

*Geology Alive*



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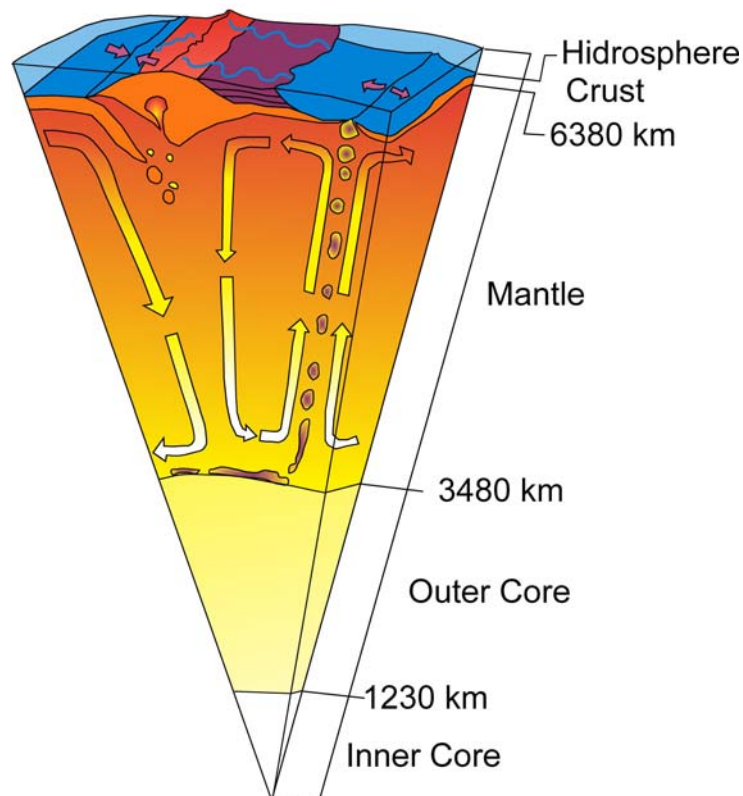
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## Introduction

Geology is the science that studies the Earth, its composition, structure and origin in addition to past and present phenomena that leave their mark on rocks. So why does society need geologists? Some of the main reasons are listed below:

- Geologists compile and interpret information about the earth's surface and subsoil, which allows us to establish the planet's past history, any foreseeable changes and its relationship with the rest of the solar system.
- Society needs natural resources (metals, non-metals, water and fossil fuels) to survive. The work of geologists is therefore a key part of finding new deposits and establishing a guide for exploring and managing resources in an environmentally-friendly way.
- The creation of geological maps allows us to identify potential risk areas and survey different land uses; in other words, they make an essential contribution to land planning and proposing sustainable development strategies in a region.
- Learning about Geology and the proper use of geological information contributes to saving lives and reducing financial loss caused by natural catastrophes such as earthquakes, tsunamis, volcanic eruptions, flooding and landslides, while also helping to develop construction projects, public works, etc.

Through the proposed activities we aim to explain some of the basic elements of the different specialities within the field of Geological Sciences. In order to do this, four sessions have been organised that will allow for a quick insight into the fields of Palaeontology, Mineralogy, Petrology and Tectonics.



## Palaeontology

**Palaeontology**, as the etymology of the word suggest (from the Greek *palaiós* = old, *ontós* = to be and *logo* = science or rule), is the science that studies living things that existed on Earth in the past. They are studied in all their aspects in an attempt to order them in time and establish possible relationships with each other and the environment in which they lived.

These studies are carried out on **fossils** – the remains of organisms and other signs of their biological activities that have reached us today by becoming a part of sedimentary rocks. Therefore, the following are all fossils: organic remains (shells, bones, skin impressions, carapaces, etc), reproductive germ cells (oogonia, grains of pollen, spores, seeds, eggs, etc.), defecations (coprolites), moulds and signs of activity (tracks, burrows, perforations), gastroliths (stones used by some dinosaurs and birds in their digestive system) and even organic molecules, indicating the chemical processes that took place in living organisms (chemical fossils).

Many fossils can be seen by the naked eye – the so-called **macrofossils** or **megafossils**. Nevertheless, they are often small in size, which means that the help of a magnifying glass or optical microscope is necessary. These ones are called **microfossils**. Meanwhile, micropalaeontological research is making increasing use of scanning electron microscopes and the fossils whose study requires this type of instrument are called **nannofossils**.

The preservation of organic remains takes place through a long physical-chemical process called fossilisation. This process is selective, which means that only some of the remains produced by the organisms are preserved in the Fossil Record. The remains of the Würm glaciation (around 13,000 years old) are currently considered to be the most recent fossils.

The most important groups of fossil organisms are:

<b>Microfossils</b>	<b>Figure</b>	<b>Macrofossils</b>	<b>Figure</b>
Blue-green algae (stromatolites)	1a-b	Plants	2a-b
Charophytes	1c	Poriferans	2c
Diatoms	1d	Cnidaria	2d-e
Coralline algae	1e	Bryozoans	2f
Calcareous Nanoplankton	1f	Brachiopods	2g-i
Radiolarians	1g	Molluscs	2j-l y 3 a-d
Foraminifera	1h-i	Arthropods	3e-f
Ostracoda (Arthropods)	1j-m	Echinoderms	3g-h
Grains of pollen	1n-ñ	Graptolites	3i-j
		Vertebrates	3k-n

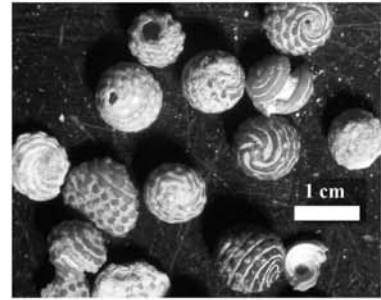
MICROFOSSILS



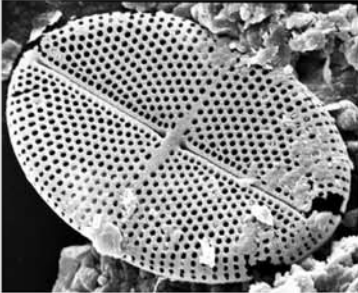
a) Cyanobacteria. Stromatolites (Picture, H. Astibia)



b) Cyanobacteria. Oncolite.



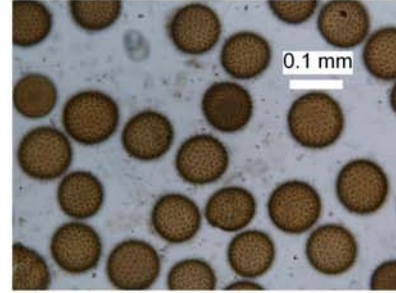
c) Charophytes. Girogonites.



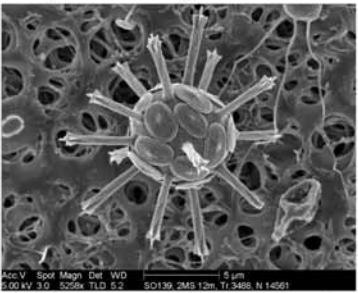
d) Diatom (Picture, Micropaleontologic Unit of the UCL).



