LANDSCAPES

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Introduction

Natural landscapes are the fruit of a delicate balance, created in geological times, between the various natural agents, the different forces, the different processes acting on the surface of and underneath the Earth's crust. It is not a static and immutable balance, but a "dynamic" one, where the processes interact with each other continuously, limiting or magnifying each other in turn. Each one of man's interventions affects this delicate balance, interfering with the natural processes, till when they are modified, at times in an irreversible manner. These forms of interference can be negative; and man, more or less knowingly, tends to trigger or amplify the geological processes that may turn out to be harmful. Through the analysis of the territory, in most of the cases it is possible to foresee the possible effects of man's interventions: landscape analysis is a very important instrument, in the defence of the territory and its rational and respectful exploitation of the natural processes.

Factors that shape

Atmosphere and hydrosphere get in contact with rocks and minerals on the Earth's surface, where rocks spontaneously adapt to the conditions of our planet. The Earth's surface is continuously evolving and modifying in time to create different landscapes. The elements that characterize a landscape are various and range from soil conformation (grasslands and mountains) to water bodies (lakes, rivers and waterfalls), animals (fauna) vegetation (flora), climate and man's works (cities, roads, castles and many infrastructures). A natural landscape, without any human intervention, is often the result of two opposite forces, a battle that has been going on for thousands of years, between the geological processes that occur inside the Earth (the movement of earth plates, volcanic activity, the processes that lead to the creation of new mountains) and the processes that occur externally to the Earth's surface (erosion and water transport of material, changes due to particular climate conditions and many others).

Factors and shape

The Earth's crust is affected by tectonic movements that hit continents, close oceans, build mountains and make the Earth's surface less uniform. In fact, there are regions with very high mountains, while others are characterized by deep depressions, like ocean trenches. The creation of a mountain or creasing of the Earth's surface is due to factors that act from inside the earth and are called endogenous agents. During the years, mountains and hills are eroded: slopes become less inclined while rock debris are deposited on the most depressed areas (sedimentary basins). This erosive action occurs continuously as a consequence of exogenous agents. The shape and the characteristics of a landscape derive from its structure (rocks and minerals it consists of), the processes that shape the structure and the length of time a specific process takes to act on it. But it is necessary to consider the activities that men carried out on the territory, modifying its shape and characteristics and contributing to the creation of anthropic landscapes, “humanized”, to be distinguished from the natural ones. Anthropic landscapes, in fact, represent the historical result of human culture and activities on nature.

Ocean floor

When we explore an ocean floor, we meet huge and long underwater mountain chains, where earthquakes occur and which are characterized by an intense volcanic activity. These long mountain chains (ocean ridges) stretch without interruptions all along the Atlantic, Indian, Antarctic and Pacific Ocean, for a total length of 80,000 km. They are very big and fragmented mountains, with an approximate height of 3 km from the ocean floor and an approximate width of 1500 km. The highest part is called the rift valley. It is formed of a deep cut (like a long and narrow trench), surrounded by mountains and plateaux. This valley is a volcano that has a very intense activity and the rocks that originated from the lava solidification form the ocean crust. The new ocean crust forms the new ocean floor and the ocean becomes bigger. In some cases the new ocean ridge emerges from the ocean surface and forms volcanic islands like, for example, Iceland and the Azores. The earth does not increase its volume since the ocean crust, that forms on the ridges, is consumed in another area. This is typical of oceans. This area is called ocean trench. Here the ocean crust submerges under the continental crust, as it happens near the Andean Cordillera and volcanic arches.

Volcanic heights

A volcano is an opening of the Earth’s surface from where lava and gases come out at high temperatures. The structure of the volcano is the result of the continuous accumulations of erupted material, which then cools down. The following volcanoes have to be distinguished:

- **linear volcanoes**, that release large quantities of very fluid lava, that expands on wide areas. A typical example of them are Iceland volcanoes: long fractures that open on the ground;
- **cone-shaped volcanoes**, that develop close to a circular conduct, from which the erupted material comes out directly. They are characterized by very steep slopes that originate immediately after the accumulation of lava fragments, ashes, lapilli, volcanic bombs (the so-called pyroclastic materials), which are violently expelled from the volcano mouth. In some cases, during volcanic activity, lava and pyroclastic materials are alternatively erupted. As a consequence, the so-called layered volcanoes are created, such as Stromboli and Vesuvio volcanoes in Italy;
- **shield volcanoes**, which have very wide structures, such as those existing in Hawaii. Their base can be hundreds of kilometres wide and their slopes are not very steep.

The creation of mountains

The origin of mountains (orogenesis) occurs after tectonic movements make rock layers fold and overlap. All the Earth's surface, the lithosphere, is divided into rigid areas called continental plates and oceanic plates. These lithospheric plates continuously move and whenever they bump into each other, they form mountain chains.

How were the Andes created? The Andes Cordillera started to form 250 – 200 million years ago after the crash between an oceanic plate (Nazca plate) and a continental plate (South-American plate). During the crash, the oceanic plate submerged under the continental plate. The movement and friction between the rock layers provoked earthquakes and a partial melting of the rocks. The melted rocks, less dense than the surrounding ones, move towards the higher part, as an air bubble would do when submerged into the water. In this way volcanoes are created, and melted rocks (magma) reach the Earth's surface. The Andes include numerous volcanoes that have formed two parallel mountain chains. The most internal and oldest chain is close to the ocean. The two chains are called Western Cordillera and Eastern Cordillera.

How was the Himalayas formed? All big Asian chains, starting from Turkish mountains, to Iran, Afghanistan, Nepal, China, Sumatra and Java result from the crash between continental plates. In particular, the Himalayan chain formed after the crash between the Indian plate and the Euro-Asian plate that 30 million years ago were still separated by an ocean called Thetis. The plate collision, that started 45 million years ago, led to the disappearance of the ocean and the compression of rocks, which corrugated, folded and were lifted towards the top. The collision between the plates has not finished yet and Himalayan mountains are still lifting at a speed of 5 centimetres every year. The Dead Sea, the Caspian Sea and the Lake of Aral are the remains of the Thetis Ocean, that disappear after the approach and crashing of the plates.

How were the Alps formed? The Alps were formed after a crash between the Euro-Asian continental plate and the African continental plate, which were also separated by the Thetis ocean. In particular, 100 million years ago, the African plate changed its movement direction and went northwards with a speed of few centimetres a year. It compressed the rocks of the Thetis ocean crust against the Euro-Asian plate. The African plate moved like a huge bulldozer, scratching and piling up all the material that encountered during its journey. When the two continents crashed, part of the rocks that formed the ocean floor were trapped by the rocks that formed the continents and pushed to the top to form the Alps. Subsequent and more complex movements occurred into different directions and led to the creation of the Apennines.

Change the shape of mountains

As a consequence of rain and storms, water fell in a more or less uniform way down the slopes and the rocky walls of the mountains, changing and breaking the rocks into many fragments. Those fragments fell towards the bottom of the mountains due to the force of gravity, forming piles of debris called debris layers. Debris layers can be easily recognized at the bottom of rocky walls on the Dolomites.

Movements and landslides. Chemical alterations and the degradation of rocks on a slope facilitate the force of gravity. This leads to the slope moving fast or slowly towards the bottom of the mountain. Landslides are the rapid movement of compact rocks, debris masses, large quantities of clay and water or a mixture of mud, soil and rock debris. Landslides originate after or during intense rainy periods. Those slopes that are characterized by dry mud after a long period of draught absorb a big quantity of water after a prolonged rain. The muddy material becomes very fluid and heavy and moves at a speed of up to several kilometres an hour. Landslides can be dangerous and have catastrophic consequences.

Climate and shape

All processes that shape the Earth's surface are interlinked and connected to climatic conditions. As a consequence, they are typical of some areas on the Earth. The Mediterranean area, the Polar area, the Tropical area, etc. are named morphoclimatic zones, and are characterized by particular exogenous and climatic factors.

