SUBSOIL

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Introduction

The solid part of the Earth is made of rocks that can be collected directly from the Earth's surface or that can be extracted from mines and by deep drilling both on dry land and on the ocean floors. The rocks can be those forming the mountain we climb up, and can also be formed by deposits created by a large number of fragments, cemented together, that we walk upon every day. Rocks are formed from the combination of a number of minerals, solid substances defined by a precise chemical formula that can be found in nature. Consequently the study and analysis of rocks and minerals is very important because it enables us to define the structure and the composition not only of the Earth's surface by also what lies inside the Earth.
Hydrocarbons are a particular type of sedimentary rock, present in nature in the solid, liquid and gaseous form, as bitumen, oil (petroleum) and gas respectively. Since a long time, man has learnt to exploit these resources. In particular, in the energy section, we shall examine in detail how these deposits are utilized and how important they are.
The mineral resources are important for industrial development. These consist of minerals or rocks whose concentration is suited for extraction and utilization by man for various purposes.
In the subsoil we do not only find rocks and minerals, but also another resource that is very important: water, that is concentrated mainly in the layer that is no more than 750 metres deep. As it is one of the principal resources that has enabled the development of life on the Earth, we have dedicated it a special section, which you can refer to for more detailed information.

Rocks and minerals

Minerals are solid substances that are present in nature and can be made of one element or more elements combined together (chemical compounds). Gold, Silver and carbon are elements that form minerals on their own. They are called native elements. Instead, ordinary kitchen salt is a chemical compound that is called rock salt, which is a mineral formed of sodium and chlorine ions. Atoms, ions and molecules that form a mineral are present in the space in a tidy way and according to well-defined geometrical shapes, which are called crystal lattices. The structure of the crystal lattice defines the shape of the crystal as we see it. For example, rock salt or kitchen salt is a mineral formed of cubic-shaped crystals. Its crystal lattice has the same shape and consists of sodium and chlorine ions that are present in the space in alternate order.
The order of atoms in the space and the way they combine with each other determine the way a mineral can laminate or exfoliate. Lamination is the property that some materials have to break according to their geometrical shape. Its chemical composition also determines the colour of the crystal, such as the yellow colour for the topaz, red for ruby, purple for amethyst quartz. Another characteristic of minerals is their hardness, which is their resistance to scratches. Hardness is classified by numbers (from 1 to 10), according to the Moh's scale.

At the beginning of the scale there are very soft minerals that can be scratched with a nail, such as talc, chalk and calcite. At the end of the scale there is the diamond, which is the hardest mineral in nature. ite. All'ultimo posto troviamo il diamante che è il minerale più duro esistente in natura.

How many minerals do we know?

In nature there are many minerals: around 2000 species are known. Some of them are very rare, while some others are very popular. But only around thirty of them compose the Earth's crust rocks. These minerals are made up of several chemical elements that distinguish them. According to their chemical composition, minerals are classified into the following groups.

Silicates are very important: only 8% of the minerals that compose the Earth do not belong to this group. These minerals are always made of silicon and oxygen, which can bind with aluminium, iron, calcium, magnesium, sodium and potassium. A very important mineral that is present in the deepest layers of the Earth is olivine, which has a very compact and dense structure, as is made of silicon, magnesium and iron. Asbestos, mica, clay minerals, quartz, feldspars (like orthoclase and plagioclase) belong to this group.

The group of carbonates is made up of two important minerals: calcite, a calcium carbonate that forms calcareous rocks and dolomite, a calcium and magnesium carbonate that forms dolomite rocks. These minerals and their corresponding rocks melt in water, and form karstic landscapes and dolomitic mountain landscapes.

In particular environmental conditions, the evaporation of sea or lake water leads to the creation of chalk or rock salt (kitchen salt). This is the group of sulphates and salts.

When oxygen binds to other elements such as iron, oxides and hydroxides are formed. Some examples are magnetite, limonite, haematite, which form rocks with a yellow-red colour, and represent the main iron source of the mining industry.

Other important mineral deposits are represented by sulphides, minerals containing sulphur and iron, like pyrite. Sulphur together with iron and copper leads to chalcopyrite. Sulphur together with lead originates galena, while sulphur and mercury results in cinnabar gold, silver and copper are deposits made of only one element. This is why they are called native elements. Both diamond and graphite are exclusively made of carbon, but they differ from the commercial and crystal structure point of view, as explained in the corresponding paragraph.

Diamond and graphite. Carbon is a native element that, on its own, forms two very different minerals: the diamond (precious stone) and graphite. The diamond is the hardest mineral in nature, as it is made up only of carbon atoms with very strong chemical bonds (covalent bonds) that are present in the space forming a tree-dimensional crystal lattice. Also graphite is a mineral that is only made up of carbon atoms, but their bonds create horizontal layers, as if they were building floors. The different floors are linked by weak chemical bonds and form a mineral whose layers easily break. The environmental conditions during mineral formation and in particular the different temperatures and pressures determine the way carbon binds to other carbon atoms.

Rocks

The 2000 known minerals can form an endless number of combinations and give life to an extremely high number of rocks. The processes that lead to the creation of a rock do not separate the different minerals the rock consists of. As a consequence, it is difficult to find rocks consisting of one single mineral. We will see that rocks are a mixture of different minerals; only those minerals that are present in a higher quantity identify the type of rock. For example granite is a magmatic rock that consists of many minerals, but especially quartz, feldspars and mica are always present in a large quantity.

The process that leads to rock formation is fundamentally important, therefore rocks are classified according to how they were formed:

- magmatic or igneus rocks derive from the cooling of a mass of minerals in melted state (magma). Those minerals are mixed with gas substances during a process called magmatic process;
- sedimentary rocks consist of rock fragments that have been accumulated during a process called sedimentary process;
- metamorphic rocks are rocks that underwent modifications during geologic ages. The process that describes these changes is called metamorphic process.

The oldest rocks on Earth. Planet Earth was formed 4.7 billion years ago, and at the beginning of its history it only consisted of material in melted state. Melted state materials are distributed at different distances from the centre of the Earth according to their density: the lightest materials occupy a layer that is close to the surface; they cool down and transform into solid compounds. These solid compounds are the oldest rocks on the Earth.

Magmatic rocks

2/3 the Earth's Crust are made up of magmatic rocks that derive from the cooling of a mineral mass in melted state, mixed with gaseous substances. The mixture is called magma: it consists of different minerals that belong to the group of silicates. The gradual cooling of the magmatic mass leads to the crystallization of minerals and rock formation. Crystal structures form more easily when the magma contains gaseous substances, which are retained more easily when the rock originates inside the Earth. In this case the cooling process is slow and gradual and leads to the creation of intrusive magmatic rocks. An example of it is granite, a rock whose crystals (belonging to different minerals) can be seen very clearly. Another example is diorite.

