ENVIRONMENTAL GEOLOGY (GEOLOGY 102)

BY SHAAS N HAMDAN

FIRST MATERIALS

CHAPTER ONE

OUR PLANETARY ENVIRONMENT

ENVIRONMENTAL GEOLOGY

- **Environment:** is the all conditions that surrounding an organism & influence it (physical & social environments)
  - **Physical environment**: rock, soil, air, water, light, temperature, & other organism around organism
  - **Social environment**: families, political system, & social customs that affect organism's behavior
- **Geology**: study of earth (physical environment), & all of geology might be regarded as environmental geology
- **Environmental geology**: geology that relates directly to human activity (humans & environments interactions)
- **Why do we study environmental geology?**
  1. Curiosity about the way the earth works
  2. How & Why of natural phenomena
  3. To solving of environmental problems
  4. To understanding of geologic processes
- Many environmental problems have come recently (e.g. acid rain, groundwater pollution), & others have always been with us (e.g. earthquake, volcanoe, & landslide)
- The geology has become more important due to:
  1. *Use of **chemistry*** to interpret the compositions
  2. *Use of **physics*** to explain properties & behavior
  3. *Use of **biology*** to understand of ancient life-forms
  4. *Use of **engineering*** to design safe structures
  5. The emphasis on "why" rather than just the "what"
- Geology is challenging because of the disparity between the scientist's laboratory & nature's

Factor	In laboratory	In nature
Condition	Controlled	Only with experiment
Time	Work on time scale (hr, yr…)	***Deep time*** & very slow to be detected in human lifetime
Materials	conduct of experiment on same materials	a material may transformed several times, under different conditions each time

FROM BIG-BANG TO EARTH!

- **The Big-Bang**: theory for the origin of the Universe, جميع الطاقة والمادة كانت مضغوطة بنقطة صغيرة شديدة الحرارة ولا متناهية الكثافة وقد انفجرت مكونة الكون والذي ما زال يتوسع الى اليوم
- **The time of the Big Bang (12-14Ga) are estimated by:**
  1. The universe's expansion (red shift affect)
  2. Astrophysical models of creation of the elements
  3. The rate of evolution of different types of stars
- ***Stars formed*** from *debris of the Big Bang*, as high mass of gasses collected by gravity & becames dense enough to form stars, & ***forming now*** from the original matter of the universe mixed with the debris of older stars
  - **The mass of material that initially formed the star determines** how rapidly the star burns
  - **Stars are not permanent**: they losing energy & mass as burn their nuclear fuel (by atomic reactions)
- **Solar system (5Ga)**: formed from rotating cloud of gas (from older stars) & dust (rocks & metals)
  - **Sun (5Ga):** Most of the mass of the flattened cloud disk have been condensed in the formation of sun
  - **Planets (4.5Ga)**: the remaining dust & gases have been condensed in the formation of the planets

Gas & Dust → Planetesimals → Planets

THE PLANETS & THE EARTH

- **Planets are differ by** composition & physical properties

planets compositions depend the distance from the sun	
Position	**Compositions**
Nearest	Fe + high melting T minerals + little water / gas
Farther	Lower T minerals + some that contain water
Farthest	Gas (even methane and ammonia)

- **The planetary density**: differences are due to chemistry & ore-forming processes (important in mining)
  1. Higher metal & rock in the planets closest to the sun
  2. Higher ice & gas in the planets farther from the sun
- **Venus**: similar to earth in size & density, marked with dense atmosphere (CO_2) that leds to greenhouse-effect
- **Mars**: very cold, surface features indicate the presence of liquid water in the past, & only small amounts of water ice have been found (fossil microorganisms)
- **Only earth gave rise to complex life-forms & ecological systems during evolving & changing:** its interior churning, landmasses shifting, & surface being reshaped
- **The early earth**: lacking modern oceans & atmosphere & having much different surface (resembling the moon)
- **Earth formed by** accretion, solid particles condensed from the nebula collected together by gravity, then water contributed by gravitational capture of icy comets
- **The earth was heated by:** (heat sources combined to raise the internal T enough that parts of it melted)
  1. Colliding of dusts & meteorites (planetesimals)
  2. Decay of radioactive elements within the earth
- **Differentiation process**: denser materials sink & lighter floated up, the result earth differentiated into several major compositional zones (Core, Mantle, & Crust)
- **The heating & differentiation led to the formation of:**
  1. **Oceans**: Minerals that had water & gas released them during heating, & as temperature decreased the water could condense to form oceans
  2. **Atmosphere:** The first atmosphere had little or no O_2 & consisted of N_2 & CO_2 dioxide (rom volcanoes) with minor amounts of methane, ammonia, & sulfur & O_2 exist by blue-green algae (by photosynthesis)
- **Only crust & uppermost mantle are analyzed directly**
- **Composition of Earth interior are studied by**
  1. Analyses of certain meteorites
  2. Analyses of composition of cloud of the solar system
  3. Geophysics indicate that earth's interior is zoned & provide information on densities of earth's layers

Geophysical data indicate the following results	
Core	Solid, mede of Fe, Ni, & a few minor element
Outer core	Molten, mede of Fe, Ni, a few minor element
Mantle	Fe, Mg, Si, O combined in different minerals
Crust	More varied in composition
Litho-sphere	Crust + uppermost mantle: form a brittle shell around the earth

- **The most common elements within the whole earth**: Fe > O > Si > Mg > S > Ni > Ca > Al
- **The most common elements within the earth's crust**: O > Si > Al > Fe > Ca > Na > K > Mg

LIFE ON EARTH

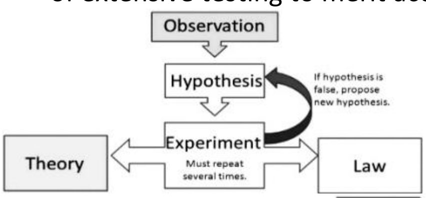
- The rock record shows when different plant & animal groups appeared, & the earliest creatures left very few remains because they had no hard skeletons, teeth, shells, or hard parts that could be preserved in rocks

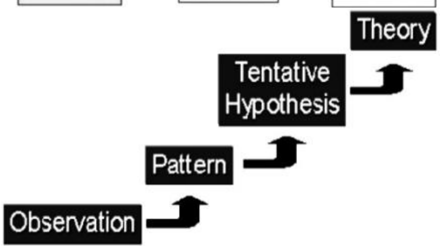
Biological Time Scale		
Yr's	hr's*	Appearing
1Ga		Multicelled O-breathing creature
550Ma	3:00hr	Marine animals with shells developed
500Ma	2:40hr	Dry land, & Fish
400Ma	2:00hr	Early land plants
300Ma		Insects
200Ma		Dinosaurs & The first mammals
150Ma		Warm-blooded animals & Birds
100Ma	0:45mi	Birds & mammals
3-4Ma		Human-type remains
0.5Ma	10sec	Rational humans (Homo sapiens)
*If we equate the whole of earth's history to a 24-hours		

- Certain energy source are formed from organisms remains. So Knowing the times at which the organisms appeared & flourished is helpful in assessing the probable amounts of energy sources & in concentrating the search for these fuels on rocks of appropriate ages

