NATURAL STONE

2 - PETROLOGY

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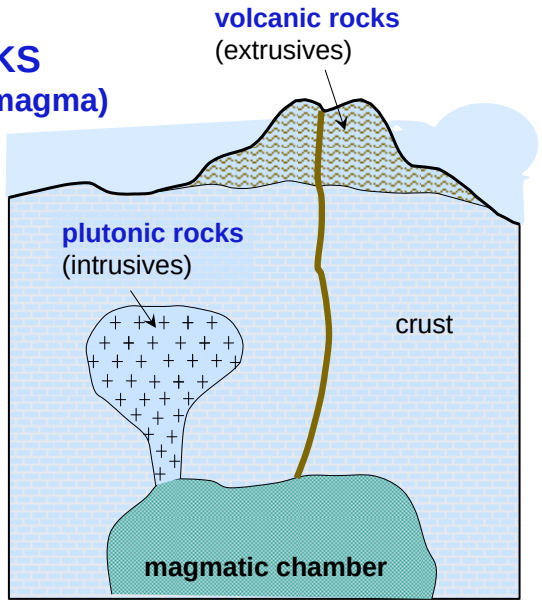
THE THREE CLASSES OF ROCKS

- Igneous (magmatic) rocks
- Sedimentary rocks
- Metamorphic rocks

IGNEOUS ROCKS
(= formed from a magma)

Magma : molten rocks (silicate solutions) located in the Earth crust or in the mantel

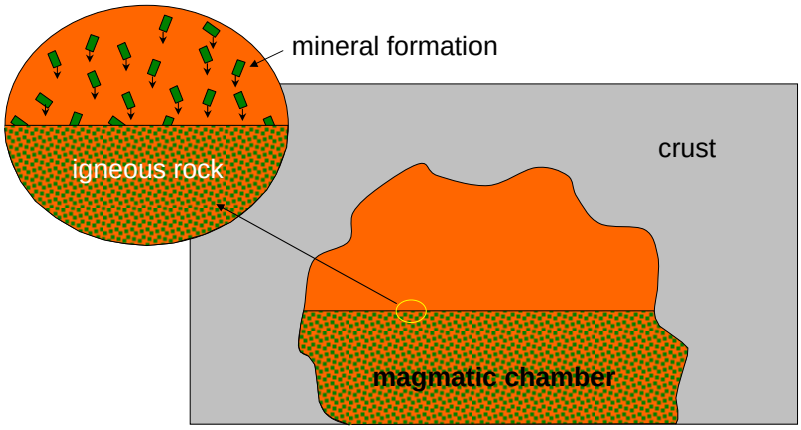
T ≈ 1200 – 1500° C



	plutonic rocks	volcanic rocks
magma	granitic	basaltic
origin of the material	crust (metamorphic rocks)	mantel (peridotites)
[SiO_2]	high	low
viscosity	high	low
rocks	intrusives	extrusives
solidification	slow	fast
cristallization	complete	incomplete or non-existent

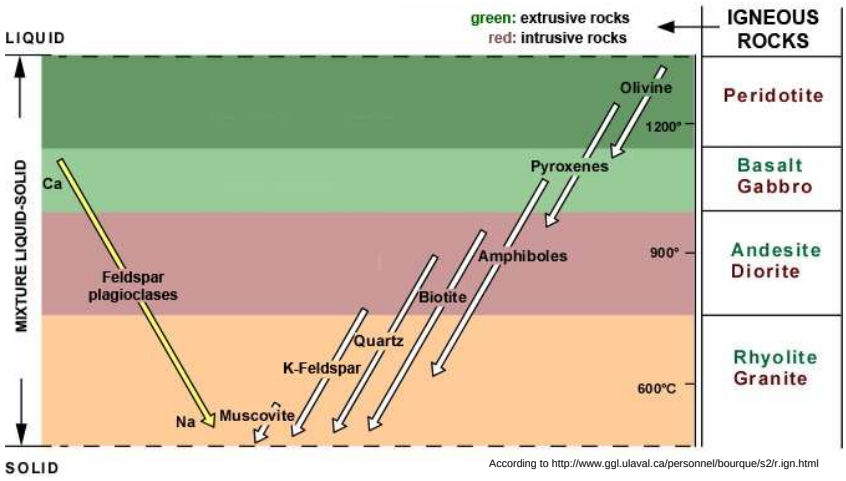
"Schematic" characterization of the igneous rocks