When the cooling process occurs on the surface, it is characterized by a sudden temperature drop. The gases contained in the magma disperse into the atmosphere; their change into solid state takes place all of a sudden and the rock is made up of very small crystals. These rocks are called magmatic effusive rocks. Examples are basalt, rhyolite, andesite, which are used in the building sector for road flooring and railway ballasts as they have a uniform colour. The colour depends on their structure where the mineral crystals are not visible. The rock that derives from the most rapid cooling of magma is called obsidian as it has a "vitreous structure", while another

very particular rock is pumice. This rock derives from a magma that has lots of gases and that hardens before the gases can disperse. Its structure is porous and the various pores, due to gas bubbles, make the rock so light that it floats on the water.
The first magma mineral that hardens at very high temperatures is olivine, that is present in large quantities in the internal layers of the Earth. Closer to the Earth's surface, magma temperature diminishes and minerals with lots of silica are formed: amphiboles, biotite, feldspars, muscovite and quartz: these minerals form magmatic rocks that are located close to the Earth's surface.
Can we see intrusive magmatic rocks? Deposits of intrusive rocks originated deep underground and are surrounded by other types of rocks that can be altered by erosive phenomena occurring on the Earth's surface. As a consequence, intrusive magmatic rocks are located on the Earth's surface. The same thing happens when a mountain chain is formed, and tectonic movements lift deposits of intrusive rocks. Those deposits of intrusive magmatic rocks that are visible on the Earth's surface are called plutons or batholithes.
Where does the magma form? The magma originates on the mantle, at a depth of 100 kilometres, at a particular temperature and pressure conditions. After it is formed, the magmatic deposit can keep still for long periods of time, and only with temperature rises or pressure reductions it moves towards the Earth's surface. This deposit feeds the volcanoes. During eruptions the magmatic material is expelled outside and acquires the name of lava.
Lava. When it is very fluid, lava is expelled from the volcano without any explosive phenomena. It reaches a temperature of 1200°C and moves on the ground with a speed of up to 100 kilometres an hour. The presence of gas and silicon favours the volcano explosive activity: the magma is broken into pieces and the surrounding rocks are fragmented and violently launched into the air. The fragments are called pyroclasts and according to their size, it is possible to distinguish between: dusts (very fine), ashes, lapilli, bombs and blocks (big dimensions). Lava blocks are launched even at 10 km of distance, where they accumulate and form pyroclastic deposits, which are sedimentary rocks.

Sedimentary rocks

The action of water and air tends to transform and demolish the minerals that are contained in the rocks, by causing their disintegration and forming fragments of different size that are called debris. Debris are transported by rivers, sea water, wind and glaciers and then accumulate on the Earth's surface depressions to form melted deposits. With time passing, transported sediments accumulate and compress the already-existing sediments underneath. Compressed debris are subject to a pressure that provokes the loss of water contained in the fragments. As a consequence, the material progressively becomes more compact. Some mineral substances melt in the water and deposit in the space between the debris, creating a "cement" that keeps them together. It takes millions of years to form a hard and compact rock through the so-called compaction and cementification of melted sediments. Physical and chemical processes are called diagenesis, which is more active in some specific periods. This leads to the creation of deposits made up of layers that can be easily seen on canyon walls or on the Dolomites.

Where are they located? Stones of different dimensions are located at the bottom of the mountains. The sand, clay, gravel and round stones that are located along the rivers are clastic sedimentary rocks. In particular, when gravels are kept together by fine sand, they is called conglomerates. Pyroclastic rocks are sedimentary rocks formed of lava fragments produced by explosive volcanic eruptions and then deposited on layers.
Organogenic rocks are very important and originate from the shells of sea molluscs. Ocean floors are covered by mud formed of planktonic organism shells such as foraminifers, radiolarians and diatoms. Other types of organogenic rocks are created by the activity of sea organisms: polyps of madreporaria build their calcareous skeletons to form coral reefs. The Dolomites are a spectacular example of coral reefs, once submerged into the ocean and now huge mountains. Some blue algae, instead, are able to extract calcium carbonate from the water and deposit it, building dome-shaped structures made up of many layers: stromatolites. Remember that the accumulation of plant material forms fossil coal.
Inside karstic caves, close to water springs or waterfalls, calcium carbonate deposits and forms stalactites, stalagmites, travertine, alabaster, while deposits of water-insoluble minerals like iron and aluminium form laterites and bauxites.
These are chemical sedimentary rocks that derive from a depositing process originated by chemical reactions. Also minerals like calcite, rock salt and chalk deposit in the sea or in a lake after water evaporation, as it happens in the Red Sea, in the eastern part of the Mediterranean and in the Dead Sea, forming evaporites. Evaporite rocks can be found in Emilia Romagna, Sicily and Marche region. They were formed 6-7 million years ago, when Europe got closer to Africa and the Strait of Gibraltar (that guaranteed water exchange between the seas) closed. The Mediterranean water evaporated, new evaporite deposits were created and new lands emerged.
Flint and its varieties like opal (valuable decorative stone) are siliceous decorative stones, made of microscopic quartz crystals. They originate from the accumulation of both marine and fresh water organism-shells. Those shells, like radiolarians and diatoms, are made of silicon.

Metamorphic rocks

Sedimentary and magmatic rocks, when tectonic movements occur, can be dragged to high depths and find themselves at extreme temperature and pressure conditions, which transform their crystal structure. This process is called metamorphic process and transforms sedimentary and magmatic rocks into metamorphic ones. For example, carbonate rocks that are subject to the metamorphic process form marble. Sandstones and clay transform into gneiss rocks.
Can rocks transform? The Earth’s crust continuously evolves because rock transformation processes are constantly active. Superficial rocks (sedimentary and magmatic) are transported into soil depth and transformed into metamorphic rocks. If high temperatures are reached, rocks melt and transform into magma. When the magma cools down and goes back into solid state, magmatic rocks are formed. Deep rocks can be brought back to the surface, eroded and form fragments that will represent the deposits of sedimentary rocks.