Hot-wet regions. Hot-wet regions are characterized by plenty of water and high temperatures that provoke intense processes of chemical alterations. Their soil is rich in humus and covered by a dense green area that protects the land from river erosion and allows water absorption.

When the mountains consist of granitic rocks, the landscape is gentle and characterized by dome-shaped heights, called inselbergs. Inselbergs can be found isolated or in groups, without soil or vegetation cover. Instead, if the mountains are made of calcareous rocks, they look like pinnacles and towers and characterize the landscapes of Vietnam and Southern China.

Dry regions. There are two different types of dry regions:

- the area of tropical deserts and the savannah, which are characterized by a strong temperature range, lack of rain and absence of vegetation cover. Rock alteration is mainly due to temperature differences, as well as to the presence of dew and wind action. There are hollows, mushroom shapes and tafones, which are typical excavations at the bottom of the rocks created by wind action;
- Antarctica belongs to dry regions because it is covered by perennial ice, humidity is extremely low and snow is the only precipitation. There are shapes created by wind action.

Mild regions. In mild regions, initially rainwater runs in a uniform way on the mountainsides and then it progressively collects along water streams. Distribution and intensity of rains vary according to the regions:

- oceanic regions are characterized by rain falls all year long and the soil has a continuous vegetation cover;

- mediterranean regions are characterised by showers after the dry season. The vegetation cover is not continuous and it is degraded.

Rainwater that runs on the Earth's surface erodes the soil and forms a series of cracks of different dimensions. In particular:

- if the slope is very steep and is made of clay rocks, the cracks are deep and separated by crests, as the gullies on the Apennines;
- if the land is formed of superficial fragments that are bigger than the ones underneath, the water forms deep cracks around the main rocks. With time passing earth pyramids form, which can reach 20-30 m height, and have the shape of a mushroom with a hat (a big rock) and a stem (made of finer compact material). We can observe earth pyramids in some places on the Alps and near the Lake of Iseo.

Periglacial regions. Rock fragmentation occurs as a consequence of ice action in the areas near the North Pole. Until 30 metres of depth the soil is frozen, but then it swells on the surface forming the permafrost.

Landscape's shape

In volcanic regions the landscape is also characterized by a series of minor but very fascinating phenomena, like geysers in Iceland. They are fountains of extremely hot water that comes out directly from the ground and is pushed very high. In Italy, instead, fumaroles are very popular. They are emissions of gases and vapours originating from fractures on the volcanic structure. For example solfatares belong to this type of phenomenon. They are particularly popular in the Campi Flegrei areas, in Campania region. They develop especially when the volcano is almost extinct. They are emissions of water vapour, carbon dioxide and hydrogen sulphide that come out and deposit as sulphur on the surrounding surface. Also the boric-acid fumaroles in Tuscany are fumaroles that produce a vapour full of boric acid. And finally, it is necessary to mention thermal springs, which are also popular in Italy, and produce water that is very rich in hot gas, sometimes enriched with minerals.

River and lake landscape

As a consequence of rainfalls, the waters that runs on the soil surface forms a rivulet that, joining other rivulets, becomes a stream. While the stream runs towards the valley, it receives water from other rivers (tributaries) and runs into the track it has formed, which is called bed or riverbed.

The flow of a river has different gradients: the river is flatter as it gets towards its mouth. Suddenly, the gradient can increase if the riverbed is made of more compact and non-erodible rocks. In these areas rapids form and if the bed has a vertical gradient, waterfalls form.

Abandoning the steepest part of its flow, and entering the flat area, the river current becomes slower and a part of the transported materials deposit: in this way a floodplain is formed. In these wider areas the river can become more meandering: it can form bends or serpentines, which are called meanders. The river flows into a lake or into the sea.

River erosion. Water, while running, manages to shape the landscape, since it erodes the rocky surface it runs on, it incorporates the eroded fragments, transports and deposits them when it gets to the valley. The erosive capacity of water depends on its speed, and it is higher when the riverbed is more inclined and during floods. The river water and current transport a mixture of organic and inorganic substances, as well as salt. They also transport clay, slime and sand particles, while big bits of sand, gravel and stones roll on the riverbed.

This form of erosion is called abrasion and creates typical shapes:

- potholes: when the current is more powerful, the river manages to dig some cracks that gradually become deeper;
- ravines, narrow and deep incisions that are created by the river on a compact rock, that keep vertical walls stable. Those incisions that become wider towards to top part are called gorges. Some examples are: the gorges of Alcantara, at the bottom of Etna mountain, or the fascinating Grand Canyon in the United States;
- river valley: by constantly carving its own bed, a water stream digs a deeper and deeper crack until it shapes a valley. This represents a wide and deep depression of the Earth's surface, and is limited by two mountainsides.

The shape of rivers. Watercourses are classified according to the shape of their flow:

- plaited: they are formed of numerous and small canals that separate and re-join once they arrive at the valley. In these cases the river transports big quantities of sand and gravel. This is typical of dry, semi-dry areas and piedmont areas. In Friuli region, in the northern Veneto plain, watercourses are named grave (like Tagliamento, Medusa and Cellina when they arrive at the plain);
- straight: watercourses with this shape are very rare and are normally located close to faults and where different types of rocks are located;
- with meanders: the water flow is narrow and with frequent curves on flat land. The movement of meanders and the slime and sand that deposit during floods form floodplains, like the Po plain.

The river flows into the sea. When a river gets to the sea, sometimes it manages to scatter the transported material. In this case an estuary is formed, like the river Thames.

When the river deposits the transported material on its mouth, a river delta is formed.

The Nile, that flows into the Mediterranean, and the Mississippi river, that reaches the Gulf of Mexico, shape the coast forming a delta with several river branches. The delta of Tevere river, that flows into the Mediterranean Sea, is modelled by the waves and sea currents and has a pointed shape. Instead the Seine, that reaches the English Channel, is shaped by sea tides and forms an estuary.

The delta of large rivers can extend for several thousands of square kilometres, according to the quantity of debris that are transported by the river and deposited close to the sea. A delta landscape (a river delta) is characterized by canals, lagoons, islands and isolated water basins.

Lakes. Lakes fill the depressions of the Earth's surface and have a limited duration in time. They can be classified as:

- river lakes, when a river plain is flooded or a river branch completely separates from the river;
- barrier lakes, when a landslide or a lava flow interrupts a river flow. They can also originate from the deposit of rocky materials that are transported by a glacier;
- tectonic lakes form on depressions that are created after movements of the Earth's crust. Examples of them are the Dead Sea (the most salty in the earth), the Bajkal lake (the deepest lake, 1741 metres), the lakes that occupy the Rift Valley in Africa, and the Caspian sea (an old sea that has been left isolated);
- crateral lakes form inside extinct or exploded volcanoes like: the lake of Bolsena, Vico, Bracciano, Albano and Nemi;
- karstic lakes when, above carbonate rocks, there is a layer of clay that makes the rocks waterproof like the Lake of Scuatari in Albania;
- artificial lakes are built by men to collect irrigation water or to produce energy.

The evolution of a lake and the marshland. Lakes do not have a long life because they tend to be filled with sediments and be invaded by the vegetation. The first transformation is the creation of a pond, which is quite shallow. Later, a marsh is formed. The marsh is a land that is covered by a thin layer of water. These waters can be rich in natural substances that favour vegetation growth. Algae, canes and floating plants are typical of this kind of landscape. They decorate the whole water surface.

Karst landscape

The word karst derives from the name of a region, the Carso, at the border between Italy and Slovenia, which is characterized by this type of landscape. Karstik environments develop in places with calcareous rocks, which are highly soluble like limestones, dolomites and evaporitic rocks. Carbonates and evaporites are rocks made of minerals that are very soluble in the water and for this reason they are easily shaped by rainfalls. Also raindrops manage to melt these rocks and dig holes, sometimes very deep ones. The erosion of calcareous rocks in a Karstik territory is called corrosion.