Concept of fractional crystallization



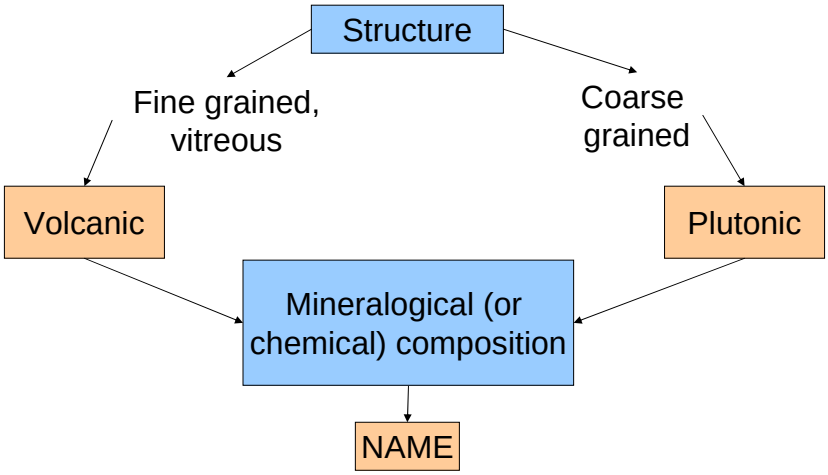
As T ↘, minerals crystallize and fall down with certain chemical elements ➔ the chemical composition of the magma is constantly evolving

Concept of fractional crystallization



According to http://www.ggl.ulaval.ca/personnel/bourque/s2/r.ign.html

Classification of magmatic rocks



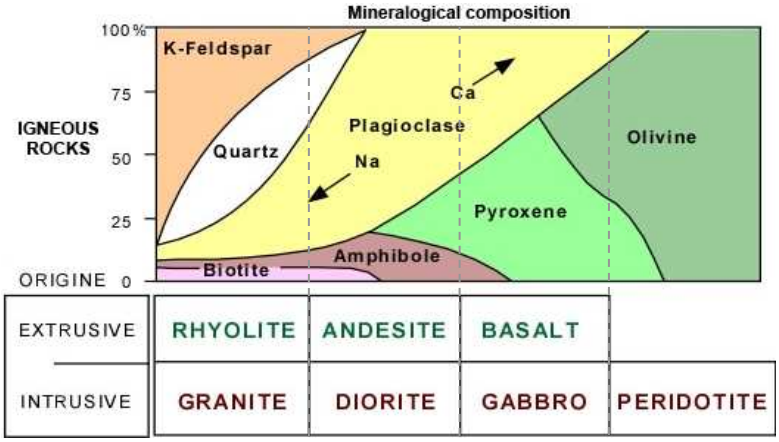
Classification of magmatic rocks

Cardinal minerals (light colours):
- quartz
- Na,K feldspars
- plagioclases (Ca,Na feldspars)
- feldspathoids

Essential minerals (dark colours):
- micas
- amphiboles
- pyroxenes
- olivine

Classification of magmatic rocks (simplified)

----------Light to dark coloured----------→



According to http://www.ggl.ulaval.ca/personnel/bourque/s2/r.ign.html

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PLUTONIC ROCKS (intrusives)

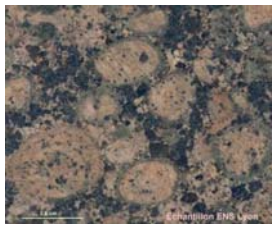
Some characteristics:

- all the cristals are visible with the unaided eye
- the cristals have no particular orientation
- the porosity is very little or non-existent
- cristals are often well formed (automorphes)

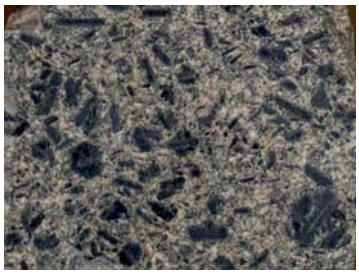
Plutonic rock: granite (≈95% vol.)