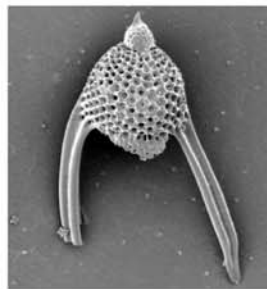
e) Coralline Algae



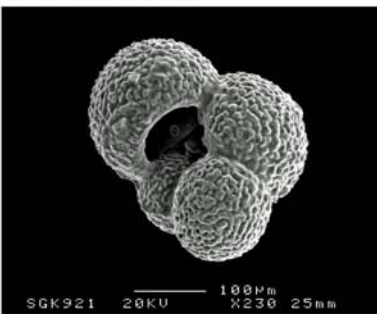
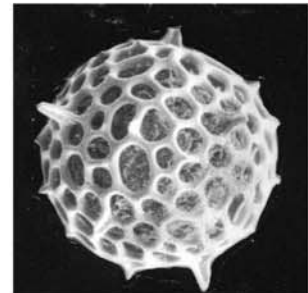
f) Pollen.



g) Calcareous Nannoplacton (Picture, BGR).



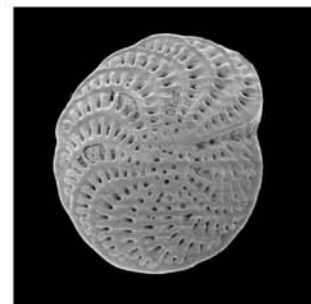
h-i) Radiolarians (Picture, Micropaleontologic Unit of the UCL).



j) Planktic Foraminifera



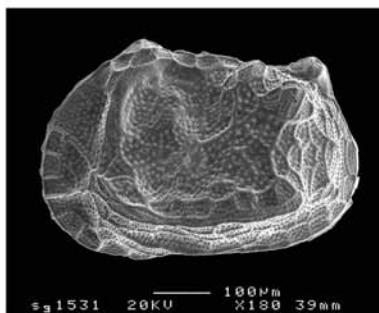
k) Benthic Foraminifera



l) Benthic Foraminifera. (Picture, Micropaleontologic Unit of the UCL).



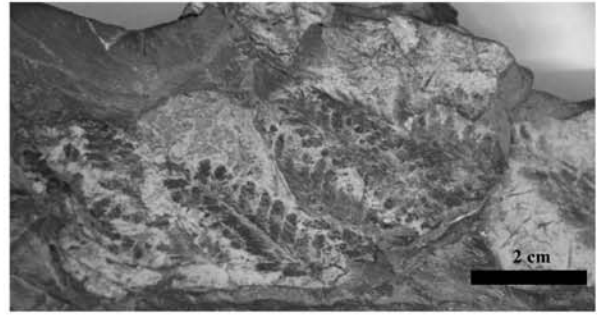
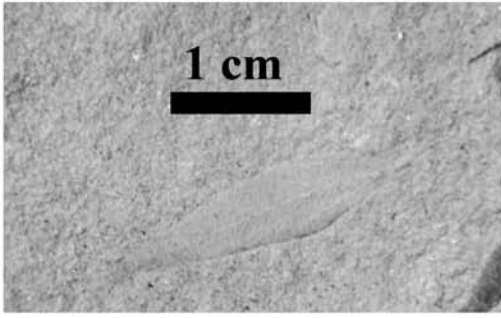
m) Foraminifera. Nummulite



n-ñ) Artropods. Ostracods



MACROFOSSILS



a-b) Plants



c) Sponge. (Poriferans).



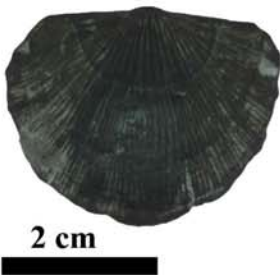
d) Corals. (Cnidarians).



e) Coral. (Cnidarian).



f) Bryozoans.



g-h-i) Brachiopods.



j) Mollusc-Cefalopod. Ammonite.



k) Mollusc-Cefalopod. Ammonite.



l) Mollusc-Cefalopod. Belemnite.

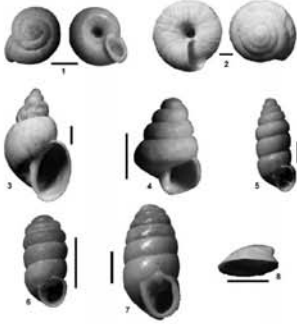
MACROFOSSILS



a-b) Molluscs-Bivalvians.



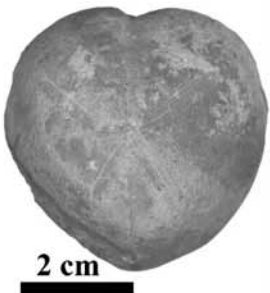
c) Molluscs-Bivalvians.Rudists.



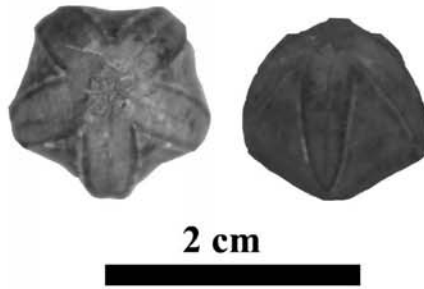
d) Molluscs-Gastropods.



e-f) Arthropods. Trilobites



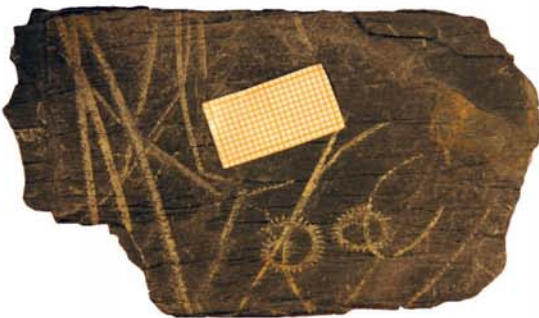
g) Echinoderm. Sea urchin.



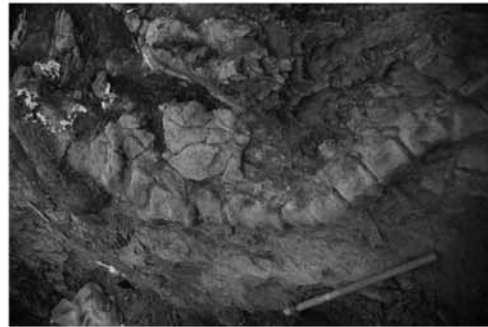
h) Echinoderm. Blastoid.



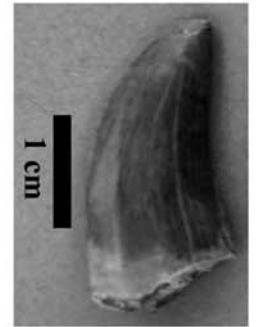
i) Graptolite.



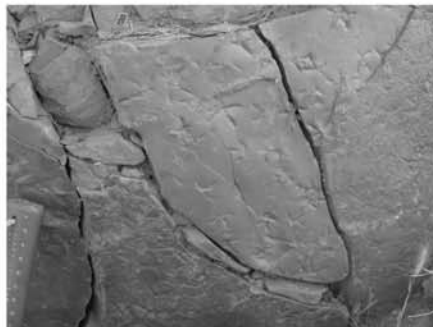
j) Graptolite.