The soil. The dark red colour of karstik soil is due to oxides and the clay content of calcareous rocks. When soluble minerals are melted by water and detached from the rock, some residual deposits are left on the spot. They consist of insoluble minerals, like iron oxides and clay minerals.

Superficial shapes. The most evident superficial phenomena are dolines: funnel-shaped depressions, 1-30 metres deep and hundreds of metres wide. The continuous action of water can favour the widening and union of several nearby dolines. In this way a single depression is formed, which is called uvala. A continuous corrosion leads to the creation of a wider and wider depression, on a flatland, called polje. These depressions can host small lakes that still have some little protuberances of harder and un-dissolved rocks. Polje can be seen in the Italian and Slovenian Carso, where they are called “piani or campi”, like campo Imperatore on Gran Sasso.

The karstik landscape that we can see has no stable hydrographic network, with a total absence of water streams or rivers. The water, by dissolving carbonate rocks, digs the subsoil, where it creates typical underground shapes.

Underground shapes. In large karstik landscapes there are no rivers or streams running on the surface. Water streams run deep underground and, after spending some time underground, they come back to the surface. The underground karstik cavities are made up of caves and canals that can host underground water streams. An example of them is the Timavo river, in Carso in Trieste area: after running on the surface, close to San Canziano, the river goes underground and re-emerges 40 kilometres afterwards, near Monfalcone.

The walls of caves that no longer host rivers are full of juts and encrustations. The most famous are stalactites that hang from the ceiling, and stalagmites that lift from the cave floor. The two protuberances, with time, can join and form columns.

Glacial landscape

A glacier is a moving mass of ice. This movement has an erosive action that shapes the Earth’s surface in cold regions. In the history of the Earth, during the Quaternary period, almost a fourth of the lands that had emerged from the sea were occupied by icecaps. Icecaps stretched to the northern regions of America, Europe and Asia that today are characterized by a mild climate. They were thousands of metres thick. When glaciers started to move forward, they deeply modified the land surface, changed river flows, stopped vegetation growth and forced animals to withdraw towards southern regions. During the hottest periods, the ice withdrew to the north, leaving deposits of the materials that they were transporting on the land. The regions that got free from the ice were now covered by forests and populated by animals but kept the traces of erosion and accumulation of glacier materials. Examples of erosion and accumulation and glacial landscapes can be seen nowadays on the Alps and the Himalayas.

Glacial erosion. The downward movement of a glacier acts on the rocks that compose the land as if it was a bulldozer: it collects and transports various blocks, of different sizes. At the end of a glacier there can be a watercourse, which exercises an erosive action on the underlying rocks, like any other river that runs on the surface. The result, once the glacier has withdrawn, are smooth rocks and cracks and grooves on the rocks. The land irregularities are reduced and the rocks look like flat humps: roche mountonnée. By observing these rocks geologists can re-build the history of the territory, since according to the hump direction it is possible to understand the direction the glacier moved to.

In an Alpine landscape, the main and the secondary valleys are shaped by the glaciers action that has eroded the valleys and the mountainsides. These valleys have a U-shape, while those valleys that have been created exclusively by the action of a watercourse or a river are narrow and have a V-shape. Glacial valleys, on the top, have a semicircular shape, which is occupied by a small glacier or a small lake surrounded by steep rocky walls. This is the glacial cirque, the place where the snow piles up. That snow is later transformed into the ice that feeds the glacier. When the depositing snow is more than the snow that melts during the hot periods, the glacier grows and moves towards the valley.
Some typical glacial valleys were invaded, after their creation, by ocean waters. They are called fjords (they are typical of Norwegian coasts). Fjords are U-shaped valleys that were carved by the glaciers that had run down from the nearby mountains during the ice periods. During those periods, the sea level was lower than today. A big quantity of water at that time existed as ice. The following ice melting provoked an increase in sea level. The water invaded the valleys near the coasts.
Types of deposits: moraines. When the ice of a glacier melts and disappears, it leaves the transported rocky material on the ground and forms:

- moraines, formed by the debris coming from the glacier surface;
- floor moraines, formed by the debris that came from the glacier floor;
- erratic blocks, that are very big and weigh some tons. They are transported for hundreds of kilometres and left on completely different rocks. When geologists find a rock that is completely different from the near ones, they understand that in ancient times that rock was transported and deposited by a glacier.

The information that can be conveyed by moraines and erratic blocks is very important, as it helps us reconstruct the events and the climate of past geological periods. Moraines indicate the shape, help us reconstruct the movements and the maximum dimension reached by the glacier. It is very important to study hills and small moraines that are present in the Plain of the Po, as they show that the area was covered by icecaps.

Aeolian landscape

The dry regions of the Earth are the most exposed to wind action, which blows in a regular way and with a speed that can range from few kilometres an hour to 200 kilometres an hour in case of a hurricane or a typhoon. Compared to water, the wind transports lighter fragments: sands and silts are transported by wind that exceeds 30-40 kilometres an hour. Trees, bushes and grass create obstacles to the wind. Also the presence of water makes soil particles heavy and hinders their transport.

Very fine particles are kept in continuous suspension by the wind that lift them very high and keeps them high for days, weeks or months and then deposits them far away. Saharan fine sands are transported by the wind towards the Mediterranean Sea until they fall down on the Plain of the Po when it rains. The result of this process is the red sand that falls on cars. Sand, silt and clay particles are dragged and rolled by the wind, that makes them jump 1-2 metres high.
When the wind removes fine materials from the soil surface, this results in gravel deserts, made of gravel, stones and big blocks. These materials together form the desert floor.
Wind erosion. The sandy particles that are more easily transported are those made of quartz minerals. Quartz is a very hard mineral, which erodes the rocks close to the ground and the materials it encounters (for example telephone and electric poles). The result is the creation of grooves and slots on clay rocks, while rocky walls and soil blocks are smoothed.
Particles deposited by the wind. When the wind stops or reduces its speed, the transported material is deposited. The sands pile up as dunes, which can be 10-100 metres high. Dunes are never isolated, but they are grouped and form dune fields that move as the wind pushes them. When, as a consequence of environmental and climatic change, dunes are covered by vegetation, they acquire a fixed shape and position. Thin sands are transported by the wind from desert regions to far away places. They deposit onto several layers and form the loss. Deposits of loss can be found in central-northern Europe, Chile and North America.
Deserts and desert regions. Desert regions are characterized by draught, and water streams are called *uadi*: they are almost always dry, because the water evaporates or filters into the subsoil before reaching the sea. When the water collects into a depression, it evaporates and leaves layers of evaporitic rock sediments. In this way the chotts form. They are “salt deserts”, located in Tunisia. Or the playa of California desert is formed. Or a black layer is created due to water evaporation and oxidation of the salts that are contained in the desert minerals. This is called desert paint. A desert cannot be completely flat. It can have heights and steep slopes, with a debris base, without vegetation. Characteristic of desert landscapes are the wide plateaux called *mesa* or *meseta* (what is left of a wide eroded flat area) and buttles (tower-shaped heights).

Coastal landscape

The coast is a strip of soil between the mainland and the sea. The coast is constantly shaped by the action of the sea (waves and tides), the wind and atmospheric agents. We do not have to forget that some organisms, such as corals and algae, can destroy or build a part of the coastal landscape. Coasts can be low or high, rocky or sandy. High and rocky coasts are characterized by steep cliffs whose base is excavated by the waves. This can favour the collapse of the higher walls and therefore the withdrawal of the coast. Typically, this landscape is characterized by bays and creeks that facilitate the construction of ports. The most typical shape of low coasts is a beach, made up of stones in the most internal part and sand that becomes finer and finer towards the sea. The waves and the material that is deposited on a river mouth manage to constantly pile up debris close to the coast, by forming borders, barriers, banks and shores.

