MINERALS AND ROCKS

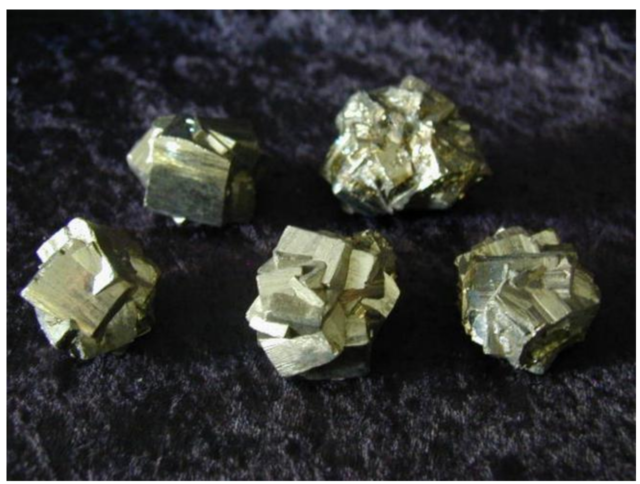
Minerals are the building blocks of rocks. A few rocks, such as limestone, contain only a single mineral (calcite). Other rocks, such as granite, are made of several different minerals.

Mineral is defined as a ***naturally occuring***, ***solid crystalline substance***, generally ***inorganic*** with a ***specific chemical composition***. Minerals are ***homogenous***; they ***cannot be divided mechanically into smaller components***.

(a) Kaliforniya, San Diego County, Himalaya Madeninden olağanüstü bir turmalin ve kuvars (renksiz) örneği.

National Museum of Natural History, Specimen #G7101

(b) Bu gerdanlığa asılan taş Güney Afrika'daki Transvaal elması olup Smithsonian Enstitüsünde bulunur.



Matter and its Composition

Anything that has mass and occupies space is **matter**. The atmosphere, water, plants and animals, and minerals and rocks are all composed of matter. Matter occurs in one of three states or phase all of which are important in geology: **solids, liquids** and **gases**.

***In this course we are concerned chiefly with solids, because all minerals are solids*.**

Elements and atoms

All matter is made up of chemical **elements**, each of which is composed of very small particles called **atoms.** Atoms are **the smallest units of matter that retain the characteristics of an element.**

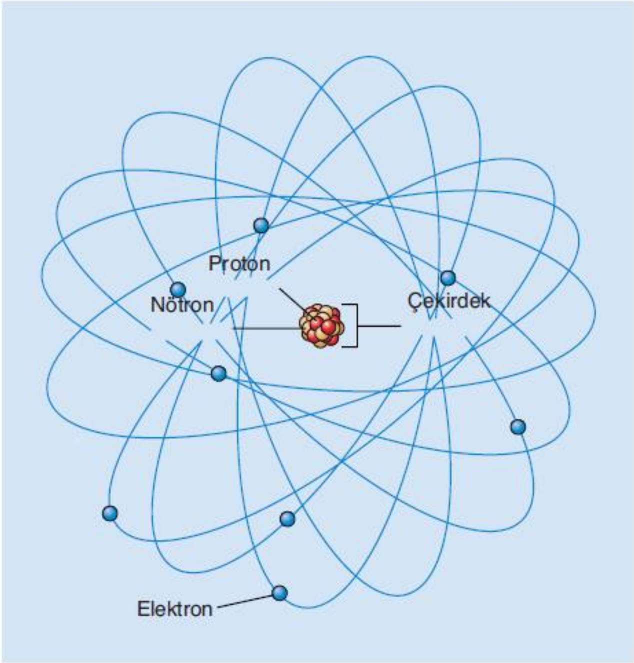
The structure of atoms

At the center of every atom is a dense nucleus containing two particles: **protons** and **neutrons**.

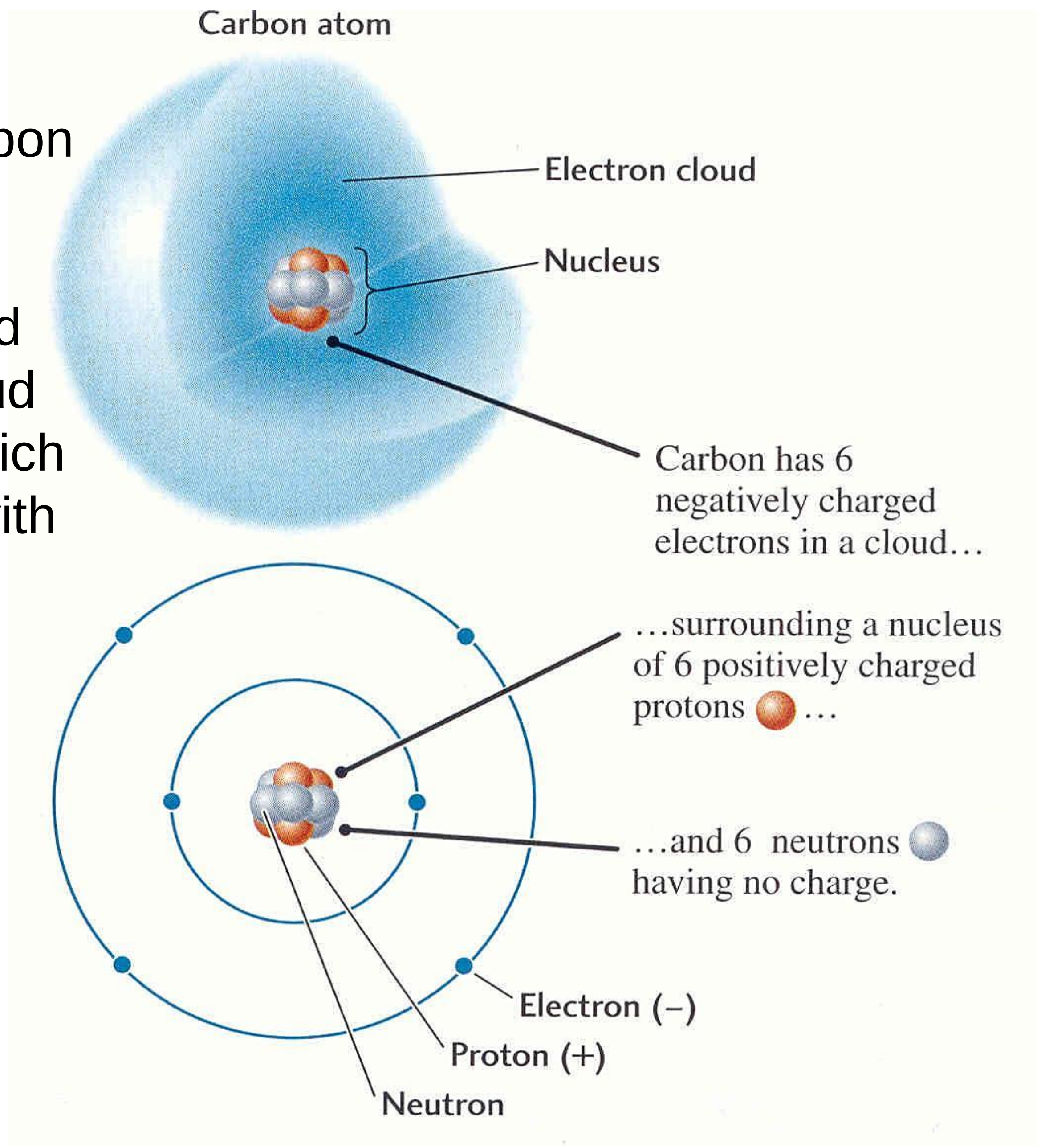
A **proton** has a positive electric charge of +1.

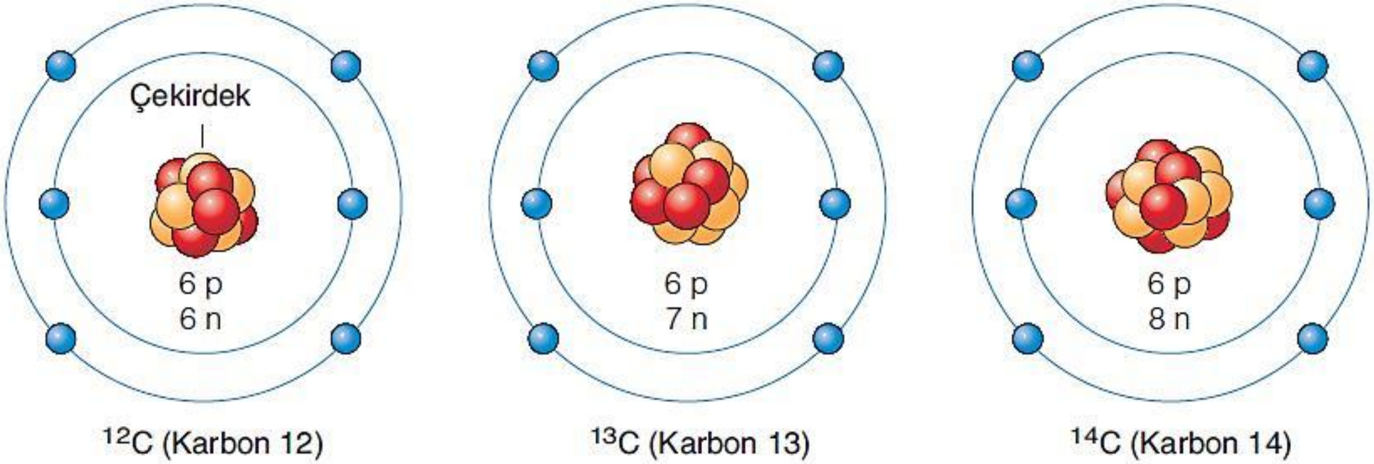
A **neutron** is electrically neutral, that is, uncharged. Atoms of the same chemical element may have different number of neutrons but the number of protons are same.

These atoms are named as **isotopes.**



Electron structure of the carbon atom (carbon-12).
The electrons, each whith a charge of -1, are represented as a negatively charged cloud surrounding the nucleus, which contains six protons, each with a charge of +1, and six neutrons, each with zero charge.
The size of the nucleus is greatly exaggerated.