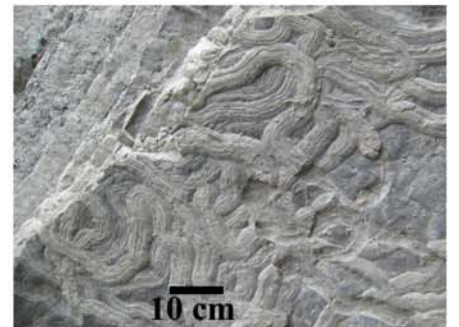
k-l) Vertebrates. Dinosaurs.



m) Vertebrate. Eggshell.



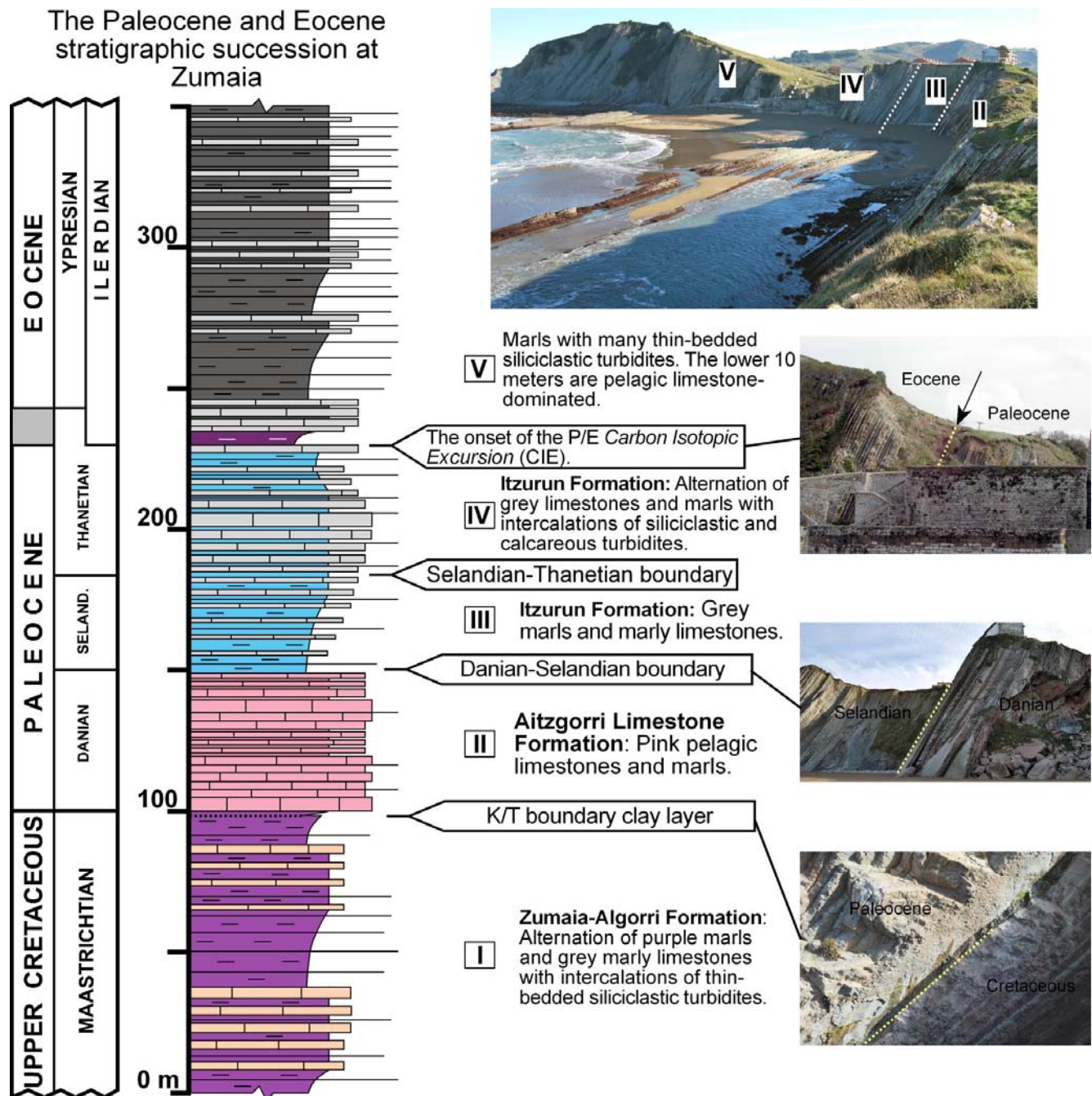
n) Vertebrates. Icrites.



ñ) Invertebrates. Icrites.

# Stratigraphy and Sedimentology

Among the different geological disciplines, Stratigraphy is the branch that deals with the evolution of the Earth in space and time via the characterisation and arranging in order of time of geological processes and their expression in the register of rocks.



The stratigrapher is a geologist who analyses and arranges in order of time the different events that have taken place on our planet over geological time which enable the history of different regions and the planet as a whole to be reconstructed via different time scales. To do so, the stratigrapher analyses the types of rock in each geological interval and the processes and conditions leading to their formation that can be deduced from them, and then arranges them in order them within the framework of a time-space succession of greater or lesser resolution. Essential tools used in this process are the establishment of



local or regional stratigraphic series (successions of rocks), the integration of data regarding age deriving from different methods (radiometric, palaeontological and cyclostratigraphical) and the sketching of time diagrams (chronostratigraphic diagrams or sketches). Stratigraphy is fed by and interacts with all geological disciplines, although mainly with Palaeontology, Petrology, Tectonics, External Geodynamics, Geophysics and Geochemistry.

Stratigraphy has an infinite number of practical applications. Among these, special mention should be made of the search for and exploitation of natural resources (above all hydrocarbons, coal and mineral ores) and the analysis of sedimentary processes and products within previous and present-day contexts (beaches, rivers and marine basins, etc.). Sedimentology specifically involves the study of this last-mentioned – this is a discipline that emerges from Stratigraphy and has undergone spectacular development over the past 50 years. The sedimentological study of sedimentary processes in present-day contexts provides basic information for the prevention of geological risks, the management of urbanised areas and infrastructures and surveys of coastal dynamics, having a direct application on the calculation of those effects that are giving rise to global climate change on our planet.



Paleocene reef limestone on top of Cretaceous deltaic sandstones (Alano mountains (range), Huesca)



Fluvial sandstones on top of Jurassic pelagic limestone (Cuchia, Cantabria).



Deltaic sandstone with ripple type cross-beddings (Cuchia, Cantabria).



Marine calcarenites with cross-beddings (Andia mountains (range), Navarre).



Currents marks (flute) on the base of an Eocene turbiditic sandstone (Punta Galea, Biscay).



Weight structures on the base of a Cretaceous turbiditic sandstone (Armintza, Biscay).