THE SCIENTIFIC METHOD

- **The Scientific Method**: discovering basic scientific principles, begins with set of observations & data, based on measurement of natural phenomena or experiments
- **Hypotheses (set of predictions)**: explain observations or data, & take many form (concept, formula…)
- Conduct experiment to test hypothesis, to determine whether experimental results agree with predictions
  - ➢ If they do, the hypothesis gains credibility
  - ➢ If they don't, the hypothesis must be modified
- **Scientific theory**: well-tested model with substantial & convincing body of evidence that supports it
- **Hypothesis Vs Theory**: A hypothesis may be advanced by one individual; but theory has survived the challenge of extensive testing to merit acceptance





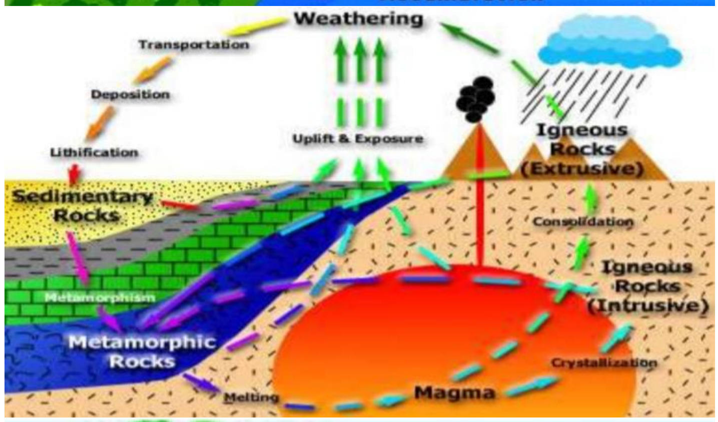
- The scientific method is not applicable to some geologic process due to difficulty of experimenting with nature!
- **The Big Bang are theory because (Evedance):**
  1. All the objects seem to be moving apart
  2. The universe's origin was very hot
  3. The predominant elements are H & He

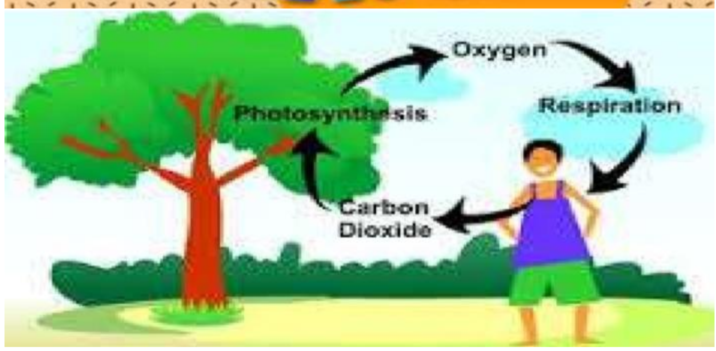
MOTIVATION TO ANSWERS

- **Search for explanations of phenomena goes on for:**
  1. Knowledge, & The need for resources
  2. solving problem(hazard: most abrupt consequence)
  3. concerns on human impacts (e.g. O_3, & warming)
- **Hazards**: such as earthquakes, volcanoes, & landslides
  - ***Flooding:*** reduced by uunderstanding of streams
  - ***Landslides & slope failures***: reduced by attention to slope stability & engineering practices
- ***As we consume more resources, we create more waste*** that leads to pollution, e.g. As fossil fuels are burned CO_2 rises in the atmosphere & lead to increase global T

EARTH CYCLES & SYSTEMS

- **The earth is a dynamic** (constantly changing): e.g. crust shifting to build mountains; lava flows out of its warm interior; ice, water, wind, & gravity reshaping its surface
- Many of the processes are cyclic in nature



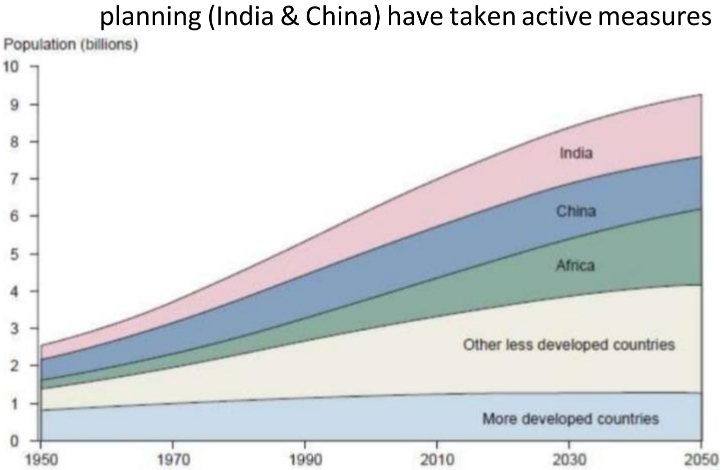


- These processes & cycles are often interrelated
  - ➢ e.g. At the coast, where the stream flow into the ocean, **coastal erosion** of beaches increases because a part of their sediment supply, from the stream, has been cut off
  - ➢ **Volcano eruption** releases water vapor, sulfur gas, & dust that influence the amount of sunlight, alter the extent of evaporation & resultant rainfall, & affect the intensity of landscape erosion & weathering of rocks by water

POPULATION GROWTHS

- Animal & human populations are limited in the areas that they occupy & the extent to which they can grow: live near food & water sources, in suitable climate, & away from predators, accidents, & disease
- If the population grows too large, disease & competition for food will cut it back to sustainable levels.
- **Number of factors had combined to accelerate the rate of human population increase**
  1. *They don't live only where conditions are ideal*
  2. *They don't live only where food can be grown*
  3. *They don't live only where there is abundant water*

- Population growth occurs when new individuals are added faster than existing individuals are removed (when birth rate exceeds death rate)
- In assessing an individual nation's:
  1. Immigration & emigration must taken into account
  2. Improvements in nutrition & health care increase life expectancies, decrease mortality rates, & thus increase the rate of population growth
- Increased use of **birth-control or family-planning methods** reduces birthrates (population growth rate)
- **Differences in growth rates among regions are due to:**
  1. Religious or social values
  2. High levels of economic development reduced rates & low levels associated with rapid increased rate
  3. Improved the education that led to prenatal & child care (increased rates), or lead to more effective practice of family-planning method (reducing rates)
  4. A few governments with large & rapidly growing have considered encouraging or mandating family planning (India & China) have taken active measures