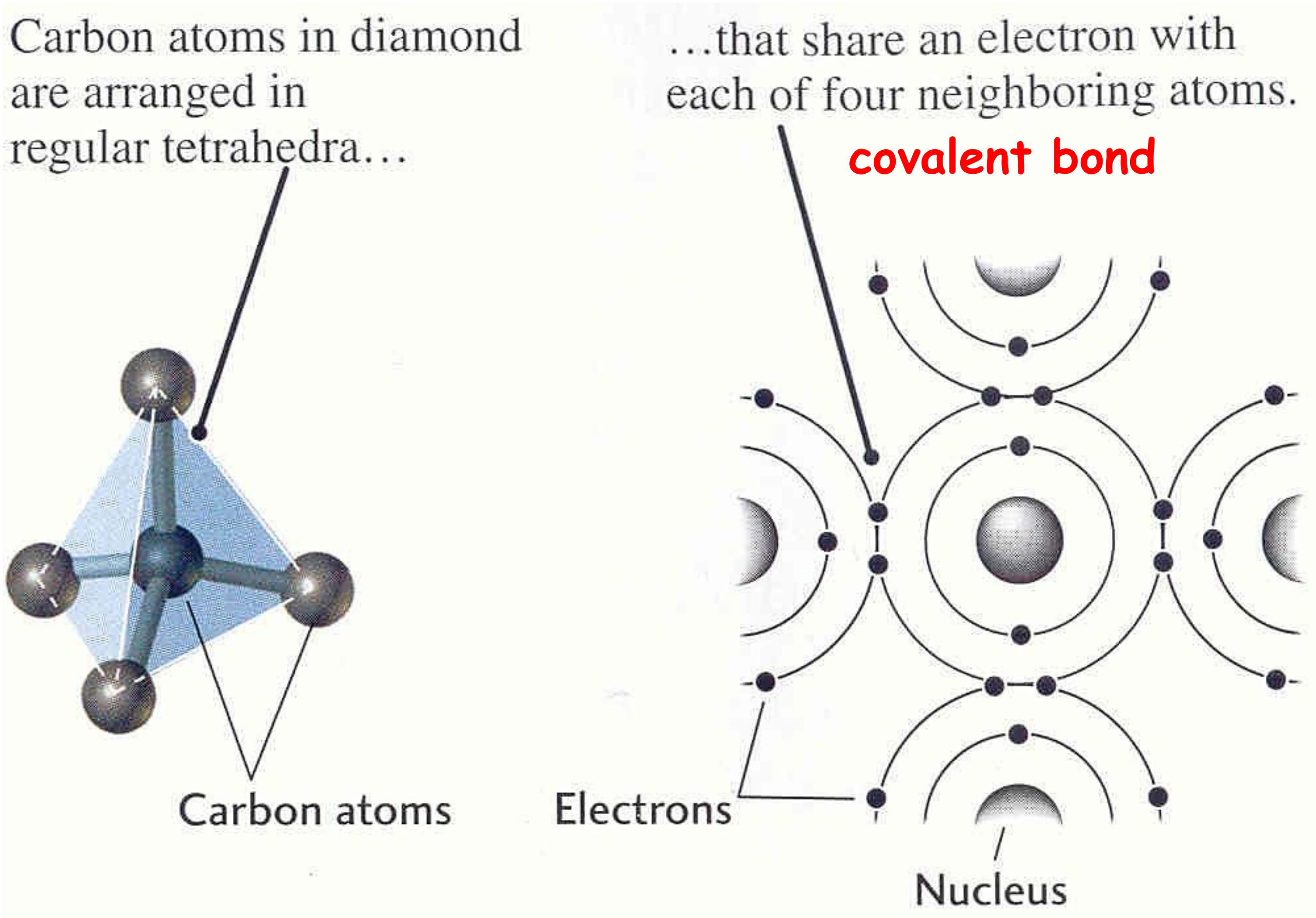
Schematic representation of the isotopes of carbon. Carbon has **atomic number** (number of protons) of 6 and **atomic mass number** (sum of the proton and neutron) of 12,13 or 14 depending on the number of neutrons (n) in its nucleus.

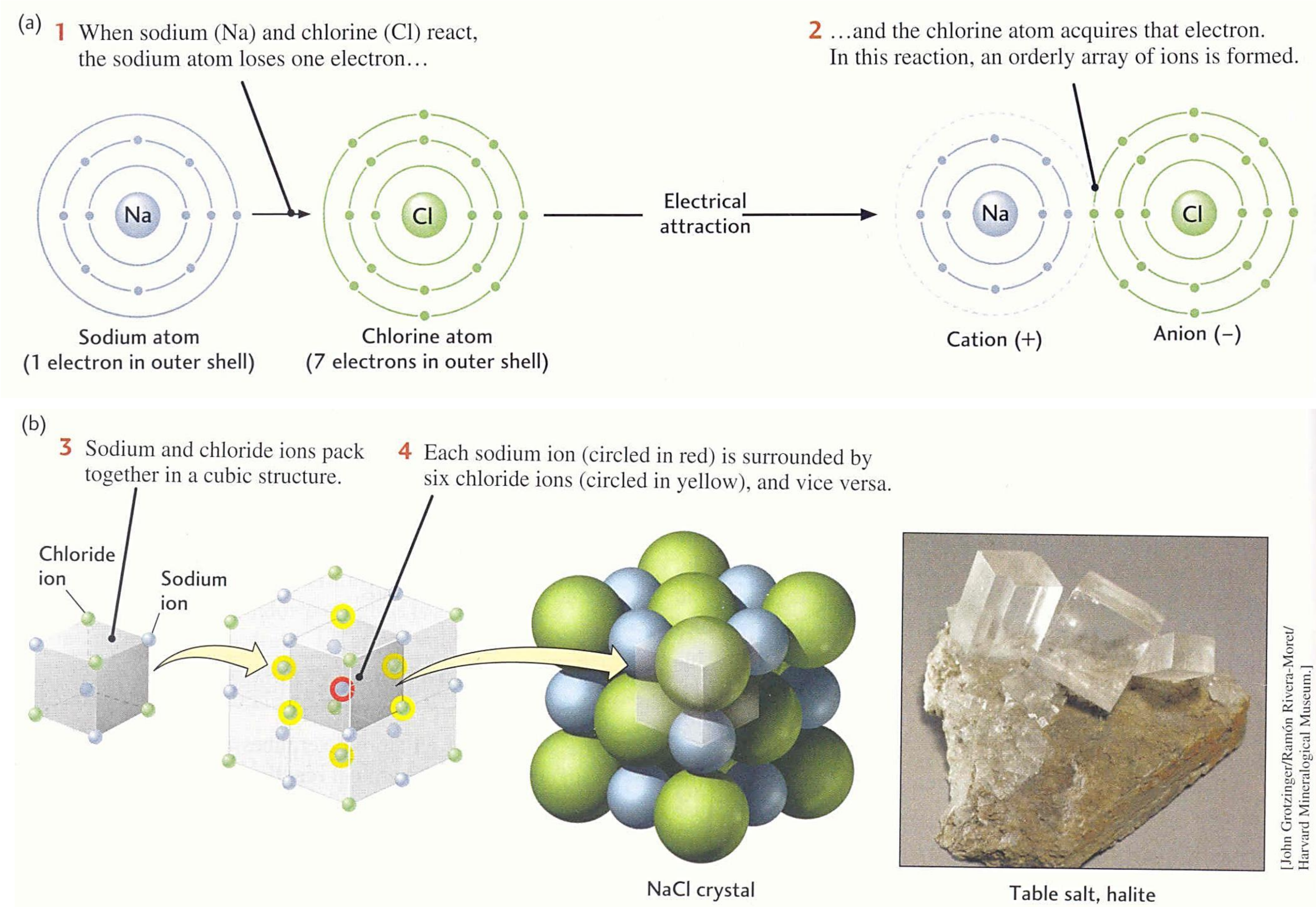
Chemical Reactions

The structure of an atom determines its chemical reactions with other atoms. Chemical reactions are interactions of the atoms of two or more chemical elements in certain fixed proportions that produce chemical compounds. For example two H atoms combine one O atom forming new chemical compound, water H_2O. The properties of a chemical compound may be entirely different from those of constituent elements. Na-sodium (metal) combines with Cl-chlorine (a noxious gas) forming Sodium chlorid (NaCl), known as table salt.

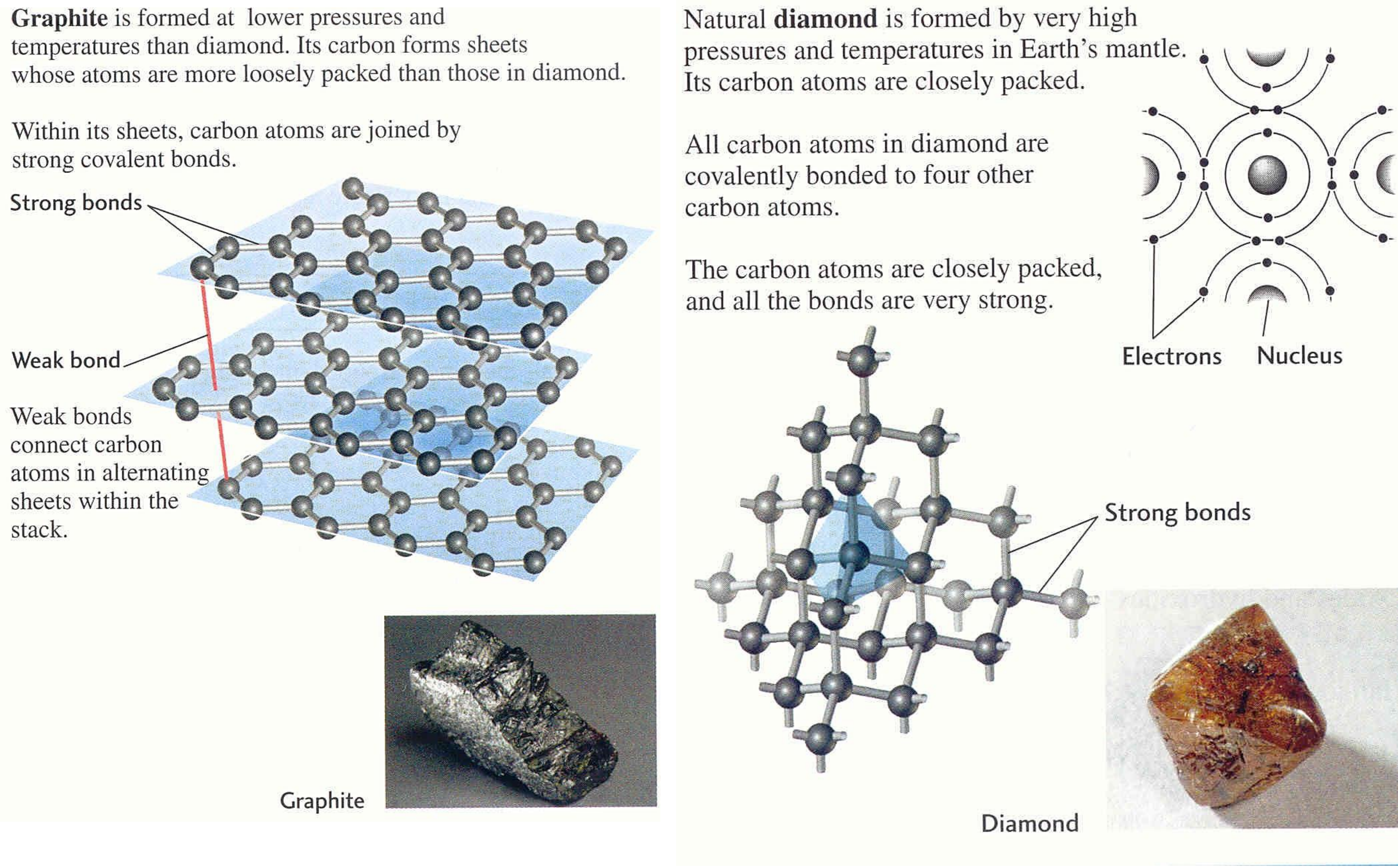
CHEMICAL BOUNDS

Chemical compounds, such as minerals , are formed either by **electron sharing** between the reacting atoms (**covalent bond**) or by **electron transfer** between the reacting atoms (**ionic bond**). Atoms of metallic elements, which have strong tendencies to lose electrons, pack together as cations and the freely mobile electrons are shared and dispersed among ions. This free electron sharing result in **metallic bounding**.





