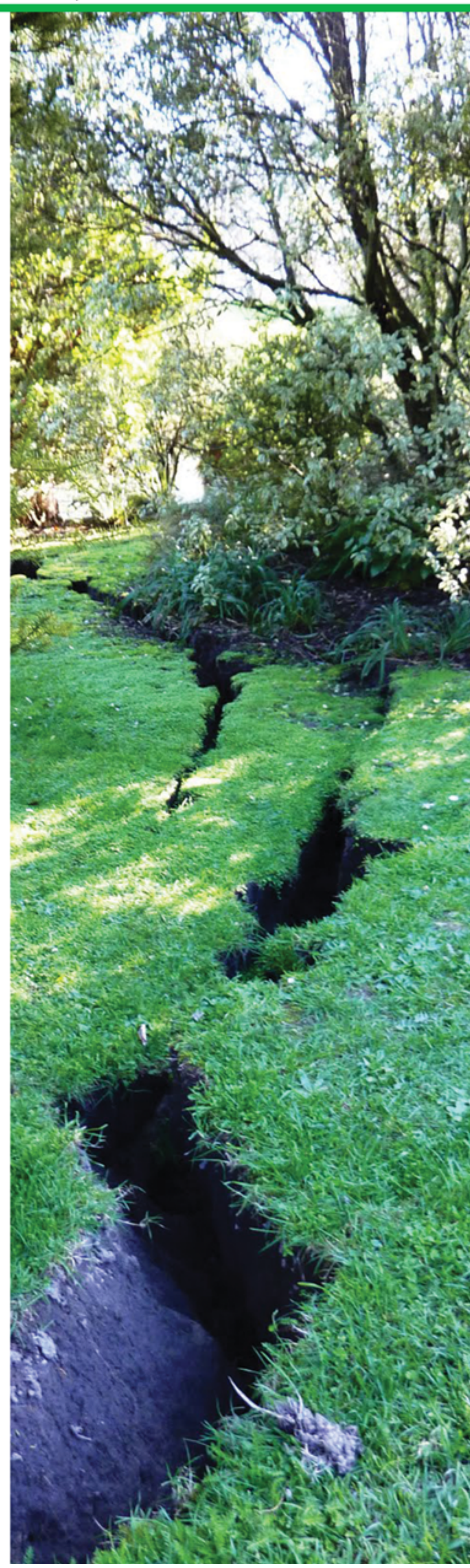
Seismic waves: Waves produced by an earthquake, including both body waves and surface waves.

Seismograph: An instrument for the recording as a function of time motions of the earth's surface caused by seismic waves.

Surface waves: Seismic waves that follow the earth's surface only with a speed less than that of S waves. These are the Rayleigh and Love waves.

S-waves: The secondary seismic wave, travelling more slowly than the P wave and consisting of elastic vibrations transverse to the direction of travel.

Tsunami: Is a series of sea waves with very long wavelengths (typically hundreds of kilometers) caused by large-scale disturbances of the ocean, such as: earthquakes, landslide volcanic eruptions.



3.2 Volcanoes, expand information on volcanic activity

3.2.1 Volcanic eruptions and phenomena

A volcanic eruption occurs when magma, as a liquid containing crystals, fragments of rock and gas rises up to the Earth surface from deep or shallow layers.
The place on the Earth surface where the magma is emitted is a volcano.
Eruptions take place both above and below water and can be effusive or explosive, moreover the same eruption can often have both effusive and explosive phases.

Effusive eruptions

Etna

An effusive eruption is characterized by the emission of magma in a continuous liquid state. The products of these eruptions are **lavas**, which can flow from an eruption vent or from extended fractures along the sides of a volcano (fissure eruptions) and form:

Lava lake Karthala

- a **lava flow** if a fluid lava spill over the crater along the sides of a volcano.
- a **lava dome**, if the magma is unable to flow due to its high viscosity and accumulates around the eruption centre.
- a **lava lake** if lava accumulates inside the crater or in a small depression.

Colata Etna 2002

Tunnel lava

The primary factors controlling lava flows are the effusion rate, the chemical and physical properties of the magma and the nature of the ground. These factors influence the size and shape of the flows and can generate **AA lavas**, with a wrinkled surface structure formed by the chaotic accumulation of fragments, or **pahoehoe lavas** with smooth or undulated surfaces forming lobe-like or rope-like structures, in relation with emitted magma viscosity. The creation of a thick superficial crust on a lava flow through cooling gives rise to the formation of a **lava tunnel**. Particular column-like structures can arise through the cooling of very thick flows of lava. Effusions of lava can also take place underwater and lead to the formation of **pillow lava**.

Lava AA Etna

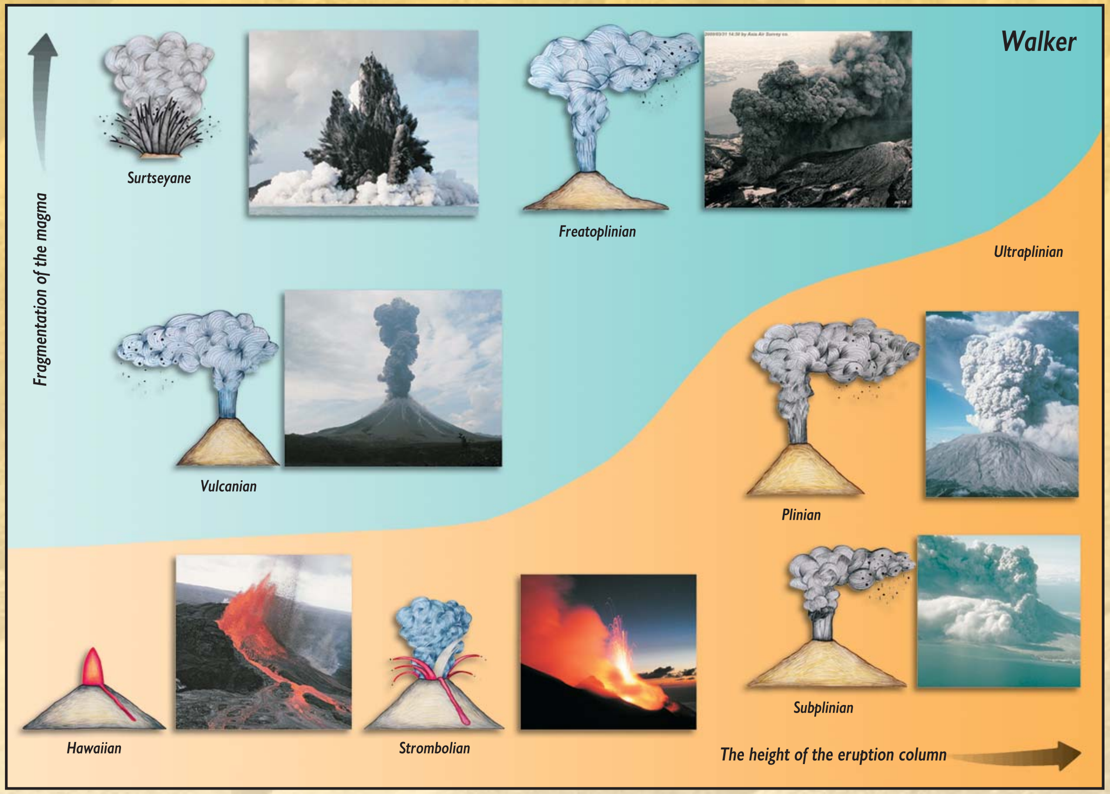
Hawaii pahoehoe

Explosive eruptions

Explosive eruptions are characterized by the fragmentation of rising magma, which changes from a liquid containing gas bubbles into a mixture of gas and fragments of magma and crystals. This mixture is then ejected violently from the vent to generate a range of phenomena which include:

- ejection of fragments of magma and rock **(pyroclasts)** that fall around the crater;
- generation of **eruption columns** that can rise as high as 50 km;
- generation of pyroclastic currents for column collapse.

Column Alcantara



The pyroclastic fragments from eruption columns can form **fall deposits**, generated by the accumulation of volcanic and distributed over an area whose size depends on the column height, and wind, or **flow deposits**, connected with mechanisms of transport and deposition of **pyroclastic currents** when parts of the columns collapse.