- New factor that strongly affects population growth in some less-developed nations is **AIDS** (e.g. Botswana)
- **Exponential growth**: Even when the population growth rate is constant, the number of individuals added per unit of time increases over time
- *The effects of exponential increases in resource demand are like the effects of exponential growth*: a prediction of how soon mineral or fuel supplies will be used up is very sensitive to the assumed rate of change of demand. Even if population is no longer growing exponentially, consumption of many resources is.
- **Doubling time (D)**: the time required for population to double in size. Estimated from growth rate (G)

$$D = 70/G\ [in\ yr]$$

The higher the growth rate, the shorter the doubling time

- The fastest growth is in the largest segments of the population: By region Africa (2.4%/yr) & Asia (1.2%/yr), & tha Avg. growth rate is 1.2%/yr (58yr doubling time)
  - The population of Europe is nearly stable (declining slightly),precipitous declines are occurring.
- **The problems of rapidly growing world population was discussed in the context of food, & major limitation are**
  1. Availability of water (rainfall or irrigation)
  2. Nature of the soil (fertility, water-holding capacity)
  3. Farmland can deteriorate by topsoil erosion
- **Genetic engineering in food production for:** High yield, Disease resistance, & Other desirable qualities
- ***So fears of global food shortages are no longer warranted***, but 2 concerns remain:
  1. Poor nations may be least able to afford a designer seed or specially developed animal strains
  2. Replacing old crop by new variety, there is potential for devastating losses if a new pest or disease
- Food is a renewable resource, but the minerals, fuels, & land are finite. There is only so much oil to burn, rich ore to exploit, & suitable land on which to live & grow food, & When these resources are exhausted, alternatives will have to be found or people will have to do without
- Estimates of sustainable world population range from under 7 billion to over 100 billion persons
- The global average population density = 49 persons/km²
- Large numbers of people consuming of materials generate quantities of wastes, Some of these wastes can be recovered and recycled, but others cannot, so it's essential to find places to put this materials
- *Uneven Distribution of People and Resources:* a few countries control the major share of one resource. Thus, economic & political complications enter into the question of resource adequacy
- *Disruption of Natural Systems:* tend toward a balance or equilibrium among opposing factors, When one factor changes, compensating changes occur in response (systems always return to its stable states)
- *Human activities accelerate changes in natural systems*: the impact of humans on the global environment is proportional to the size of the population, & the level of technological development achieved (pollution)

CHAPTER TWO

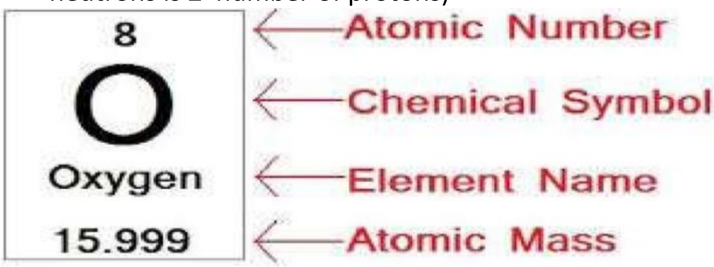
ROCKS & MINERALS

EARTH MATERIALS

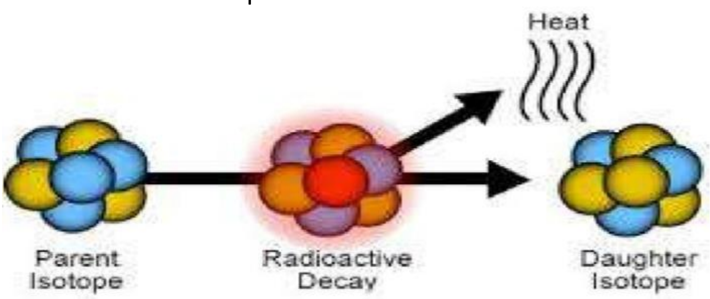
- The differences in the physical properties of rocks, minerals, & soils determine their suitability for different purposes (extraction, construction, agriculture, waste disposal, manufacturing) & arise from their composition
- All natural substances on earth are made from the 90 naturally occurring chemical elements
- **Atom:** is the smallest particle in which element can be divided & retain chemical characteristics of element
- **Nucleus**: center of atom, contain protons & neutron

Particles	Proton	neutron	Electron
Charge	+ve	0	-ve
Mass	Heavier	Heavier	Lighter
Position	Nucleus	Nucleus	Nuclear Cloud

- **Atomic number**: is the number of protons in the nucleus & determines what chemical element that atom is
  - ➢ e.g. H = 1, O = 8, C = 6, Fe = 26…
- **Atomic mass**: number protons + number of neutrons (All nuclei contain neutrons except of H, the number of neutrons is ≥ number of protons)



- **Isotopes**: atoms with the same number of protons but different number of neutrons, have different behaviors
- Some elements have single isotope, while others may have 10 or more due to principles of nuclear physics & processes of producing elements in the interiors of stars
  - ➢ **O-isotopes**: most common O^{18}, then O^{16}, & O^{17} rare
  - ➢ **H-isotopes**: protium H^1, Deuterium H^2, Tritium H^3
  - ➢ **C-isotopes:** most common C^{12} (6n + 6p), & the two rare isotopes are C^{13} (6p + 7n) & C^{14} (6p + 8n)
- **Radioactivity**: nuclei decay (break down) into nuclei of other elements, & releasing energy
- Each radioactive isotope will decay at its own rate, allows us to date geologic materials & events
  - ➢ C^{14} used to date material with carbon (archeological remains such as cloth, charcoal, & bones)
- Differences in properties of 2U isotopes are important in understanding nuclear power options: one of the 2 common U isotopes is suitable for use as reactor fuel



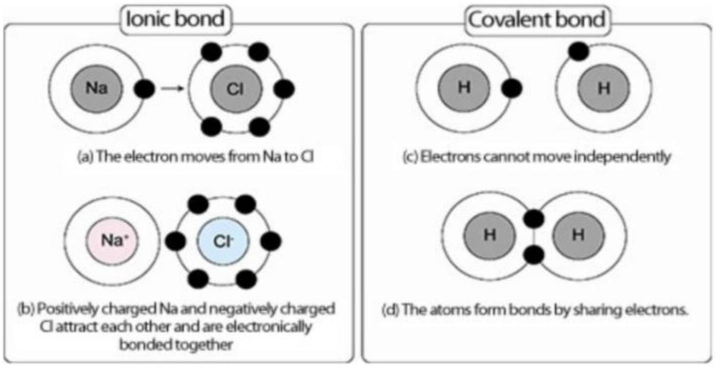
- Radioactive-waste disposal such a challenging problem, because no treatment can make those wastes nonradioactive & inert

IONS, & COMPOUNDS

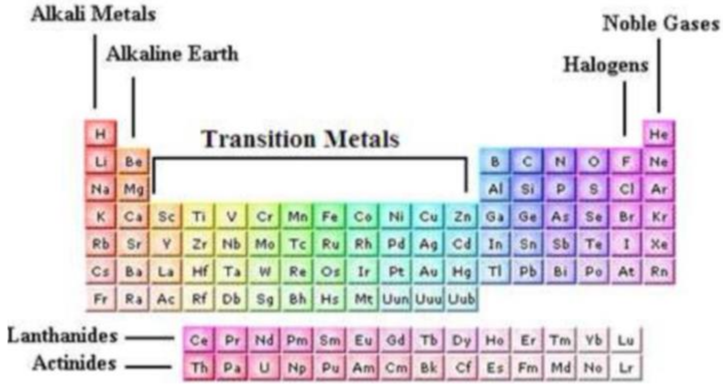
- In an electrically neutral atom, the number of protons & the number of electrons are the same
- **Ion**: are +ve or -ve charged atom (gain or lose electrons)

Ions	Anion	Cation
Electrons	Gains of electrons	Loses of electrons
Charge	-ve	+ve

- Both solids & liquids are electrically neutral: free ions do not exist in solids (cation & anion are bonded together)
- In a solution, individual ions may exist & moves
- Many minerals break down into ions as dissolve in water & ions may then be taken up by plants as nutrients
- **Acidity**: determined by concentration of H ions (pH)
- **Compound:** combination of chemical elements, bonded together in particular proportions, that has a distinct set of physical properties
- In minerals, most bonds are ionic or covalent (or a mix)
  - ➢ **Ionic bonding**: based on the electrical attraction between oppositely charged ions (such as in halite)
  - ➢ **Covalent bonding**: if the atoms share electrons