Plutonic rock: diorite



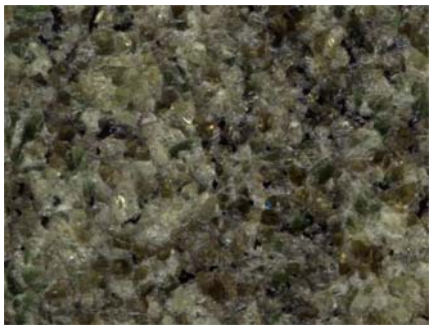

Plutonic rock: gabbro






Plutonic rock: peridotite






VOLCANIC ROCKS
(extrusives)
Effusives and pyroclastics rocks

Some characteristics:

- the matrix is always amorphous, glassy or fine grained
- the porosity can be very high
(vacuoles in pyroclastic rocks => trapped porosity)
- If cristals exist, they often are orientated

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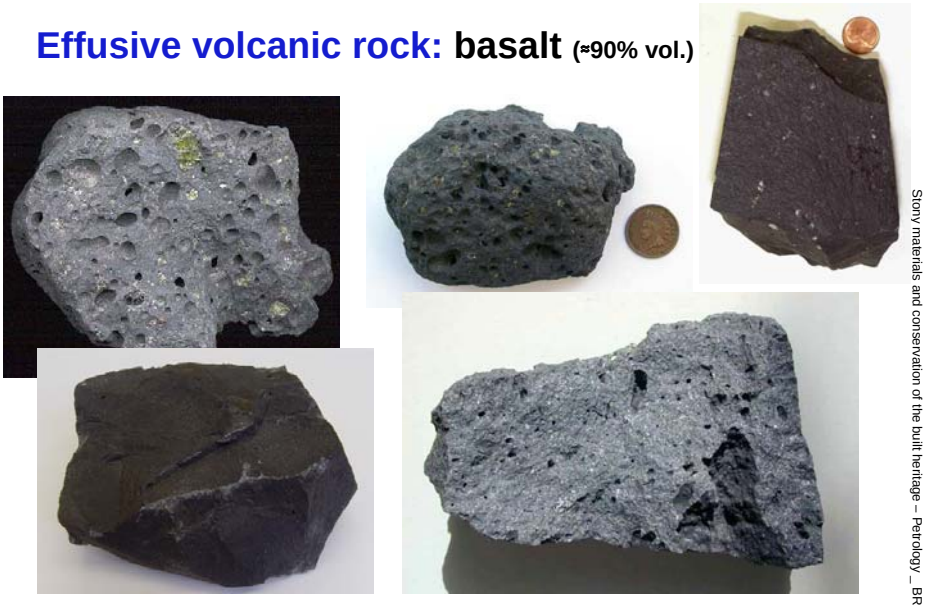
Effusive volcanic rocks
come from effusive volcanos:

Effusive volcanic rock: rhyolite

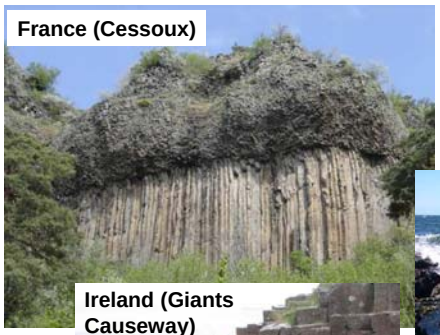
Effusive volcanic rock: obsidian (rhyolite)

Effusive volcanic rock: andesite

Effusive volcanic rock: basalt (≈90% vol.)



Basalt columns



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Pyroclastic volcanic rocks come from explosive volcanos:

Pyroclastic volcanic rock: bombs, blocs

Pyroclastic volcanic rock: pumice

THE THREE CLASSES OF ROCKS

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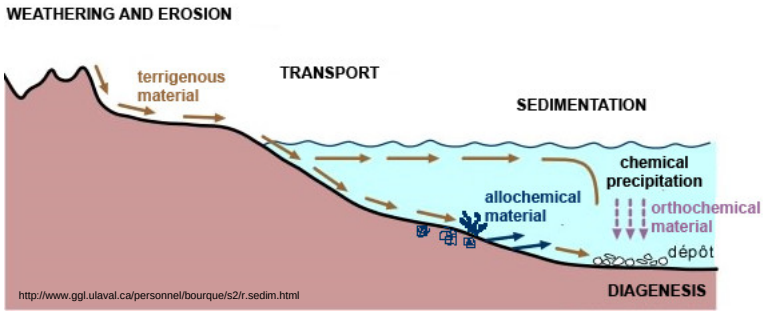
Genesis of the sedimentary rocks

Processes: weathering, transport, sedimentation, diagenesis



Material: terrigenous, allochemical (shells, skeleton,... from the sedimentary basin) orthochemical (chemical precipitation within the sed. basin)

Weathering and erosion

mechanical: mechanical disintegration (freez/thaw, roots of plants)

chemical: the minerals in imbalance with the atmospheric conditions are easily attacked (high temperature minerals or minerals with high solubility)

biochemical: plants take the elements they need from the minerals of the rocks

These 3 mechanisms => erode the preexisting rocks and produce debris of all dimensions

Sediment transport

Transporting mediums: rivers, glaciers, wind, ocean currents and tides (*marées*).