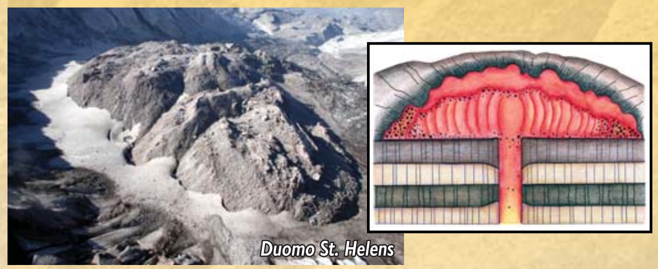
Explosive eruptions, characterized by interaction between rising magma and water are named **Phreatomagmatic** and are characterized by the immediate vaporization of the water producing high magma fragmentation. The emission of these mixtures results both in low eruption columns and in dilute and turbulent pyroclastic currents called - **pyroclastic surges**. **The area covered by fall deposits** and the percentage of fine particles emitted are used for a classification of magmatic and phreatomagmatic explosive eruptions. Eruptions are classified as Hawaiian, Strombolian, Subplinian, Plinian and Ultraplinian on the basis of the energy of the explosions involved the fragmentation of the magma and the height of the eruption columns. Surtseyan, Vulcanian and Phreatoplinian eruptions share the common characteristic of explosions due to interaction between water and magma but differ as regards the height of the eruption columns and the area of distribution of volcanic products.

3.2.2 Types of volcanoes

Most of the volcanic material emitted accumulates around the eruption vent or mouth to form volcanic edifices varying greatly in shape and size. Volcanoes are divided into monogenetic, which are formed through accumulation of the products of a single eruption, and polygenetic, which are instead formed through accumulation of the products of a several eruptions.

DOME VOLCANO

A generally monogenic volcano caused by the accumulation of highly viscous lava that does not give rise to a flow but builds up around the vent.



Duomo St. Helens

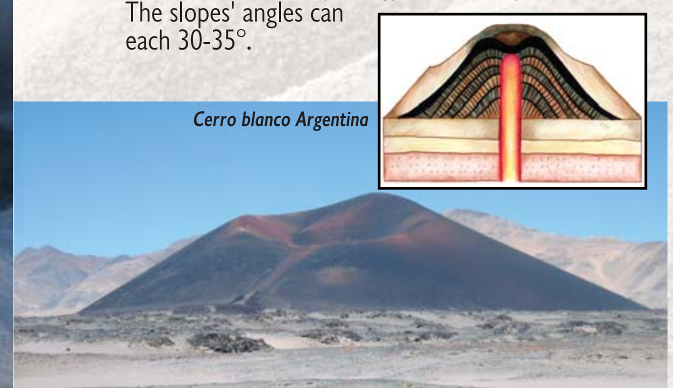
SHIELD VOLCANO

A polygenetic volcano resulting from frequent eruptions of fluid lava from summit craters or along the side of a volcano edifice. Shield volcanoes are cones with slope at a low inclination angle (of about 5°), often with lateral eruptive centers.

Mauna ulu

SCORIA OR CINDER CONE

A monogenetic volcano formed during moderate energy explosive activity, through accumulation of volcanic scoria emitted in a fluid state but already solidified on falling to the ground. These cones can vary from perfectly circular to elliptic, mainly in relation to the morphology of the eruption conduit. The slopes' angles can each 30-35°.



Cerro blanco Argentina

TUFF CONE

A monogenetic volcano generated by a phreatomagmatic eruption and composed of surge deposits and, subordinately, of pyroclastic flow and fall deposits. It has a large crater, with inner and outer walls at a low angle (< 10-12°).

Cono di tufo Alaska

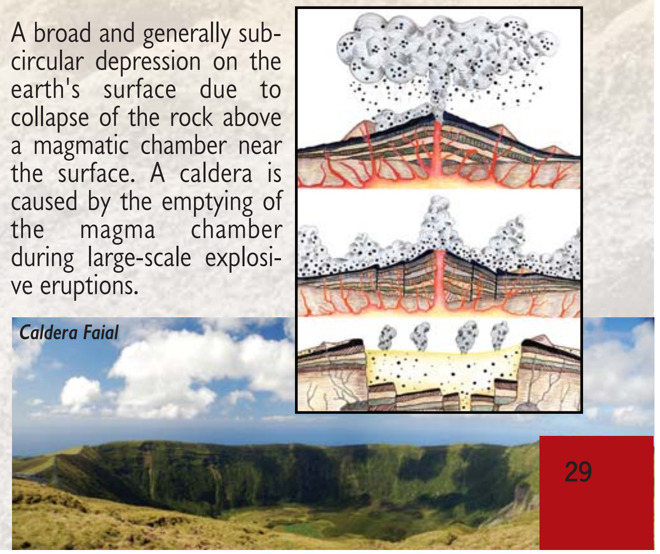
STRATOVOLCANO

A stratovolcano or composite volcano is a polygenetic one, made up of overlying layers of deposits of effusive and explosive activity (lava flows and pyroclastic deposits). The cone is generally of several kilometers or tens of kilometers in diameter, steep slopes and a summit crater. The shape can be extremely irregular as a result of collapse and the growth of lateral edifices.

Fujii

CALDERA

A broad and generally subcircular depression on the earth's surface due to collapse of the rock above a magmatic chamber near the surface. A caldera is caused by the emptying of the magma chamber during large-scale explosive eruptions.



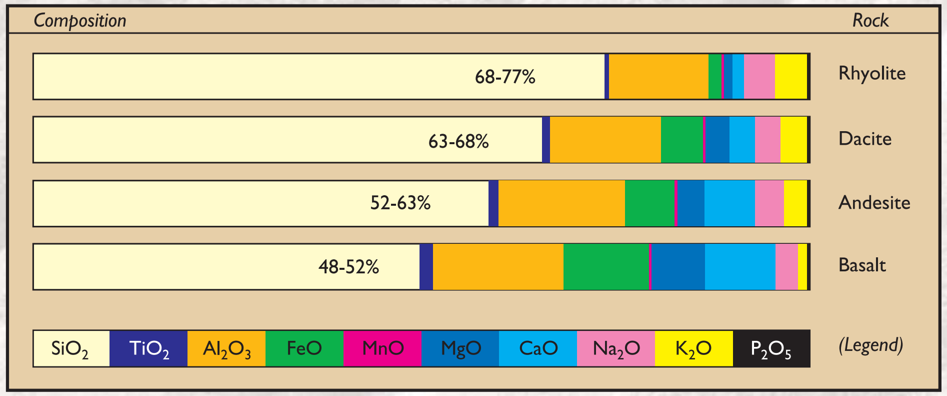
Caldera Faial

3.2.3 Volcanic rocks

A rock generated from magma emitted during a volcanic eruption is called Volcanic Rock. Quick cooling of erupted magma inhibits efficient crystallization of the rocks which are generally characterized by a glassy ground-mass with micro-crystals containing bigger previously generated crystals called phenocrysts.
Volcanic rocks are classified into four basic types on the basis of the amount of silica (SiO2):

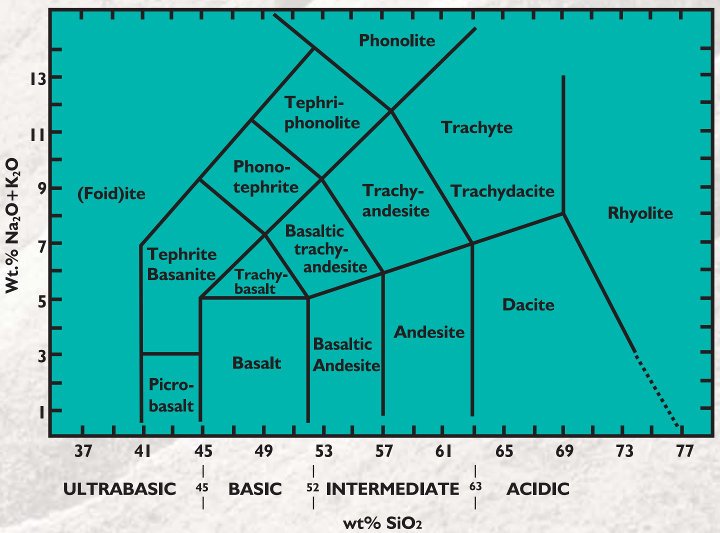
BASALT = 48-52% silica
ANDESITE = 52-63% silica
DACITE = 63-68% silica
RHYOLITE = > 68% silica

A simple classification scheme of volcanic rocks, based on chemistry is reported on the following figure.



Classification of volcanic rocks based on major chemical elements (J.Johnson-USGS).

A more complete classification of volcanic rocks, based on the silica (SiO2) and alkali (Na2O and K2O) content, is reported in the TAS (Total Alkali-Silica) diagram:



TAS (Total Alkali-Silica) diagram for the classification of volcanic rocks using silica (SiO2) and alkali (Na2O and K2O) content.

Rhyolite lavasample.

Basalt lava sample.