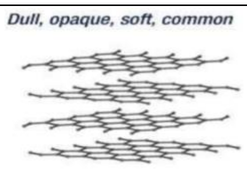
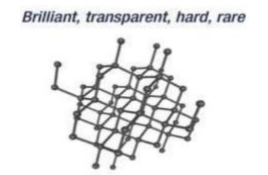


- ***The periodicity of chemical behavior can be related to the electronic structures of the elements***: electrons occur in shells of different energies, each of which can hold a fixed number of electrons
- Additional new elements must be created, not simply discovered, because these very heavy elements (atomic numbers > 92) are too unstable, like plutonium (Pu 94), are by-products of nuclear-reactor operation

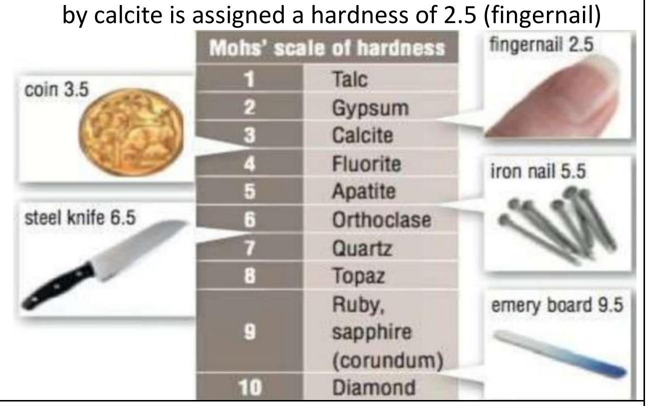


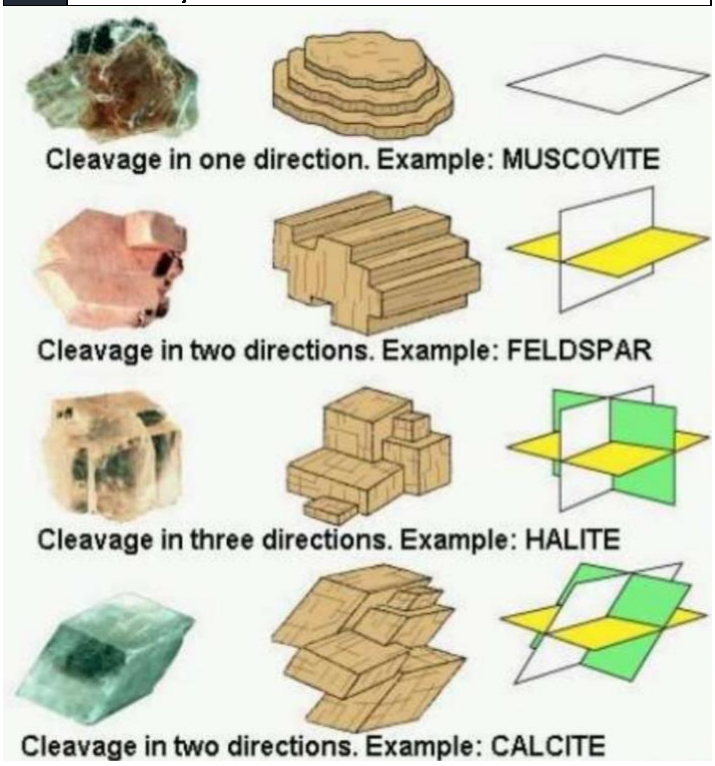
MINERALOGY

- **Mineral**: naturally occurring materials, inorganic, solid, with a definite chemical composition & crystal structure (at least on the microscope scale)
- Chemically, minerals may consist of 1 element (e.g. diamonds C), or of two or more elements
- **Crystalline materials** are solids in which the atoms or ions are arranged in regular & repeating patterns, & these patterns may not be apparent to the naked eye, & can be recognized using X rays & other techniques
  - e.g. Na & Cl are arranged in halite in cubic patterns
  - e.g. Ca & CO_3 are arranged in complex way in Calcite to produce trigonal crystal system
  - e.g. glass & plastic are noncrystalline solids
- **The fundamental characteristics of a mineral**: chemical composition & crystal structure
- e.g. **Diamond & Graphite** have different physical properties due to deferences in internal structures

Ions	Graphite	Diamond
Chemicals	Pure C	Pure C
Structures	Hexagonal	Cubic
Bounding	bonded in 2D sheets, but the sheets are weakly held in 3D	Each C is bonded in every direction by covalent bonds
Physical Properties	Black, opaque, soft, & its sheets tend to slide apart due to weak bonds	clear, colorless, hard, & can be cut into beautiful precious gemstones
Shape		

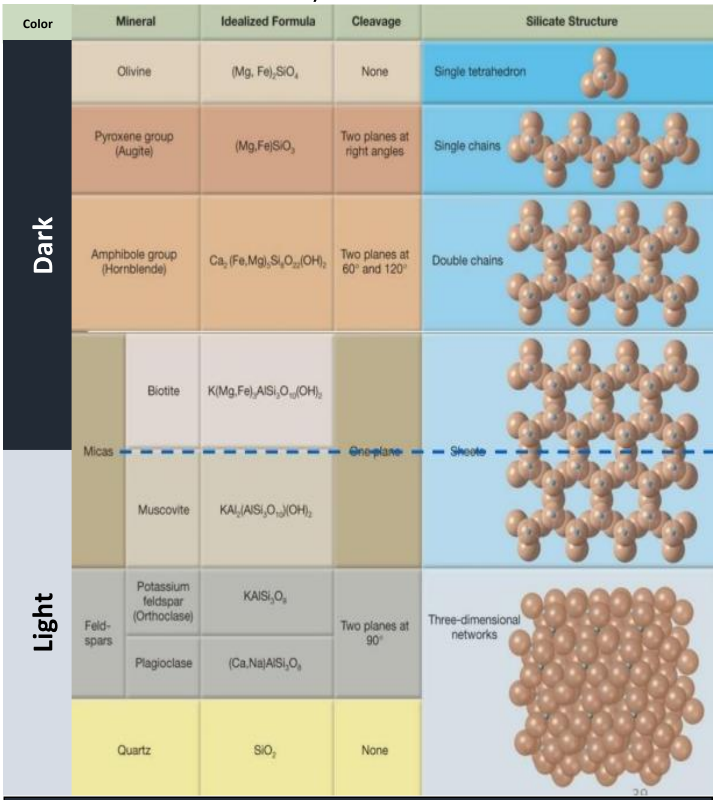
- A mineral's composition & crystal structure can be determined only in the laboratory
- **Mineral identification** based on physical properties that reflect the mineral's compositions & crystal structures
- Many minerals share similar external forms, & the same mineral show different external but same internal forms