Some atoms transfer electrons, forming **ionic bonds**.



Carbon forms two **polymorphs**, graphite and diamond, that are alternative structure of a single chemical compound

Physical Properties of Minerals

Hardness, cleavage, fracture, luster, color, streak, density, crystal habit are most important **physical characteristics** of minerals.

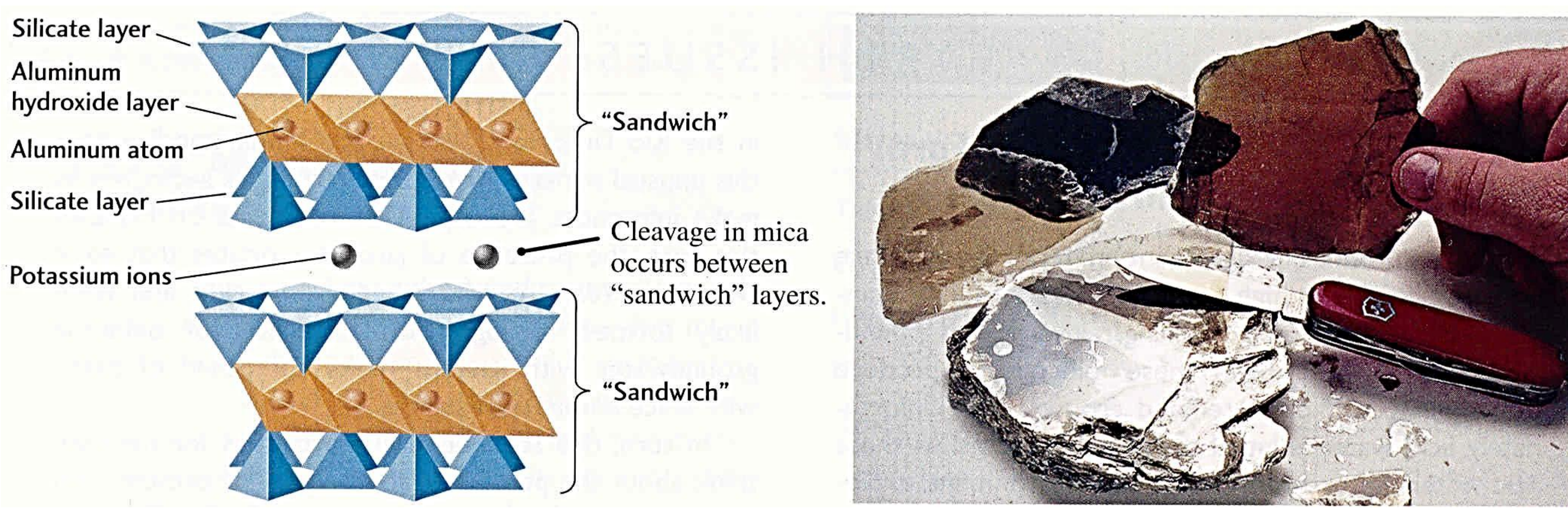
Hardness is a mineral's resistance to abrasion and is controlled mostly by internal structure. For example graphite (1-2) and diamond (10).

Mohs Scale of Hardness

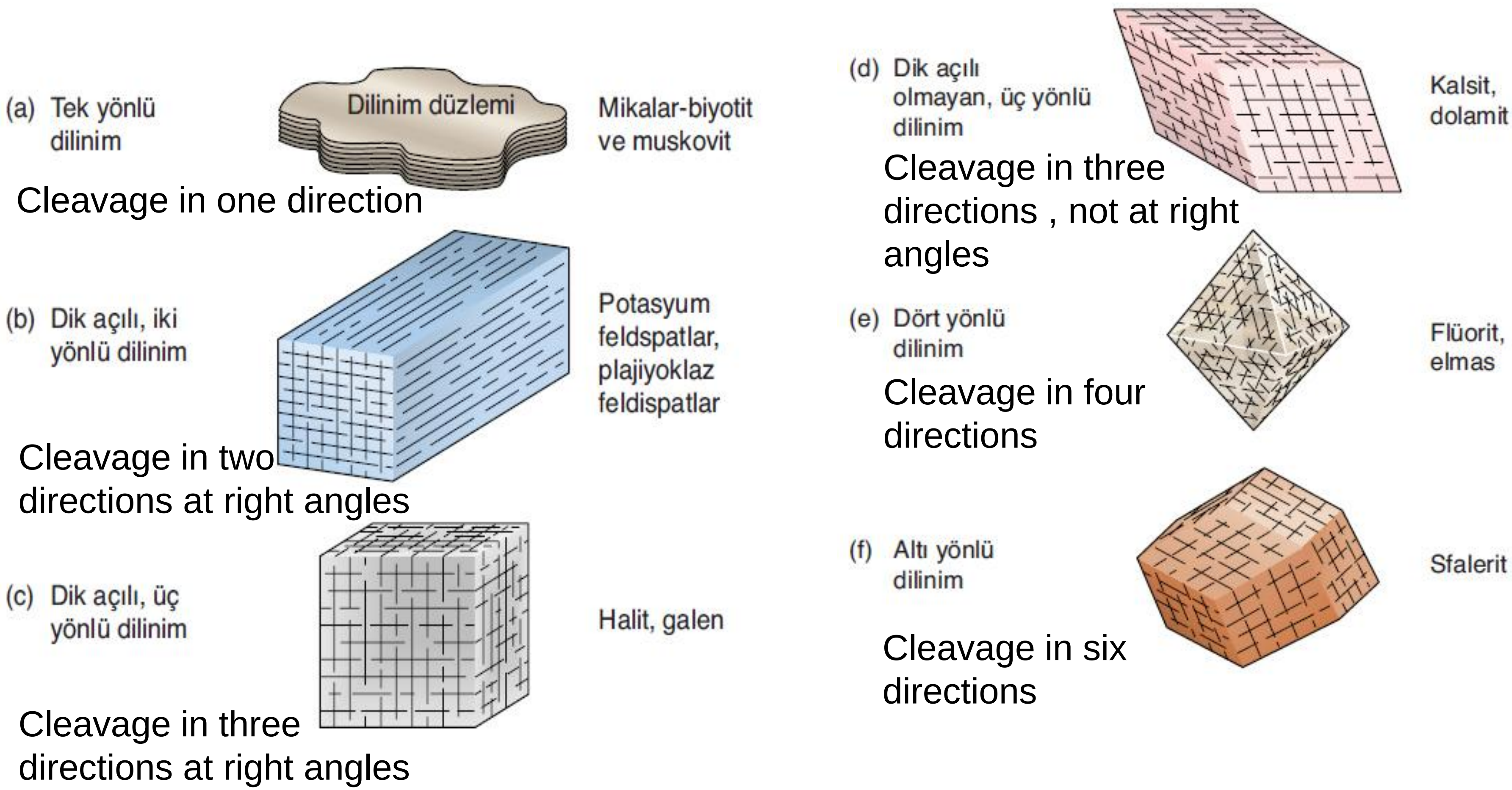
Mineral	Scale Number	Common Objects
Talc	1	
Gypsum	2	—— Fingernail
Calcite	3	—— Copper coin
Fluorite	4	
Apatite	5	—— Knife blade
Orthoclase	6	—— Window glass
Quartz	7	—— Steel file
Topaz	8	
Corundum	9	
Diamond	10	

Cleavage is a smooth plane or planes of weakness determined by the strength of bonds within a mineral structure along which it tends to split or break.

Fracture is a mineral breakage along irregular surfaces. Any mineral can be fractured if enough force is applied, but fracture surfaces are commonly uneven or conchoidal (curved) rather than smooth.