Internal part of the Earth

The Earth is a spherical body that is made up of several internal layers, with a different thickness (crust, mantle, external nucleus, and internal nucleus). The passage from one layer to another is characterized by discontinuities:

- at 30-40 km of depth, the crust is divided from the mantle by Mohorovicic or Moho discontinuity;
- at around 2900 km of depth the mantle is separated from the external nucleus by the Gutenberg discontinuity;
- at around 5100 km of depth the external nucleus is separated from the internal nucleus by Lehman discontinuity.

The crust. The crust is the most external layer of the Earth. It is divided into earth and ocean crust. Continental crust has an average thickness of 40 km and is made of magmatic rocks (granites) and metamorphic rocks. The superficial layer of continents is mainly covered by sedimentary rocks. The ocean crust is less thick, as it measures around 6-8 km thickness and is made of different types of igneus rocks. In fact the first layer is made of basalts and then, underneath it, there are gabbro and metamorphic rocks. The surface of the ocean crust is also covered by sediments.

The mantle. The mantle is a layer that mainly consists of magmatic rocks (peridotites), which are denser than the gabbro and basalts that form the crust. The minerals that compose these rocks are fundamentally olivine and pyroxenes. The speed and direction of seismic waves through the mantle experience sudden changes showing that rocks are not always solid. Let us remember that magma originates at a depth of around 100 kilometres. In fact, between 70 and 200 kilometres of depth (immediately under the crust) there might be melted rocky material.

The nucleus. The behaviour of seismic waves brings up the hypothesis that the external nucleus could be composed of melted rocks, since it has the same characteristics as a liquid material. Researchers think that it is full of iron mixed with silicon and other metals like nickel. The internal nucleus, instead, behaves as a solid material, as it is rigid and elastic: it seems to be made of solid rocks.

Earthquakes

An earthquake, as the word itself describes, is a quake or a movement of the Earth, also known as seism from the Greek word that means shock or tremor. The Earth is a planet that is “alive”, it moves continually under our feet due to its internal dynamics and the tectonic processes. In fact the coasts of America and Europe separate a few centimetres every year. Normally the movements take place in a continuous imperceptible manner, however at times, due to the resistance opposed by the rocks, the thrust and tectonic deformations accumulate progressively like loading a spring. When the resistance of the rocks is exceeded, suddenly there is a break, and a movement along the surface of the fracture: this provokes a sudden release of energy that then spreads inside the Earth, producing a series of vibrations, the seismic waves, till they reach the surface. It is here that we note the often destructive, at times catastrophic effects of the earthquakes. The points where the rocks break and move are known as faults, the surfaces may at times be immense, kilometres long, where different rocks and also entire continents, pushed by the tectonic forces, come into contact with one another, and are deformed up to the final breakage. The size of the faults varies greatly – from enormous scars that cut across our entire planet, marking the points of contact between the various lithospherical plates, to small surfaces of only few square metres. The energy of an earthquake, however, not only depends on the extension of the surface but also on the amount of movement and the amount of energy that had accumulated before the breakage. Generally, however, seisms of a greater intensity are located near the larger faults. Together with these, usually smaller superficial movements occur, which may provoke seisms of a minor intensity, at times as a consequence of a more important seism, as in the case of the ground settling after shocks that follow the main event. The earthquake that occurred some days ago in Indonesia could in fact be of this type, a secondary movement, even though of great intensity, following the very big earthquake in December. Very active faults, that move continually, may seem dangerous because they generate a large number of small earthquakes, however the faults that do not move much and therefore get "loaded" very slowly with large quantities of energy are the ones that must be feared most.

Why here?

Studying the distribution of the bigger seisms, with the patient collection of thousands of data, in the Sixties, a map was created for the entire planet. This map shows that the earthquakes are not distributed at random, but the more frequent ones, with the greatest intensity, are distributed in very precise belts. Comparing this map with the map of the margins of the lithospherical plates or layers (the large rigid blocks, which the most superficial part of our planet is subdivided into, that move, and drift on the underlying plastic mantle), it can be seen that the distribution of the earthquakes, almost perfectly outlines the limits of the plates. However there is even more: if the earthquakes are divided according to the depth in which they occurred and the energy that was released, it can be seen that the more superficial and less powerful earthquakes are located near the ocean ridges (diverging plate margins) where the plates separate from each other and where the crust is thinner (3-5 km) and, breaking, allows magma to rise from the Earth's mantle, and the formation of submarine volcanoes. The deeper earthquakes, the ones that release a greater quantity of energy, instead, are located in the areas where the plates collide (converging plate margins): in this case the margin of one of the two plates is forced to slide under the other one, in a process called subduction, till, slowly heated, it is reabsorbed by the mantle in a kind of large "recycling" circuit of the lithosphere. Earthquakes in these areas are the result of the friction and deformations that the forced sliding of a plate under the other one produces, and the maximum depth of these earthquakes indicates the depth where the subducted plate is still rigid enough to break, thus giving origin to a seism: the maximum depth registered for these earthquakes is 640 km. Through a study of the earthquakes in these areas, it is possible to "follow" the sliding process of a strip of lithosphere towards the mantle: earthquakes are distributed along an inclined plane called the Wadati-Benioff plane, whose name comes from the researchers who first identified it, drawing the profile of the descending plate almost perfectly. It is therefore clear that the distribution of earthquakes is surely not a casual event and there are areas of our planet in which these events more than a risk are a certainty. For this reason it should not surprise us if seisms are repeated in the same areas. What happened in South East Asia is simply the consequence of the collision of the Pacific Ocean plate and the complex system of small plates to be found between Indonesia and the Philippines. Along the western coasts of Indonesia is one of the deepest trenches in the planet, the Java Trench, near which the subduction of the plates one under the other takes place, leading to the formation of the islands of the Indonesian archipelago. Observing the atlas, we can understand where the lithosphere plates collide and one of the two slides below the other. In fact if one observes the Pacific coasts it is possible to see numerous groups of islands with a typical arc shape, characterized by strong seismicity and intense volcanism; this indicates the presence of subduction plates. It is not a chance that volcanoes and earthquakes are often connected: the presence of an active volcano implies a constant high seismic risk. The study of the Earth's surface therefore gives us precious elements and proofs of a possible seismic and volcanic risk.