Physical Properties of Minerals	
Color	***Are not a reliable guide to mineral identification*** (many minerals vary from specimen to specimen, & the color of a mineral can vary within a single crystal) **Variation in color** are due to chemical impurities, common in light-colored or colorless minerals • **Quartz**: cannot be recognized by its color (colorless, milky white, pink, yellow, smoky brown, purple…) • **Tourmaline** are rich colors gemstones • **Corundum:** Al + O, & quite hard which makes it a good abrasive, colorless but trace impurities can transform it into highly prized gems: 1. **Ruby:** deep bluish-red gem, corundum with Cr 2. **Sapphire:** is corundum tinted blue by Fe & Ti
Streak	**Color of powdered mineral when the mineral is scraped** may be quite different from the color of the bulk sample, & more consistent for a single mineral
Hardness	**Is ability to resist scratching, usually doesn't uniquely identify the mineral, measured on the Mohs scale** **Mohs scale**: 10 minerals arranged in order of hardness, & unknown minerals are assigned a hardness on the basis of which minerals they can scratch & which scratch them • e.g. A mineral that scratches gypsum & is scratched by calcite is assigned a hardness of 2.5 (fingernail) 
Luster	**Is the appearance of surfaces (glassy, metallic, pearly)** 1. **Metallic Luster (M):** such as Galena 2. **Non Metallic (NM):** Greasy (e.g. Graphite), Pearly (e.g. Talk), or Earthy (e.g. Shale)
Cleavage	**Is the tendency of a mineralto break along smooth planes parallel to zones of weak bonding** Some minerals as struck shatter to irregular fragments (**fracture**), but others break in preferred directions that correspond to planes of weak bonding (**cleavage faces**) • Cleavage surfaces are characteristically **shiny**
Other	**Specific Gravity:** Some minerals are denser than most **Magnetics:** a few are magnetic, attracted to magnets **Slickness:** of talc (main ingredient of talcum powder) **Malleability & Conductivity** of copper **Taste** table salt (halite) **Durability** of diamond



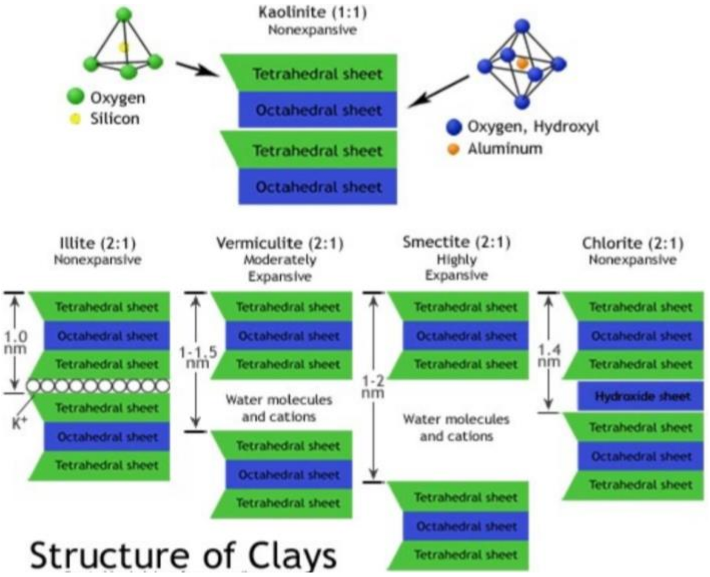
- Physical properties give minerals value
- Some nonunique properties (color, hardness, cleavage, density…) can identified without complex instruments

- Minerals can be subdivided based on the 2 fundamental characteristics: ***composition & crystal structure***
- Compositionally, classification is based on ***ions or ion groups*** into silicates & non silicates (Si & O are the most common elements in the earth's crust, so the largest compositional group of minerals is the silicate group)
- **Silicates minerals**: compounds containing Si+O±other elements, & subdivided on the basis of crystal structure (in which the Si & O atoms are linked together)
  - **Building block**: tetrahedral of 4O (anion) around the smaller Si (cation) that linked into chains, sheets, or 3D frameworks by the sharing of oxygen atoms
  - Some of the physical properties minerals are closely related to their crystal structures



Color	Mineral	Idealized Formula	Cleavage	Silicate Structure
Dark	Olivine	$(Mg, Fe)_2SiO_4$	None	Single tetrahedron
Dark	Pyroxene group (Augite)	$(Mg,Fe)SiO_3$	Two planes at right angles	Single chains
Dark	Amphibole group (Hornblende)	$Ca_2(Fe,Mg)_5Si_8O_{22}(OH)_2$	Two planes at 60° and 120°	Double chains
Dark	Micas – Biotite	$K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$	One plane	Sheets
Light	Micas – Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$	One plane	Sheets
Light	Feldspars – Potassium feldspar (Orthoclase)	$KAlSi_3O_8$	Two planes at 90°	Three-dimensional networks
Light	Feldspars – Plagioclase	$(Ca,Na)AlSi_3O_8$	Two planes at 90°	Three-dimensional networks
Light	Quartz	SiO_2	None	Three-dimensional networks

Common Silicates Minerals	
Quartz	simplest composition silicate (only Si + O) with framework (tetrahedra) that making it hard & weathering-resistant **Used** in the manufacture of glass Quartz-rich sand & gravel are used in construction
Feldspar	Is the most abundant group of minerals in the crust, composed of Si, O, Al, with Na, K, or Ca or mixtures of these elements (elements abundant in the crust) They are used in the manufacture of ceramics
Ferromagnesian	Silicates containing Fe & Mg with or without another elements, usually dark-colored (black, brown, or green) • Most of these minerals weather easily (unstable) • **Olivine:** major in the mantle, gem-quality olivines are the semiprecious gem peridot • **Micas:** are sheet silicates of linked Si & O, the sheets can easily broken apart due to weak bonding
Clays	Sheet silicates, the sheets tend to slide past each other (leds to slippery feel) & structures absorb or lose water • Clays expand as soak up water & shrink as they dry, absorbed water increase the slippery tendencies A soil rich in expansive clays is a very unstable for building **Used:** in ceramics, building materials, or as lubricants in the muds used to cool the drill bits in oil-drilling rigs