During transportation, edges are smoothed.

Depending on the medium and the energy, transport can last a few hours to several days/weeks/months/years

Deposition occurs when the speed of the transporting medium becomes insufficient to hold the particles

Sedimentation

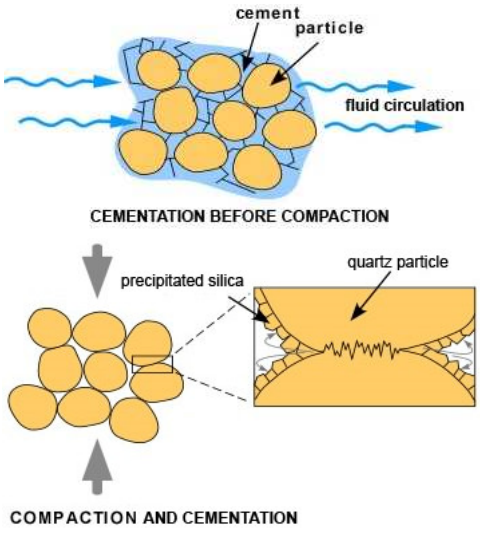
The transported material accumulates in a **sedimentary basin** in the form of successive layers whose composition, size of the particles, colour, etc, vary in time => **stratifications** (cf Gd Canyon, Jura,)

Sedimentation

Vosgien sandstone
(Vosges Mountains, France)

Diagenesis: transformation of a sediment into a hard rock

Chemical and mechanical processes which modify a sedimentary deposit after its deposition (dehydration, burying, compaction, dissolutions, recrystallizations, neo-formations, cementation)



Identification criteria of the sedimentary rocks

Stratification:

sedimentary rocks are mostly laminated

(except reef limestone, tuf limestone, glacial moraines)

Fossil content:

presence of substances or objects related to the living world (the hard parts of animals, plants footprints, holes, signs of grazing *(pacage)* or locomotion)

Classification of sedimentary rocks

The classification is based on the formation process.

The subdivisions are based on the chemical composition, the mineralogy or again on the formation process.

(Several classifications exist)

- **Clastic rocks**
- **Biogenic rocks**
- **Chemical rocks (evaporites)**

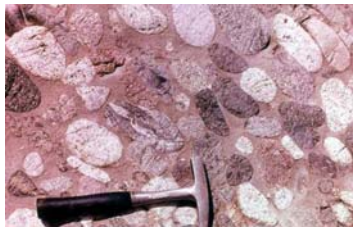
CLASTIC ROCKS

Composed of fragments of materials derived from other rocks (original rock can be **easily identified**). Largely composed of **quartz** with other common minerals (feldspars, amphiboles, clay minerals,…)

Clastic rocks

Coarse grains (>2mm)	Rounded clasts (of any rock type)	**Conglomerate *(poudingue)***
	Angular clasts (of any rock type)	**Breccia *(brèche)***
Fine grains (63 μ m to 2mm – can be seen / naked eye)	Quartz +/- feldspars, micas, clay minerals – Sandpapery feel and scratches glass	**Sandstone *(grès)***
Very fine grains (<63 μ m – cannot be seen / naked eye)	Quartz + clay minerals	**Siltsone *(pélite)***
	Clay minerals – non laminated	**Mudstone *(argilite)***
	Clay minerals –laminated	**Shale *(shale)***

Clastic rocks / conglomerate *(poudingue)*



Ex. near Lausanne: the poudingue from the Mont Pelerin

Clastic rocks / breccia *(brèche)*

Clastic rocks / sandstone *(grès)*

Clastic rocks / molasse sandstone *(molasse)*

Ex. in Lausanne: the Aquitanian molasse limestone of the cathedral

Clastic rocks / siltstone *(pélite)*

Clastic rocks / mudstone *(argilite)*

Clastic rocks / shale *(shale)*

Biogenic rocks
= biological or biochemical origine

Biogenic sedimentary rocks contain materials generated by living organisms, and include carbonate minerals created by organisms, such as corals, molluscs, and foraminifera (animals of the plankton), which cover the ocean floor with layers of calcite which can later form **limestone**.