The different types of coast are:

- high coasts with cliffs: they are characterized by a vertical rocky slope straight on the sea (ie. Coasts of Normandy, English coasts on the English Channel, coasts of Scotland and Ireland). At the bottom of the walls the waves carve some deep cracks that form spectacular shapes like arches, rocks and caves. The cracks can be quite deep and provoke the collapse of the rocky wall. In this way the cliff wall withdraws. Coasts are not only shaped by the action of the sea, but they are also shaped by tectonic movements of the Earth's crust and by sea movements. In fact, we can find some sea caves that are now located tens of metres above the current sea level, while others are completely submerged. Examples are the sea caves of Circeo, of the channel of Otranto, Capo Palinuro, Capri, Sardinia and Liguria
- coasts: they originated as a consequence of the sea invading old river valleys. The heights form peninsula and capes. Examples are Galicia, western Corsica, central-southern Greece. Deep gulfs and creeks that host ports are typical of this type of landscape. Old valleys that were occupied by glaciers and that are now invaded by the sea have formed the fjords, while the skjars (rocks garden) are coasts formed of several small islands and rocks. They are typical of Finland and Sweden;
- low coasts: they form when the destructive action of the sea is weaker and the river material settles. This material is distributed along the coast by weak sea currents and deposited on shallow waters, in areas that are protected by promontories. Waves move these deposits by forming long submerged piles that gradually emerge from the sea surface in order to form sandbanks and the typical beaches with a tongue or arrow shape that extend from the promontories. These beaches can stretch more and set the borders of the bay, forming a lagoon. The evolution of the lagoon into a coastal lake occurs when there is a complete separation from the sea (Lakes of Lesina and Varano in Puglia region). Tombolos are created when sand strips connect the island with the mainland (Argentario mountain and Orbetello ponds). Beaches are a typical deposit of low coasts.

Lagoons. A lagoon is a stretch of sea, often some kilometres wide, with shallow waters and a low and sandy coast. The lagoon can be connected to the open sea by canals that facilitate water exchange and the lagoon cleaning. Usually, with time passing, the canals close and form coastal lakes. These small lakes are gradually filled with river material. Among the most famous lagoons in the world is the lagoon of Venice, located between the Po delta and Piave mouth.

Industrial landscape

Industrial landscapes are obviously typical of those areas where industrial activities are very intense. Therefore it is necessary to make a distinction between industrialized and poorly-industrialized countries. The latter are located in the so-called South of the world. They are scarcely developed and their populations live in poverty. Instead, the North of the world is

populated by highly industrialized countries, the rich ones, i.e. North America, Western Europe, Japan. Also Australia and New Zealand can be included in this group.
The north, more developed, hosts ¼ of the world population, but owns 80% of global incomes and 90% of the industrial production. Between the north and the south are all those countries (Hong Kong, Taiwan, Singapore, Brazil and Mexico) that, in the latest years, have experienced a gradual industrialization process. These countries, in order to reach a higher industrial development, exploit their raw materials and low-cost labour force.

Agricultural landscape

As agriculture is the first human activity, agricultural landscapes are spread in all continents and populations. Like the industrial landscape, agricultural landscapes are not equally distributed between the developed and underdeveloped world. North America and Europe are characterized by a wide presence of rural landscapes, with intensive agriculture. In these areas, large agricultural fields are subject to a periodic rotation of crops. In this way, by using modern equipment, huge quantities of produce are exported and devoted to industrial production. Also animal farming is very developed: it represents the main economic support for Denmark and Ireland.
Instead, in most of African, Asian and South American countries, agriculture still represents a subsistence activity. Agricultural production, obtained with primitive techniques, only manages to satisfy the needs of few people. Moreover, travelling agriculture is very popular. It is a very precarious activity, which is also very dangerous for the landscape. It is based on the deforestation of surfaces, after setting the vegetation on fire. Subsequently, the soil is farmed but, as it is not taken care of, nor fertilized, it becomes sterile and it is abandoned. In these countries monoculture is very developed. Wide lands are farmed with a determined type of plant, generally the most requested for exports. This, of course, impoverishes the heterogeneity of the landscape.

Alps and Apennines

The term orogeny was born from the Greek words *oros* (mountain) and *genesis* (origin); it indicates all the geological processes that engender the formation of a mountain chain. Independently from the geographical position, climate or altitude, all mountain ranges are the result of a collision between lithospheric plates that, just like a mosaic, make up the external part of our planet. The collision takes place in the subduction zones, between plates that are constituted entirely by oceanic crust that give birth to volcanic islands, or between an oceanic crust plate that, being thicker and heavier, slides beneath a lighter continental crust plate forming cordilleras, such as the Andes or Rocky Mountains. When there is a clash between the continental crust plates, which have the same density, none of the two is willing to slide easily underneath the other and little by little, but inescapably, the huge pushes of the two continents facing each other create the most spectacular chains, higher and with more complex structures, like the immense mountain arc that goes from the Pyrenees and the Betic Chain to the Alps, from the Dinarids to the Tauri, up to the Karakorum and Himalaya. Mountain chains are therefore the enormous scars that testify the movements of the lithospheric plates and show their ancient borders. Thousand of km of the Earth's surface are covered by these "scars", some young and very long, very high and with rough and jagged reliefs like the Alps, Karakorum, Himalaya, other more ancient and with softer curves, almost like hills, such as the Urals, the Appalachi or the French Massif Central: the shapes observed are the combined result of orogenic processes and tectonic alterations, that lift the chains, and of erosion processes, that shape the reliefs and tend to "delete" in the course of time the height differences and reliefs created by endogenous processes, in a never-ending cycle.

A constant evolution

Mountainous reliefs constitute an important element in our country's scenery: mountains are visible from any point of our Peninsula, even at the center of the Padana Plain, even if often hidden by fog! It's easy therefore for us to consider mountainous reliefs like something that is fixed and unchangeable, that has always existed and always will exist, but this is not so. Geologically speaking, our mountains are very young and they have been part of the Italian scenery only for 100 million years, a relatively short time in geological history. Alps and Apennines are "live" mountains: they move, transform and continue to grow, they do it so slowly that the process is not apparently perceptible to the scale of human life. Geologists, though, know how to recognise the phenomena that testify how the growth of Alps and Apennines still continues under our eyes: measurements with high-technology instruments even allow to measure the rises and falls of mountains. Moreover, if we observe the distribution of earthquakes in Italy, it's easy to understand how earthquakes are distributed along belts that skirt the margins of Alps and Apennines, as a testimony of the movements that still take place in these areas. The lifting movements along ranges are also one of the causes of slopes' instability and of the numerous landslides that charcterise the mountains and hills of the Peninsula.

The structural and geological conformation of Italian mountains is influenced by a long and complex history, which still carries the marks of a very ancient chain, the Ercinic chain, which molded itself more than 300 million years ago, however the more evident reliefs, Alps and Apennines, are recent structures in geological terms. They are the result of the compression exerted by the African plate through its rotational movement on the enormous Euroasiatic plate: the edges of the two plates have thus "curled up", "doubled over" and deformed one against the other. As the two plates slid laboriously one beneath the other, the long arcs of the Alps and, immediately after, of the Apennines were formed. The same compression movement has generated the mountainous chains of all the countries that look out on the Mediterranean (from Greece to Albania, to Croatia, up to Spain, Tunisia, Morocco and Algeria), and is responsible for the seismic and volcanic activity of the Mediterranean regions, apart from creating the deep basins of the Thyrrenean Sea, of the Balearics and of the Ionic Sea and progressively shrinking the Adriatic Sea.

How is a mountain chain made?

Mountain chains look like elongated belts, aften arched, of reliefs and successions of high peaks, bordered at the margins by flat areas. You can distinguish an "internal" zone within the chain, less deformed, and an "external" one, towards which goes the alteration process. The external zone, not yet altered, towards which moves the chain, is called foreland. Between the foreland and the chain is the foredeep, a depression below which the subduction of one of the two plates takes place: it is here, in the foredeep, that the majority of the detritus and sediments produced by the dismantling of the chain settles. The foredeep appears on the surface as a flat and untroubled plain, but in its depths it's the most active area of the whole chain where the crust fractures and great tectonic nappes fold and pile one on top of the other, doubling the normal thickness of the crust.