Measuring the released energy

In Italy, the energy that is released by an earthquake is often calculated using the "Mercalli scale" (actually it is a modified Mercalli-Cancani-Sieberg scale). It is one of the first scales that were elaborated in order to evaluate the intensity of seisms, when more precise instruments were still not available (the first version of the Mercalli scale dates back to mid 1800) even though it is still commonly used today. However this is not a real "measurement" of the energy that it is released. In fact it is based on an assessment of the damages caused by the earthquake. These certainly depend greatly on the intensity of the seism, but are also conditioned by geological factors (such as the type of rocks or the presence of loose sediments, the types of constructions that have been affected, population density, advance warning given, the time in which the earthquake occurred (it is well known that at night there is a greater number of victims), and also if the population is used to the experience of earthquakes (during the recent tsunami in South East Asia, many people were saved due to the awareness of some Japanese tourists who, knowing the phenomenon well, advised those who were present to move away from the beach): a seismic event of the same intensity in a town with a high population density without antiseismic constructions will certainly cause greater damages than in a city with few inhabitants or built with suited antiseismic criteria. For this reason seismologists discourage people from using this scale, and prefer to use other types of scales that are more objective, as for example the Richter magnitude scale. This scale, which was adjusted by Richter and Gutemberg in the Forties, is obtained by measuring the maximum amplitude of the waves drawn by the seismographs. This amplitude, is used with suitable formulas to calculate the quantity of energy that was actually released by the earthquake. It is a scale that potentially does not have a maximum level because it only measures the intensity of earthquakes that have occurred: the highest level ever recorded was 9.5 in 1960 in Chile. However nothing prevents even greater earthquakes from taking place. The Richter scale is a logarithmic scale, therefore a degree of difference in magnitude is equivalent to a wave amplitude that is approximately 10 times greater and energy that is released that is 30 times greater, two degrees are equivalent to an amplitude 100 times greater and an energy 900 times superior and so on. Therefore you can see how the energy of earthquakes can be very different and in some cases, can be frightful. To have a vague idea of the energy that is involved, it suffices to think that an earthquake of magnitude 9 has an energy of 2 $x10^{18}$ joule, where the energy used every year in the entire USA amounts to 6×10^{19} joule!

Energy released on the surface

The energy released by an earthquake propagates into the rocks of the Earth's crust and lithosphere through two types of seismic waves – P waves or primary waves, so-called because they are the first ones to reach the seismographs, and S waves or secondary waves, which are slower. P waves are compression waves, similar to sound waves. When the internal waves reach the Earth's surface, they are modified and propagate using different mechanisms. These are the waves that we feel and the ones that provoke the greatest damage. Normally undulatory or sussultatory types of vibrations are felt. The latter, which have a strong vertical component, are the ones that potentially cause most damage. Together with the moving waves, often earthquakes are accompanied by strong rumbling: this is the effect of the propagation in the air of the compression waves. These low-frequency sounds, often infra-sounds that are near the limit of the auditory threshold, in fact often produce that particular feeling of alarm and anxiety that can even be felt during mild earthquakes, that makes one immediately distinguish between a seismic tremor and the passage, for example, of a train, with equally intense vibrations. At times particularly sharp ears can hear these sounds of the Earth even many days before: some animals, for example, dogs, pigs, fish and snakes are particularly sensitive to these sounds and can help foresee earthquakes. The duration of the vibrations in general, is a few seconds, at times some minutes (the earthquake of these days in Indonesia, lasted approximately three minutes): the gravity of the destructions that take place depends to a great extent also from the duration of the tremors. Generally an earthquake is not an isolated event, but it is preceded and followed by a series of tremors of minor intensity. Repeated tremors or settling tremors often continue for months. Apart from vibrations, an earthquake generally also produces other effects, that contribute to making the situation even more dramatic. At times large amounts of water vapour are released and perturbations in the electromagnetic field take place: this can produce optical phenomena, such as light "domes", or electric phenomena such as lightning storms. At times gases are freed, often containing sulphur, and produce bad smelling fumes. The movements of the Earth's surface can also violently dislocate large masses of air, thus interacting with the atmospheric phenomena. In 1969, during an earthquake in Japan, a temporary rise, of 1.6 km, of the mass of air was observed, above the epicentre, at a height of 330 km.

Not only earthquakes

Earthquakes have a very strong destructive power, on one hand due to the direct effects of the vibrations, on the other because they can provoke numerous undesired effects, at times of a magnitude that is even greater than the damages provoked by the tremors. Very strong earthquakes can induce dramatic modifications in the landscape, setting off landslides, opening fissures in the ground, deviating watercourses and consequently causing floods and triggering off or summing to volcanic eruptions. Geysers of sand and mud, liquefied by the vibrations, may form, and their jet may reach over 6 metres in height. In the urban centres, destruction caused by seisms may lead to the breaking of gas pipes or oil pipelines, may provoke short circuits, causing fires or explosions. Many of the victims recorded, are due to the fires. When the hypocentre is in the sea, some types of movements may cause the feared tsunami waves, whose devastating effect is still under our eyes with the dramatic images of what occurred in South East Asia some months ago.

Some statistics. Every year, seismographs all over the world record over 600,000 tremors of intensities below 2 of the Richter scale, that can be perceived only by instruments. Other 300,000 earthquakes with an intensity between 2 and 2.9 can be felt only by persons who are particularly sensitive. 49,000 more earthquakes with a magnitude between 3 and 3.9, are felt by those who live near the epicentre, while 6,000 tremors, of intensities between 4 and 4.9 provoke minor damages. For the higher intensities, that always provoke damages, approximately 1,000 are of an intensity between 5 and 5.9, 120 between 6 and 6.9, approximately 14 with a magnitude between 7 and 7.9, while earthquakes with an intensity between 8 and 8.9 occur every 5-10 years. Fortunately, earthquakes of a magnitude greater than 9 are rare, approximately 1-2 times in a century. But these are only statistics, or annual averages – in South East Asia two seisms of a great intensity took place (greater than 9 and approximately 8.7) in around 3 months, which completely distorted the statistics, and this does not exclude that similar events might take place again in the short term.

Locating an earthquake

The hypocentre is the point, deep in the Earth, where the breakage that provoked the earthquake occurred. The epicentre is the equivalent point on the Earth's surface. Normally the area of the epicentre is the one in which the most severe damages are recorded, while the intensity of an earthquake decreases as one goes further away. By studying the time it takes the waves to reach particular stations placed at different distances from the epicentre, it is possible to determine the position of the hypocentre precisely, and also to identify the mechanism of movement that produced the earthquake. The seisms of a greater intensity naturally produce waves that can be felt very far away, at times they cross the entire planet and bounce several times along the various internal "layers" of the Earth. At times, on the occasion of the more powerful earthquakes, the Earth continues to oscillate for a number of days and the effects are so significant that some of the terrestrial parameters may be changed, as for example the inclination of the axis, as apparently occurred with the event of the 26th December. However, these are

events that do not bear any consequences on life on the planet, and if the events are measured by the instruments, they are not felt by most living beings.
The information collected during earthquakes of great intensity, have enabled the study and understanding of how the Earth is made inside, determining its structure in concentric “shells”, based on the type of waves and the speed at which these propagate in different materials. Disastrous and catastrophic events on the other hand can, at times, offer precious insights in the study of the behaviour of our planet, and enable us to build forecasting models for the future. For this reason, rescue teams work to bring aid to the affected populations alongside teams of seismologists and geophysicists who are always, silently, at work to better understand the behaviour of our restless planet.