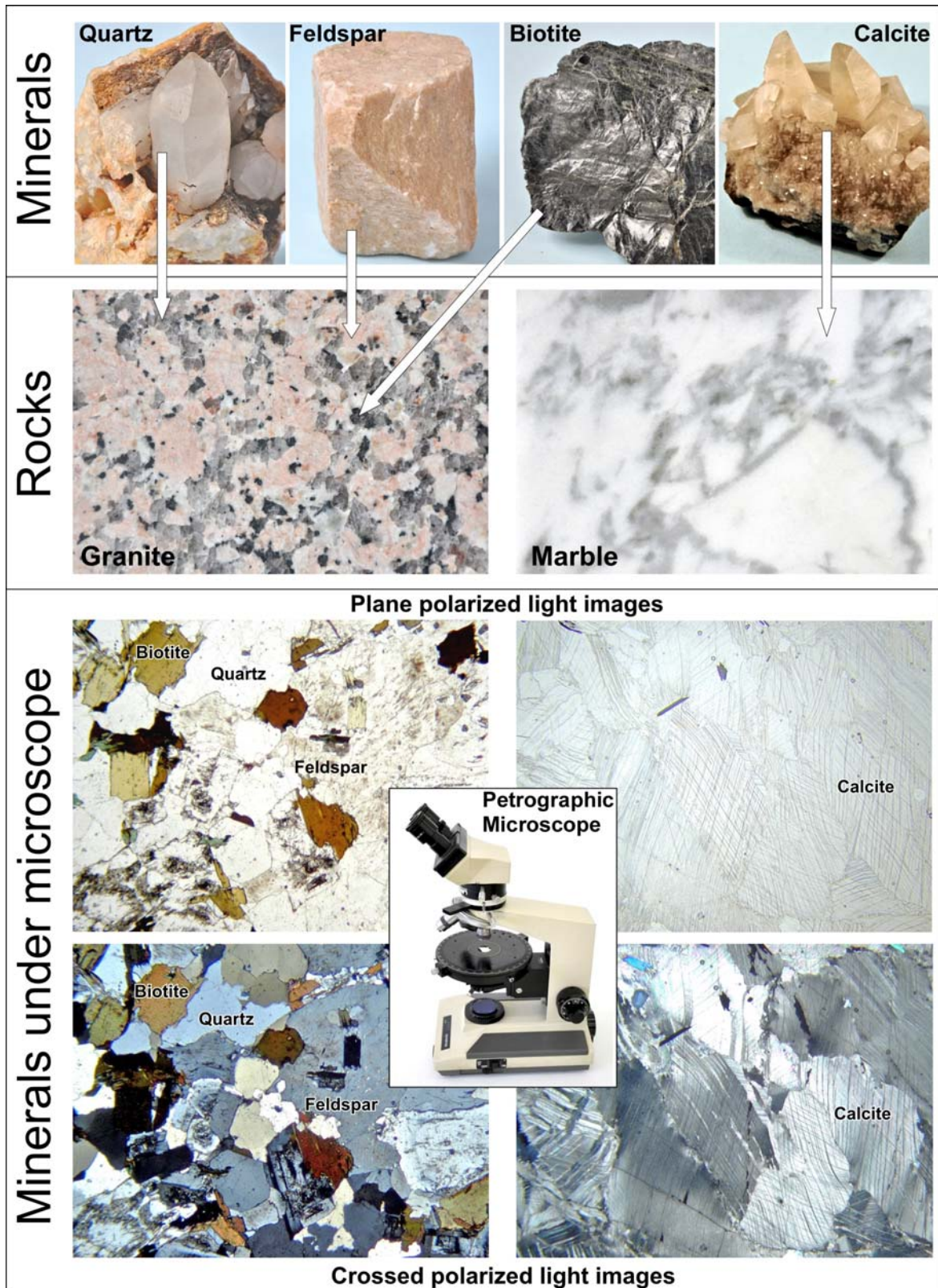
# Mineralogy

Consider for a moment what would be our daily lives if we removed the minerals and metals they contain: the buildings would collapse without steel, cement and glass, we could not had access to electricity, we would have no batteries or paper, and the home appliances would not exist ... and in that way a long etc. In this regard it should be noted that: which is not cultivated, comes from a mine.

## *Everyday Use of Minerals*

	<b>Mineral</b>	<b>Uses</b>
<b>QUARTZ</b>		
<b>HALITE</b>		
<b>GYPSUM</b>		










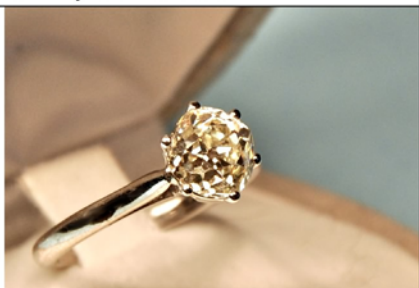
Do not confuse the concepts of rock and mineral, although they are closely related. A mineral is a natural compound, solid, inorganic, with an ordered internal structure (its atoms are arranged in a defined pattern) and a fixed chemical composition, (which can vary within limits). In contrast, a rock is a solid material consisting of one or more minerals. While limestones are composed almost exclusively of calcite [CaCO<sub>3</sub>], in other rocks like granites, we can find a wide variety of minerals: quartz [SiO<sub>2</sub>], potassium feldspar [KAlSi<sub>3</sub>O<sub>8</sub>], biotite [K (Mg, Fe)<sub>3</sub>AlSi<sub>3</sub>O<sub>10</sub>(OH)<sub>2</sub>] and others.



In the Earth's crust, approximately 3500 minerals species appear, which can be differentiated through their different physical characteristics: habit (external form), color, luster, streak, specific gravity, hardness, cleavage, fracture, etc...

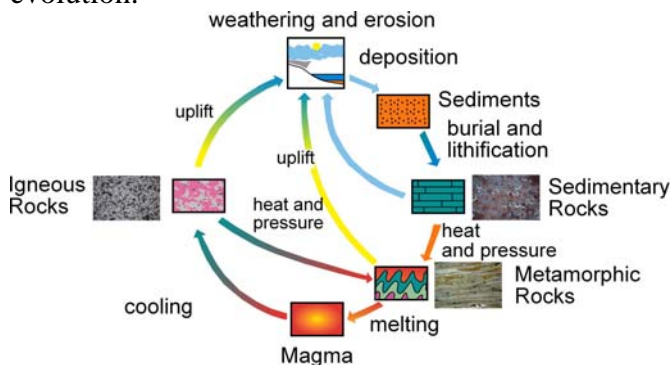
Color and Streak					
	<p><b>ALLOCHROMATIC MIN.</b> Beryl</p>	<p><b>IDIOCHROMATIC MINERALS</b> Malachite</p>	<p><b>IDIOCHROMATIC MINERALS</b> Azurite</p>	<p><b>Streak</b></p>	
	Habit				
		<p><b>INDIVIDUAL CRYSTAL</b> Garnet</p>	<p><b>TWINNED CRYSTALS</b> Staurolite</p>	<p><b>AGGREGATE</b> Muscovite</p>	<p><b>DENDRITE</b> Pyrolusite</p>
Cleavage and fracture					
		<p><b>PLANAR CLEAVAGE</b> Muscovite</p>	<p><b>RHOMBOHEDRAL C.</b> Calcite</p>	<p><b>OCTAHEDRAL C.</b> Fluorite</p>	<p><b>CONCHOIDAL FRACT.</b> Quartz</p>
	Luster				
		<p><b>VITREOUS</b> Quartz</p>	<p><b>SILKY</b> Gypsum</p>	<p><b>METALLIC</b> Pyrite</p>	<p><b>ADAMANTINE</b> Diamond</p>