Other examples include siliceous biogenic rocks like **diatomite**, **flint** nodules, **coal** and **oil shale.**

Biogenic rocks / biological

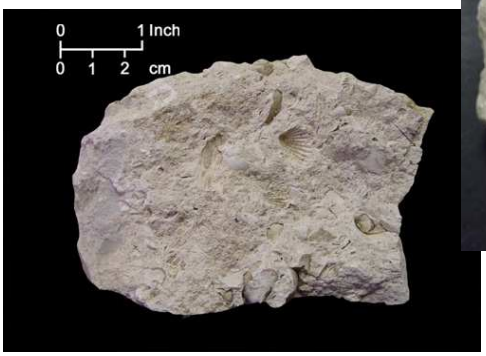
Mostly calcite ($CaCO_3$) Fizzes with cold dilute HCl (10%)	Muddy matrix with fossils	**Fossiliferous limestone/dolostone**
	Shells or shell fragments (>2mm) poorly cemented to form porous rock	**Coquina *(calcaire coquiller/lumachelle)***
	Shells or shell fragments (<63 μ m) poorly cemented to form porous rock	**Chalk *(craie)***
	Shells or shell fragments (<4 μ m) well cemented to form dense rock	**Micrite**
Mostly quartz (SiO_2) scratches glass	Made of radiolarians, red coloured, dense, alternation of dark and bright layers	**Radiolarite**
Mostly quartz (SiO_2) scratches glass	Made of diatoms, light coloured, extremely light weight, friable	**Diatomite**

Biogenic rocks / biological

Dull brown and plant-like	Porous and easy to break apart in plant fragments	**Peat *(tourbe)***
	Woody appearance, light weight	**Lignite**
Highly altered plant remains (carbon)	Black, dense and brittle or porous and sooty	**Bituminous coal *(charbon bitumineux)***

Biogenic rocks / limestone

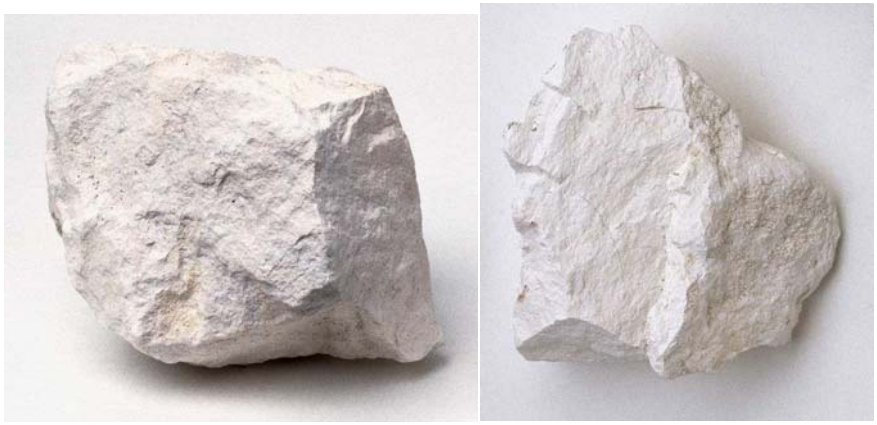
Biogenic rocks / dolostone



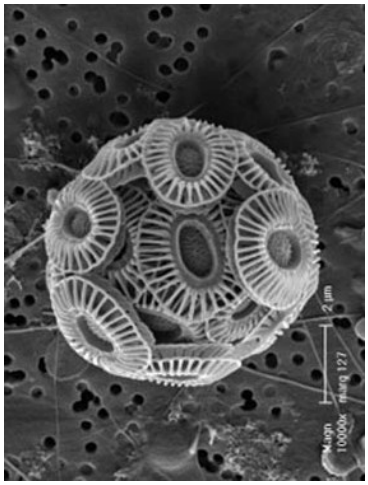
Biogenic rocks / fossiliferous limestone