The course of history

Earthquakes are linked to geologic and tectonic situations and therefore tend to recur in time and in the same areas, often in a similar manner. It is very important, therefore to collect the historical data of seismic events that date as far back as possible in time. Some geological studies also enable the reconstruction of seismic events of the even more remote past, through studies, for example, of particular forms of the ground, ancient landslides, or the breakage of concretion inside caves. In this manner, maps of the seisms of the past are drafted for every region, enabling the creation of general seismic risk maps, which illustrate the so-called seismic zoning. For each area it is important to note the intensity of the different seisms that occurred in succession, in order to determine the “periodicity” of the seisms of greater intensity. In practice, the statistics of the more intense events are elaborated, and a forecast is made determining after how many years an earthquake of a certain magnitude has occurred. The earthquakes of a greater intensity generally have a longer periodicity, that can be measured in years or decades or centuries. It cannot be exactly forecasted when an earthquake will take place but it is known that it will occur within a certain amount of time, so the more time passes, the greater the probabilities that certain events might take place. If the Earth remains quiet, therefore, it must not mean we can stay off-guard – but rather, the contrary! A classic example is the San Andreas Fault in California, one of the most studied seismic zones. The San Andreas Fault is over 1000 km long and 32 km deep. It is where the North American plate clashes with the Pacific plate – here the calculation of the periodicity for a recurring seism of great intensity is estimated to be 100-150 years. The last event of a great intensity occurred in 1857, therefore it is increasingly probable that a strong earthquake might take place now or in a few years time. Therefore the wait has begun for what the Californians call “The Big One”. Other studies have highlighted an increase in the microseismicity and deformations around the zone of the fault, these are all precursory signs of a subsequent important movement: it is therefore estimated that there is a 60% probability that a violent earthquake may occur in the next 30 years. The Big One is awaited, hoping everything is ready to face it!

Seismic zoning

If the periodicity of earthquakes in a particular zone is known, all human constructions must bear it in mind and opportune defences must be carried out, first of all the realization of anti-seismic constructions. Examples of anti-seismic constructions are extremely old, as may be observed, for example, in the walls built by the Incas in Cuzco, Peru. An anti-seismic construction, naturally, cannot resist against all possible earthquakes – in order to be truly safe, it is sufficient (and necessary) that it is able to resist an earthquake of the highest intensity registered in the region. An earthquake of an unusual intensity, however, although not very probable, may still occur, thus thwarting all the preventive efforts – for this reason, for those living in areas with a strong seismic activity, it is necessary to learn to live with a certain degree of risk. An example of this can be seen in a country like Japan, that is prepared and equipped to face most of the earthquakes, which however at times incur severe damages, notwithstanding the rigorous building regulations. Notwithstanding all the precautions, therefore, it is practically impossible to eliminate seismic risk. Furthermore, in many zones, including many areas in Italy, the criterion used to adapt anthropic structures to the seisms of maximum intensity ever recorded, would entail prohibitive costs for all human structures. Therefore the periodicity of the major earthquakes is taken into consideration. If this interval is very long, in other words hundreds of years, or even many decades, it might be economically more advantageous to build with less restrictive criteria, bearing well in mind however that the duration of the construction will not be able to exceed the periodicity of the more intense seism. This is particularly true for structures that are not designed to last in time, as for example a dam or a bridge, which however generally require updating after a few years and a great amount of maintenance. It is this criterion that will enable the construction of the much discussed bridge over the Strait of Messina. Simple, isn't it? Unfortunately in this approach there is a terrible illusion, the periodicity that is calculated using statistics, is an average; on average, there are, let us say, two seisms of magnitude 7 in a century – one every 50 years. Therefore, what is the conclusion? Nothing is certain, as in the case of the numbers of State lottery game, the same number can be extracted twice in a row, and then not be extracted for several months, likewise two earthquakes of magnitude 7 may occur in two months, and then nothing else for the following 100 years. Therefore to decide the level of risk that is acceptable and the resistance criteria for the constructions in order to colonize an area calls for very delicate choices. Building with anti-seismic criteria is very expensive, and it is even more so to redesign existing structures, therefore in purely economic terms it could be more advantageous to let a scarcely probable event take place without having taken adequate measures or having taken measures that are not sufficiently efficient, and then reconstruct, according to the statistics perhaps, once every 100 years… The problem is to succeed in evaluating the probability factor correctly, and on the other hand consider the weight of the social costs: the loss of human lives, in fact, has no price, not even once every 100 years…

Is a forecast possible?

Apart from the forecasts that can be made on the basis of statistics, the analysis of events that took place in history, have shown that the movements that generate an earthquake usually are not sudden, but are preceded by a series of premonitory signs, and if these are noted in time, they can help to foresee the onset of the event. Unfortunately, however, these signals are often feeble and can only be recorded instrumentally, and often they are hardly noted. Furthermore none of these can exactly forecast the date and time of an earthquake, which makes it very difficult to programme the alarms and the necessary evacuation of the population, sometimes even many months before the event. Quite often cases of alarms given immediately, perhaps too early, were later withdrawn because they were apparently without foundation, and were then followed by the pre-announced seismic event. At times the uncertainty of the forecast is considered a negative forecast, in a field in which a conditional response is a must, just as it should be for patience. In fact which one of us would be ready to abandon his home and job for a few months because "perhaps" there could be an earthquake in the vicinity?

Among the more common premonitory signs, which are also the most confirmed signs, there is an increase in the low intensity earthquakes, the so-called microseisms, that can only be recorded instrumentally, accompanied by deformations in the crust, the opening of small fractures, movements along the faults at times marked by an increase in the number of small landslides, some variations in the property of rocks, such as an increase in electric conductivity due to the formation of microfractures, the liberation of particular gases such as radon, caused by the microfractures, the increase in the level of the water table, that is easy to monitor by checking the water levels in the wells. The problem is that often these phenomena do not occur together and they almost never are of an intensity that is high enough to attract attention, and even worse, many very intense seisms occur without even one truly apparent precursory symptom. Many animals, and at times, some people, are able to feel the nearing of an earthquake, probably because they are sensitive to the variations in the electromagnetic field that precede an earthquake, or because they can hear the infrasounds that are tied to the propagation of seismic waves. Here, though, we are entering the field of "premonitory signs" more than forecasts, therefore, if no instrumental monitoring systems are present, it is difficult to rely on the state of agitation of Fido the pet dog or of the fish in the garden pond: it is difficult to analyze whether it is all due to the nearing of an earthquake or only because of a wandering kitten in the neighbourhood.