## Mohs Scale of Mineral Hardness

Mohs scale of hardness with reference minerals (1 softest - 10 hardest)	
1	
<p>TALC (<math>Mg_3Si_4O_{10}(OH)_2</math>) <i>Easily scratched with a fingernail</i></p>	
6	
<p>ORTHOCLASE (<math>KAlSi_3O_8</math>) <i>Scratched with a steel file</i></p>	
2	
<p>GYPSUM (<math>CaSO_4 \cdot 2H_2O</math>) <i>Hardly scratched with a fingernail</i></p>	
7	
<p>QUARTZ (<math>SiO_2</math>) <i>It scratch the glass</i></p>	
3	
<p>CALCITE (<math>CaCO_3</math>) <i>Scratched with a copper coin</i></p>	
8	
<p>TOPAZ (<math>Al_2SiO_4(OH,F)_2</math>) <i>It scratch all the previous</i></p>	
4	
<p>FLUORITE (<math>CaF_2</math>) <i>Scratched with a knife</i></p>	
9	
<p>CORUNDUM (<math>Al_2O_3</math>) <i>Only scratched by the diamond</i></p>	
5	
<p>APATITE (<math>Ca_5(PO_4)_3(OH,Cl,F)</math>) <i>Hardly scratched with a knife</i></p>	
10	
<p>DIAMOND (C) <i>The hardest mineral of the earth</i></p>	

# Petrology

The term Petrology comes from the Greek Petra (rock) and Logos (Science or Rule) and corresponds to the branch of geology that studies rocks. A rock is any natural aggregate of one or more minerals that are part of any material found in the Earth's crust or mantle. Rocks have been an essential part of the development of life and human evolution.



Rocks are classified according to their origin as: a) igneous, b) sedimentary and c) metamorphic. These three types of rock are interrelated through the Rock Cycle.

*Igneous* rocks are formed through the solidification of magma, either inside the crust (plutonic rocks) or on the surface (volcanic rocks). *Sedimentary* rocks are formed through the depositing and lithification of particles that derive from the denudation of any type of rocks (igneous, metamorphic or sedimentary) that were previously elevated above the earth's surface. Meanwhile, heat, pressure and/or chemical agents cause the rocks on the inside of the crust to transform and create *metamorphic* rocks.

Rocks have information inside them about the process and/or conditions under which they were formed. Thanks to this information, we can distinguish different types of rocks and understand the history and evolution of the Earth. The texture of rocks is just one of the characteristics that allows us to observe this mark.

Igneous rocks, for example, have crystalline or glassy textures according to the speed of crystallisation. In other words, if the magma has cooled slowly inside the crust, the plutonic rock that is formed will have well-formed crystals, visible to the naked eye. On the other hand, if the magma rises to the surface of the crust, the speed of cooling will be quick, meaning that the crystals will not have time to develop and either small crystals, invisible to the naked eye, will be formed or the rock will be mostly glass (amorphous material). When volcanic eruptions occur, explosions often cause the break-up of magma. The falling and solidification of these fragments creates pyroclastic volcanic rocks.

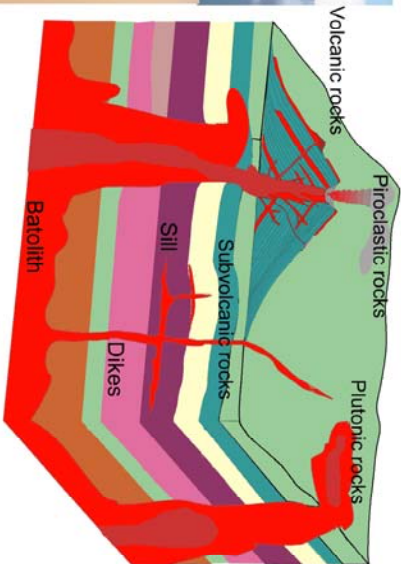
There are three main sedimentary rock groups:

- **Detrital Rocks (siliciclastic)**, formed through the accumulation of particles proceeding from the denudation of other rocks.
- **Biogenic, biochemical and organic rocks**, formed from the organic activity of different organisms (e.g. calcites and siliceous rocks) or through the accumulation of organic material (coal).
- **Chemical rocks**, formed through the precipitation of minerals in solution, such as gypsum or salts. Evaporation and upwelling are the main elements of this process.

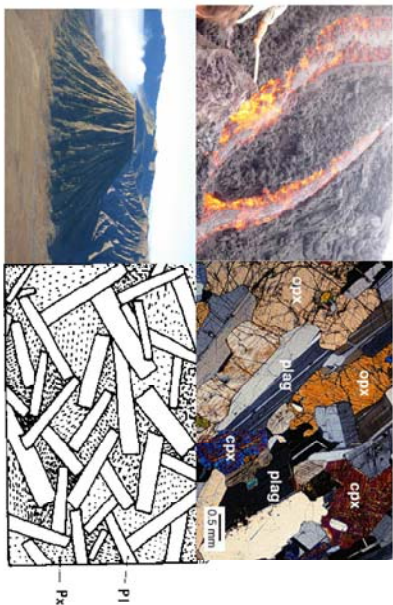
With metamorphic rocks, heat and pressure provoke the destabilisation of the original minerals and chemical reactions are produced that generate new metamorphic minerals. By studying these new minerals, the conditions under which these rocks were formed can be understood. In addition, the existing pressures in the environment drive the minerals in certain directions, creating planar structures (foliation) and/or linear structures (lineation) in the rock.

# Igneous Rocks

## PYROCLASTIC ROCKS



## VOLCANIC ROCKS



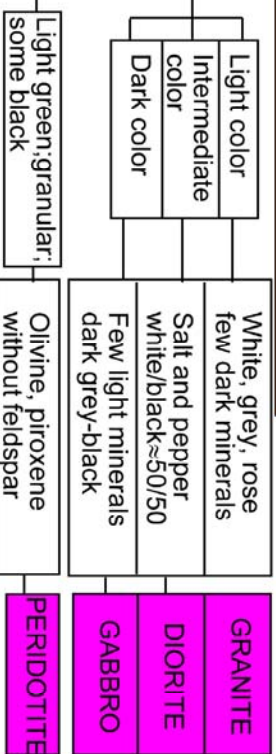
## PLUTONIC ROCKS



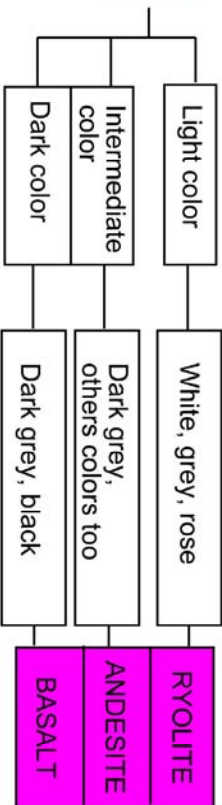
Identification clues for igneous rocks:

- 1- Rock crystals grain size
- 2- Rock color

**COARSE GRAINED**  
phaneritic  
seen by naked-eye



**FINE GRAINED**  
afanitic  
not seen by eye





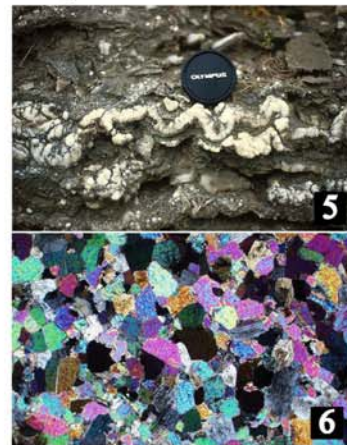
# Sedimentary Rocks

## Siliciclastic Rocks

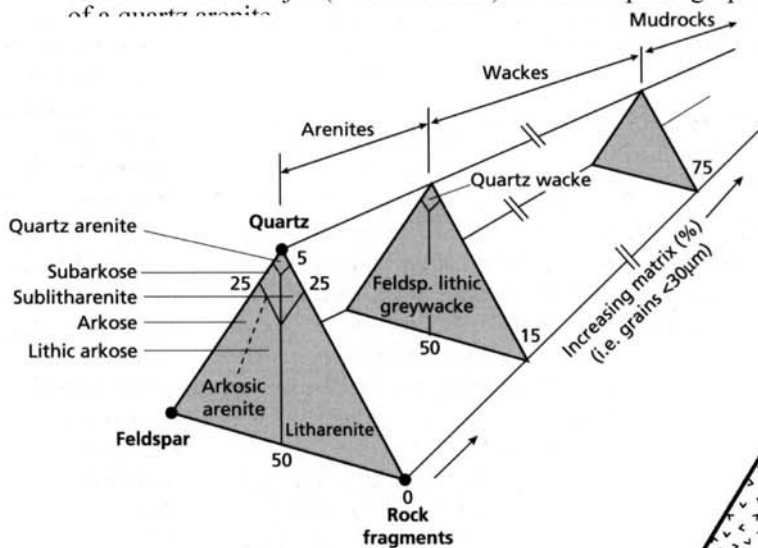


1.- Conglomeratic braided bars in the Isábena river (Huesca). 2.- Coral dunes (Utah, USA). 3.- Paraconglomerate bearing basaltic clasts in Ajui (Fuerteventura). 4.- Microphotograph of a quartz arenite.

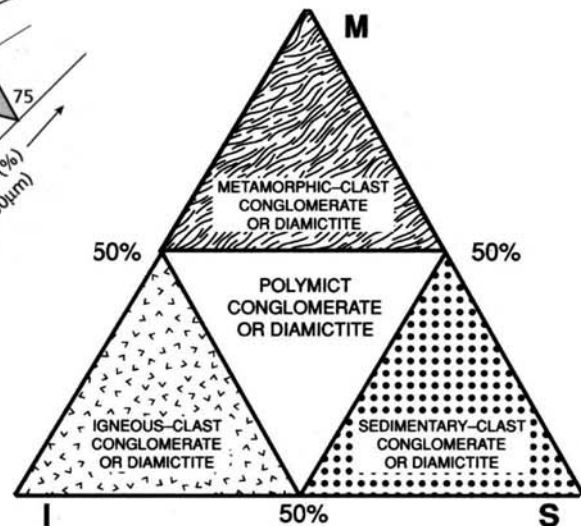
## Evaporitic Rocks



5.- Enterolithic folding in Tertiary anhydrite layers from Briviesca (Burgos). 6.- Microphotograph of an equigranular anhydrite.

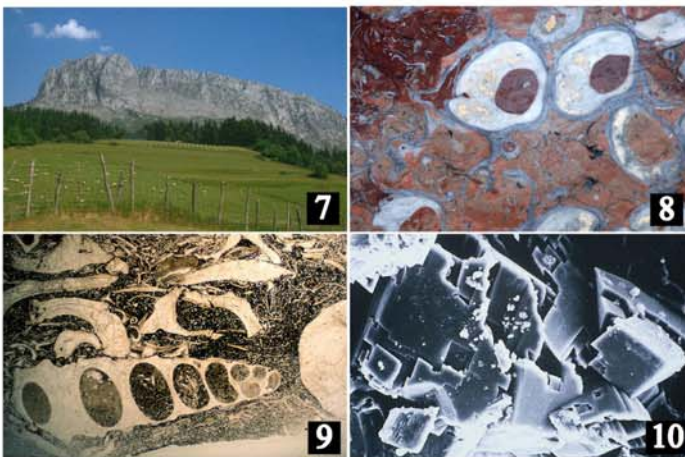


Classification of sandstones after Pettijohn, Potter and Siever (1972)



Classification of rudites after Boggs (1992)

## Carbonate Rocks



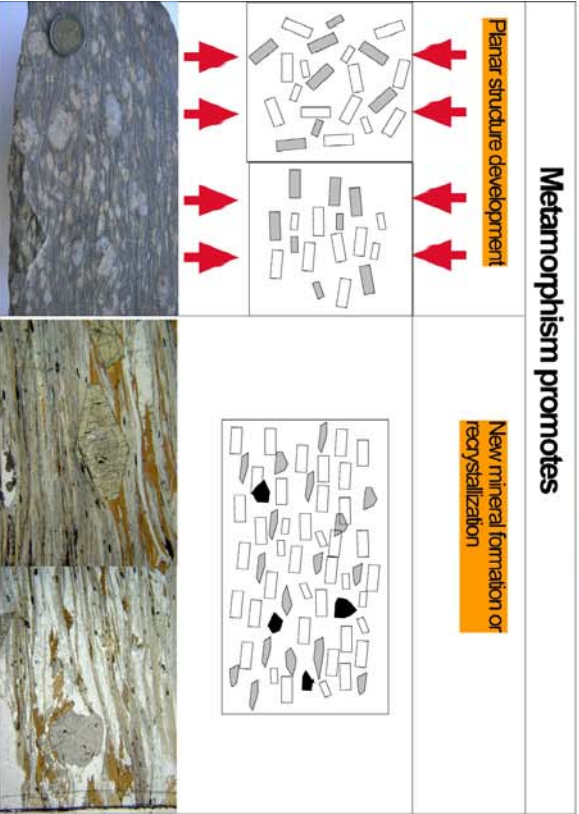
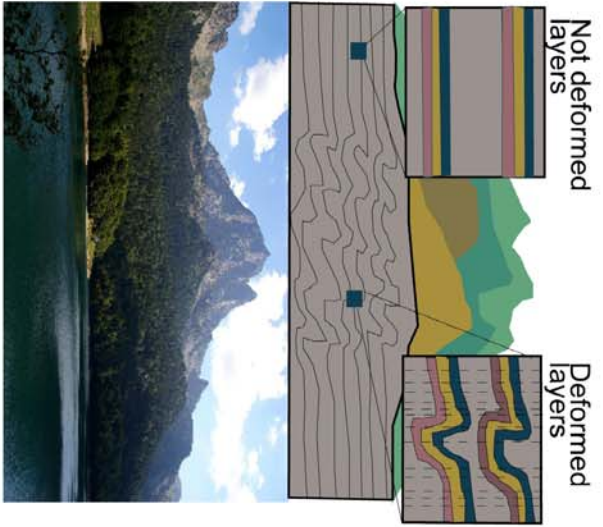
7.- Panoramic view of a reefal talus in Itxina (Bizkaia). 8.- Polished rock section of the so-called "Rojo Bilbao", showing transversal sections of caprotinid rudists (Ereño, Bizkaia). 9.- Microphotograph of gastropod shells of the genus Paraglauconia (Areatza, Bizkaia). 10.- Scanning Electron Microscope image (SEM) of dolomite rhombic crystals (Quecedo de Valdivielso, Burgos).