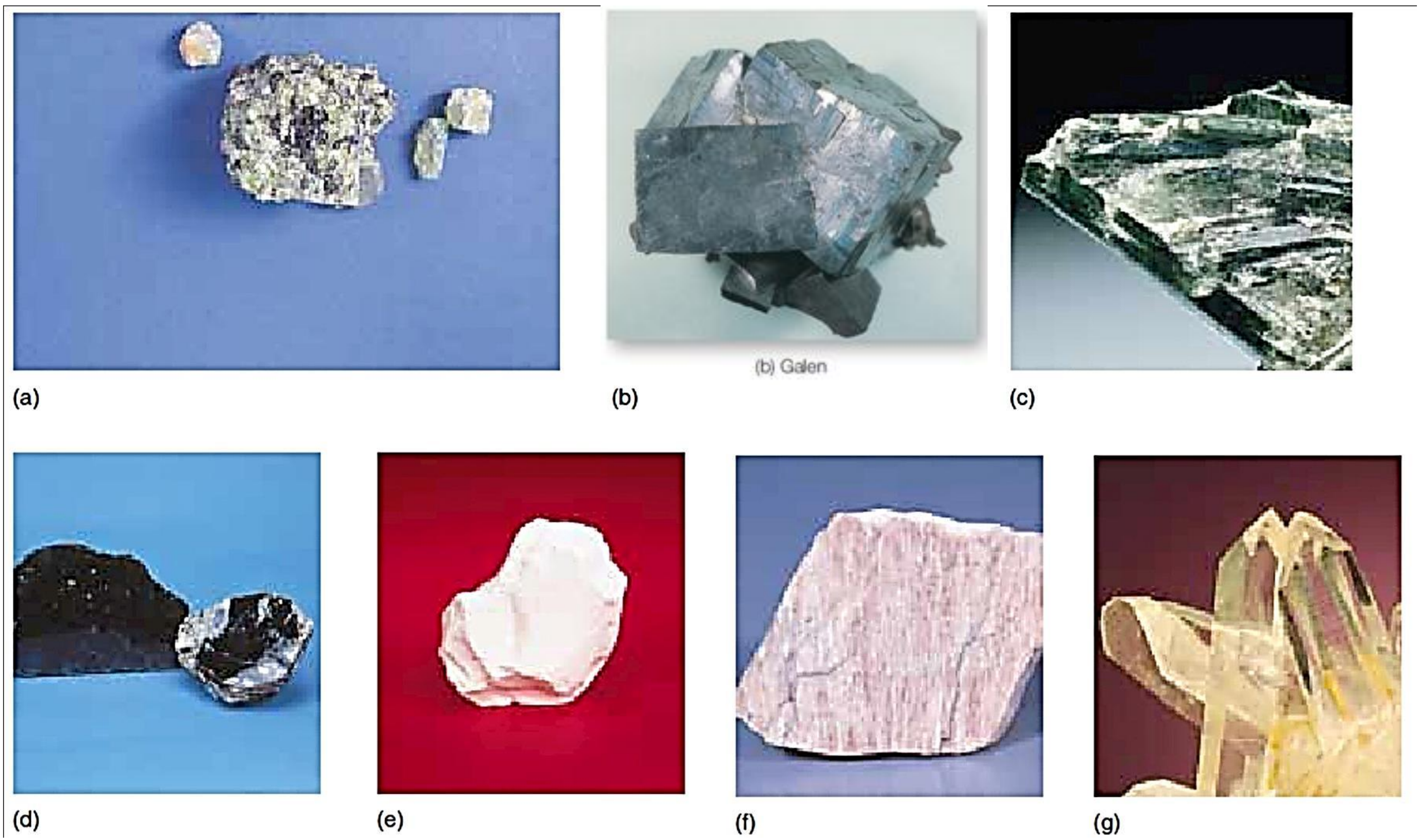


Cleavage of mica. The diagram shows the cleavage planes in the mineral structure, oriented perpendicular to the plane of the page. The photograph shows thin sheets seperating along the cleavage planes.



Several types of mineral cleavage

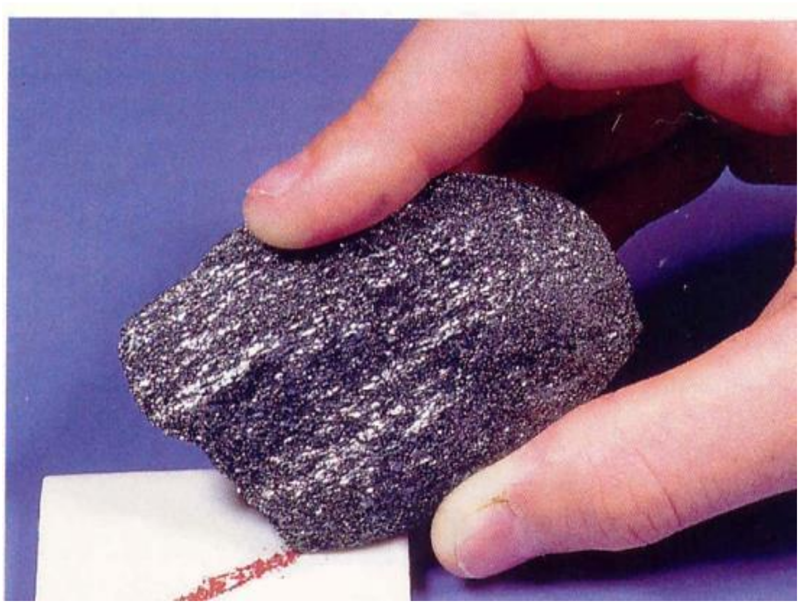
Luster (*parlaklık*) is the quality and intensity of light reflected from surface of mineral. Two common types: metallic and nonmetallic. Types of nonmetallic luster are: glassy or vitrous (quartz), dull (*donuk*) or earthy, waxy (*mumsu*), greasy (*yağlı*), and brilliant (diamond).



Mineral Luster

Luster	Characteristics
Metallic	Strong reflections produced by opaque substances
Vitreous	Bright, as in glass
Resinous	Characteristic of resins, such as amber
Greasy	The appearance of being coated with an oily substance
Pearly	The whitish iridescence of such materials as pearl
Silky	The sheen of fibrous materials such as silk
Adamantine	The brilliant luster of diamond and similar minerals

Streak refers to the color of the fine deposit of mineral dust left on an abrasive surface, such as a tile of unglazed porcelain, when a mineral is scraped across it.



Hematite may be black, red or brown, but it always leaves a reddish brown streak when strached along a ceramic plate.

Mineral’s **crystal habit** is the shape in which its individual crystals of aggregates of crystal grow.

(a) Dumanlı kuvars

Important physical property of calcite: it will react vigorously with the **dilute hydrochloric acid** and releases carbondioxide which causes the acid to bubble or effervesce.

Property	Relation to Composition and Crystal Structure
Hardness	Strong chemical bonds give high hardness. Covalently bonded minerals are generally harder than ionically bonded minerals.
Cleavage	Cleavage is poor if bonds in crystal structure are strong, good if bonds are weak. Covalent bonds generally give poor or no cleavage; ionic bonds are weak and so give excellent cleavage.
Fracture	Type is related to distribution of bond strengths across irregular surfaces other than cleavage planes.
Luster	Tends to be glassy for ionically bonded crystals, more variable for covalently bonded crystals.
Color	Determined by kinds of atoms or ions and trace impurities. Many ionically bonded crystals are colorless. Iron tends to color strongly.
Streak	Color of fine powder is more characteristic than that of massive mineral because of uniformly small size of grains.
Density	Depends on atomic weight of atoms or ions and their closeness of packing in crystal structure. Iron minerals and metals have high density; covalently bonded minerals have more open packing and so have lower density.
Crystal habit	Depends on planes of atoms or ions in a mineral's crystal structure and the typical speed and direction of crystal growth.

Classification of Minerals

Class	Defining Anions	Example
Native elements	None: no charged ions	Copper metal (Cu)
Oxides and hydroxides	Oxygen ion (O^{2-}) Hydroxyl ion (OH^-)	Hematite (Fe_2O_3) Brucite ($Mg[OH]_2$)
Halides	Chloride (Cl^-), fluoride (F^-), bromide (Br^-), iodide (I^-)	Halite ($NaCl$)
Carbonates	Carbonate ion (CO_3^{2-})	Calcite ($CaCO_3$)
Sulfates	Sulfate ion (SO_4^{-2})	Anhydrite ($CaSO_4$)
Silicates	Silicate ion (SiO_4^{-4})	Olivine (Mg_2SiO_4)

NATIVE ELEMENTS

About 20 elements occur naturally in their native states as minerals. Fewer than ten, however, are common enough to be of economic importance. ***Gold, silver, platinum, and copper are all mined in their pure forms***. **Iron is rarely found in its native state in the Earth's crust, but metallic iron is common in certain types of meteorites.** ***Native iron and nickel are thought to comprise most of the Earth's core.***

OXIDES

The oxides are a large group of minerals in which **oxygen is combined with one or more metals.** Oxide minerals are the most **important ores** of iron, manganese, tin, chromium, uranium, titanium, and several other industrial metals. **Hematite** (iron oxide, Fe_2O_3) occurs widely in many types of rocks and is the most abundant ore of iron. Although typically red in color, it occasionally occurs as black crystals used as semiprecious gems. **Magnetite** (Fe_3O_4), a naturally magnetic iron oxide, is another ore of iron. **Spinel** ($MgAl_2O_4$) often occurs as attractive red or blue crystals that are used as inexpensive, **semiprecious gems**. Synthetic spinels are also commonly used in jewelry. **Ice,** the oxide of hydrogen (H_2O), is a common mineral at the Earth's surface.

SULFIDES

Sulfide minerals consist of **sulfur combined with one or more metals**. Many sulfides are **extremely important ore minerals**. ***They are the world's major sources of*** copper, lead, zinc, molybdenum, silver, cobalt, mercury, nickel, and several other metals. The most common sulfides are pyrite (FeS_2), chalcopyrite ($CuFeS_2$), galena (PbS), and sphalerite (ZnS).

SULFATES

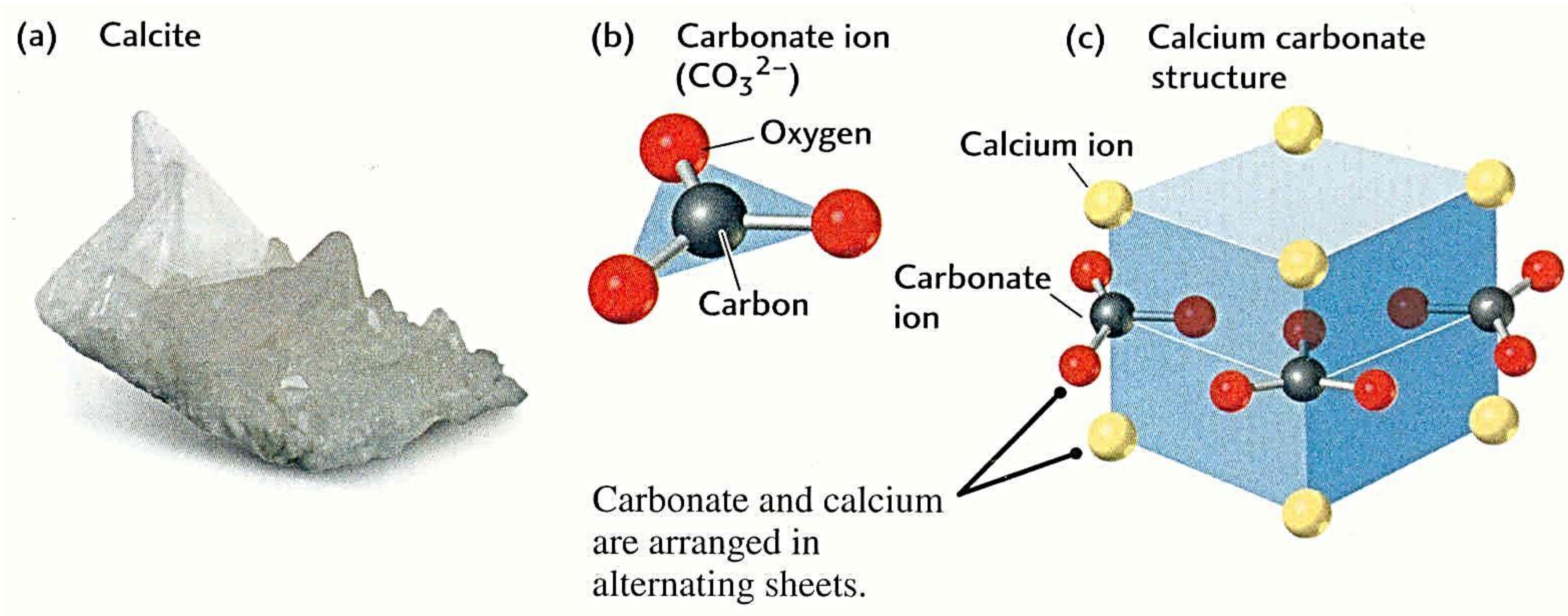
The sulfate minerals contain the **sulfate complex anion** $(SO_4)^{-2}$. Gypsum ($CaSO_4$ $2H_2O$) and anhydrite ($CaSO_4$) are two important industrial sulfates used to manufacture plaster (*alçı*) and sheetrock ("*alçıpan*"). Both form by evaporation of seawater or salty lake water.