Geological history of Italy

If we could observe Italy as it was 250 million years ago, we would surely have great difficulty in recognising the places and sceneries that are so familiar to us today! The continents were grouped in the big Pangea mass, in which opened a great channel, the Tethys Sea. Our country used to be in the Western corner of this big gulf, underneath the waters of a shallow sea (200-300 m), very similar to today's Adriatic, the margins of which used to have a landscape similar to the Bahamas carbonate platforms. This ancient sea's deposits are still found in the sedimentary sequences of the Alps and Apennines. The only emerging parts of what would become our peninsula were a small area between Pisa, the Argentario and Sardinia. The lithospheric movements created big fractures and new litospheric plates started moving again, to move away and then collide with one another. So, subduction of the Tethys oceanic crust towards N ended up provoking a movement of the African bloc that, in our region, opened a new Ocean (the Ligure-piemontese Ocean). This ocean extended roughly in N-S direction, separated on the E from the vast Vardar Sea by a peninsula that extended N from the African coasts towards the European plate, the so called African Promontory, or Adria: the greatest part of the territory that would become Italy was on the Adria plate, apart from Sardinia, which was on the opposite European margin. In the Medium Cretaceous (100 My) an extremely important event for the evolution of the Mediterranean area took place: the expansion movements ceased and the Ligure-piemontese Ocean started to close under the pressure of the African plate that started to rotate on itself in anti-clockwise direction. The dense and heavy oceanic crust went in subduction once again beneath the African continental coast until the Ligure-piemontese Ocean completely disappeared: there are still traces of the crust that formed the bottom of this ancient ocean in the ophiolitic rocks (the "green rocks") in Corsica, in the Western Alps, in Liguria and Greece, while the sediments that covered it now form the rocks that constitute the shell of our country.

At the same time, to further complicate the situation, a fragment of the European margin got unstuck, and created what are now Corsica and Sardinia.
Once the crust of the Ligure-piemontese Ocean disappeared, the European and the African plate found themselves one in front of the other and, since they had the same density, they started to undergo consistent reshapings, under the unstoppable pressure of the African rotation. Thus the formation of the Alpine chain started and, at the same time, of the chains that go through Corsica, the Balearics and Southern Spain and of the various basins that form the Mediterranean.

A short history of the Alps

The Alps stretch for about 1000 km, with a width of 150-200 km, and constitute an arc that separates geographically our country and the Mediterranean area from the rest of Europe. The Alps continue towards NE with the Carpati, in the heart of Europe, and towards SE with the Dinaride chain, that descends from Istria and Croatia towards Greece. Towards W the Alpine chain arches and comes into contact with the Apennine chain in correspondence with an important tectonic lineament, the Sestri-Voltaggio Line. The Alps are among the most studied chains in the world and here they have seen the birth of many of the most important geological theories. This chain's history is very complex, but in broad terms its birth is due to the collision between the European plates and the Adria Promontory. The European plate went into subduction underneath the African one and the collision deformed the rocks and sediments of both margins, that crossed one over the other to give the typical alpine structure, called by geologists "blanketing nappes" structure. The alpine chain structure is complex and can be divided in two sectors separated by an important tectonic lineament, the Insubric Line or Periadriatic Lineament: this series of very long faults runs from W to E along the whole Alpine arc and separate the Alpine domain, mainly made of metamorphic rocks, from the Southalpine domain (or Southern Alps), where the faults are mainly made of sedimentary rocks.
The Alpine chain thus has a peculiar structure, that geologists call "double vergence" structure, with nappes taken towards N and towards the foredeep and fore-European country, and also towards S and towards the foredeep of the Padana Plain and the Apennine forecountry. The anti-clockwise rotational movement of the African plate started in the Cretaceous and, with alternate phases of varying intensity, it still continues to these days. Three peak phases can be individuated: in the Cretaceous the eoalpine phase, the most ancient, during which the Ligure-piemontese Ocean disappeared; from Eocene to Inferior Oligocene (30 My) when the real continental collison started with the mesoalpine phase; from the Superior Oligocene to (25 My) the Alps gained the current double vergence with the neoalpine phase.
As the alpine chain was being moulded in the depths of the terrestrial crust, the first reliefs started gradually to emerge. The erosive processes immediately started to modify the landscape of the newborn chain producing an enormous quantity of sediments and detritus that settled at the reliefs' feet, in the foredeeps. In the southern foredeep the vast sedimentary basin that constituted the Padana Plain was formed, and there in a few million years very thick deposits

were collected: geologists calculate that under the Padana Plain the thickness of the sediments deposited in the last 5 My (Pliocene) reach 7000 m in the area of Parma and Reggio Emilia!

Brief history of the Apennines

If the Alps constitute the Northern border of our country, the Apennines chain forms the peninsula's "backbone": it extends towards NNW SSE, from Genova where it grafts with the Alpine chain along the Sestri-Voltaggio Line, until the Sibari Plain in Calabria where after a short interruption due to the wedging of the Arco Calabro bloc, it continues in the Sicilian mountains with a NE-SW trend and the connects with the Maghrebide chain and the Tellian Atlas in Tunisia, Algeria and Marocco. The Apennines' history is also long and complex, but in short it can be reconnected to the rotational Eastern movements of the Corsica-Sardinian Bloc, contemporaneous to the collision of the European and African plates, which was creating the Alpine chain in the North. This rotation started a bit later compared to the Alps' birth, between the Superior Oligocene and Inferior Miocene (30-16 My): the Apennines are therefore younger than the Alps.

The Corsica-Sardinian Bloc's movement has had two important consequences: on one side it has generated a compression from W to E that caused the subduction of the Adrian Western margin under the Corsica-Sardinian Bloc itself, creating the corrugation of the primitive Apennine chain and its progressive movement towards the Dalmatian coasts, while on the other side it has provoked the progressive opening of two deep oceanic basins: the Provence Basin and the Thyrrenian sea. Precisely the progressive expansion of the Thyrrenian sea has brought, in the course of the last 7-8 million years (starting from the superior Miocene) to the formation of the Apennine chain as we see it today, with the Calabrian Arc bloc that detaches itself from the alpine chain and gets attached to the southern part of the Apennine.

The Thyrrenian Basin is the youngest of the Mediterranean basins and, with its 3600 m, one of the deepest: on its expanding seabeds are some of the most important Mediterranean underwater volcanoes. Its opening, which still continues today, is dismembering the Apennine chain. The constant compression along the eastern margin induces the formation of great folds and pushes the Apennines against the Dalmatian coasts by 1 mm/y. The western margin presents a distensive tectonic domain, with deep tectonic trenches (Graben) and distensive faults, that open the way to the rise of magma and subsequent volcanic phenomena (in Tuscanay, Lazio, Campania): the western Apennine margin is thus characterised by vast tectonic basins (Val d'Elsa, Valdarno, Florence plain, Val Tiberina, for example), once covered by sea, then the site of great lakes (of which the only testimony that remains is lake Trasimeno).

What happens beneath our feet?