DEPOSITIONAL TEXTURE RECOGNIZABLE				DEPOSITIONAL TEXTURE NOT RECOGNIZABLE
Original Components Not Bound Together During Deposition		Original Components Bound Together During Deposition		
Contains mud		Lacks mud and is grain-supported		Crystalline carbonate (Subdivisions based on texture or diagenesis)
Mud-supported	Grain-supported			
< 10% grains	> 10% grains			
Mudstone	Wackestone	Packstone	Grainstone	Boundstone

Classification of carbonate rocks after Dunham (1962)

# Metamorphic Rocks

## METAMORPHIC ROCKS



## Identification scheme for metamorphic rocks

NOT FOLIATED (granular)		FOLIATED	
Translucent light color	Granular	Fine grained	Grey, black, dull green
Opaque dark color	Dense, compact conchoidal fracture	Coarse grained	Banded: light and dark bands
Translucent many colors	Granular	Squidlose; quartz/ feldspar/mica mixed	light bands (quartz/feldspar) dark bands (biotite/amphibole)
	Andalusite, cordierite	Garnet, staurolite, kyanite, sillimanite	smooth and flat layers
	Quartz recrystallized		
	Carbonate and Ca-Mg silicates mix		
	<b>QUARTZITE</b>		<b>SLATE</b>
	<b>HORNFELS</b>	<b>GNISS</b>	<b>PHYLLITE</b>
	<b>MARBLE</b>	<b>SCHIST</b>	

## Internal Geodynamics

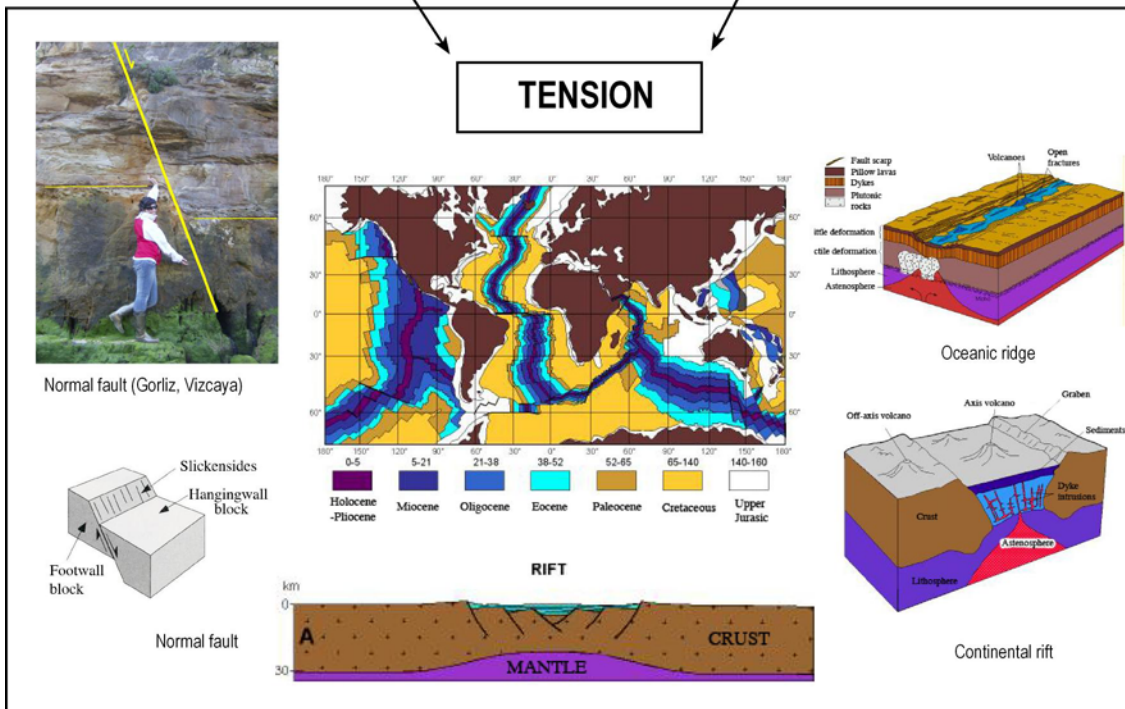
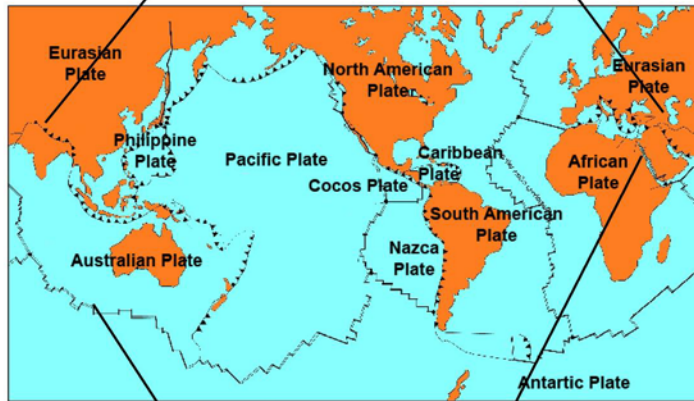
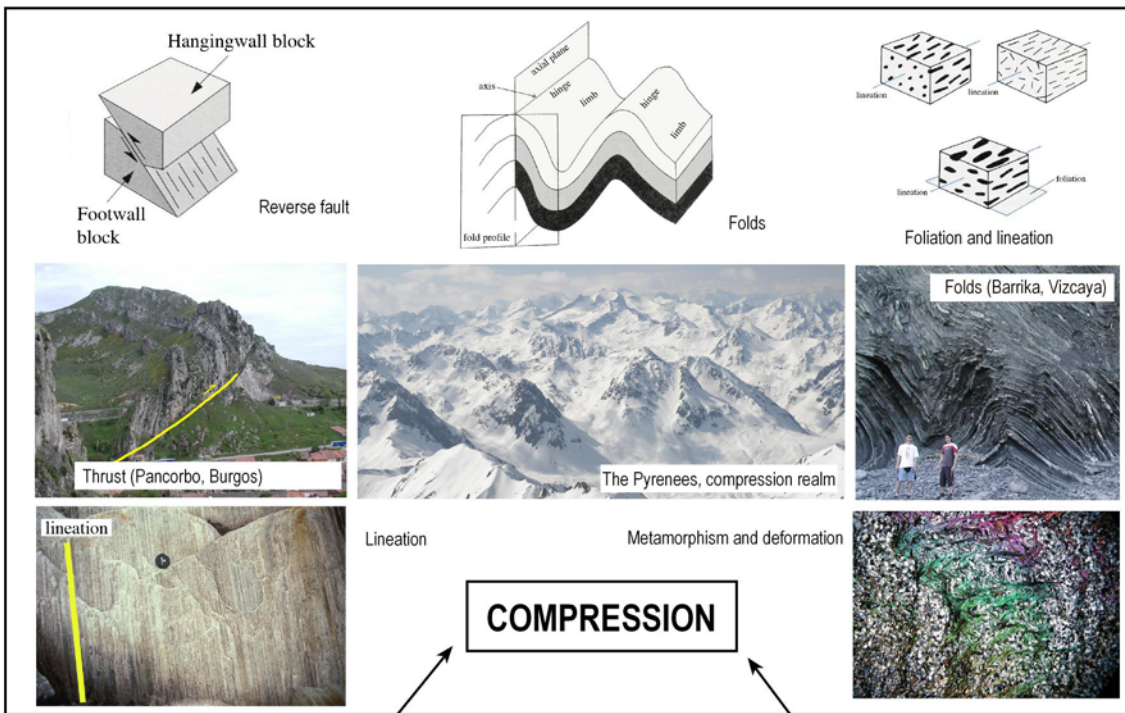
The internal dynamic forces of Nature are responsible for all the geological processes that take place in our planet. Some of them may be eye-catching due to their power and beauty, but at the same time they can turn into a source of fear and panic: earthquakes, volcanic eruptions, tsunamis or the continental relative motions are just some examples. These internal forces are the cause of the movements among the main tectonic plates at the Earth's surface. Tectonics is the part of Geology in charge of the study of these movements and related processes. The motion of the tectonic plates determine the occurrence and action of stresses that may give rise to mountain ranges such as the Himalayas or oceans such as the Atlantic. The structures developed in rocks as a result of the deformation accommodated within them (folds, faults...) are studied by another branch of Geology, namely Structural Geology.