Explosive eruptions products

The products of magma fragmentation due to explosive eruptions are classified on the basis of their dimensions in: **Bombs** (or blocks) if dimensions are more than 64 mm; **lapilli** if dimension are between 2 and 64 mm; **ashes** if dimensions are less than 2 mm.
Depending the vesicularity (cavities inside the clast) and density, the pyroclastic fragments can be distinguished in **pumices** and **scoriae**. Pumices are well vesiculated, with low density and glassy with some crystals. Scoriae are less vesiculated, and more dense and generally are darker then pumices.
Explosive deposits could contain also fragments called **lithics**, which are pieces of pre-existent rocks carried out by raising magma, and loose minerals.
Spherical fragments called **accretionary lapilli** are volcanic ash accreting into layers around a small particle which acts as a central nucleus.
Obsidian are volcanic glass, black in color and gives conchoidal fractures; they generate after a very quick cooling of a viscous magma.

Pumice fragment

Scoria

Accretionary lapilli

Obsidian

Detail of a Tuff sample (Neapolitan Yellow Tuff-Italy)

The consolidation and compaction of pyroclastic currents and ash fallout, containing mainly volcanic ashes and subordinately pumices and lithics, generate a rock called **Tuff**. If the components were sufficiently hot at time of deposition, they welded together and a **Welded Tuff** will create.

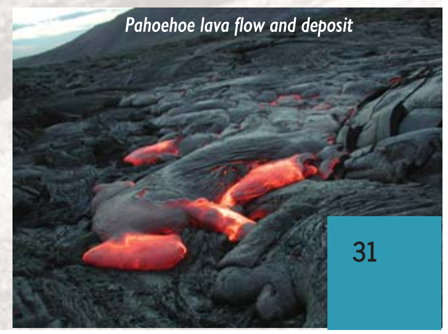
Effusive eruptions products

The products of a effusive eruption are lavas. The main factors that controls size and shape of a flow are the effusion rate, the chemical and physical properties of the emitted magma, and the morphology of the ground on which the lava pour. Effusive activity can generate aa lavas, with wrinkled surface structure, formed by chaotic accumulation of sharp rocks fragments, or pahoehoe lavas with smooth and undulated surfaces, formed lobe like or ropy.like structures. When lavas are emitted underwater, they commonly form pillow lavas, which are mounds of elongate lava "pillows" formed by repeated oozing and quenching of the hot low viscous lava Their peculiar formation occur when first, a flexible glassy crust forms around the newly extruded lava, forming an expanded pillow., next, pressure builds until the crust breaks and new lava extrudes like toothpaste, forming another pillow. This sequence continues until a thick sequence may be deposited.

Pillow lava formation

Pillow lava deposit

Aa lava flow and deposit



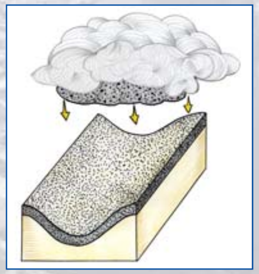
Pahoehoe lava flow and deposit

3.2.4 Volcanic hazard

The activity of a volcano can be characterized by the slow emission of modest quantities of magma with limited effects on the environment or, on the contrary, by catastrophic, eruptive events capable of radically altering the surroundings of the volcano and disturbing the climate also at the global level.
Catastrophic events generally take the form of high-energy explosive eruptions during which huge amounts of volcanic material are emitted. Effusive eruptions instead have less destructive power, even though they can be characterized by the emission of huge volumes of lava.


Etna 2006


Fall




Plinian Lascar

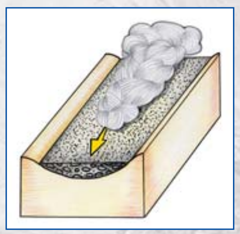

Averno

The products of explosive eruption are pumice and ash fall, and pyroclastic currents deposits.
Pumice and ash fall deposits can covers large areas, mainly respect to winds direction. The size of the falling particles, deposit thickness and the affected area cannot be predicted in advance. These deposits can reach such thickness and weight to damage building's roofs, even causing their collapse. Volcanic ash is highly dangerous in particular due to its ability to infiltrate and fill every empty space and to its abrasive character. It can also cause respiratory problems and reduced visibility as well as significant damage to the engines of cars and planes.


Pinatubo


Ash effects

A **pyroclastic current** is capable of destroying or burying practically all of the objects or structures in its path. A pyroclastic current is a mixture of gas and particles at high temperature of between 200 and 700°C, which can set fire to buildings and materials. These flows contain fragments of rock that vary in size from one millimeter to tens of centimeters and sweep over the ground at speeds generally in excess of 80 km/h.
While pyroclastic flows vary considerably in size and speed, even those of limited scale can cause the destruction of homes, forests and crops.

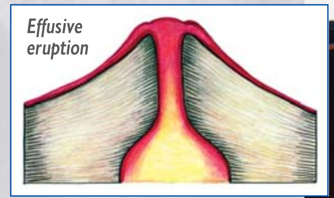



Pyroclastic flow


Pinatubo lahar


Plymouth's clock

Deaths and injuries to people and animals can be caused by inhaling gases or particles of fine ash.
Lava flows can have destructive effects on the territory, as everything in their path is flattened, buried and subjected to combustion. While lava flows can cause great damage to buildings and vegetation, but their low speed (max 30 km/h) make it possible for people and animals to escape. Although, seldom there are casualties connected directly with lava flows due to explosions when molten lava comes into contact with water, to inhalation of poisonous gases released, and generation of mudflows triggered by the melting of snow and ice through an emission of lava below. The burial of cultivated fields, houses and roads beneath thick layers of lava also causes great damage and can have serious socio-economic repercussions.


Effusive eruption


Lava flow


Kilauea lava effects


Effects of lava flow

Lahar is an Indonesian word to define a debris flow composed of pyroclastic material mixed to water. It can originate as a direct and immediate result of an eruption or time after the eruption occurred, as result of mobilization of loose tephra by heavy rain or meltwater on steep slopes of volcanoes.
Lahars flows at high velocities in the gullies of the volcano and expand in the alluvial plain till tens of kilometers far from volcano, causing great economic and environmental damages.

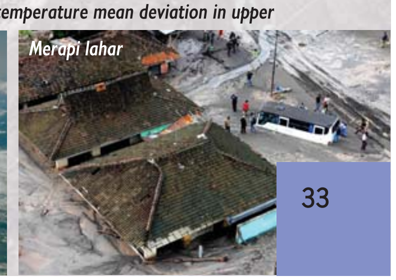
Volcanic eruptions and Climate Change

During major explosive eruptions huge amounts of volcanic gas and ash are injected into the stratosphere. Mostly of the injected ash falls are usually removed within days, causing little impact on climate, while volcanic gases, like sulfur dioxide (SO2) can cause global cooling, and volcanic carbon dioxide (CO2), a greenhouse gas, likely promotes global warming. The most significant climate impact from volcanic injections into the stratosphere derives from the amount of sulfur in the erupting magma, and then the occurring of sulfur dioxide (SO2) conversion to sulfuric acid (H2SO4), which condenses rapidly in the stratosphere to form fine sulfate aerosols. The aerosols increase the reflection of radiation from the Sun back into space, cooling the Earth's lower atmosphere or troposphere. The longer permanence of sulfate aerosols, not the ash particles which fall out within a few months of an eruption, is the dominant controlling factor
Several eruptions during the past century have caused a decrease in the average temperature at the Earth's surface of up to a 1-2 C° degree, for periods of some years. The SO2 released in contemporary volcanic eruptions has sometimes caused global cooling of the lower atmosphere, while the released CO2 has never caused evident global warming of the atmosphere. This is probably because this amounts of CO2 has not been sufficient to produce s recordable global effects. For example, present-day subaerial and submarine volcanoes release less than a percent of the CO2 released by human activities. Probably in geologic past, the CO2 from intense volcanic activity was the cause of global climate effects and possibly mass extinctions.
A so called volcanic winter has been documented that large volcanic eruptions, such as Tambora (1816 AD), Krakatoa (1883 AD) or Pinatubo (1991 AD) can cause severe climate changes in global scale, expressed by a long term sudden decrease of atmospheric temperature.
This phenomenon, described as volcanic "winter" is the result of mainly plinian eruptions and the emission up to the higher levels of the atmosphere of large amounts of ash and gasses, like aerosols of sulfuric dioxide. Soon after the eruption these products can fully cover the Earth. Solar energy is either trapped by gasses or dammed by the ash, dropping down surface temperature for several degrees Celsius. Studies on mean tree ring density documented such changes for several years in past.

Figure: The temperature of the Earth's land surface, asdetermined from over 36,000 temperature stations around the globe. The data is well fit by a simple model containing only known volcanic eruptions and carbon dioxide (dark line). No contribution from solar variability was necessary to make a good match. The rapid but short (decadal) variations are believed to be due to changes in ocean flows, such as El Nino and the Gulf Stream.