Therefore it is quite difficult to make accurate forecasts, specially in precise terms of hours or days. In China, one of the greatest earthquakes ever registered was forecasted 5 years before, however this was not sufficient to save the 250,000 persons who lost their lives, perhaps because of the long, excessive lapse of time between the alarm and the event.

International alarms

In Italy there is a network of stations for monitoring seismic events, managed by public research organisms and universities. In particular, the *Istituto Nazionale di Geofisica* (Italian Geophysics

Institute) manages the 32 national monitoring stations distributed across the Italian territory and connected in real time to the central office in Rome. Since 1981 there is a National Group that studies the problems inherent to defence from earthquakes, promoted by the Council of Ministers, while the *Servizio Sismico Nazionale* (Italian Seismic Service) has the task of monitoring the application of the seismic law that regulates building laws in seismic environments. A seismic classification of the entire territory has been elaborated and is also updated constantly, over 8000 municipalities have been subdivided into 3 different levels of seismic hazard, which involve precise building restrictions for constructions and anthropic structures. Together with the Civil Protection Office, intervention plans have been laid out in case of particularly severe seismic events.
Seismic monitoring networks in many countries worldwide are, or should be, in constant contact with each other, so as to establish an efficient connecting and warning network. Often these warning systems are efficient, as for example in the case of the tsunami monitoring and warning system for the Pacific, while in other cases coordination is very difficult, as it was dramatically seen in the events that took place in December 2004. The recent earthquake in the same area instead, showed, how with a minor level of cooperation and a minor financial commitment it was possible to warn the populations of the entire area of the risk of a tsunami. The fact that subsequently, this time, whimsical nature did not create a “killer wave”, surely must not be an invitation to stand off-guard!

And in Italy?

Italy, as it is well-known, is a country that is particularly exposed to seismic hazard. The Mediterranean, in fact, is closed between the grip of two giants, Africa and Europe, which are inexorably drawing closer to each other. The contact between the two plates created, in the past, the Alpine chain of mountains, therefore it is evident that the forces that are involved are certainly not negligible. There are important subduction zones, as in the Alpine mountain range, under the plains of the Po river and in a strip that extends from Sicily to the Aegean Sea. The raising of the Apennine mountains, pushed against the Dalmatian coasts, and the presence of numerous zones of intense volcanic activity, are often, but not always, tied to the clashing of the plates of the Mediterranean, making our country (Italy) a zone of very high risk in which to live. In the past 2000 years, thousands of earthquakes have been recorded, of which at least 150 of great intensity, with over 450,000 victims (equal to 10% of the victims of equally intense earthquakes worldwide). Only Sardinia and the Salento peninsula are historically “immune” to earthquakes (even though, naturally, they are affected by the earthquakes in other areas). In the Alpine Mountain range, seismicity is relatively low, with the exception of the Trentino, Friuli and Piemonte regions, while all the remaining regions of the Italian peninsula are classified high seismic hazard zones, in particular the Central and Southern parts of Italy, where in the Campania, Basilicata, Calabria ad Sicily regions, approximately 50% of the historical earthquakes have been recorded.

Subsoil: a resource

Easily pliable limestones, sandstones and igneus rocks are often used for some specific constructions, like frames, building fronts, columns and pillars. In some rustic buildings, especially on the mountains, thin natural layers made of slate are used instead of roof tiles.
For extremely elegant buildings or monuments, marble, tufa and alabaster are widely used.
As a precious covering, sedimentary rocks with very pretty drawings are used. They are called “onyxes”. Magmatic rocks, metamorphic and especially calcareous rocks, which can be easily polished and are resistant to tear and wear are widely used for interior flooring. Instead, for road flooring, river stones or even more resistant rocks like granites, porphyries, syenite and gneiss are used. Gravel and crushed stones are used for roadbeds and railway ballasts (the ground where asphalt and tracks are set). In order to protect riverbanks, lake or sea shores, big heavy and very resistant rocks are usually used, especially compact and dark effusive and metamorphic rocks.

Iron working

Pure iron is very rare in nature. It can be found more frequently in combination with other elements inside minerals. These minerals are called iron minerals. Among them, the most important ones are haematite, pyrite and siderite. The first stage of iron mineral working occurs in hot furnaces and leads to the creation of a particular product that is called cast iron.
The hot furnace is made up of two cone trunks whose bases are interconnected and that have a cylindrical support. The furnace is 20-30 metres high and has an 8-10 metre diameter. Iron minerals, coal and fluxes (special materials that are used to eliminate that part of the minerals that cannot be used) are supplied from the top. (See image “Hot furnace”) From cast iron, through a “de-carburisation” process, steel is obtained. With a further “de-carburisation”, ductile iron is formed. De-carburisation is a cast-iron refining process. Carbon and impurities like silicon, phosphorus, sulphur and manganese are removed from the cast iron.

Bricks and ceramics

Clay is used as a raw material for different industrial productions, in particular for the production of bricks and ceramics (mainly bricks, roof tiles and tiles). Also bentonite is important from the economic point of view. It is a special clay deriving from the alteration of volcanic ashes in a lake environment. Bentonites are used for soil drilling (as they are able to support the hole walls), to build casting moulds in foundries, or as catalysts in oil cracking processes.
Another economically important group of clays are “fire-clays”, which are used for the production of refractory ceramics. These products resist at very high temperatures (more than 1500 °C) without being subject to any shape or volume modification.
Clays are used for many other productions: in the paper industry as a raw material for paper coating, for the production of insecticides, rubber, linoleum, and paintings.

Rocks as insulators

Asbestos is a material that was frequently used as an insulator in the past. In fact, asbestos is particularly resistant to high temperatures, and it is used for the production of cartons, fabrics and fireproof ropes. Since 1994 any use of asbestos has been prohibited, as this material releases hazardous fibres into the air, provoking serious diseases to the respiratory system. Vermiculite and perlite have been used more recently. Vermiculite is a mineral that is extremely full of water and that is "expanded" as a result of heating at 900 – 1000°C. In this way the water is rapidly expelled and the mineral, that becomes extremely light, can be used as an insulating infill for wall cavities (the space between two nearby walls that is created in order to be filled with insulating material). Perlite is an effusive rock that is used for plaster together with chalk, cement and lime. Also pumice, a volcanic rock that is full of cavities, is often used as a thermal and acoustic insulator, after being milled and mixed to mortars.