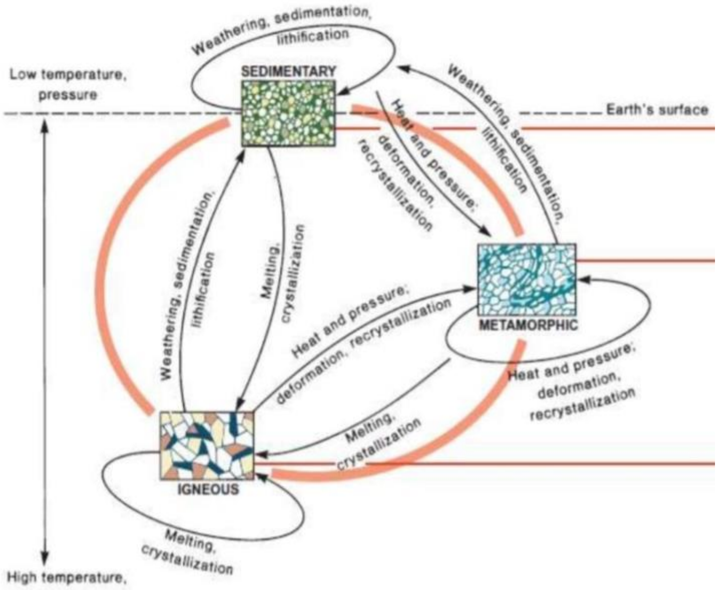


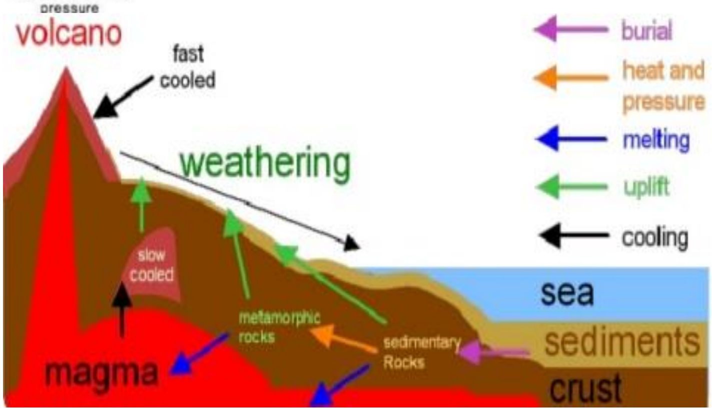
- **Nonsilicate**: defined by characteristic constituent, the common component is the same -ve ion or atom groups

Carbonates CO_3^{-2}	All are dissolve easily (acids), & the oceans contain dissolved carbonate & precipitation of Ca-carbonate from seawater formed marine rocks • **Calcites $CaCO_3$**: most common, cement materials • **Aragonite $CaCO_3$**: less common than calcite • **Dolomites $CaMg(CO_3)_2$:** also common • Carbonates may contain Fe, Mn, or Pb **Limestone & Marble** consist mainly of carbonates are used for building & sculpture
Sulfates (SO_4^{-2}) & Sulfides (metal+S)	**Sulfates**: All contain S + O in the ratio of 1:4 (SO_4) • **Gypsum($CaSO_4 2H_2O$)** most important, abundant, & commercially useful (in plaster of paris) • **Barite $BaSO_4$:** Br-ore • Sulfates may include barium, lead, & strontium **Sulfides**: sulfur without oxygen, & comprise many economically important metallic ore minerals • **Pyrite (FeS_2)**: fool's gold because its metallic golden color, but not a commercial source of Fe • **Galena (PbS):** Pb-ore, Illinois gave town its name • **Cinnabar (HgS):** mercury ore • Sulfides may include Cu, Zn, & other valuable ores **Sulfides may problematic**: when pyrite associated with coal is exposed by strip-mining & weathered, the result is sulfuric acid in runoff water from the mine
Oxide / Hydroxide	**Oxide**: Containing one or more metals with O^{-2} • **Magnetite (Fe_3O_4)**: navigational aids (compasses) • **Hematite (Fe_2O_3)**: red color, gives soils red-color • **Al-oxides**: Corundum Al_2O_3, & Spinal $MgAl_2O_4$ • The Mars's orange color are due to Iron oxides **Hydroxide**: Containing one or more metals with OH^- • **Gibbsite** $Al(OH)_3$, & **Brucite** $Mg(OH)_2$
Native elements	Consist of single chemical element (minerals' names are usually the same as the corresponding elements) • Most prized materials (Au, Ag, Pt) is NE • **Examples:** Diamond & graphite (native carbon), tin (Tn), iron (Fe), antimony (Sb)… • Sulfur may occur as a native element, either with or without associated sulfide minerals
Halides (halogens): Halite NaCl, Fluorite CaF_2	

PETROLOGY (ROCKS)

- **Rock**: solid & cohesive aggregate of one or more mineral or volcanic glass, consists of many individual mineral grains (crystals) or crystals & glass
- **Beach sand** consist of many mineral grains, but it is not a rock, but grains may cemented together to form a rock
- The property of rock determine suitability for particular applications (e.g. construction materials, building)
- Each rock contains a **record** of its history, in their minerals & in the way the mineral grains fit together
- **Categories of rocks**: igneous, sedimentary, & metamorphic, distinguished by the processes of the formation, & linked by the rock cycle
- **Rock Cycle**: Rocks of any type can be transformed into another rocks due to geologic processes
  - e.g. **sandstone**: weathered & lithified to transport into sedimentary; or buried, heated, & compressed to transform into the metamorphic quartzite; or heated & melted to transform into the igneous rock
  - e.g. **schist**: broken to form a sediment; or subjected to intense metamorphism & transform into gneiss…



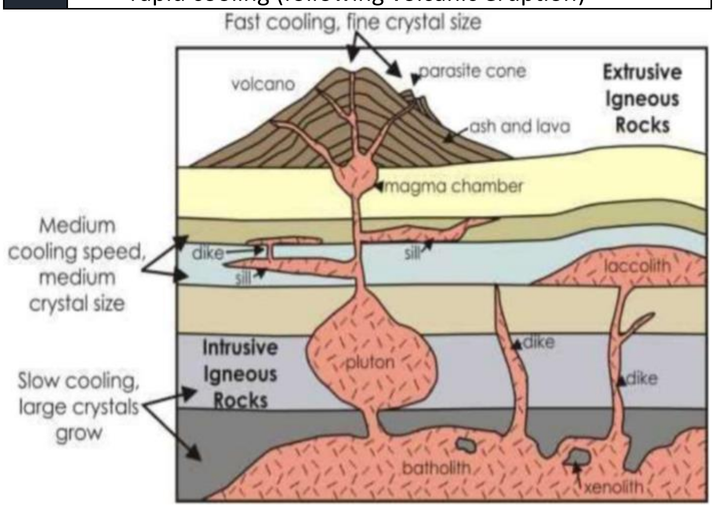


- **Crustal rocks** can be carried into the mantle & melted; fresh magma cools & crystallizes to form new rock
- **Erosion & weathering** processes constantly chip away at the surface
- **The appearance (texture)** of a rock can offer a good first clue to the conditions under which it (last) formed
- Rocks are always subject to change, there is no any rock that has remained unchanged since the earth formed

IGNEOUS ROCKS

- **Magma**: naturally hot & molten rock materials, Silicates are most common minerals, consist of silica, dissolved water, gases & solid crystals suspended in the melt
- **Lava:** Magma that flows out on the earth's surface
- **Igneous rock (fire)**: formed by the solidification & crystallization of molten material at high temperatures
- Magmas form at some depth below the surface, & may or may not reach the surface before it cools & crystallize
- The depth at which a magma crystallizes will affect how rapidly it cools & crystal sizes in the resultant rock