PHOSPHATES

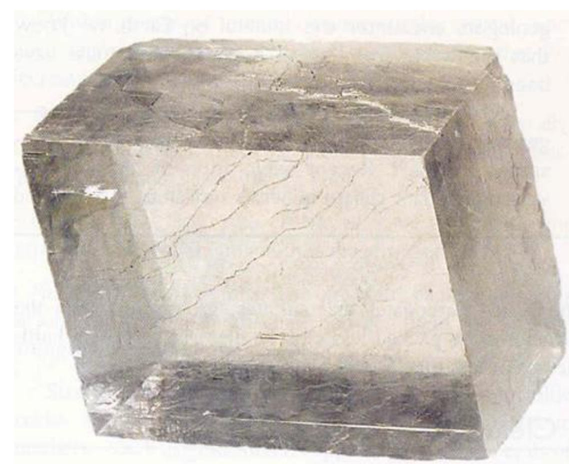
Phosphate minerals contain the **complex anion (PO_4)$^{-3}$**. **Apatite**, Ca5(F,Cl,OH)(PO_4)$^{-4}$, is the substance that makes up both teeth and bones. **Phosphate** is an essential fertilizer in modern agriculture. It is mined from fossil bone beds near Tampa, Florida, and from great **sedimentary apatite deposits** in the northern Rocky Mountains.

CARBONATES

The complex **carbonate anion** $(CO_3)^{-2}$ is the basis of two common rock-forming minerals, **calcite** $(CaCO_3)^{-2}$ and **dolomite** $[CaMg(CO_3)_2]^{-4}$. Most limestone is composed of calcite, and dolomite makes up the similar rock that is also called dolomite or sometimes dolostone. Limestone is mined as a **raw ingredient of cement**. Aragonite is a polymorph of calcite that makes up the shells of many marine animals.



(a) Carbonate minerals, such as calcite (calcium carbonate, $CaCO_3$), have a layered structure. (b) Top view of the carbonate building block, a carbon ion surrounded in a triangle by three oxygen ions, with a net charge of -2. (c) view of the alternating layers of calcium and carbonate ion.



SILICATES

The **silicate minerals** contain the $(SiO_4)^{-4}$ complex anion. Silicates make up about 95 percent of the Earth's crust. They are **so abundant for two reasons**. **First**, silicon and oxygen are the two most plentiful elements in the crust. **Second**, silicon and oxygen combine readily.

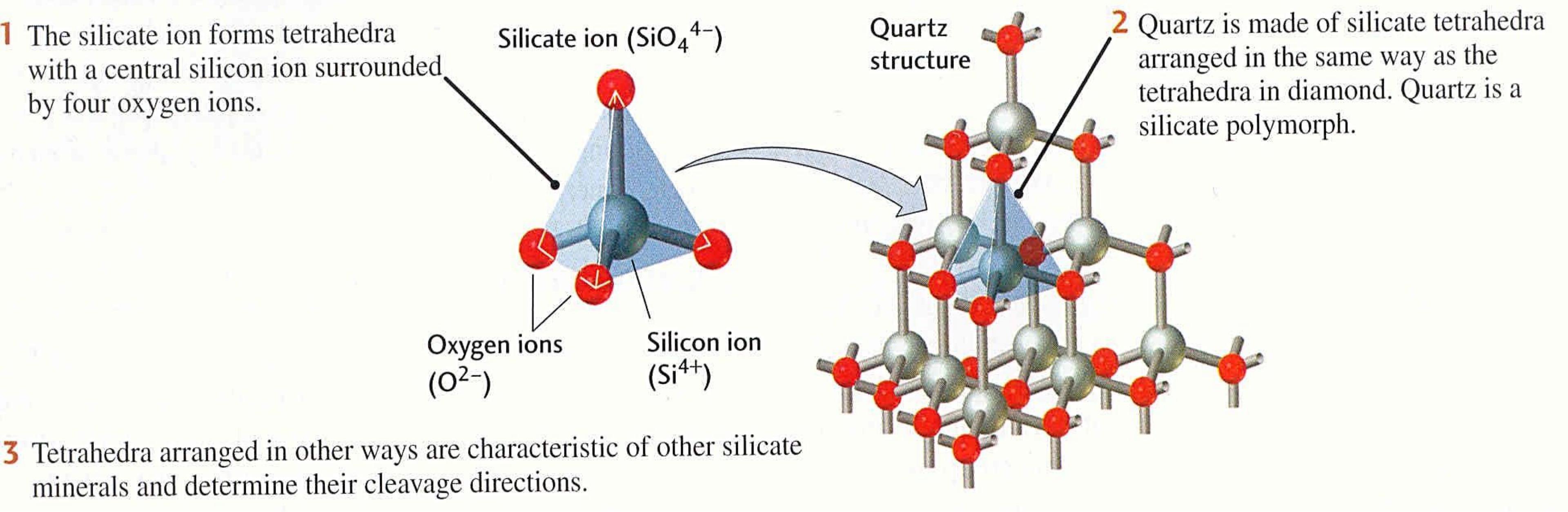
To understand the silicate minerals, remember four principles:

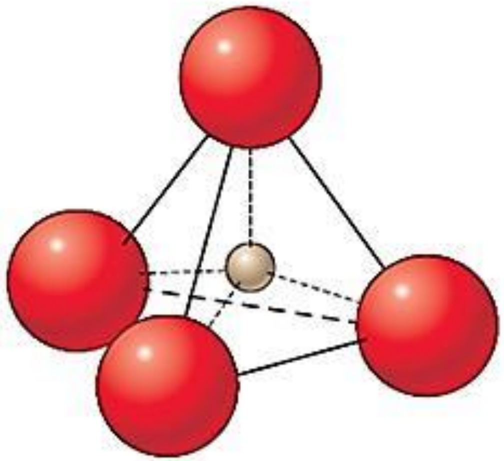
1. Every silicon atom surrounds itself with four oxygens. The bonds between each silicon and its four oxygens are very strong.

2. The silicon atom and its four oxygens form a **pyramid-shaped structure** called the **silicate tetrahedron** with silicon in the center and oxygens at the four corners. The silicate tetrahedron has a 4 charge and forms the $(SiO_4)^{-4}$ complex anion. **The silicate tetrahedron is the fundamental building block of all silicate minerals.**

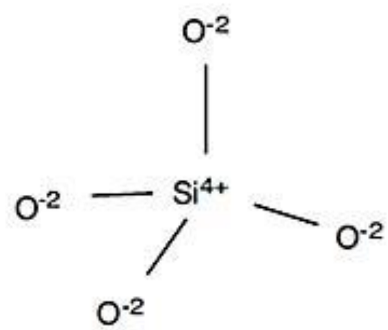
3. To make silicate minerals electrically neutral, other cations must combine with the silicate tetrahedra to balance their negative charges. (The lone exception is quartz, in which the positive charges on the silicons exactly balance the negative ones on the oxygens.

4. Silicate tetrahedra commonly link together by sharing oxygens. Thus, two tetrahedra may share a single oxygen, bonding the tetrahedra together.





$(SiO_4)^{-4}$



The silicate tetrahedron consists of one silicon atom surrounded by four oxygens. **It is the fundamental building block of all silicate minerals.**

ROCK-FORMING MINERALS, ACCESSORY MINERALS, GEMS, ORE MINERALS, AND INDUSTRIAL MINERALS

Although about 3500 minerals are known to exist in the Earth's crust, only a small number - between 50 and 100 - are important because they are common or valuable.

ROCK-FORMING MINERALS

The rock-forming minerals make up the bulk of most rocks in the Earth's crust. They are important to geologists simply because they are the most common minerals. They are **olivine, pyroxene, amphibole, mica, the clay minerals, feldspar, quartz, calcite, and dolomite**. The first six minerals in this list are actually mineral "groups," in which each group contains several varieties of **Rock-Forming Minerals**, **Accessory Minerals**, **Gems**, **Ore Minerals**, and **Industrial Minerals** with very similar chemical compositions, crystalline structures, and appearances.

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ACCESSORY MINERALS

Accessory minerals are minerals that are common but usually are found only in small amounts. Chlorite, garnet, hematite, limonite, magnetite, and pyrite are **common accessory minerals.**

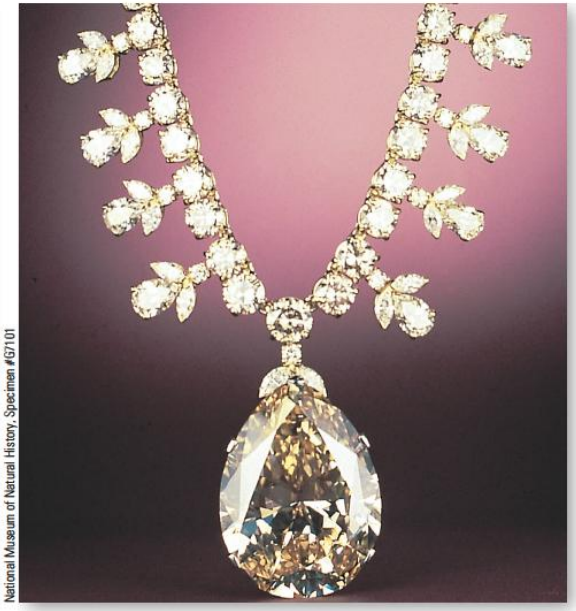
ORE MINERALS

Ore minerals ***are minerals from which metals or other elements can be profitably recovered***. A few, such as **native gold** and **native silver**, are composed of a single element. However, most metals are chemically bonded to anions. **Copper, lead, and zinc are commonly bonded to sulfur to form the important ore minerals chalcopyrite, galena, and sphalerite**.