Dust emission during past eruptions (bottom) and temperature mean deviation in upper


Lahar eruption

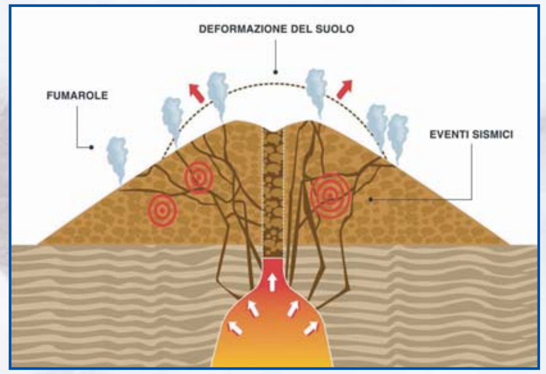

Merapi lahar

3.2.5.Volcano surveillance

The evolution of a volcanic system from a quiescence state to an impending eruption implies the ascent of the magma from a certain crust depth to the surface. This raising can cause a variation in a set of physical-chemical parameters, both in the magma and in the surrounding rocks, the effects of which can be recorded on the surface. These variations are the precursory phenomena of an eruption. Their evolution over time, detected through surveillance systems, is the basis of short-term forecasting.

The precursory phenomena most commonly studied are:

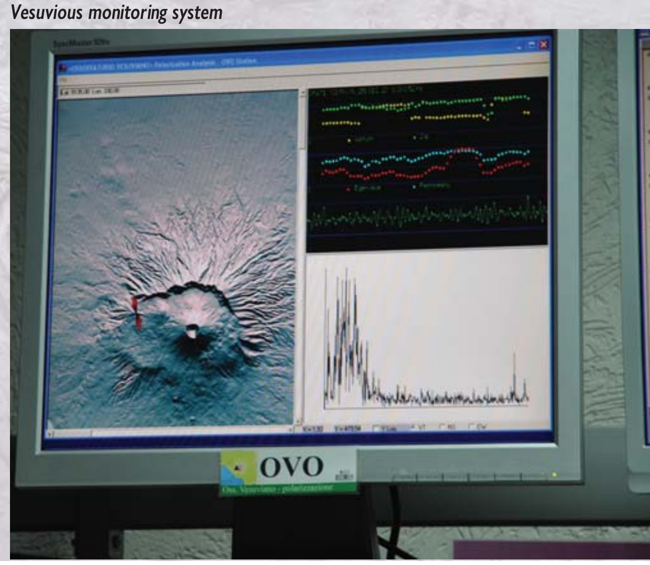
- Volcano seismicity. The movement of magma or volcanic gases in the crust causes the progressive rocks deformation till causing their fracture, with a sudden release of energy that is transmitted through seismic waves propagation. Before the eruptions an almost continuous tremor can be also recorded. These phenomena are due to movement of the rising magma in the conduit
- Ground deformations and changes in the volcanic edifices shape. Deformation of the volcanic can be produced by movements of magmatic masses in depth. Some ground movement can also be related to changes in fluids pressure in the geothermal system associated with the volcano
- Geochemical variations. The ascent of magma through the crust causes a more intense migration to the surface and a change in the composition of fluids that feed the fumaroles, and hydrothermal and geothermal systems. These fluids can be released from the same magma (magmatic fluid), from overheated wall rocks, or from groundwater systems boiling (geothermal-hydrothermal fluids). All gases are characterized mainly by the presence of water vapor (H2O) and carbon dioxide (CO2), with consistent different percentages of gases as hydrochloric acid (HCl), hydrofluoric acid (HF), sulfuric acid (H2SO4), of whose fluids with magmatic origin are quite rich.
- Changes in the gravitational field, magnetic and electric fields. These variations are produced by the intrusion of magma or by the circulation of fluids, both characterized by high temperature and different densities in solid rocks and relatively cold.



Volcanic monitoring

Volcanic eruption risk is a matter that scientist can deal in a more successful way. Several warning phenomena precede a volcanic eruption and can be monitored through various systems. Increase of heat flow near volcano, slow ground motions in calderas, progressive increase of local seismicity are some phenomena that can be recorded by satellites, seismographs and field station and can alert for a forthcoming eruption.

Vesuvious monitoring system



3.2.6 Famous Active Volcanoes in Mediterranean

Mediterranean active volcanoes are located in the Southern Italy and Aegean Sea. Volcanism of Aeolian Islands (Stromboli and Vulcano islands - Italy) and Aegean Archipelago (Milos, Santorini and Nisyros - Greece) is due to the subduction of the African plate under the European one. Vesuvio, Campi Flegrei, Ischia and Etna volcanism is related to magma rising along distensive structures of the upper crust.

Vesuvio (Italy)

Type of volcano: stratovolcano
Main type of activity: phreatomagmatic, plinian, effusive
Beginning of eruptive activity : >300.000 years
Last eruption: 1944
State of activity: quiescent **Hazard:** high

Vesuvius is a volcanic cone, 1,281 m a.s.l. high, with a crater about 500 meters in diameter and about 300 m deep, which is grown within the caldera of the older edifice of Mt.Somma. The Somma-Vesuvius volcanic history is characterized by long periods of rest with obstructed closed conduit, interrupted by violent explosive eruptions of either Plinian or Sub-Plinian type. Since the last Sub-Plinian eruption of 1631, Vesuvius entered in such an open-conduit phase that lasted until 1944. Actually Vesuvius is in a closed conduit quiescence phase and is probably the volcano with the highest risk in the world as over 550,000 people are fatally exposed in case of new eruption and hundreds of thousands of more people are exposed to severe ash fallout and lahar hazards.

Campi Flegrei (Italy)

Type of volcano: caldera
Main type of activity: Phreatomagmatic, Plinian, strombolian, fumarolic
Beginning of eruptive activity: >80,000 years
Last eruption: 1538
State of activity: quiescent **Hazard:** high

Campi Flegrei is a volcanic filed characterised by a peculiar landscape including several volcanic landforms. The main volcanic feature is a caldera structure formed during the two main events of the Campanian Ignimbrite (40 kyr) and Neapolitan Yellow Tuff (15 kyr) eruptions. During the last 15 kyr within the caldera several volcanic edifices grew and destroyed as results of about 70 eruptions. The last eruption of Monte Nuovo (1538 AD) occurred after about 3,500 years of rest. The caldera was affected by ground deformation phenomena in its central part, during the last 10.5 kyr. Recently slow ground movements events, named bradiseism, occurred (1970-72 and 1982-84 unrest crises). They were accompanied by hundreds earthquakes and by 3.5 m of ground uplift, forcing the town of Pozzuoli to be evacuated.

Ischia (Italy)

Type of volcano: caldera
Main type of activity: sub-plinian, strombolian, effusive, phreatomagmatic, fumarolic
Beginning of eruptive activity: >150.000 years
Last eruption: 1302
State of activity: quiescent **Hazard:** low-intermediate

Ischia is the top of a volcano which rises for more than 1,000 m from the sea bed in the north-western part of the Gulf of Naples. Volcanism at Ischia started more than 150,000 years ago and continued, alternating with long periods of quiescence, until the most recent eruption which formed the Arso lava flow (1302 AD). The dominant high of Mt. Epomeo (787 m a.s.l.) is a resurgent block in the caldera formed by the violent explosive Mt. Epomeo Green Tuff eruption occurred 55,000 years ago. Recent volcanism has been particularly intense, with over 46 effusive and explosive eruptions concentrated mainly in the last 3,000 years. Although recent seismicity is very low, chronicles registered a disastrous earthquake which heavily damaged the town of Casamicciola in 1883.

Vulcano (Italy)

Type of volcano: stratovolcano
Main type of activity: phreatomagmatic, plinian, effusive, fumarolic
Beginning of eruptive activity : >120.000 years
Last eruption: 1888-90
State of activity: quiescent **Hazard:** low-intermediate

Vulcano, which is 500 m a.s.l high, is the most southern island in the Aeolian archipelago. Its complex morphology is due to the superimposition of variable volcanic structures generated by the alternation of constructive phases, with effusive or low-energy explosive eruptions, and destructive phases characterized by violent explosive eruptions. The oldest structure (from 120,000 years ago) is a stratovolcano, truncated around 100,000 years ago by a caldera. On north-west of this structure a second caldera, surrounded by a series of lava domes, contains the La Fossa tuff-cone which is connected on the north to the younger Vulcanello peninsula (2,000 years). The last eruption at Volcano took place at La Fossa in 1888-90 and at present the island exhibits widespread fumarole activity and lower seismicity. Between 1985 and 1994 seismic and intense fumarole activity together with ground deformation at La Fossa, caused alarm and the fear of a new eruption.