From Oligocene to this day, a period of about 25 My, it has been calculated that the average rise of the Alpine chain has been of about 1 mm/y: this means that, if there had not been erosion processes, the peaks of the Alps could now reach the incredible height of 25.000 m! It also means

that, during the course of a human life, mountains like Cervino or M. Bianco rise about 7-8 cm: too little to observe with a naked eye, but still sufficient for geophysical measures to quantify the deformations.
Some areas of the chain are more active than others and show rising values much higher than average: thus, for example, in Friuli, between Trieste and Tarvisio, a series of measures taken after the 1979 earthquake and confronted with previous 1952 geodetic measures has shown that the increase has taken place with the speed of a few mm/y, a value that is 10 times higher than the average of the Alpine chain. The most active areas from the seismic point of view are usually the areas where the rising values are higher: for example, in the Cuneo area, in the Brescia area and in the already mentioned Friuli. This greater rise is due to a tentative of the African plate to "squeeze" in subduction under the European plate, below the Alpine structure.
As for the Apennines, the part that is actively rising is the oriental one, from Romagna, Marche, Abruzzo, Molise until Basilicata, while along the Western part, that which geologists call the "internal" part of chains, the opening of the Thyrrenian basin is causing distensive phenomena that result in a general lowering of the area and in numerous volcanic phenomena. In both cases, the deformations come with a high seismicity, always an index of tectonic activity. Towards S, the opening of the Thyrrenian Basin combines with the contemporary subduction, in the Ionic Sea, of African lithosphere below the Calabrian Arc, thus originating the volcanic activity of the Eolian islands and to the intense tectonic and seismic activity of Calabria, from Sibari until the Messina Strait (see Special on Mediterranean seabeds): the Sicilian coast goes farther from the Calabrian one by 1 cm/y and rises by 4 mm every 10 years, against a rise of the Calabrian coast by 1,5 mm/y. Subduction of the African crust also takes place in the Aegean Sea, below Greece and this explains the seismicity and volcanicity of these area which, although are not geographically part of our country, influence its geological evolution. Geophysics keep constantly under control the movements and deformations of our territory through a network of measuring stations (instituted on a national scale in the '80s), both with the traditional geodetic methods (geometric leveling and accurate measures of corners and distances), and with the modern methods of satellite bearing (GPS), that allow to see even minuscule movements in real time. The national network is then connected with those of other countries, particularly the countries that look out on the Alpine arc, in order to control the situation along the whole chain. Precisely these measures, repeated in time, have allowed to understand the relations between the evolution of Alps and Apennines and the seismic and volcanic phenomena that, sometimes with great intensity, characterise many zones of our country.

The Padana Plain: flat only on the surface

The Padana Plain extends to the S of the Alps and separates it from the Apennines: flat and monotonous on the surface, in reality it hides a very complex and active geological structure. It constitutes, in fact, the foredeep of the central part of the Alpine chain, but also that of the younger Appenninic chain: it is therefore the area where two important chains, still in the making, stand one in front of the other. The result is that underneath the Padana Plain, below a 300-400 m cover of river and lake sediments, starting from Pliocene (3,9 My) big folds and tectonic slices have formed, and continue to form and stack one on top of the other. This structure is of fundamental importance, not only from the geologic point of view, but also in economic terms, since this structural asset is the one that favours the formation of hydrocarbon traps, of which the Padana Plain's subsurface is particularly rich.

Landslides

Landsliding is a phenomenon in which rocks of different sizes or loose earth detach and move downwards. A landslide is the result of landsliding and consists of all the fallen material. The detachment and the movement of materials are due to one, very simple cause, that controls all our actions and movements: gravity. In Nature, two fundamental forces are opposed to gravity: friction and cohesion. Friction is the resistance that an object (a small pebble, a big mass, a house, part of a mountain) opposes to the force of gravity, that tends to drag it as far down as possible, while cohesion is the force that 'keeps together' particles (crystals, granules, bricks, layers of rock) that make up an object or a material. 'Geological' objects (masses of earth, layers of rock, sides and walls of mountains) are in a situation of delicate equilibrium between these forces: when gravity prevails over the other two, then the object, or the rocky mass, will move downwards. Many factors can interfere, naturally or due to man's intervention, to disturb this delicate and unstable equilibrium, either modifying the friction or the cohesion of the material or influencing the force of gravity by varying the weight of the material. The kind of movement and its speed, the volume of the material and the possible premonitory signs depend on just these factors. It is for this reason that it is difficult to classify the different types of landslides and even harder to try and foresee and prevent them. On many of these factors man has no control, but many of them, instead, derive from human activities, and it is on these that we can intervene to reduce the risks of landslide events and to limit their damages. As in the case of seismic risk, even landslide risk cannot be eliminated, but unlike earthquakes, on which we have no control and to which we can only react by limiting their potential damages as much as possible, many landslide events are more or less indirectly produced by man, so that in this field we have a wide margin of action as far as prevention is concerned.

Causes

Even though gravity is the main 'motor' of landslides, there are numerous factors, mainly of geological and climatic origin, that make a soil or a mountain more liable to landsliding: these are the so-called predisposing factors. Among these, of particular importance are the geological nature of the material (the kind of rock, its resistance, if it is made up of coherent material like rock or loose material, like a sediment or soil), if it is fractured or modified – this would influence its resistance (intuitively, compact rock without fractures will have a greater resistance than a heap of stones made of the same material), but also the gradient of the slope on which they are situated plays an important part (even to those who are not geologists it is clear that a vertical wall of bare rock is potentially more dangerous than a gentle slope covered with soft grass…but this isn't always true, appearances can be deceptive!).

All these factors make some areas more hazardous than others, but usually for a landslide to occur, 'something' has to happen to disrupt the delicate equilibrium. The conditions that bring about a landslide are those that occur, at times unpredictably, and modify the equilibrium thus acting as a 'detonator' of a sort of geological 'time bomb'. Among the different triggering causes, the most tragically well-known are those connected to heavy and long-lasting rainfall, that bring about a reduction in friction and cohesion and an increase in the weight of the material. The phenomenon is more evident when landslides and land instability are the immediate consequence of long and violent precipitations, but the same cause can work in a hidden and secret way: an example is water infiltration on the bottom and sides of an artificial basin (this occurred in 1963 in the well-known disaster of the Vajont dam, for example). Sudden movements, as in the case of an earthquake, can destabilise sides and masses of rock; it is for this reason that earthquakes and violent volcanic eruptions are often accompanied by landslides. Slow tectonic upward movements, however, can produce the same effect, probably even more insidiously. Thawing phenomena can cause landslides and mud flows or the detachment of blocks of rock, because the cohesion provided by ice, that keeps materials together, disappears: this phenomenon can clearly be seen at high altitudes in the mountains or in permafrost areas. Even phenomena of fluvial erosion at the foot of the mountain sides can start off landslide processes: ablation of material at the base, in fact, makes the masses on top unstable. Unfortunately most of the triggering causes that provoke landslides are of anthropic origin: the increase in weight on one side of a mountain due to big and heavy constructions, uncontrolled deforestation that reduces the cohesion provided by the roots of trees, or, on the contrary, reforestation with unsuitable plant species (that are too heavy or their root system is unsuitable), the construction of roads and tunnels that 'cut' the mountain sides, the cementing of river-beds leading to accelerated erosion along the unprotected banks…the list could be even longer without taking into account the fact that among the 'natural' causes mentioned earlier, man can make his own contribution, like in the afore-mentioned case of water infiltrations or triggering subsidence phenomena connected to excessive exploitation of the water-table. There are some types of clayey soil, fortunately quite uncommon, and not present in Italy, that have the unique characteristic of 'becoming liquid', behaving like a very dense liquid when subjected to abrupt stimuli (behaving a bit like quicksand): in Scandinavia, where these soils are quite common, serious cases of landslides have occurred due to the vibrations created by the passing of a train that literally 'liquefied' entire hills!

Many processes, many types

The conditions and causes for a landslide are so many and so varied that there are many different types of landslides. Their classification is, therefore, very difficult and complex. They can, however, be divided into (not taking the volume of the moving material into consideration):

- falls: these occur on rocky mountain slopes with the detachment of blocks of rock, like those taking place on many mountain tops in the Dolomites at present: these landslides are not very dangerous, because usually the volume of material is small, but they rarely give warning signals since the detachments are always sudden (even though, it must be said, the conditions of the sides or of the slopes can offer many clues regarding the probability of the phenomenon);
- slides: the volume of moving material of these landslides can be very big; they slide along a surface that can be relatively flat, like a stratified layer of rock, like in the famous 'marocche' of the Adige river valley, or a concave surface, in which the material follows a rotational movement;
- flows: loose material, like debris, soil, clayey terrains and volcanic ashes that easily absorb water can bring about flows, in which the materials flow downhill like a very viscous fluid. The movement can either be that of a slow flow towards the valley or take place in such a rapid and very violent way that they have earned the name of 'rock or debris avalanches'.