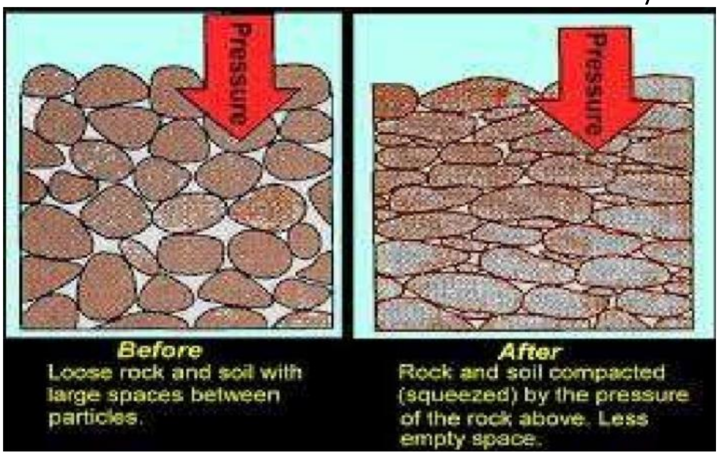
Igneous rock classification	
Plutonic	**Intrusive rocks, formed from magma within the earth (cools slowly), as a result these rocks are coarse grained** • Has large mineral grains seen by naked eye (because crystals have enough time to form & to grow) • **Granite:** quartz + feldspars + some ferromagnesian minerals, make up much of the mass of continents
Volcanic	**Extrusive rocks, formed from lava near the earth surface (cools rapidly), as a result tgese rocks are fine grained** • There is less time for large crystals to form • **Natural glass & Obsidian**: are noncrystalline solid, formed when cooling occurs very fast, crystals not form because atoms are frozen in a disordered state • **Basalt:** dark rock rich in ferromagnesian minerals & feldspar, make up of oceanic floor • **Porphyry**: coarse crystals in finegrained groundmass, formed when melt crystallize slowly at depth, then rapid cooling (following volcanic eruption)



- **Differences in the chemical compositions of magmas lead to differences in their physical properties**
  - Magmas richer in silica (SiO_2) tend to be more viscous (affect the behavior of the volcanoes)
  - Hawaiian volcanos erupts so quietly (safety), while Mount St.Helens & Philippine volcano are prone to violent, sudden, & devastating explosions
- **Igneous rocks have common textural characteristics**
  - Their crystals are tightly interlocking or intergrown
  - If glass is present, crystals tend to be embedded in or closely surrounded by the glass
  - The crystals tend to be angular (not rounded)
  - There is little pore space (occupied by water)
  - Most plutonic rocks are relatively strong unless they have been fractured, broken, or weathered

SEDIMENTARY ROCKS

- **Sediments (debris of preexisting rocks)**: loose & unconsolidated materials that transported by wind, water, or ice, or shifted by gravity, & then redeposited
  - e.g. Beach sand, & mud on a river bottom
- **Soil:** is a mixture of mineral, sediment, & organic matter
- Sediments originated directly or indirectly by
  1. **Physical weathering:** breakup of preexisting rocks into finer materials (crystals & fragments)
  2. **Chemical weathering:** breakup of preexisting by solution followed by precipitation of crystals
- The physical properties of sediments & soils bear on a broad range of environmental problems, from the:
  1. Stability of slopes & building foundations
  2. Selection of optimal waste-disposal sites
  3. How readily water drains away after a rainstorm
  4. how likely that rain is to produce a flood
- **Sedimentary rocks**: formed when sediments deposited, when sediments are compacted or cemented together into a solid, cohesive, & denser mass
- **Lithification**: processes (compaction & cementation) by which sediments are transformed into sedimentary rock



- Sedimentary rocks are formed at or near the earth's surface, at surface temperatures (low temperature)

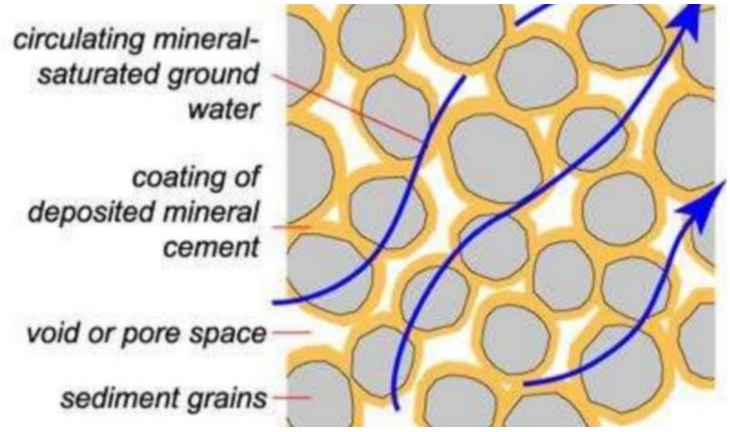
Sedimentary rock classification

Clastic sedimentary rocks

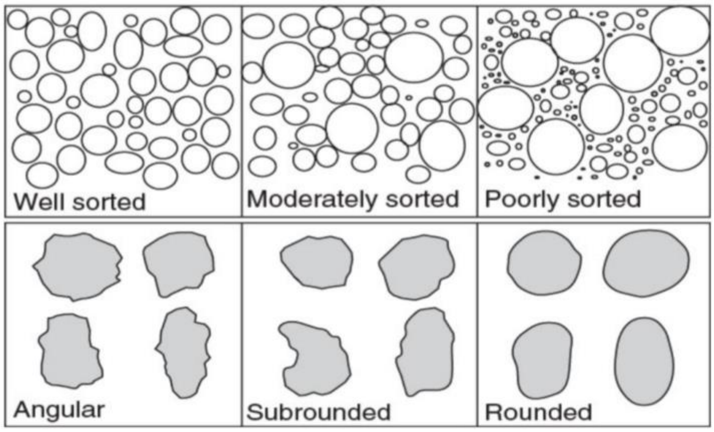
Formed from the products of the mechanical weathering, & named on the basis of the average size of the particles, & tend to have pore space between grains

Conglomerate	Coarse-grained (fragments >2 mm)
Sandstone	Sand-sized particles (1/16 - 2 mm)
Shale	Finer-grained sediments

- Physical weathering processes attack rocks exposed at surface: Rain & waves pound them, Windblown dust scrapes them, Frosts & Tree roots crack them
- The wearing results transported by wind, water, or ice, & accumulate in streams, oceans, deserts, soils…
- Burial of sediments (under weight), pack the loose particles into a cohesive mass
- **Compaction** alone is rarely enough to transform very fine-grained sediment into rock
- **Cementation:** water seeping via sediments & precipitate dissolved mineral that bind the sediment
- As particles are transported they become more rounded & thus not pack together very tightly, so many of these rocks are not strong structurally, unless they have been extensively cemented



Cementation



Chemical rocks

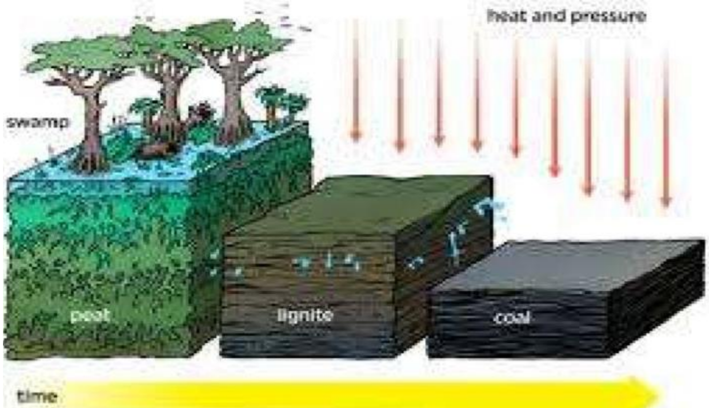
Formed by precipitation or growth from solution

- **Limestone ($CaCO_3$):** deposited from fresh/salt water
- **Rock salt (NaCl):** salt deposit may form when a body of salt water is isolated from an ocean & dries up