Stromboli (Italy)

Type of volcano: stratovulcano
Main type of activity: strombolian, effusive, fumarolic
Beginning of eruptive activity: 200.000 years
Last eruption: in course
State of activity: persistent **Hazard:** low-intermediate

Stromboli, the northernmost island in the Aeolian archipelago, reaches a maximum height of 924 m above sea level and rises from a depth of 1500-2000 m below sea level. The active craters, at about 700 m a.s.l., are situated on the upper portion of the Sciara del Fuoco, a collapse structure on the volcano's north-eastern flank.

The outcropping rocks are mainly lavas and pyroclastic deposits from typical Strombolian activity consisting of mild intermittent explosions ejecting scoria 'bombs', lapilli and ash from an open eruption conduit in which magma is present at shallow depth. The explosions are accompanied by continuous degassing of the magma. This type of activity is periodically interrupted by lava flows down the Sciara and more violent explosions which eject m-sized blocks which sometimes have reached the settlements of Stromboli or Ginostra.

Etna (Italy)

Type of volcano: stratovolcano
Main type of activity: effusive, strombolian, fumarolic
Beginning of eruptive activity: 550,000 years
Last eruption: 2011
State of activity: semipersistent
Hazard: low-intermediate

Etna, Europe's largest active volcano, is 3,330 m high at the summit and covers a surface area of about 1,200 km2. Rocks from Etna are mainly lavas, with a lesser quantity of ash and scoria produced by eruptions varying from effusive to highly explosive, caldera forming eruptions (Plinian eruption of 122 BC). During recent centuries the volcano's activity has been more or less continuous, with frequent low-energy explosive eruptions and effusions of lava issuing from both the summit craters and lateral vents. These eruptions, lasting from several days to several years, have many times damaged urban areas along the volcano slopes with ash and scoria fallout and lava flows. Of particular note is the lateral eruption of 1669, when the city of Catania was partly destroyed by a lava flow.

Milos (Greece)

Type of volcano: stratovolcano
Main type of activity: explosive, phreatic explosions, fumarolic
Beginning of eruptive activity: 3.5 Ma
Last eruption: 19 kyr (magmatic), 200 AD (hydrothermal)
State of activity: quiescent **Hazard:** low

Milos is a stratovolcano 751 m a.s.l. high, whose volcanism manifested since 3.5 Ma. The most recent magmatic events consist of two big explosive phreatomagmatic eruptions that built up Trahilas (380 kyr) and Fyriplaka (19 kyr) tuff rings. Although magmatic historic eruptions have not been registered, both the intensive shallow seismicity and the high heat flow suggest that the reactivating of the volcano with hazardous explosive phreatomagmatic eruptions is not improbable. Historic hydrothermal explosions (80-200 AD) involve serious volcanic hazard at Milos due to the presence of overheated steam (320 oC) at a depth of < 1 Km in the central area of Milos.

Volcanic risk in Milos island is relatively low, considering the low probability of occurrence of volcanic events in the near future.

Santorini (Greece)

Type of volcano: caldera
Main type of activity: phreatomagmatic, plinian, strombolian, effusive
Beginning of eruptive activity:
Last eruption: 1950
State of activity: quiescent Hazard: high

Santorini is a volcanic archipelago formed by five islands. The biggest one is Thera which is 564 m a.s.l. high composed of overlapping shield volcanoes cut by at least four partially overlapping calderas. The oldest one formed at 180 kyr, the younger generated at about 3.6 kyr during the Late-Bronze-Age Minoan eruption, responsible of a highly destructive tsunami. Following explosive (mainly surtseyan) and effusive intracaldera volcanic activity from 197 BC formed two islands (Palea and Nea Kameni) in the center of the caldera. In 1650 AD a submarine explosive eruption took place outside the caldera at NE of the island, building up the Kolumbo volcano, whose collapse generated a tsunami which damaged Santorini's coasts and caused fatalities.

Last eruption (1950 AD) was effusive, preceeded by phreatic explosions, and took place at Nea Kameni island in the center of the caldera. In 1956 a strong earthquake devastated many villages in the island.

A large amount of people visit Santorini yearly.

Nisyros (Greece)

Type of volcano: stratovolcano
Main type of activity: phreatic explosions
Beginning of eruptive activity: 150,000 years
Last eruption: 1950
State of activity: quiescent Hazard: high

Nisyros is a 700 m a.s.l. high stratovolcano which is the upper emerged portion of a larger edifice formed by volcanic activity aged before 150,000 years. A devastating eruption occurred on the island approximately 40,000 years ago with the formation of the ancient caldera in which grew a large lava dome. Subsequent activity produced a large volcanic cone as product of the succession of tephra and lava deposits. The current shape is the product of a plinian eruption non younger than 24,000 years which formed a 3.8 kilometres large caldera. Post-caldera activity was characterized by the emplacement of lava domes inside and outside the floor of the Nisyros caldera (Lakki Plain).

All explosions recorded on Nisyros during historic times were phreatic explosions. At least 13 phreatic eruptions occurred in historical times and the most recent ones occurred in 1871-1873 and 1888.

Famous eruptions

The Minoan Eruption of the Santorini Volcano (Greece, ca. 1613 BC)

Santorini Island is the most well-known and active volcano of Greece, in the south Aegean Sea. The most recent large eruption is "the Minoan Eruption", one of the biggest known in historic time worldwide emitting in the atmosphere at least four times more volcanic products than Krakatoa eruption. It occurred at around 1613 BC (late Bronze Age) in four phases.
Activity began with a plynian eruption of hot pumice falling out from the eruption column that reached about 40 km height. The pumice fall-out blanketed the whole of the island, the surrounding Aegean islands and the coasts of Middle East and Turkey. The second phase resulted in base surge deposits and enabled the entrance of sea water into the magmatic chamber. The third phase produced large quantities of mud flows whereas the last eruption was a typical pyroclastic eruption. The removal of such a large volume of magma from underneath the volcano caused it to collapse into the emptied magma chamber, producing a large crater (a caldera) in the place of the volcano.
The eruptions were then followed by a huge tsunami that affected in several minutes the Aegean islands and Crete and soon after all eastern Mediterranean.
It devastated not only Santorini, but had a deep impact on the whole of the Eastern Mediterranean, destroying communities and agricultural areas on nearby islands and on the coast of Crete resulting in the collapse of Minoan civilisation. In Santorini it buried out the Cycladic/Minoan settlement Akrotiri, often called the "Pompeii of the Bronze Age" to stress the similarity to the Roman city buried under the pumice of Vesuvius. Since no human remains have been found at the site, it is assumed that preliminary seismic and volcanic activity gave people time to evacuate their island before the eruption. The spectacular discoveries have induced speculations that relate the destruction of Santorini Island to Plato's story of Atlantis.
The Minoan eruption left behind thick layer of white pumice and ash on the island of Santorini.
Volcanic ash from the Minoan Eruption covered most of the Eastern Mediterranean area, with ranging thickness (here in cm).
The late Bronze Age settlement Akrotiri was buried under a thick layer of volcanic ashes during the Minoan Eruption. Recent excavations reveal a highly developed civilization for the Minoan inhabitants of Santorini before the great volcanic eruption.

The 79 A.D. Pompeii ERUPTION

The 79 A.D. Pompeii eruption undoubtedly is Vesuvius' most famous eruption, and perhaps even the most famous volcanic eruption in history. It was described by Pliny the Younger in two well-known letters to Tacitus, which constitute valuable documentation for volcanologists (see "Historical Eyewitness Accounts"). In the letters he recounts the death of his uncle, Pliny the Elder, who set off from Miseno by ship to rescue people during the eruption. This is the origin of the term Plinian eruption to denominate this particularly violent and destructive phenomenon.

In Roman times, at the beginning of the first millennium, Vesuvius was not considered to be an active volcano, and several cities flourished on its slopes attracted by the fertility of the soil and beauty of the area. In 62 A.D. the Vesuvian area was struck by a violent earthquake which caused the collapse of many buildings and damage even in Nocera and Napoli. At the time, hypotheses of a link be-tween the earthquake and the volcanic nature of the area had not yet been made.

Fresco at Pompei showing Vesuvius before 79 A.D. eruption.

On 24th August 79 A.D. activity on Vesuvius resumed after a period of quiescence which had probably lasted for eight centuries, spreading about 4km3 of magma in the form of pumice and ash over the surrounding areas in little more than thirty hours.
The eruption started at around 13 o'clock in the afternoon of 24th August; the conduit opened after a series of explosions due to the immediate vaporisation of surface water coming into contact with rising magma. Then an eruption column of gas, ash, pumice and lithic fragments rose up into the air to a height of about 15 km above the volcano. This phase of the eruption lasted until around 8 o'clock the next morning, and was accompanied by frequent earthquakes.
During the night many people took advantage of an apparent lull in the eruptive activity, to go back to their homes which they had abandoned in haste. But they were surprised during the course of the morning by the reawakening of the volcano. This time there was a total collapse of the eruption column, causing the formation of pyroclastic flows which led to the total destruction of the areas of Ercolano, Pompei and Stabia.