Some types of basalts are melted at 1300 °C in order to obtain a particular vitreous material that is called "mineral wool". This material is used as a thermal insulator, as it has the capacity to resist at temperatures around 1000 °C. Since it is an excellent acoustic insulator, it is widely used in modern buildings.

Cement and chalk

Binders are products that are used in the building sector. These substances, mixed with water, allow to obtain mortars that, after a particular chemical phenomenon (called "setting"), hardens and acquires mechanical resistance. Binders are classified into aerial and hydraulic binders, according to the kind of setting they have. The setting occurs when getting in contact with air or water. Limestones are raw materials for the production of lime, which is used to obtain the popular mortar that is largely applied in the building sector. Hydraulic limes harden both in the air and under the water, therefore they have "hydraulic" properties. This particular type of limes is obtained by firing marly limestones, i.e. calcareous rocks containing clay. Pozzolana is a volcanic tofa (a rock resulting from the cooling of magma that comes out of the subsoil during volcano eruptions) that contains both small grains of vitreous substance and different kinds of silicates. If pozzolana is mixed with lime the result is a binder with hydraulic properties. Rocks made of limestone with 25% of baked clay at 1500 °C lead to the production of one of the most popular hydraulic binders, which is called Portland cement. Natural chalk is used to prepare rapidly hardening chalk and filling chalk.

Glass

The main raw material to produce glass is silicon. Silicon is present in nature inside sand and in some compact rocks (quartzites). The sands that are used are very pure and fine. The materials, pulverized, are heated at 1200 – 1400 °C for a few hours. Then, after a slow cooling, the mass is subject to moulding. The melted mass is moulded and, in order to prevent the product from breaking, it is necessary to gradually cool it down. The glass, completely cooled, is then subject to several refining operations.

Glass sheets without flaws can be used to produce mirrors. The reflecting surface can be obtained by applying a thin layer of white metal on the glass: the layer can be made of silver for precious mirrors, lead for dark mirrors, tin and aluminium for ordinary mirrors.

Gems and precious stones

Diamond. The most precious gem is the diamond, made of carbon. The characteristics that make it so valuable are: its hardness, un-alterability, brightness and transparency. The most common diamonds are usually colourless. However the most popular ones tend to have a pale yellow or brown colour. Red, green and blue diamonds are extremely rare and expensive. India is the country where the first deposits were discovered. Now those deposits have been exhausted, while relevant quantities are still present in Brazil and South Africa.

Opals and emeralds. Opal is one of the most fascinating gems in the world thanks to its changing colours. The mineral is made of hydrated silica ($SiO_2.nH_2O$, this means that the mineral structure also includes water molecules) and it is shapeless. The most appreciated varieties are: noble opal, milky and with vivacious iridescence, harlequin opal, and fire opal, which is more transparent than noble opal and has a bright orange colour.

The turquoise variety has a cerulean colour and looks like porcelain. The most beautiful examples come from Iran, while the American turquoise variety is less valuable since it is more degradable. The name emerald comes from the Greek “smaragdos”, which means green stone. The most ancient deposits, exploited by Pharaohes, were located on the Egyptian coast of the Red Sea. At the moment, most of the production comes from Columbia, Brazil and the Ural Mountains. The green colour of emeralds is due to the presence of vanadium and chromium oxide.

Aquamarine, rubies, sapphires … Aquamarine, a sea-blue stone, probably owes its colour to the presence of iron. The main deposits are located in different areas of Brazil, Ural Mountains and Madagascar. Extremely small and clear crystals were found on the Island of Elba. Ruby and sapphire represent the most valuable varieties of corundum. The colour of ruby can range from pink to red, also very dark red. Ruby is one of the most precious stones and its colour derives from the presence of chrome oxides. Sapphire is less expensive and less precious than emerald and ruby. Its colour varies from light blue to deep blue and derives from the presence of titanium and iron. The main deposits of sapphire and ruby are located in Myanmar, Thailand and Sri Lanka. Topaz is a stone that can have different colours (light yellow, dark yellow, pink, red, light blue, greenish) and can reach big dimensions. The main deposits are in Brazil and Russia.

Mineral deposits

By mineral deposit we mean those areas where minerals and rocks are extracted to be later used by men. It is necessary to specify that, from a formal point of view, we can talk about mineral deposits only if the quantity and quality of rocks and minerals allow men to economically exploit the resource. Some metallic minerals that are exploited in the industrial field (for example mercury) are now present in limited quantities and areas and may be depleted in just a few years' time, making recycling compulsory or forcing to replace these substances with other ones.

Exploiting a deposit. Before starting to exploit a mineral deposit, a series of analyses must be carried out on the soil and subsoil in the area. This phase necessarily begins with a careful observation of the geological maps of the area concerned. A geological map uses different colours to show the area of each rock formation, highlighting the contact lines between rocks of different types and ages. The choice of a particular area, where a quarry will be located, depends on the quality and abundance of the rock, as well as the ease or lack of access to it via major lines of communication (railway lines, ports, motorways) in order to be able to easily and cheaply distribute the product. What drives this type of choice is mainly the economic calculation, which leads to locating activities in areas where the economic conditions for extracting and transporting the material are the most convenient. Even before mining begins, rock samples are taken and analysed in a laboratory to determine their physical and mechanical properties. Deposits may be worked by surface or underground mining. In open field cultivation, the soil is gradually excavated, starting from the top, thus building 10 to 20 metre high steps. When the resource lies at great depths, however, underground mining takes place.

Extraction activities in 5000 B.C. The first extraction techniques date back to the Neolithic period (5000 B.C.): the stone was extracted mainly with the use of sticks and picks. Around 3000 B.C., in Egypt, a new technique was adopted and it was still used until a short time ago in small caves without modern equipment. It consisted of inserting some wooden wedges into the cracks of rocky walls. Once they were wet, their volume increased and with their pressure they caused the rocks to come apart. This method was used in ancient times also by the Romans. Another technique consisted of inserting iron wedges by hitting them on the top with heavy sticks. At the beginning of the 18th century the use of explosives developed: dynamite was inserted into underground passages inside the rocks. This provoked a big quantity of stones to fall down. However this procedure resulted to be disadvantageous due to the excessive waste of material. It also resulted dangerous for workers.