Biogenic rocks / coquina *(calcaire coquiller ou lumachelle)*

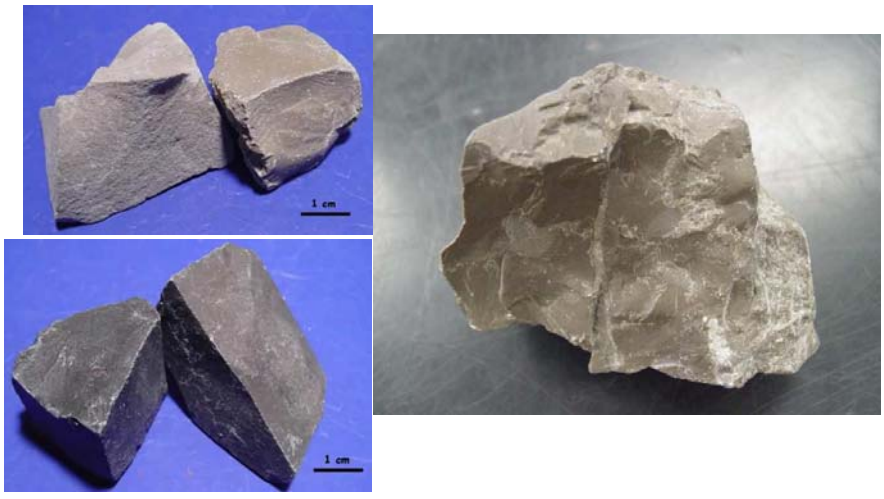
Biogenic rocks / chalk (made of coccolithophore)



Biogenic rocks / Coccolithophore (plankton)

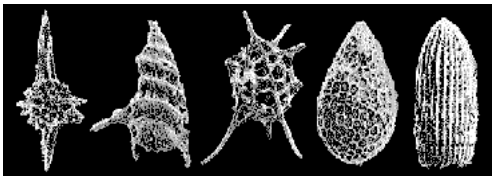


Biogenic rocks / micrite



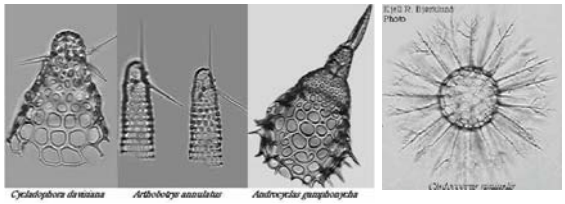
Biogenic rocks / radiolarite (made of radiolarians)

Biogenic rocks / radiolarians (plankton)



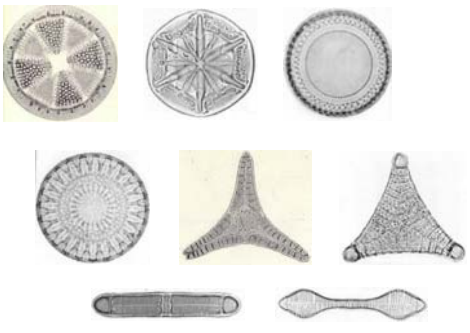
Fossilized radiolarians
x 150

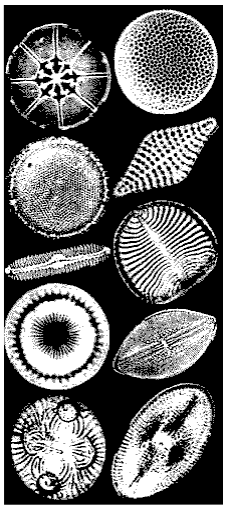
Today's radiolarians
x 150



Biogenic rocks / diatomite (made of diatoms)

Biogenic rocks / diatoms (plankton)





Biogenic rocks / peat *(tourbe)*

Biogenic rocks / lignite

Biogenic rocks / bituminous coal *(charbon bitumineux)*

Chemical rocks (evaporites)

Chemical rocks are mineral sediments that result from the evaporation of surficial oversaturated water or that precipitated from mineralized oversaturated solutions.

This usually happens in an arid environment with a small sedimentary basin fed by a limited input of water (evaporites: halite, gypsum,…) or in an environment where water undergoes drastic modifications of pressure/temperature conditions (stalactite, stalagmite, travertine,…).