During the final part of the eruption, probably in the late morning of 25th August, pyroclastic flows continued to form; their deposits totally buried the surrounding villages while a dense cloud of ash spread into the atmosphere reaching as far as Capo Miseno.

Body casts of some victims from Pompei

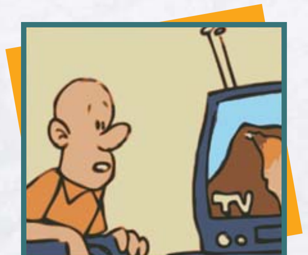
3.2.7 Preparedness measures

Unlike other natural phenomena such as earthquakes, volcanic eruptions are usually foreseeable, thanks to distinctive precursory occurrences that can be detected by monitoring networks created for such purpose. Risks from volcanic eruptions encompass the release on earth surface of all kind of volcanic products, as well as by the intensity and the speed that such phenomena can develop. The duration of volcanic eruptions may vary from a few hours to tens of years (the Kilauea Volcano in the Hawaii Islands has been erupting since 1986).
Thus, there are various types of volcanic eruptions, each of which may pose different dangerous phenomena like lava flow; fall of coarse material (volcanic bombs and blocks of various sizes); fall and deposit of fine material (ashes and lapilli); pyroclastic flows; gaseous emissions; and mudflows. The most dangerous among these phenomena are pyroclastic flows and mudflows.

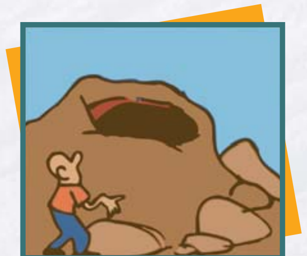
What to do... if you live or find yourself in a volcanic area:

1. Inquire about the emergency plan of your municipality,
in order to act adequately and carry out possible evacuation operations

2. During the eruption obey the prohibition to enter the affected area,
although eruptions seen spectacular and generate curiosity, these places are dangerous



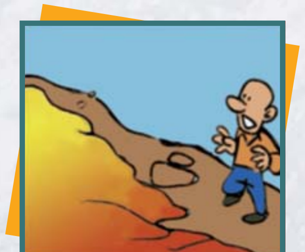
3. Follow exclusively the instructions indicated by civil protection authorities.
During critical situations unfounded news may easily be given, thus hindering the rescue intervention



It is dangerous to go near craters even when the volcano is not active,
sudden explosive phenomenon and/or gaseous emissions are always possible

In case of a lava flow:

1. Do not approach an active lava flow even if it is flowing down regularly,
They are very hot, release gases, and can cause falling incandescent rocks and sudden explosions.



2. Even after the eruption has ended do not walk on the surface of a lava flow.
The flows retain their heat for years.

In case of falling volcanic bombs:

1. Inquire whether the area where you are is subject to falls of coarse material. It is highly destructive phenomenon for buildings, which cannot therefore constitute a shelter.

2. Examine the emergency plan of your municipality and get ready for a possible evacuation. The preventive departure from affected area is the only possible defence.

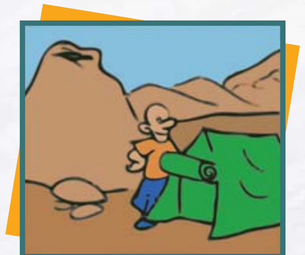
In case of falling volcanic ashes:

1. Stay home with closed windows and check the deposit on your house roof. Volcanic ash is heavy and its build-up could cause the roof to crack or cave in.

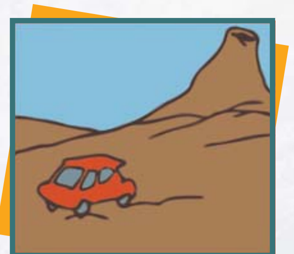
2. Outdoors wear a respirator and protective glasses and drive carefully. Ashes provoke trouble to the respiratory sy-stem and to the eyes, and cause the road surfaces to become slippery.

In case of gaseous emissions:

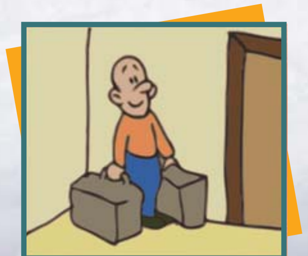
1. Avoid stopping or camping in volcanic areas and do not enter under-ground places. Carbon dioxide is an odourless gas, heavier than air and is lethal in high concentration.



2. Do not think that you are safe if you stop from the crater, gaseous emissions can reach even distant areas.

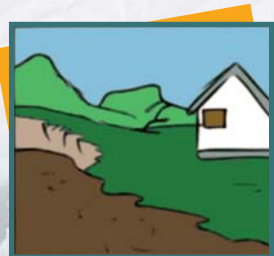


In case of pyroclastic flows:



1. Get ready for possible evacuation. The only defence from this type of flow is the preventive departure from the area at risk.

In case of mudflows:



1. Follow the civil protection plan which pinpoints the waiting areas and move away from the areas at risk. Fire ashes can trigger dangerous mudflows that pour along watercourses.

3.2.8. Volcanic Glossary

A'a lava flow
Hawaiian term for lava flows that have a rough rubbly surface composed of broken lava blocks. The very spiny surface of a solidified `a`a flow makes walking very difficult.

Ash
Fragments of rock, mineral, and volcanic glass smaller than 2 mm in diameter, that were ejected from a volcano during an explosive eruption

Bomb
Volcanic bombs are lava fragments that were ejected while viscous (partially molten) during an explosive eruption, and larger than 64 mm in diameter

Caldera
A caldera is a large, usually circular depression at the summit of a volcano formed when magma is erupted from a shallow underground magma reservoir. The removal of large volumes of magma may result in loss of structural support for the overlying rock, that leads to collapse of the ground and formation of a large depression.

Fumarole
Vents from which volcanic gas escapes into the atmosphere. The rapid change in pressure and temperature that a fumarole undergoes when emitted in the air, causes the precipitation and crystallization of minerals

Lapillo
Volcanic rock fragments between 2 and 64 mm (0.08-2.5 in) in diameter that were ejected from a volcano during an explosive eruption

Lava flow
Masses of molten rock, containing any or very few gas, emitted during an effusive eruption. Both moving lava and the resulting solidified deposit are referred to as lava flows.

Lava fountain
A jet of lava and gas sprayed into the air during very low energy explosive eruption. Lava fountains typically range from about 10 to 100 m in height, but occasionally reach more than 500 m.

Magma
Magma is molten or partially molten rock beneath the Earth's surface. When magma erupts onto the surface, it is called lava. Magma typically consists of: a liquid portion; a solid portion made of minerals that crystallized directly from the melt; solid rocks fragments; dissolved gases.

Magma chamber
An underground reservoir the Earth's crust filled with magma, from which volcanic materials raise to be then erupted the chamber can have variable dimensions and can be connected to the surface through a volcanic conduit.

Mud flow (Lahar)
Also called Lahar, (an Indonesian word) are rapidly flowing mixture of rock debris and water that originates on the slopes of a volcano. They form mainly by intense rainfall on loose volcanic rock deposits, or the rapid melting of snow and ice by pyroclastic flows.

Pahoehoe lava flow
Hawaiian term lava that has a smooth, ropy surface. A pahoehoe flow typically advances as a series of small lobes and toes that continually break out from a cooled crust

Plinian eruption
A large explosive events that form enormous dark columns of volcanic fragments and gas high into the stratosphere (>11 km). Such eruptions are named for Pliny the Younger, who carefully described the disastrous eruption of Vesuvius in 79 A.D. This eruption generated a huge column of volcanic material into the sky, and pyroclastic flows and fall.

Precursors of a volcanic eruption

The set of phenomena related to changes in physical-chemical properties of a volcanic system prior to eruption..

Pumice
A light, porous volcanic rock that forms during explosive eruptions. It resembles a sponge because it consists of a network of gas bubbles frozen within friable volcanic glass and minerals. Pumice floats in water.