Deposits and mines in Italy

In Italy most of the mines that existed at the beginning of 1900 have been closed. Quite large deposits of mercury (as cinnabar) are present on Mount Amiata, whose exploitation is finished in the 70s of last century, and fluorine minerals (fluorite) were extracted in Sardinia mines in Silius until few years ago. Instead, iron mines (located in Cogne, in Val D'Aosta region, on Elba island and Sardinia) and coal mines (in Sulcis area, Sardinia) have been abandoned due to the low concentration of minerals and high production costs when compared to other deposits abroad. More important is the production of the so-called "second-category" materials, like limestones, marble, granites, clays, travertine, sands, etc. In particular, Italy is the world-leading supplier of pumice stone, as its production accounts for half of the total world production. Extracted pumice stone mainly comes from Lipari. Furthermore, Italy is in second place in Europe and third in the

world for the production of feldspar and occupies the tenth place in the world in the production of talc (third in Europe).
The exports of natural stones (above all marble) all around the world are very developed. Marble in Italy is located in many areas. The most important geographical areas for the production of white marble is Tuscany, specifically on Apuane Alps. Lazio, Lombardy, Puglia and Veneto are other very important areas for the extraction of coloured marble.

Fossil fuels

Modern industrial society consumes high quantities of energy for heating, transport and industries. The main energy sources are natural fuels, and in particular fossil fuels. Fossil coals originate in the subsoil from plant material that come from ancient forests, subject to chemical and physical processes for millions of years. During that period plant material looses hydrogen, oxygen and nitrogen, but acquires carbon, therefore increasing its heating value. The younger coal, which still has a relevant content of water, is called peat. Anthracite, instead, has a high content of carbon and a high heating value. The process that leads to carbon enrichment continues until graphite is formed. Graphite is a mineral consisting only of carbon. These fuels are typical of lands that originated 280 – 350 million years ago (Carboniferous period), as the previous period had been characterized by the growth of large forests with wooden trunk.Hydrocarbons, instead, are a particular type of organogenic rocks and result from the decay of organisms without oxygen. These substances accumulate on porous rocks and can be present in solid (bitumen), liquid (oil) and gaseous (natural gas) state. They are very light materials that move up to the top through permeable rock layers. When a rock layer hampers their movement, they accumulate and form a deposit.

Metals

Men extract many minerals from the subsoil. Subsequently, by means of suitable refining techniques, the substances to build products, machines and tools are obtained. Metals are an example of this procedure: iron, copper, aluminium, zinc, cobalt, manganese, titanium, chromium and platinum can be worked easily and have the capacity to transmit electric power. In most of the rocks, the quantity of useful minerals is quite low. Therefore, the extraction is convenient only if the needed mineral has formed a deposit, and is present in a large quantity in a specific area. At the moment, the current situation of metal reserves rises many worries about the future. This is why people are now looking for new deposits.
In fact it was discovered that large quantities of metal minerals are present on sea floors. More precisely, they are “polymetallic nodules”, which are full of manganese and iron, with lower quantities of sodium, calcium, strontium, copper, cobalt, cadmium, nickel and molybdenum. Approximate estimates concluded that sea floors contain a reserve of around 2000 million tons of nodules from which precious metals could be extracted. This particular reserve is 1800 times as high as all mines on emerged land. Also clay, sand (for example silicon sands for glass production) and potassium minerals are extremely abundant.

Exploiting the subsoil

All the resources of the subsoil have the characteristic that they can be depleted in a more or less short period of time. Therefore also rocks and minerals cannot be extracted infinitely by man. And also for these, as in the case of energy, the recommendation is to use them in a cautious, efficient manner, without waste and specially, wherever possible, incentivizing material recycling.

Besides the problem of the limited availability of resources in the subsoil, there is a more general problem, which in some cases is even more important, i.e. the pollution that is associated with the extraction activities. In fact, among the various human activities that have a strong impact on the environment, we can surely point out the activities related to extraction of lithoid materials (clay, sand, gravel, stones, etc.) carried out near watercourses, on mountain slopes or on the plains. Very often the owners of the mines abandon the sites in a state of degradation that is so bad that they cannot be recovered. Since a few years various interventions have been promoted, aimed at cleaning up and reinstating the environmental conditions of these mines. The main scope is to reinstate the area that was previously excavated back in the surrounding environment, with regard to the landscape and with regard to the quality of the water and the soil near to the mine, that are often greatly polluted by the mine's extraction activities.

The best reintegration results have been obtained when the planned extraction activities of the mine already contemplated the recovery of the entire area from the very beginning, instead of awaiting the depletion of the extracted resource and the end of the mine extraction activities. In fact it is much harder to intervene afterwards. The restoration activities must be carried out, as far as possible, at the same time as the excavation activity, and must not be postponed to the end of the extracting activity. In doing this, the same machinery and equipment used on the site, can be utilized with an evident containment of costs.

Rehabilitation of a mine

If the open mine is in a plain, the excavated area can partly be filled with the topsoil that was removed previously and then covered with agricultural humus. For this reason, when exploiting the resources of a mine, attention must be made not to mix the topsoil that was removed and the waste materials. If instead the clayey bottom of an excavated mine comes in contact with the water table, the excavated area could be used to create a small lake. These basins, that are the residues of the extraction activities, can be allocated to sports fishing activities, hobbies, ichthyculture, irrigation uses, naturalistic oases or if they are quite large, to sea-sports. Examples of this are: the Parco della Fornace Carena park in Cambiano (TO) and the Unieco ecologic park, and the Fosdondo furnace in Correggio Emilia.

If the mine is on a mountain slope, the principal need is to reintegrate the excavated area back in the surrounding landscape, and at the same time guarantee the stability of the slope where the activities were carried out. Therefore it is necessary to rapidly grow a plant cover which will allow an efficient consolidation of the escarpment, and will also mitigate the erosive phenomena. Particular attention must also be paid to the possibility of using depleted quarries as landfills for waste. In the case of clays, for example, the mines are dug in not very permeable rocks, whose characteristics can be considered suited to act as “containers” for polluting substances derived from waste treatment. Clays have also been indicated by the EEC as rocks that can solve the problem of eliminating radioactive waste. It can be concluded that the negative effects related to the extracting activities can be greatly limited if an intervention is carried out preventively, during the planning stages. Lastly it is important to point out that the excavated area, once it has been recovered, is extremely fragile from the point of view of its ecosystem, and therefore it must be controlled constantly.

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