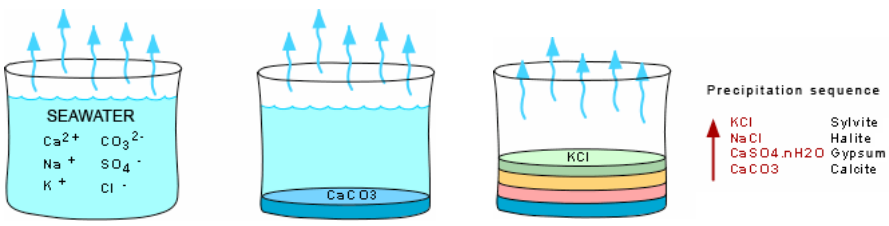
Chemical rocks (evaporites)

Mostly calcite ($CaCO_3$) Fizzes with cold dilute HCl	Spherical grains like tiny beads with concentric laminations	**Oolitic limestone (or oolithic)**
	Banded	**Travertine**
	Highly porous, recognizable plant debris (mosses, twigs, leaves) and / or angular gravel	**Tuf limestone**
Very fine grained Chalcedony (SiO_2)	Light coloured, scratches glass	**Chert *(chaille)***
	Dark coloured, scratches glass	**Flint *(silex)***
Fine to coarse cristalline gypsum ($CaSO_4,2H_2O$)	Can be scratched with fingernail	**Rock Gypsum *(pierre à plâtre)***
Fine to coarse cristalline halite (NaCl)	Salty taste	**Rock Salt**

Evaporites

Minerals precipitate out of solution in the reverse order of their solubilities, such that the order of precipitation from sea water is:

1. Calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$)
2. Gypsum ($CaSO_4$-$2H_2O$) and anhydrite ($CaSO_4$).
3. Halite (NaCl)
4. Potassium and magnesium salts



Chemical rocks / oolitic limestone

Chemical rocks / travertine *(travertin)*

Roman travertine (Italy)

Travertin Gerdoo'i (Iran)

Chemical rocks / travertine *(travertin)*

Hot Springs at Pamukkale, Turkey

Chemical rocks / tuf limestone *(tuf calcaire)*

Tuf from Corpataux, Escaliers du court chemin, Fribourg

Chemical rocks / tuf limestone *(tuf calcaire)*

Beaume-les-Messieurs, France, Jura

Chemical rocks / chert *(chaille)*

Chemical rocks / flint *(silex)*

Chemical rocks / rock gypsum *(pierre à plâtre)*

Chemical rocks / rock salt

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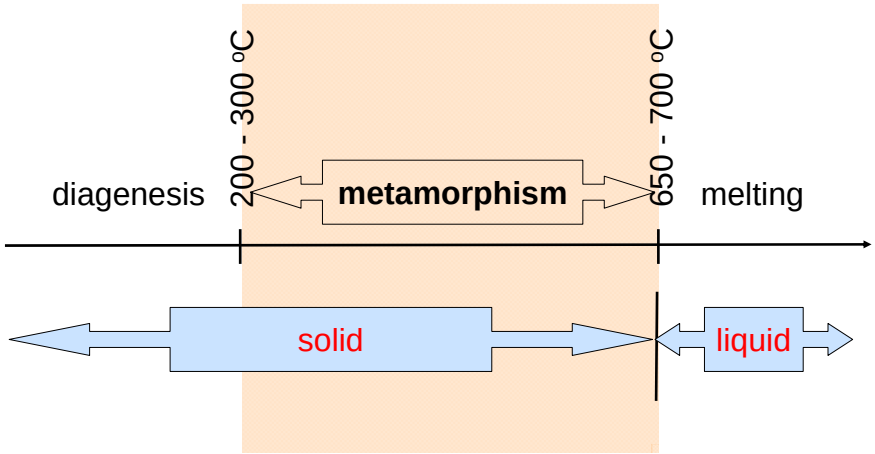
Metamorphic rocks

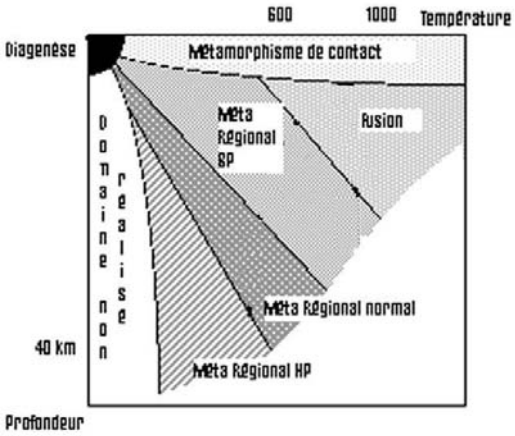
A metamorphic rock is the result of the transformation of a pre-existing rock type (protolith), in a process called metamorphism. The protolith is subjected to heat, extreme pressure and tectonic movements causing profound physical and/or chemical change. Protolith = sedimentary rock, igneous rock or another older metamorphic rock.