Pyroclastic-fall
Gravitational fall and accumulation as a deposit, of volcanic rocks fragments ejected by explosive eruptions

Pyroclastic flow
A pyroclastic flow is a ground-hugging avalanche of hot ash, pumice, rock fragments, and volcanic gas that rushes down the side of a volcano as fast as 100 km/hour or more

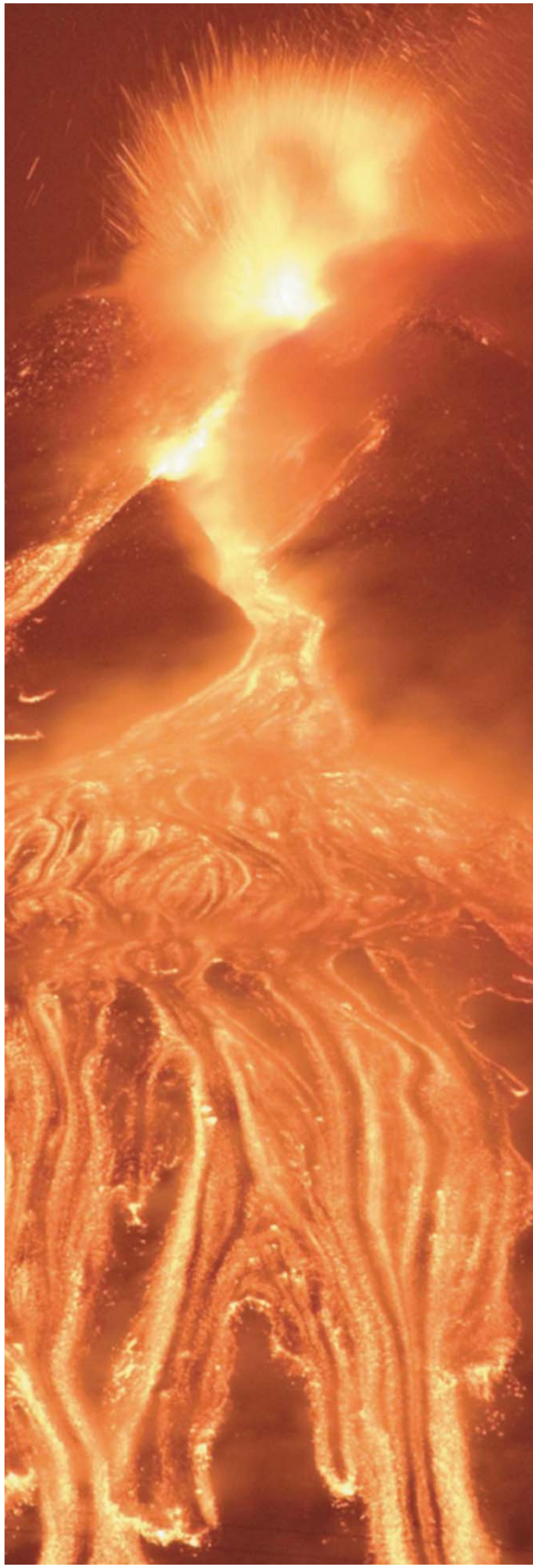
Scoria
Vesicular (bubbly) volcanic rock ejected during explosive eruption. The bubbly nature of scoria is due to the escape of volcanic gases during eruption. Scoria is typically dark gray to black in color. A scoria doesn't float in water

Strombolian eruption
An eruption characterized by the intermittent explosion or fountaining of basaltic lava from a single vent or crater. Each episode is caused by the release of volcanic gases, and they typically occur every few minutes or so, sometimes rhythmically and sometimes irregularly. The lava fragments generally consist of partially molten volcanic bombs that become rounded as they fly through the air.

Volcanic Eruption
Emission of magma, volcanic fragments, or gas, or all at once, through a vent into the atmosphere. The eruption may be effusive or explosive.

Volcanic surveillance system
Set of measuring instruments, located throughout a volcanic area and generally connected to a central data receiver, that collects geophysical and geochemical parameters related to a volcanic system.

Volcano
A vent at the Earth's surface through which magma (molten rock) and associated gases erupt, and also the cone built by effusive and explosive eruptions.



4. Psychosocial consequences

4.1 In case of an earthquake

The earthquake is a sudden, stressful event and a traumatic experience, because it doesn't offer time for psychological preparation, reduces the sense of control that can be gained on nature and life and causes intense fear and a sense of helplessness in children and adults, modifying for longer time the biological and psychological equilibrium.

Earthquake and family

Very often, during an EQ children may be separated from parents and this lack of direct psychological support and consolation can increase the stress caused by the catastrophic event because they may fear that they won't meet again or worry about the safety of their parents.
Furthermore, parents may present for many years mental problems in significant proportion that can be transferred to their children, mainly because they look at their parents to distinguish their emotions and react accordingly. Thus even in such cases parents should be available and supportive to their children.
The evacuation of damaged houses may offer some relief because they resort to a safer place but it disorders the collective rehabilitation and reorganization of life developed with the neighborhood which often has a therapeutic effect.

Factors that influence the reactions of children

Children may experience a variety of emotional reactions after a disaster and it is important to understand that these reactions are, to some extent, natural.
Most children and adolescents experience a catastrophic event without facing serious problems. The reaction of a child depends on several factors, including:

- The age of a child affects the way it reacts to a catastrophic event. A six year old may refuse to go to school, a teenager may be irritable, fight with his parents, neglect his homework.
- The reaction of a child also depends on the extent of the damage experienced. If a family member or a familiar person has been killed or seriously injured, if the house or the school has been severely damaged, it is more likely for the child to react more intensely.
- The reaction of the parents and other adults. Children generally understand parents' concerns and are particularly sensitive during a crisis. Parents who react with panic affect their children, which react accordingly.
- Previous traumatic experiences of the child. The disruption of the family, a traumatic divorce of his parents or a recent bereavement makes the child more vulnerable to new traumas.
- Children's Psychological problems. Separation anxiety, depression or other serious disorders that may pre-exist, are risk factors for the occurrence of severe psychological effects after a catastrophic event.

Children's reactions after an earthquake

After an earthquake children fear that the event will happen again and put themselves and their family in danger. These fears and unpleasant feelings may be a product of their imagination, but they should be taken seriously by adults. However, some children, as well as adults, may experience a certain psychological disorder known as Post Traumatic Stress Disorder (PTSD). Symptoms of PTSD usually occur within the first 3 months after the traumatic event, but often continue for years.
Apart from PTSD, often children display symptoms of depression.
Other secondary effects are: anxiety disorders, separation anxiety, school avoidance, psychosomatic problems and bedwetting.

Post Traumatic Stress Disorder (PTSD)

There are three groups of symptoms regarding PTSD:

When Re-experiencing of the traumatic event

- Younger children may play repetitive games, where issues and aspects of the trauma, are expressed.
- Recurrent distressing dreams or nightmares relevant to the event. Younger children may dream of scary monsters.
- They feel or behave like the traumatic event is being recurring and they are reliving it.
- They feel intense psychological distress or fear, remembering the traumatic event.
- They present physical reactions, such as restlessness, startle, and tremor when they remember the event.

Persistent avoidance of stimuli associated with trauma

- They avoid thinking or talking about the traumatic event.
- They avoid activities, places or people that remind them of the trauma.

• They have difficulty remembering an important aspect of the event.
• There is a markedly diminished interest or participation in activities, play is reduced.
• They feel detached or estranged from others.
• They have a limited range of emotions, for example, unable to have loving feelings.
• They feel that they will not live to finish school, study, marry, etc.

Persistent symptoms of increased anxiety or arousal

• Difficulty falling or staying asleep.
• Exhibit irritability or outbursts of anger.
• Concentration difficulties.
• Hyper-vigilance: sensitive in recognizing sounds, smells, images or other stimuli that remind them of the event.
• Exaggerated startle response, over-reaction to the unexpected.

For diagnosing PTSD **must be** present: **at least one** of re-experiencing symptoms, **three** avoidance symptoms and two of the symptoms of increased arousal for **at least one month**.

Parents and teachers are those people who will be closer to children either during or immediately after a natural disaster. More important, they know very well pre-disaster children's behavior and character, thus being able to recognize and understand the emotional signs of a psychological burden and respond immediately on a proper way.

4.1.1 The parent's response

Parents and teachers are those people who will be closer to children either during or immediately after a natural disaster. More important, they know very well pre-disaster children's behavior and character, thus being able to recognize and understand the emotional signs of a psychological burden and respond immediately on a proper way.

The parents, even if they are afraid themselves, which is reasonable, they mustn't lose the control of the situation. Thereafter, when the danger is gone, they should focus on their children emotional needs. More specifically, after a disaster the parents may:

Organising daily life:

• Keep the family members together to the greatest extend.
• Encourage children to participate in all efforts needed in order for the family to stand on its feet, and particularly in repairing the damages.
• Begin new fun activities for the family
• Reassess the family's preparedness for emergencies.
• After some time, make a collective reevaluation of what has happened

Offering psychological support:

• Present a realistic, yet manageable, view of the destruction.
• Explain the situation to children in a calm and constant way.
• Encourage children to express their fears and describe how they feel.
• Apart from their children, parents should also share their fears and experiences in family discussions.
• Reassure children with sensitivity and love, until they realize that life will again come to normal.
• Maintain physical contact with their children, ie hug and touch them often.
• Be supportive and not critical to children.
• Give and receive support from family members, friends and society.
• Try laughing and using humor
• Confirm and complement each other within the family.