The aim of this section is to give some insight into the relationship between Tectonics and Structural Geology. Thus, we will try to make it clear and detail what are the necessary requirements to be fulfilled during the formation of a mountain range, e.g. the Pyrenees, or an ocean, e.g. the Atlantic, as well as the main geological structures associated with these processes.

On the one hand, mountain ranges (Himalayas, Pyrenees...) are the result of the action of convergent stresses. These are characteristic of collision realms between two continents and may lead to thickening of the continental crust. The main geological structures formed under the above-mentioned conditions are the following:

- **Thrusts and reverse faults:** The convergent motion between two walls is accommodated by the relative up-going displacement of the rock body above the fracture surface (hangingwall block). Normally the dip of the fracture surface is quite low.
- **Folds:** Planar geological surfaces (bedding, schistosity planes, faults, dykes...) get curved as the result of the action of compressive stresses. When the oldest materials occur in the core of the folded structure, the fold is an anticline and, on the contrary, when the inner part is younger than the outer zone it is a syncline.
- **Foliation and lineation:** The spatial and geometric configuration of all the elements that make up the rock (minerals, grains, aggregates...) is known as the "fabric of the rock". As the rock gets deformed this internal arrangement may be modified and reorganized acquiring a planar (foliation) or linear (lineation) preferred orientation.

On the other hand, oceans may form after the fracture and splitting of continental masses. It is quite hard to imagine how the action of a certain tensile stress can eventually break up large continents. Initially this stress just makes the continental crust thinner and forms the so-called "continental rift" (Eastern Africa rift) that will evolve from a narrow ocean (Red Sea) to the complete formation of a large ocean. Normal faults are the hallmark of these realms. These structures accommodate the motion of the blocks moving apart from each other by the relative down-going displacement of the hangingwall block (rock body above the surface) along the fracture surface. These fractures are usually high-dipping surfaces.



# Geotechnics

All buildings are constructed upon geological materials. The nature and behaviour of these materials determine the stability buildings and engineering works.

## Geological reconnaissance

Geological reconnaissance is essential when studying the foundations of buildings, bridges and viaducts, the stability of slopes, tunnels, dams and earth structures (earth-fills and rock-fills).



The design of foundations of structures such as buildings requires a knowledge of ground properties.



Geologists analyse the stability of slopes and establish the appropriate corrective measures.



Tunnelling demands a detailed geological knowledge of underground materials.



In the case of dam projects, the analysis of hydrogeological characteristics and the

## Foundations

In the case of studies of foundations, the aim is to recognise the features of the subsoil by carrying out trial pits, boreholes and specific field and laboratory tests. A distinction is drawn between two major groups of materials in Geological Engineering: soils and rock masses. The most suitable materials for laying foundations are determined from such a study, thus avoiding problems with foundation failures and/or collapse of buildings.

### Stability of slopes

Those factors that intervene in rock falls or landslides in road works (mainly roads and railway lines) and natural and excavated slopes are identified in terms of the stability of slopes. The courses of action and corrective measures that need to be taken to ensure safety are then established.

### Tunnels

A major field of Geological Engineering is related to the design and construction of tunnels. The characterisation of rocky masses and soils carried out by the geologist plays a fundamental role in determining the advance to be made in the tunnel face and the supporting structures required to prevent rock falls and optimize tunnelling work.

### Dams

Lastly, geological-geotechnical surveys are essential for ensuring the stability of dams and determining the possibility of using materials excavated during the course of earthwork and in quarries for use in earth structures.

# GEOLOGICAL TIME SCALE

Eon	Era	Period	Epoch	Interval (Million years)	Duration (Million years)	Mayor Events	
Phanerozoic	Cenozoic	Quaternary	Holocene	0.01	0.01		
			Pleistocene	0.01 - 1.8	1.79	Extinction of large mammals Evolution of hominids	
		Tertiary	Pliocene	1.8-5	3.2		
			Miocene	5-23	18		
			Oligocene	23-37	14		
			Eocene	37-55	18		
			Paleocene	55-65	10		
			Mesozoic	Cretaceous		65-140	75
		Jurassic		140-210	70	First flowering plants First birds First mammal marsupials	
	Triassic			210-250	40	Mass extinction of Triassic/Jurassic boundary First dinosaurs	
	Paleozoic	Permian		250-290	40	Mass extinction of Permian/Triassic boundary Disappears over 90% of life on Earth	
		Carboniferous		290-360	70	Abundant insects First reptiles Forests of large trees which led to accumulations of coal	
		Devonian		360-410	50	First amphibians First gymnosperms	
		Silurian		410-440	30	First land plants Early terrestrial invertebrates	
		Ordovician		440-500	60	Mass extinction of Ordovician/Silurian boundary	
		Cambrian		500-550	50	Mass extinction of Cambrian/Ordovician boundary	
		Precambrian	Proterozoic	Neoproterozoic		550-900	350
	Mesoproterozoic			900-1600	700		
	Paleoproterozoic			1600-2500	900	First Eukaryotes	
Archean	Paleo/Meso/Neo Archean		2500-3600	1200	First living beings prokaryotes		
	Eoarchean		3600-4560	860	Formation of Planet Earth		