GEMS

A **gem** is a mineral that is prized primarily for its beauty, although some gems, like diamonds, are also used industrially. Depending on its value, a gem can be either precious or semiprecious. Precious gems include diamond, emerald, ruby, and sapphire. Several varieties of quartz, including amethyst, agate, jasper, and tiger's eye, are semiprecious gems. Garnet, olivine, topaz, turquoise, and many other minerals sometimes occur as aesthetically pleasing semiprecious gems.

Los Angeles County Museum specimen, © Harold and Erica Van Pelt



National Museum of Natural History, Specimen #G7101

(a) Kaliforniya, San Diego County, Himalaya Madeninden olağanüstü bir turmalin ve kuvars (renksiz) örneği.

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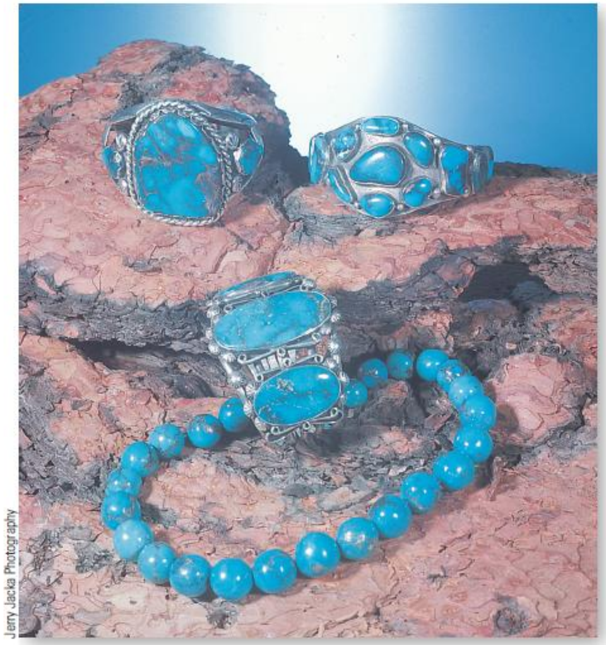


Jerry Jacka Photography

Jeffrey A. Scovil

(c) Firuze - gök mavisi, mavi - yeşil ya da açık yeşil renkli hidratlı bakır alüminyum fosfat olup mücevherat ve dekoratif amaçla kullanılan yarı değerli bir taştır.

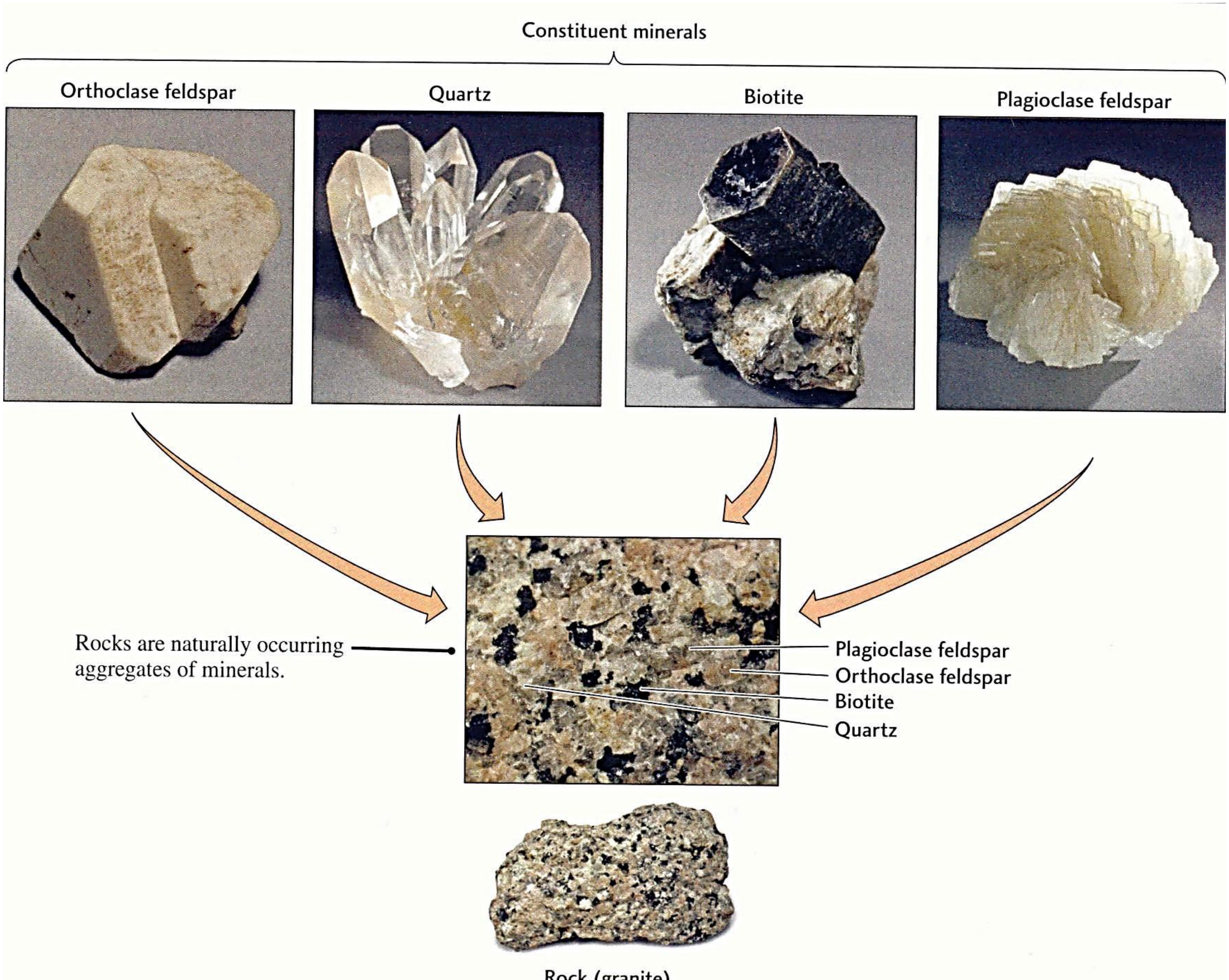
(d) Arizona Madencilik ve Mineral Müzesi, Flagg Koleksiyonunda iki bakır minerali, azurit (mavi) ve malahit (yeşil).

INDUSTRIAL MINERALS

Several minerals are **industrially important**, **although they are not considered ore because they are mined for purposes other than the extraction of metals**. **Halite** is mined for ***table salt***, and **gypsum** is mined as the raw material for ***plaster and sheetrock***. **Apatite** and other **phosphorus minerals** are sources of the ***phosphate fertilizers*** crucial to modern agriculture. Many **limestones** are made up of nearly **pure calcite** and are mined as the ***raw material of cement***.

Minerals are the building blocks of rocks

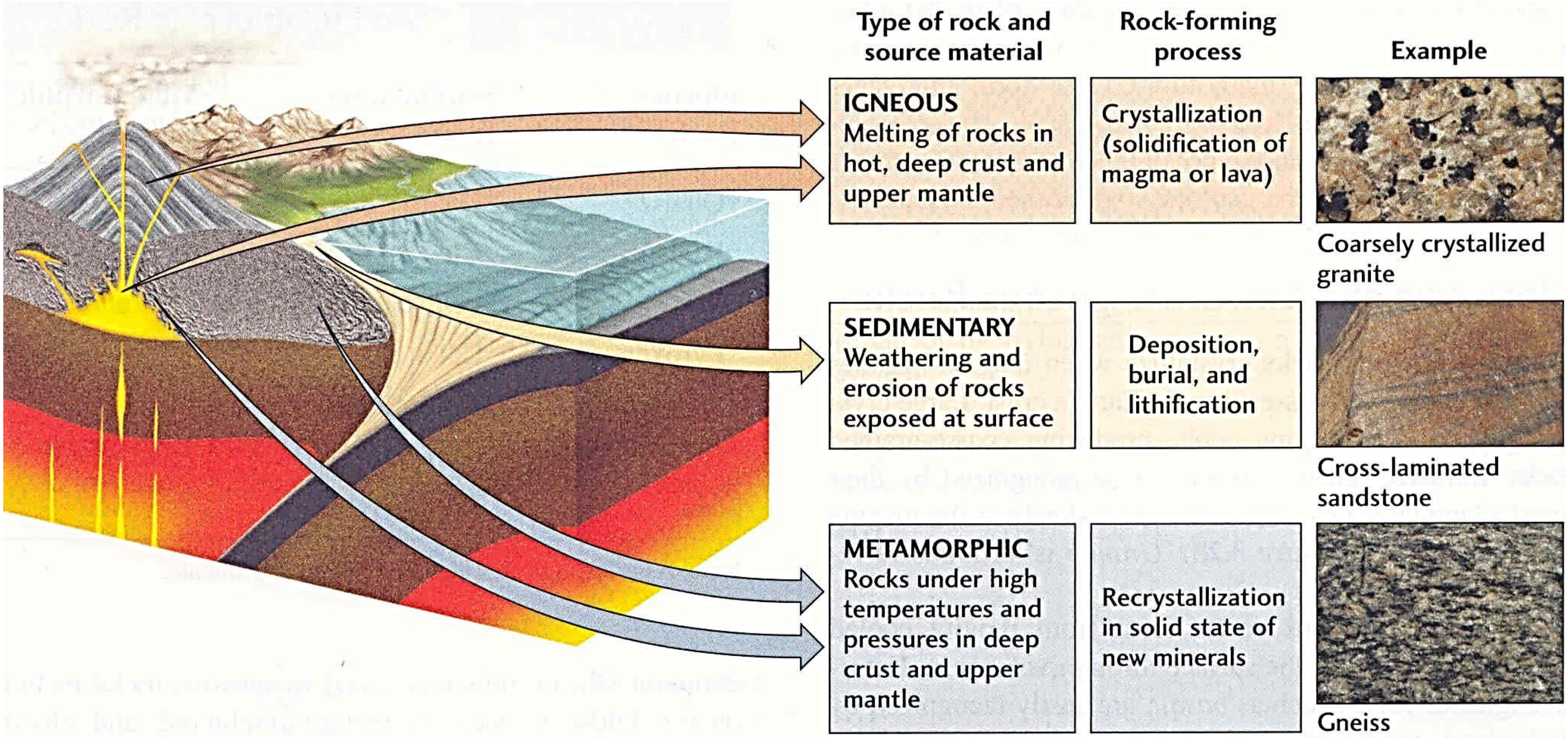
Rocks are defined as a solid aggregate of one or more minerals.