In between flows and floods there are a particular type of landslides known as debris flows or mud flows, that involve materials which are greatly saturated with water; these are particularly dangerous because of the speed at which they move and the extensive damage caused by the passage of the material: on our mountains, these phenomena build up alluvium cones at the mouth of small and big valleys. Furthermore, because of their elevated position and the fact that they receive more sunlight than the surrounding lands, the areas on these cones have been greatly anthropized even though they are extremely dangerous, as can be seen, for example, driving through the Valtellina area.

During explosive volcanic eruptions, that produce a great amount of loose material, specially fine ashes, after strong rainfall or the melting of snow at the top of the volcano, often dangerous mud flows may be triggered off, the so-called lahars, that are particularly destructive because of the speed of the moving material (for example, in 1985 in Columbia, on the occasion of the eruption of the Nevada de Ruiz volcano).

What a landslide looks like

Even though a landslide often appears to be a very rugged and complex area, usually the scar is clearly visible, bounded by the scarp that marks the area where the detachment of the sides has taken place, often crowned and surrounded by fractures and cracks that have opened uphill and by a slump block made up of accumulated material. Whatever the kind of landslide, usually the latter is an irregular topographical area, with numerous depressions, often with a 'toe' that spreads at the base covering the terrain on which the landslide has slipped. It is very important to be able to recognise the shape of antique landslides because generally these phenomena tend to be repeated in time since the geological characteristics of the materials do not change.

Fast and slow movements

Landslides are often characterized by sudden movement, often at great speed, in which great masses of material are dragged downhill. These are surely the most dangerous landslides, because they rarely give the affected populations time to get out of danger. However, there are other movements that are very slow, which imperceptibly influence the lives of human beings, and are inexorable and unrelenting. Often they involve enormous masses of rock, at times, entire mountains, and take the name of deep-seated gravitational slope deformations. Usually, in the short term, they produce only small damages, like the opening of fractures and trenches and the deformation of the land, but they can be responsible for the triggering off of other types of landslides in areas inclined to these phenomena: connected to the deep gravitational deformations, therefore, there can be rockfalls and debris flows. In addition to this, the great volume of material that imperceptibly, but inexorably, slides downhill can cause serious damage to man-made infrastructures. An example of this can be found in the tunnels of the modern highway that connects Lecco to Valtellina: the slopes of Mount Legnone are sliding towards Lake Como causing continuous deformations of these tunnels and it is very difficult to solve this problem, as the solution would be to support the whole mountain!

How the Italian territory is affected

Italy is one of the countries with a high risk as far as landslides are concerned. This derives from the geological characteristics of our territory. In the first place, as much as 77% of our territory is made up of mountainous and hilly areas, this is a destabilising factor in itself. In addition, the territory is geologically young and very active, with many areas presently rising, like many parts of the Alps and Apennines, and with numerous volcanic areas with high seismic risk, all conditions that increase the risk of landslides. To add to this, vast areas are covered by recently formed loose deposits, often of clayey nature, as in many areas of the Apennines; these materials are very sensitive to both the pull of gravity and to imbibed meteoritic waters, therefore, they are a natural characteristic of our country, rooted in its geological history. However, the disquieting news of current or feared landsliding events increases constantly year by year. This does not necessarily imply that the number of land slides is increasing: it is the number of landslides that are reported that is increasing and these hit the headlines of the newspapers as the anthropic pressure on the territory is constantly increasing. The areas that are inhabited on permanent basis have increased. These were once used for agriculture and sheep farming. There is also an increased interest in the high mountain areas for tourism, while on the other hand all maintenance and environmental recovery activities have been abandoned, such as the controlled felling of trees in the woods and the cleaning of the torrent beds. Unfortunately we are losing a precious heritage of farming culture and wisdom: even though they did not have many opportunities to study or use sophisticated testing instruments, our grandfathers had a deep-rooted knowledge of the mountains, and the old “malghe” as the shepherd’s huts in the mountains are called in the Alps, or old farmhouses were rarely to be found in dangerous positions with the risk of landslides and floods. With the exception of the Po valley, the Puglia and Sardinia regions, all the Italian regions are exposed to the risk of landslides, and with the constant expansion of urban settlements, the municipalities that are exposed to the risk of landslides are constantly increasing. Consequently, it is necessary, in many regions, to comply with the regulations that require a geological and technical survey before planning the towns and dealing with new unauthorized buildings. Also the decision to evacuate, or in more severe conditions, to move entire urban settlements, often has to face much opposition, due to comprehensible economic reasons, and also due to human reasons, unfortunately even in the presence of severe and clear situations of danger. Therefore it is quite clear how a natural situation that is already extremely favourable for severe landsliding phenomena, is further aggravated by anthropic factors.

Risk or danger?

When studying landslide phenomena, it is opportune to distinguish between the risk that is tied to the probability that an event may occur, and the danger of the event, which instead is tied to material damages that the phenomenon can provoke, and the toll of human lives. Enormous landslides in uninhabited areas modify the landscape irreversibly, but are not particularly dangerous, instead, a single mass that balances on a mountain-side above an urban centre can be very dangerous, even though the volume is small, because it might fall directly on things or people, provoking severe economic and human damages. In general, this is the criterion used when deciding the type of preventive interventions and protections to be carried out in an area that is subject to landslides. Landslides, therefore are not all of the same “value”. However it is important, especially in the case of landslides with a large volume, to evaluate all the consequences of the landslide event well, including all possible changes in the landscape and other geological processes. It isn’t rare, in fact, that in its fall, the landslide may obstruct a waterway, provoking the formation of a lake, that is generally unstable, and this may consequently cause severe floods if it overflows (as in the case of the Val Pola landslide, in 1987, in Valtellina) or it may provoke an inundation if it falls directly into a natural or artificial water basin (as in the case of the Vajont dam). Some landslides falling into the sea or underwater events, can provoke giant waves or tsunami, like the one many geologists have foreseen for the collapse of the Cumbre Vieja volcano on La Palma Island in the Canary Islands. This topic can be further explored in the article on Tsunami in the Maldives in the special reports section

Studying landslides

Often landslides are highlighted in the headlines of the news, described as sudden catastrophic events that occur with no warning signals on the population that is totally unaware of the danger.

Actually, due to all the considerations listed above, landslide events are certainly not unpredictable and their unpredictability is only the result of a poor knowledge or a questionable sensational policy of the information media. As in the case of earthquakes, what cannot be foreseen is the exact time in which the landslide will occur, the precise course it will take and the exact volume of material that will fall, but it is certain that in many areas the signs of a possible detachment are quite evident. Knowledge about the landslide mechanisms generally enable the identification of the triggering causes, and very often the rescue units such as Civil Protection Office are warned preventively, particularly when meteorological events that can trigger landslides and landslips take place. Areas that are potentially at risk, are often monitored, some for many years (the movements of the Spriana landslide, in Valtellina, have been known since 1589, in case of a collapse, the entire city of Sondrio would risk being flooded). Monitoring involves scrupulous and continuous observations. The premonitory signs that announce an imminent detachment or movement are often slow and imperceptible, at least in the initial phases, and can be recorded only through instrumental observations, therefore only a constant control of the territory enables the collection of this precious information, which cannot estimate a precise date of the event, but which however provide data regarding the possible acceleration of movements and deformations taking place. Observation and measurement of the deformations of the land are surely the most reliable method to evaluate the activity of a landslide and the onset of the landsliding event. Using aerial photography and from satellites, combined with precise measuring instruments, such as the GPS, it is possible to observe the variations in the shape and topography of the land, the opening of fractures and cracks, and it is possible to measure the shifting of preset points, which are sometimes for this purpose fixed into the ground, compared to observation points that are surely not involved in the movement. With the help of special instruments such as strain gauges and deformation gauges, it is possible to evaluate the progressive aperture of fractures or the movement of rocky blocks away from the sides, or to measure the deformations more in detail, thus identifying the position of the surfaces that could possibly slide. Also the study of the level of imbibition of the soil provides important data, because many landslide phenomena are triggered by this factor. Naturally also a keen observation of the weather forecasts is part of the monitoring of a landslide-area, or an area that could potentially lead to a landslide. As it may be seen, for experts in this sector, landslides, in most cases are actually not at all unpredictable and sudden phenomena.