Metamorphims ("change in form") = solid state recrystallisation of pre-existing rocks due to changes in heat and/or pressure and/or introduction of fluids **without** melting. There will be mineralogical, chemical and crystallographic changes

Limits of the metamorphism

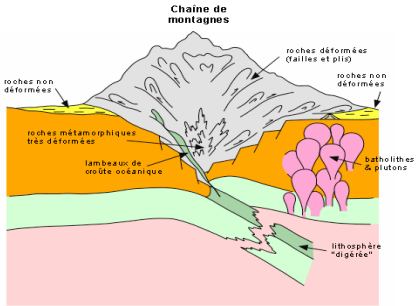


Conditions of the metamorphism

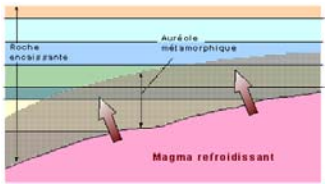


Types of metamorphism

regional m.



contact m.

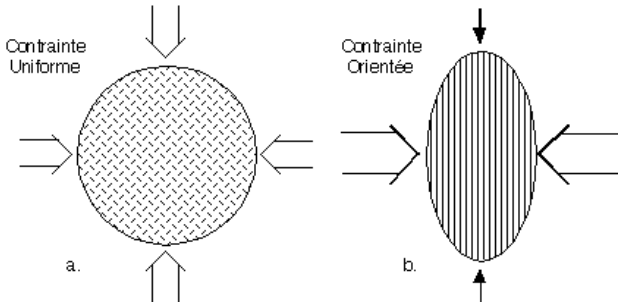


shock m.

Meteor Crater in Arizona

Metamorphism effects

- **orientated structure or foliation**
- **very small porosity**



Orientated structures

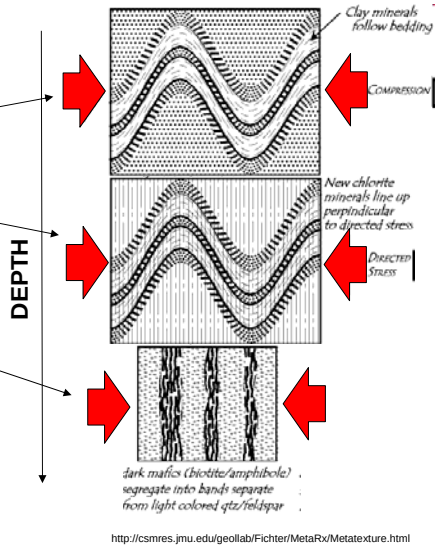
In the compression zones:

- at a shallow depth: only **fold deformation**

- at a medium depth: fold deformation + mechanical flow = **schistosity**

- at a high depth: schistosity + alternations of distinct mineral beds = **gneisocity (foliation)**

- at a very high depth: no orientated structure



http://csmres.jmu.edu/geollab/Fichter/MetaRx/Metatexture.html

Classification of metamorphic rocks (simplified)

Schistosity *(schistositée)*	Clay minerals, micas	Dense, easy to split into thin sheets	**Slate *(ardoise)***
	Micas, chlorite, talc, garnet, kyanite, staurolite, feldspars, quartz, tourmaline,…		**Schist**
Gneisocity *(foliation)*	Feldspars, quartz, micas, ferromagnesian minerals – Color banded		**Gneiss**
Non foliated, non orientated grains	Calcite ($CaCO_3$)	Fizzes with dilute HCl	**Marble**
	Dolomite $(Ca,Mg)(CO_3)_2$	Fizzes with dilute HCl only when powdered	**Dolomitic marble**
	Quartz (SiO_2)	Scratches glass	**Quartzite**
	Amphiboles	Generaly black prismatic crystals (2 cleavages 60º/120º)	**Amphibolite**

Metamorphic rocks / Slate *(ardoise)*

Metamorphic rocks / schists

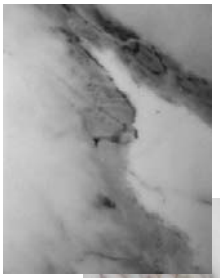
Metamorphic rocks / schists: serpentinite

Metamorphic rocks / Gneiss





Metamorphic rocks / Marble


Metamorphic rocks / Quartzite