There are three major groups of rocks namely, **igneous**, **sedimentary** and **metamorphic rocks**.

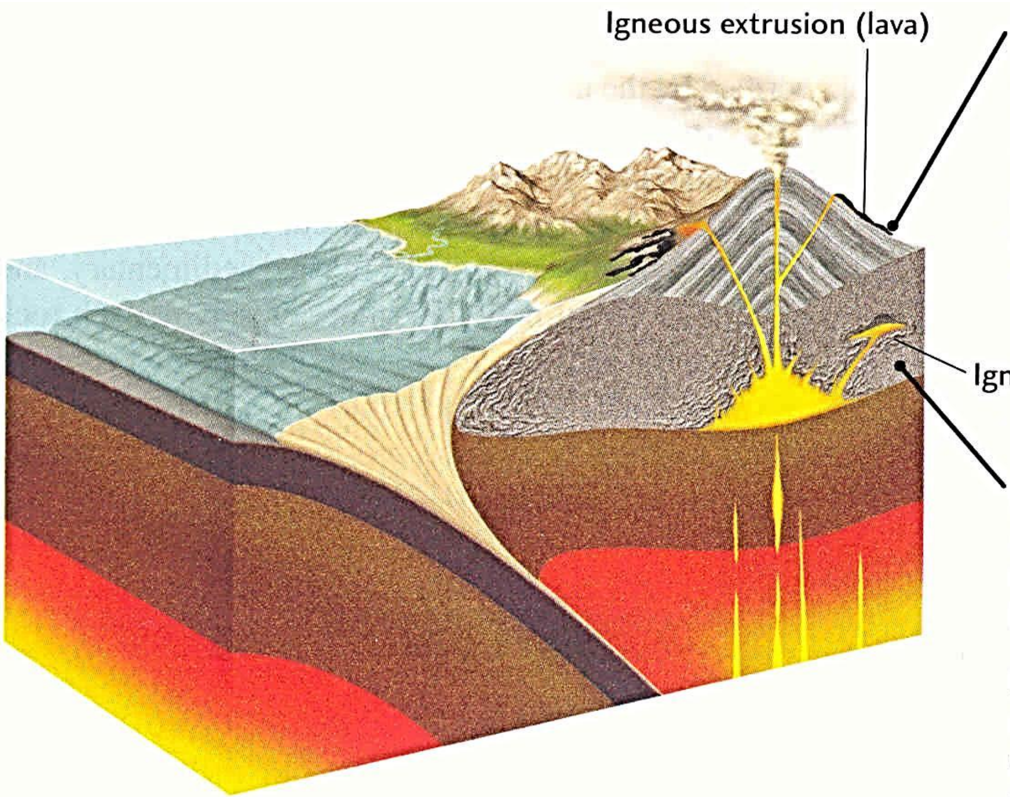
Igneous Rocks	Sedimentary Rocks	Metamorphic Rocks
*Quartz	*Quartz	*Quartz
*Feldspar	*Clay minerals	*Feldspar
*Mica	*Feldspar	*Mica
*Pyroxene	Calcite	*Garnet
*Amphibole	Dolomite	*Pyroxene
*Olivine	Gypsum	*Staurolite
	Halite	*Kyanite

Note: Asterisk indicates that the mineral is a silicate.



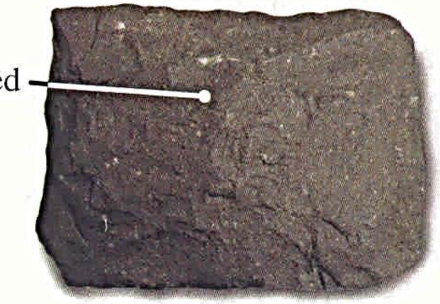
The three rock groups are formed in different environments by different geologic processes.

Igneous rocks



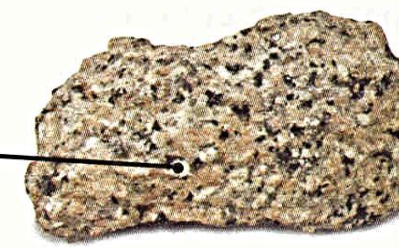
Extrusive igneous rocks form when magma erupts at the surface, rapidly cooling to fine ash or lava and developing tiny crystals.

The resulting rock, such as the basalt sample here, is fine-grained or has a glassy texture.

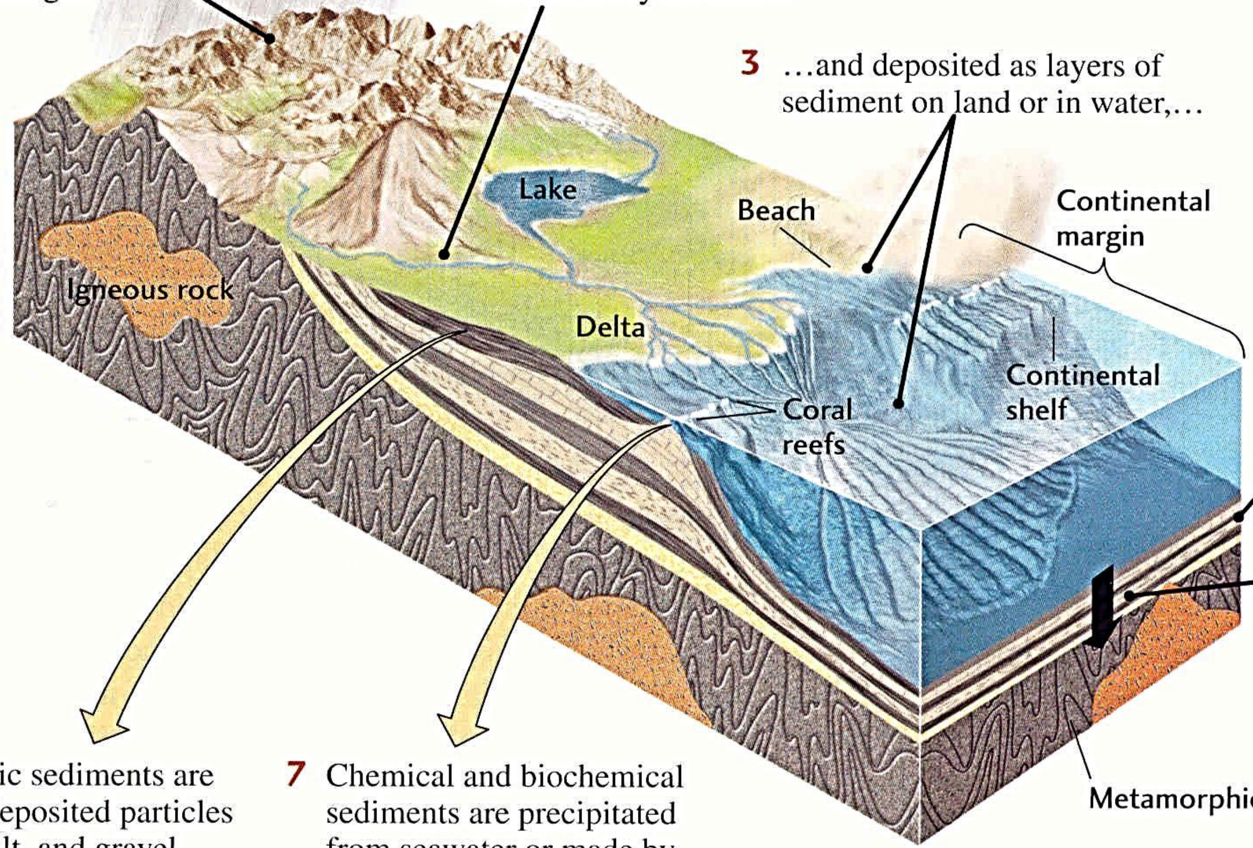


Intrusive igneous rocks crystallize when molten rock intrudes into unmelted rock masses in Earth's crust.

Large crystals grow during the slow cooling process, producing coarsely grained rocks such as the granite sample shown here.