Some chemical rock have biological contribution

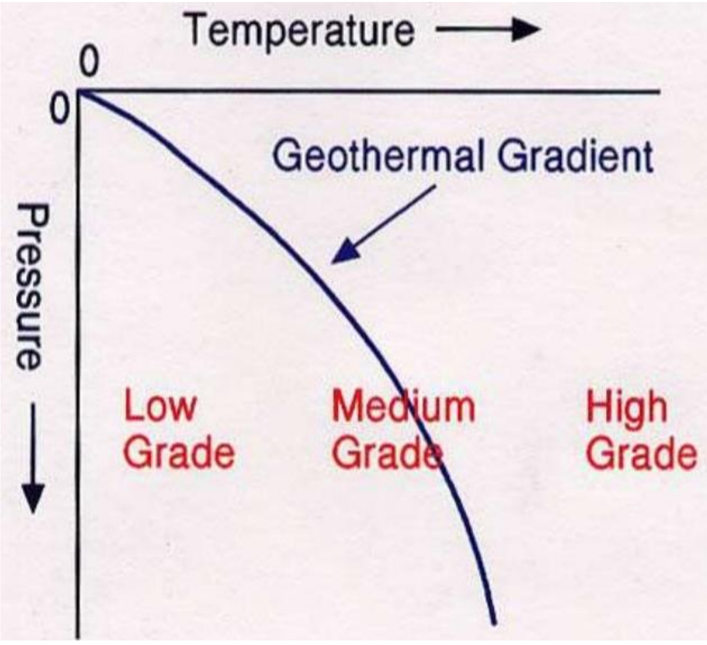
- **Biochemical rocks such as chert**: formed by organisms living in water that made of $CaCO_3$ or SiO_2
- **Coal**: include layers of organic sediments, C-remains of land plants died in swamps

- **Gravity** play a role in the formation of sedimentary rock
  - Mechanically broken-up bit of materials accumulate (when wind or water moves weakly to overcome gravity & move the sediments)
  - Minerals crystallized from solution (organisms shells) settle out of the water under gravity
  - Layering, is a very common feature of sedimentary rocks & derived by gravity
- Sedimentary rocks can yield information about the settings in which the sediments were deposited
  - Sandstone reflect the presence of ancient beach
  - Distribution of glacier-deposited sediments reflect global climate change & plate tectonics

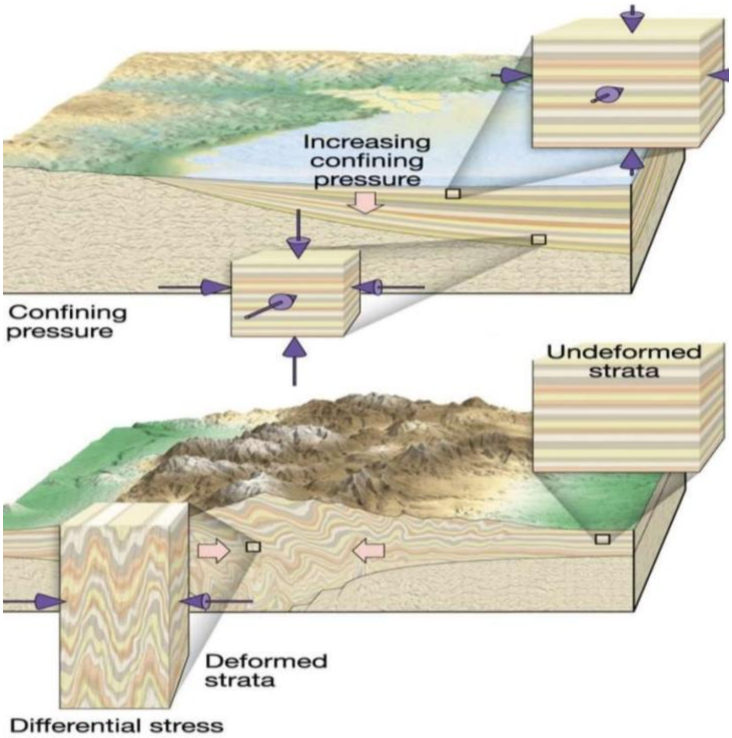


METAMORPHIC ROCKS

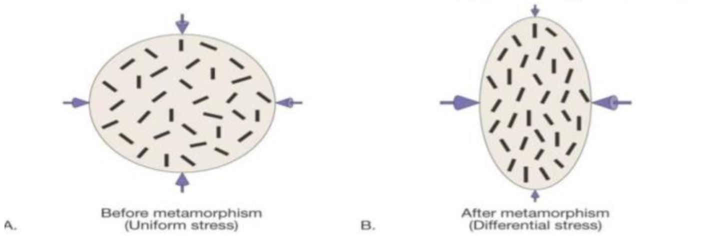
- **Metamorphic rock:** formed by preexisting rock when subjected to heat & pressure in a solid state (metamorphism temperatures < melting temperature)
- **Significant changes to rock can occur:** Minerals recrystallization, Formation of larger crystals & new minerals, & Pressure cause deformation (compressed, stretched, folded, or compacted)
- **The sources of the elevated pressures & temperatures**
  1. weight of overlying rock (burial) increase pressure
  2. Temperatures increase with depth in the earth (geothermal gradient = 30˚C/km)
  3. Deep in the crust, rocks are subjected to enough heat & pressure to deformation & recrystallization
  4. Cooling magma is heat source: heats the adjacent, rocks & may be generates contact metamorphism
  5. During mountain building, stresses & heating can cause a regional metamorphism



- **Some names of metamorphic rocks suggest what the parent rock was such as the following:**
  - **Metaconglomerate**: derived from conglomerate
  - **Metavolcanic:** is metamorphosed volcanic rock
  - **Quartzite:** is metamorphosed Qz-rich sandstone
- **Some metamorphic names indicate rock composition**
  - **Amphibolite**: metamorphic rock rich in amphibole, derived by sedimentary, metamorphic, or igneous
  - **Quartzite:** metamorphic rock rich in quartz
- **Other rock names describe the texture of the rock**
- Metamorphic rock are more tightly interlocked, more compacted, denser, & stronger than original rock
- **Marble**: metamorphosed limestone in which the calcite grains recrystallized & tightly interlocking, layering in limestone may be folded, deformed, or completely obliterated by the recrystallization
- **The types of metamorphic pressure may be directed stress** (not uniform in all directions) that led to compression or stretching in a particular direction, & elongated or platy crystals line up parallel to each other. (**Foliation texture**)



اعادة تبلور المعادن باتجاه متعامد لاتجاه الضغط وهذا يعطي مظهر متطبق (foliated)
تكون البلورات في خطوط متوازية.



- **Slate**: metamorphosed shale that developed foliation under stress, tends to break along the foliation planes (parallel to the alignment of those minerals) & makes it easy to break up into slabs for flagstones
- **Schist**: coarser-grained, mica-rich, in which the mica flakes are similarly oriented, presence of foliation can cause planes of structural weakness in the rock.
- **Gneiss:** have different minerals that concentrated in dark irregular bands (e.g. ferromagnesian) alternating with light bands (e.g. feldspar & quartz)
- Because these terms ***(i.e. schist, gneiss)*** are purely textural, the rock name modified by adding key features of rock composition (e.g. biotite-schist, granitic gneiss…)