Defences

Structures built to defend the land from landslides are constructed with the aim of restoring stability of the slopes, eliminating the causes of the movement or reinforcing the materials. For this purpose, different structures can be constructed as a defence, depending on the type of landslide, the geological characteristics, the terrain and the risk: danger ratio.

The aim of some of the defensive structures is to eliminate or minimize some of the triggering causes, as for example the creation of drainage structures to take away excess water from land

that is at risk by putting the water courses on a steady state, growing new plants and new trees, or consolidation of material, alternatively, protective structures can be built to prevent movement of the material, by constructing supporting walls, valleys and falling masses prevention nets, through consolidation work in the case of loose soils or fragmented rocks, and mounting tie-beams to hold back unstable blocks, and structures for fending off unstable material (that is made to fall artificially, in a controlled manner).
However, when the volumes of material that are involved are large, the task of keeping landslide phenomena under control becomes more difficult. When, as in the case of deep-seated gravitational slope deformations, the volumes amount to the whole mountain, the only prevention that is possible is to move away all settlements and human activities from the area. This is often a difficult and painful choice because it is not easy to convince the inhabitants to abandon their homes, their fields, or their work activities.

Prevention

Two main attitudes are observed when in the face of natural disasters. On one hand there is a tendency to minimize or ignore the risks till the calamity takes place, and then rapidly **seek shelter** or accept the whims of nature with atavic resignation. On the other hand there is an attempt to understand how the natural systems work, and to foresee the possible situations of risk, to prevent the occurrence of the phenomenon by avoiding behaviours that can aggravate the situation, creating opportune protection and monitoring structures, predisposing evacuation plans in case of real danger. All this, naturally involves large economic and social costs, and very often preference is given to a postponement of the prevention and protection expenses, without bearing in mind that the interventions to check a disaster that has taken place involve costs that are generally much greater than the prevention interventions, without considering that it is impossible to find a remedy for certain types of damages, such as the loss of human lives, works of art or landscapes. Finally, in recent times, also due to new laws regulating the development of constructions in areas at risk, and mainly due to the sensitization effort carried out on the public opinion, there is a greater awareness on the part of the public administration and the population.
In the case that prevention is chosen as a defence against landslides, there are many types of interventions that can be carried out. Depending on the type of movement and materials, these will be more or less expensive and more or less effective. However a complete final recovery of a landslide-area is still impossible to carry out at present. The correct attitude when faced with these phenomena, therefore is to take note of the same, study them and better understand them, monitor them through an efficient network, and intervene, wherever possible, with opportune structures to defend the land and to avoid all attitudes or human activities that may in some way contribute to triggering or aggravating the phenomena. This can also include the abandoning of particularly dangerous areas or having to renounce building structures that interfere **too greatly** with the delicate natural equilibrium. Information regarding the real risks and possible interventions is fundamental because the population is also involved in the choices

that are made with greater awareness, even if at times they may be difficult and troubled, as in the case of having to renounce building in an area that is devastated by landslides.

Environment and territory

The environment is a system whose processes are continuously interacting with the organisms that live in it. We have seen, for example, that rainwater changes the Earth's surface, and that vegetation plays an important role in rock disintegration and soil formation. There are many human beings in the environment. Man is the only individual to be able to build and use equipment that can modify the landscape in a very short time. Nature would take thousands of years to produce the same changes as the ones produced by man. Human activities on the environment strictly depend on the type of economic activity and how society is organized. In some cases, human activities aim at recovering environmental upheaval. As a consequence, man can be considered as an important landscape-modifying agent.

The construction of big works

The building of dikes, piers, roads, energy plants, etc. modifies the landscapes and interferes with natural processes. These changes have to be kept in mind during the first planning stages. Let us image to stop a river flow by building a dike. We will have to take the following aspects into consideration:

- the stability of the building;
- the quantity of river sediments that will not reach the sea but that will deposit on the dike lake;
- the danger of erosion for the beaches that are located close to the river mouth.

The accurate study about the environmental compatibility of a building during its design is called assessment of environmental impact.

Surface water erosion

In order to stop surface water erosion it is necessary to reduce water speed. At this regard and in order to protect a riverbed, men build river bridles, i.e. a series of steps along the river flow. In order to prevent floods, instead, artificial banks are built. When building them, it is important to calculate the natural space the river needs in order to let floodwater drain off. In order to reduce the quantity of water of a riverbed during a flood, water tanks (that can provisionally transmit a certain quantity of water) and drainage channels (that divert the river flow) are designed.

How to protect from landslides

Landslides provoke serious damages to things and people and they can be prevented by consolidating the area at risk. First of all, it is necessary to detect the sliding land and avoid building or excavating in the area. Moreover, it is necessary to prevent big quantities of water from running on the surface of this land: drains have to be built and vegetation growth is to be encouraged. Support walls or gabionades are built to contain material that otherwise would move to the bottom of the slope.

Vajont landslide. In 1957 a dike in the Vajont river started to be built. Above the dike a lake was formed and geologists highlighted that the mountainsides that surrounded it were not stable: the sedimentary rocks on the sides were set on poorly compact layers of clay. After a first landslide, on 9th October 1963, 300 million cubic metres ran from the Toc Mountain to the lake and provoked a wave of 40 million cubic metres of water that went over the dike. The effects were devastating since the wave swept Longarone village and other villages away. In this case human responsibility is obvious, as the geologists' studies were not taken into consideration, nor during the dike designing stage or after the first landslides.

Environmental Impact Assessment

The Environmental Impact Assessment was born in the United States in 1969 from the National Environment Policy Act (NEPS) and it anticipated, by almost ten years, the basic principle of the concept of Sustainable Development, defined as a "sustainable economic development that meets present needs without compromising future generations ability to meet their own needs" enunciated by the World Commission on Environment and Development, Our Common Future, in 1987. In Europe, this procedure was introduced by EEC Directive 85/337/EEC (Council Directive dated 27 June 1985, on the Assessment of the Effects of Certain Public and Private Projects on the Environment) and was subsequently implemented in the regulations of the Member States, soon becoming a fundamental instrument in environmental policies.

EIA is a study that evaluates the consequences that a project will have on the territory and on its inhabitants. The examined territory must not only include the areas that are in the immediate vicinity, but it must include all the areas that are near and far, that may feel the impact of the project on the environment in some way.

Environmental Impact Assessment Studies must provide competent authorities the elements for them to decide, as follows:

- Global environment and Project description stage, which also includes atmosphere, hydrosphere, biosphere and anthroposphere.
- Identification and assessment stage, of the impacts of the project on the environment, such as interferences and environmental components.
- General assessment stage, by the party proposing the project or intervention, after having defined the chosen methods and criteria.

EIA is also a process in which the citizens participate, and in this way are informed of the complex environmental and social condition. This enables citizens to control the coherence and the efficiency of the work carried out by the competent authorities and enrichen the decision-making process, with their observations.

Floods

In Italy watercourses are often characterized by dry periods and short but intense floods due to heavy precipitations. The water rise provokes an increase in the water running speed. As a consequence, the water goes out of its banks. Deforestation, fires, buildings in risky areas are some of the reasons why these phenomena occur.
The waters of the Po River run inside the artificial banks that stretch for 510 km, out of 652 km of the river total length. In this way the danger of sudden floods increases, the water goes over the artificial banks and invades the nearby areas by provoking serious damages to agriculture and inhabited centres.

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