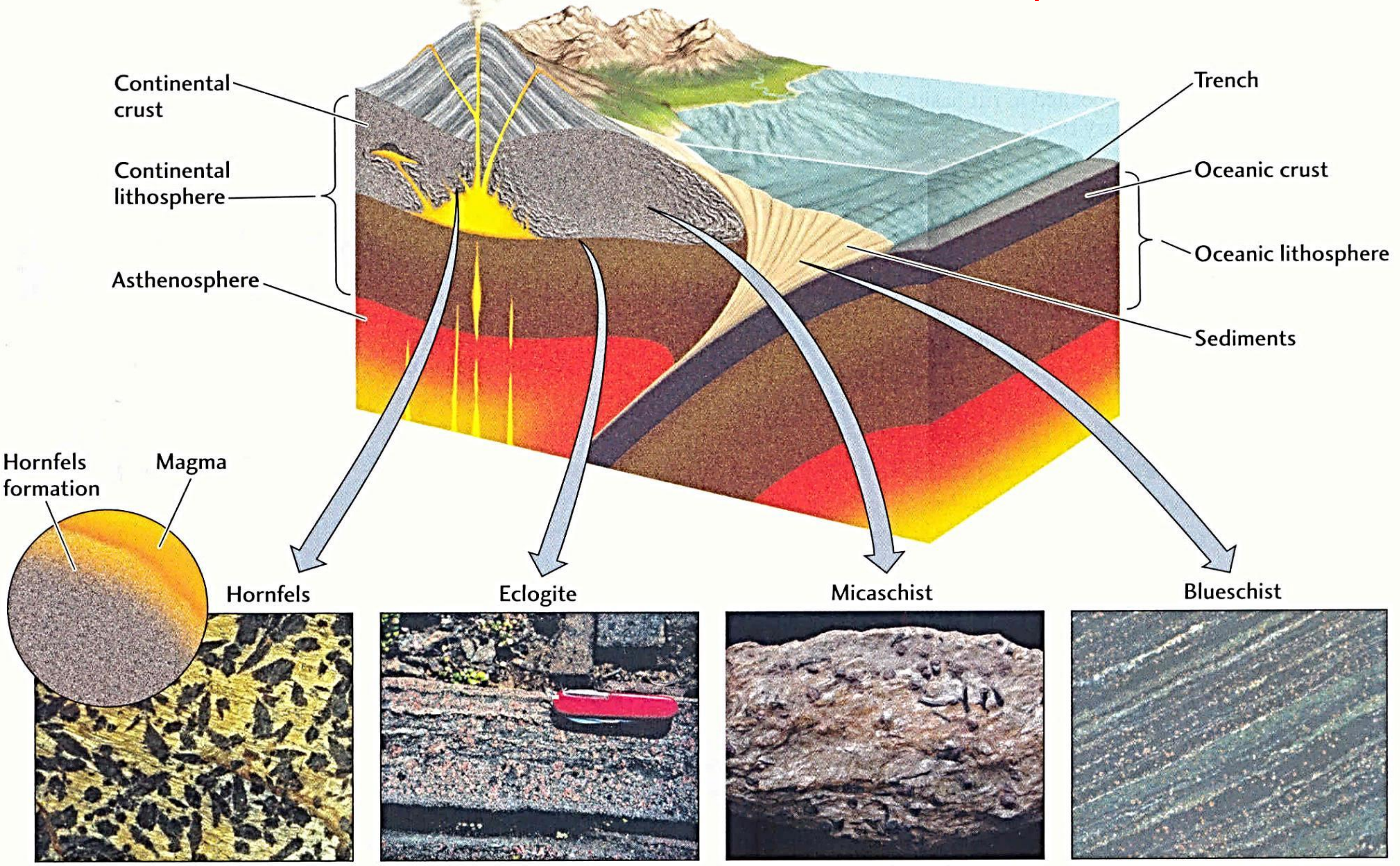
Sedimentary rocks



6 Siliciclastic sediments are made of deposited particles of sand, silt, and gravel.

7 Chemical and biochemical sediments are precipitated from seawater or made by coral reefs and shells.

Metamorphic rocks



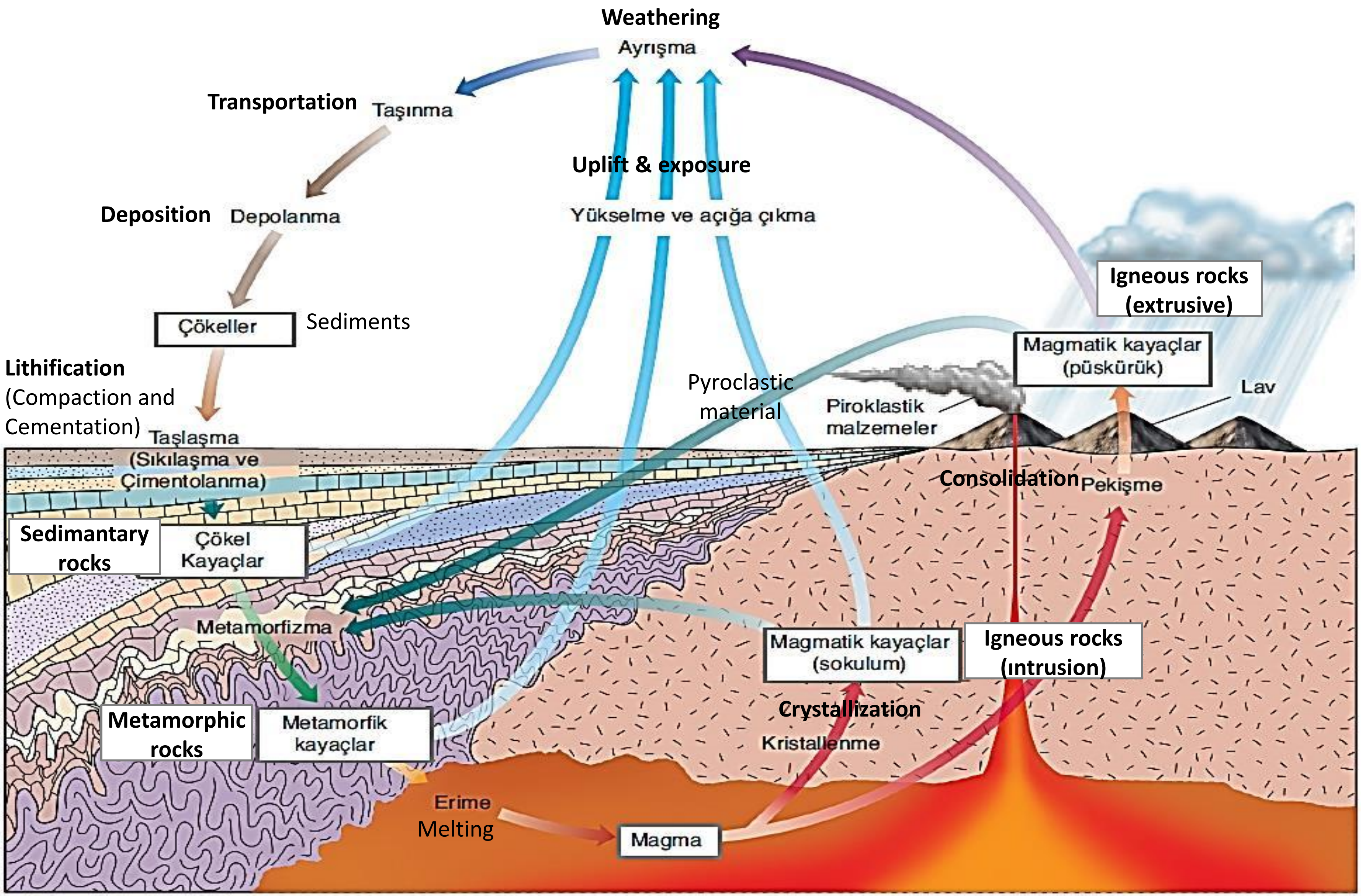
Contact metamorphism occurs in limited areas where magma intrusion metamorphoses neighboring rock by its heat, forming hornfels.

Ultra-high-pressure metamorphism occurs deep in the continental lithosphere and oceanic crust.

Regional metamorphism occurs where high pressures and temperatures extend over large regions.

High-pressure, low-temperature metamorphism occurs where oceanic crust subducts beneath the leading edge of a continental plate.

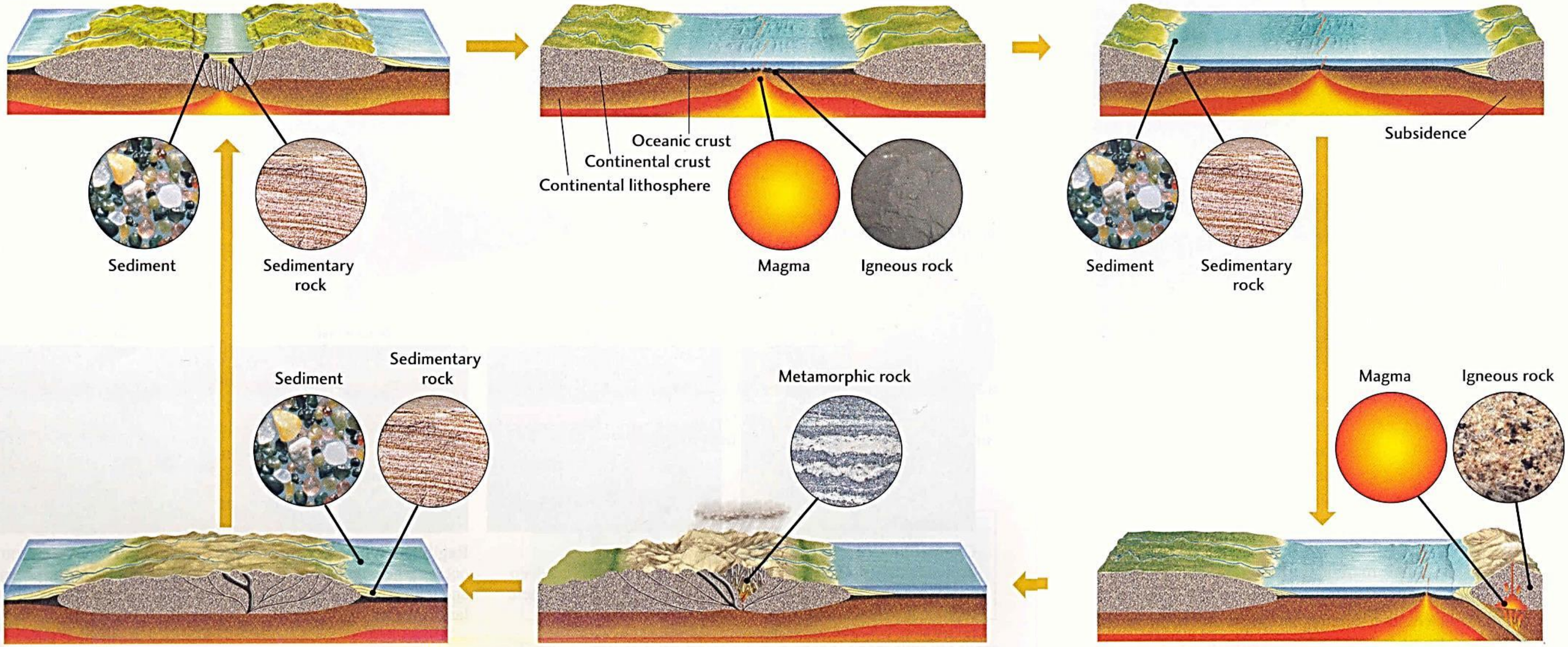
All the three basic group of rocks can evolve from one to another. This concept is named as a **rock cycle** showing the interrelationships between Earth's internal and external processes and how the three types of groups are related.



The cycle begins with rifting and development of a divergent margin within a continent. Sediments erode from the continental interior and are deposited in rift basins, where they are buried to form sedimentary rocks.

2 Rifting and spreading continue, and a new ocean basin develops. Magma rises from the asthenosphere at mid-ocean ridges and chills to form basalt, an igneous rock.

3 Subsidence of the continental margin—sinking of Earth's lithosphere—leads to accumulation of sediment and formation of sedimentary rock during burial.



4 Oceanic crust subducts beneath a continent, building a volcanic mountain chain. The subducting plate melts as it descends. Magma rises from the melting plate and mantle and cools to make granitic igneous rocks.

5 Further closing of the ocean basin leads to continental collision, forming high mountain ranges. Where continents collide, rocks are buried deeper or modified by heat and pressure, forming metamorphic rocks. Uplifted mountains force moisture-laden air to rise, cool, condense, and precipitate. Weathering creates loose material—soils and sediment—that erosion strips away.

6 Streams transport sediment away from collision zones to oceans, where it is deposited as layers of sand and silt. Layers of sediment are buried and lithify to form sedimentary rock.