Acting practically:

• Discuss with children what to do if an earthquake happens again.
• Maintain their principles considering their children upbringing, but be more flexible in less important matters.
• Stay close to children when they go to sleep.
• Keep children away from television.
• Encourage children to do their homework and play with their friends.

Dealing with symptoms:

• Be empathetic to possible regressive behaviors such as bedwetting and soiling, and behaviors displayed at younger ages.
• Observe children for headaches, abdominal pains and other complaints, as anxiety is often expressed with physical symptoms.
• Try to distinguish and understand the factors that cause anxiety and fears to children.
• Allow their children to "mourn" for loved things that they might have lost because of the earthquake,
• If children face problems at school, the parents should ask for the cooperation of their teachers.
• Be aware that while most emotional reactions of children do not last long after the disaster, there might be some reactions which show up for the first time (or even reappear) after several months.
• Let time heal the psychological traumas.
• Be more tolerant with children and other family members
• When children do not respond to their parents' interventions and still have problematic behavior, seek help from mental health experts.

4.1.2 The role of teachers

Teachers can help children get back faster to normal activities, carrying fewer traumas, and consider the earthquake as a life experience. Below are some suggestions that might be useful for educators to follow:

During the earthquake

• Maintain their composure.
• Remind the appropriate behavior in case of an earthquake, which they themselves have taught children at a previous time.
• Give sharp commands in a decisive manner, but not shout or speak rough as that may cause greater panic
• Reassure children who are upset and are likely to scream or cry.
• Be aware that if they react in panic to an earthquake, this will affect their students.

Immediately after the earthquake

• Lead children to a safe place and stay with them.
• Embrace young children who are crying.
• Be empathetic to the children's fear.
• Reassure children's concerns.
• Assure children that the danger is gone.
• Look after the children until they are picked up by their parents.

Following period after the earthquake

• Return to school schedule as soon as possible.
• Give honest answers to the questions that children may pose regarding the facts;
• Express their own fears and as it is natural to have such feelings.
• Create a supportive environment where children feel comfortable to share their feelings.
• Ask children to write down or draw anything they want about earthquakes.
• Show understanding to children who behave as if they are of younger age and complain of pains not due to physical reasons.
• Be reassuring and optimistic about the outcome of the situation without giving non-realistic promises, like such an event won't happen again.
• Answer patiently to repeatedly-posed questions, because children often ask again and again the same thing in order to confirm the information.
• Observe 'post-traumatic symptoms', i.e. if after some weeks a child keeps showing withdrawal, concentration difficulties, easy crying, reduction of their interest, irritability.
• Communicate and cooperate with parents.
• Seek counseling by mental health specialists.

4.2 In case of a volcanic eruption

Volcanic eruption: peculiarity of this natural disaster in relation with the psychosocial consequences

A volcanic eruption occurs in many shapes and sizes and in a variety of geological settings. It also varies greatly in the frequency and violence of the different kind of eruptions.

Differently from an earthquake, the Volcano has a particular appeal for children. A recent study of Gomez Christopher ("Exposure to Volcanic Hazards, and Influence on Perception: A Case Study in Japan, Ten Years After the Unzen Fugendake Eruption") puts in evidence that the perception of pupils about volcanic eruption is quite fascinating, even if they live near a volcano. In their drawings children represented ashes and clouds coming out the volcanic, main vent, lava, explosions, projections… So, while children emphasized the appealing aspects of this natural hazard, adults emphasized the human consequences representing the buildings destroyed, the inhabitants running away from the danger, the human vulnerability.

This put in evidence the general different perception of a volcano between grown-up and pupils.

This fascinating image is completely destroyed after the volcanic eruption because the disaster cancels these appealing metaphors.

Differently from an earthquake, volcanic events can also have some predictability even periodicity but, despite this, the strong impact, the fact that it continues to be present in the children mind (an earthquake is something not clearly re-conducted to a specified place while an eruption is linked to a visible volcano), the wrought of the destruction, the fact that the traumatic fear is related to something "real", makes this disaster a stressful event, a traumatic experience (in some cases even more grave than an earthquake) because it causes intense fear and a sense of helplessness in children.

Several studies underlines that volcanic eruptions do not affect everyone in the same way. At an individual level, some may experience the disaster with few psychological consequences, while others will go through the same disaster and be emotionally devastated. Of course, beyond individual variation, certain categories of people, children in particular, are especially vulnerable or vulnerable in specific ways.

That's because those with the least resources are most exposed to the adverse effects of a volcanic eruption. For children, the effects are magnified by the fact that the child's personality is still developing and because they don' have the dimension of the "prediction" of the eruption. The child has to construct his or her identity within a framework of the psychological damage done by the volcanic disaster (very often the post-disaster reactions include flashbacks and frightening memories of the experience, just looking at the volcano). Any reminder may trigger these feelings and just viewing the mountain children often re-experience the events or have intrusive memories.

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Children's reactions after a volcanic eruption

Studies investigating the impact of volcano eruption on children and adolescents have found negative emotional and behavioural consequences, to varying degrees.
While diagnosable psychopathology may not be present, many children do report significant levels of emotional distress and frequent occurrence of sub-clinical levels of post-traumatic stress disorder (PTSD)
Concerning the psychosocial impact of a volcanic eruption, if the degree of involvement and distress is the same, it must be pointed out that it's not so different from the psychosocial impact of an earthquake.

Reactive fear and Ifest?ophobia

For this natural disaster, children can experience a certain psychological disorder known as Reactive Fear and Ifestiophobia.

Reactive fear

Larger stress responses are defined as greater sympathetic activation, arasympathetic withdrawal and cortisol increases to stressor tasks.
Children who have experienced a volcanic eruption frequently re-live the traumatic event through nightmares, flashbacks and daydreaming. Any experience that is in some way reminiscent of the traumatic event can trigger a stress reaction.
Children in a reactive fear state may be behaviorally impulsive, hyper vigilant, hyperactive, withdrawn or depressed, may have sleep difficulties (including insomnia, restless sleep and nightmares) and anxiety. In general, these children may show some loss of previous functioning or a slow rate of acquiring new developmental tasks. Children may act in a regressed fashion. In addition, many of these children have persisting physiological hyper-reactivity with resulting fast heart rate or borderline high blood pressure.
Unfortunately, a great majority of children who experienced a volcanic eruption also have a concomitant major disruption in their way of life, their sense of community, their family structure and are often exposed to a variety of on going provocative reminders of the original event. All these elements increase the reactive fear. Particularly in the case of a volcanic eruption these situations are linked to the role of the mass media.
The effects of the post eruption can be considered by the children as traumatic as the event itself: the toxic ashes, the radio-active materials can be felt as elements that increase the reactive fear.
For this reason the psychologists recommend integrated interventions between volcanologists, psychologists, social operators and the mass media before giving information about the disastrous effects after a volcanic eruption.

Ifestiophobia

In case of volcanic eruption children can also develop the Ifest?ophobia syndrome.
Ifest?ophobia is the fear of the intense fury of volcanoes. This naming strategy involves taking the Greek word for fear (Ifest?o) and combining it with the designation phobia. It is a persistent and complex fear surrounding the molten display of fire, lava and ash.
Ifestiophobia means fear the heat, potential death and the knowledge that this is a natural event without control over. The defence mechanism is to avoid the object of fear while expressing panic over the pending loss of personal control.
If a person who fears volcanoes is forced by life situations to live near a volcano (active or dormant) there may be the persistent worry that the volcano will erupt at any time. They may cast a wary eye toward the volcano - even when it simply appears to be nothing more than a mountain peak. These individuals will also insist on fleeing if and when they hear that the volcano has become active.
Other symptoms may include…

- Heart rates that are erratic or elevated
- Air hunger
- Panic attacks
- Nausea
- The feeling to be dying
- Elevated body temperature
- Sense of dread
- Repetitive dreams about volcano eruptions

Some of the best ways to overcome the fear of volcanoes is to understand more about them. The truth is if an evacuation is requested in the area of an active volcano there is generally no loss of life. There may be issues of cleanup from falling ash, but technology now provides a means of determining the potential of volcanic activity and appropriate steps can be taken to alert the public.

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Internet resources

1. **http://www.tulane.edu/~sanelson/geol204/index.html**
2. **http://www.usgs.gov**
3. **http://www.jma.go.jp**
4. **http://www.volcano.si.edu/info/products/eqerupt/eqerupt.cfm**
5. **http://www.wikipedia.org/**
6. **www.elsevier.com/locate/geomorph**