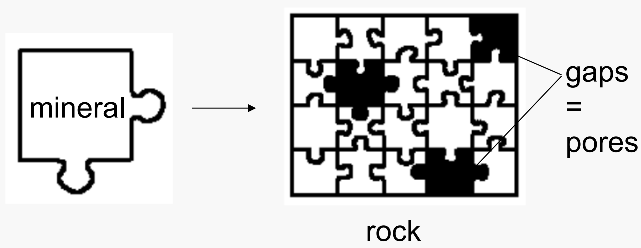
NATURAL STONE

1 - MINERALOGY

Definitions

Natural Stone = Rock = natural material constituting the crust and mantle. Generally, it is solid (≠ unconsolidated sediments like sand) and made of aggregate of **minerals** more or less closely knitted together (gaps = **pores**)



Conservation Science Consulting Sàrl

Definitions

Mineral = **inorganic** natural compound (although some of them may be bioproducts like apatite, calcite, oxalates...) with a **definite chemical composition**, an **atomic structure** and **physical properties** of its own.
Generally, it is **solid** (≠ mercury)

Cristal = **homogeneous solid** composed of atoms, ions or molecules with an **organized arrangement** that is **repeated periodically** in three dimensions of space
(cristal ≠ amorphous compounds)

Conservation Science Consulting Sàrl

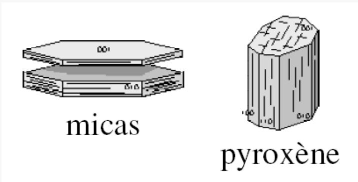
Classification of minerals

According to chemical composition and crystal structure.
Example: Nickel-Strunz Classification - 10th edition
(system adopted by the International Mineralogical Association):

1. **Native elements** (C, S, Au, Ag, Cu, Bi, As, Sb,…)
2. **Sulfides** (S^{2-}) **and sulfosalts** (selenides, tellurides, …)
3. **Halides** (Cl^-, F^-,…)
4. **Oxides** (O^{2-}), **hydroxides** (OH^-)
5. **Carbonates** (CO_3^{2-}), **nitrates** (NO_3^-)
6. **Borates** (borax,...)
7. **Sulphates** (SO_4^{2-}) (+ thiosulfates, chromates, molybdates,…)
8. **Phosphates** (PO_4^{3-})
9. **Silicates** ($(Si,Al)_xO_{2x}$+/-alk. and alk. earth met.)
10. **Organic compounds** (formates, oxalates, acetates, hydrocarbons, amber...)

The identification criteria of minerals

Cleavage / fracture: in some minerals, bonds between layers of atoms aligned in certain directions are weaker than bonds between different layers. In these cases, breakage occurs along smooth, flat surfaces parallel to those zones of weakness

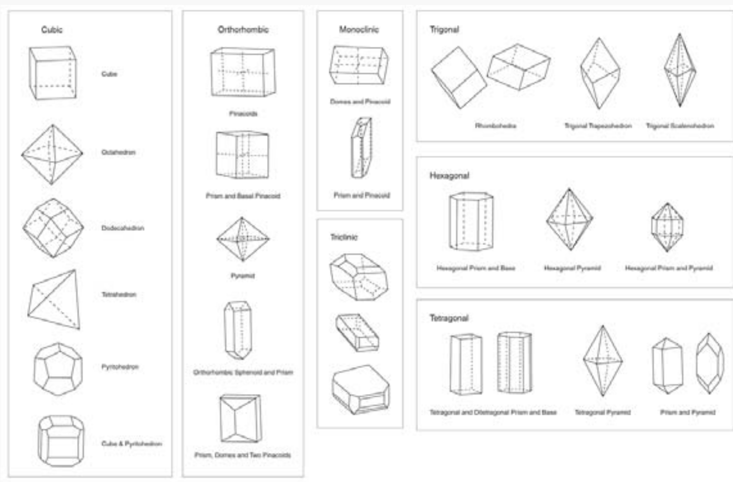


≠

conchoidal fracture

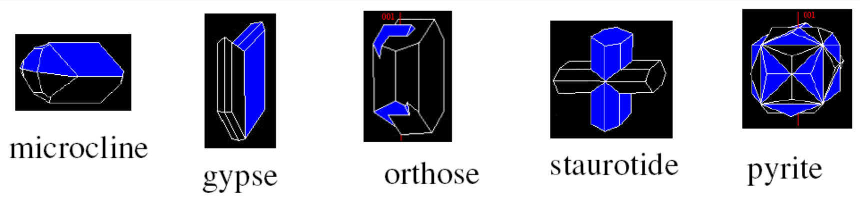
The identification criteria of minerals

Crystal shape: the 7 crystal systems



The identification criteria of minerals

Twinning (macle): Crystal twinning occurs when two separate crystals share some of the same crystal lattice points in a symmetrical manner. The result is an intergrowth of two separate crystals in a variety of specific configurations.



The identification criteria of minerals

Density: physical constant (2.7 g/cm^3 for silicates)

Colour: not a differential criteria

Streak *(trait)*: colour of the powder, more reliable than the colour of the mineral itself (Scratch unglazed porcelain => This only works for minerals which are softer than a ceramic tile (hardness ~ 7))

Luster *(éclat)*: aspect of the surface mineral when it reflects light

Flam test: the color of flames depends on the chemical composition (Ca: red, Na: yellow, Cu: blue or green, K: violet…)

The identification criteria of minerals

Hardness: Mohs scale of relative mineral hardness

The identification criteria of minerals

Reaction with dilute HCl (10%):
carbonates + HCl 10% => emission of CO_2 = effervescence (calcite ($CaCO_3$) fizzes readily in either massive or powdered form, but dolomite ($Ca,Mg(CO_3)_2$) reacts best as a powder or with heated acid)

Touch

Flavour

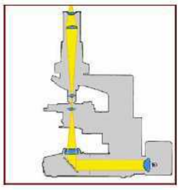
Smell

Radioactivity

Magnetism,...

The identification criteria of minerals

Optical properties:



Polarizing microscope

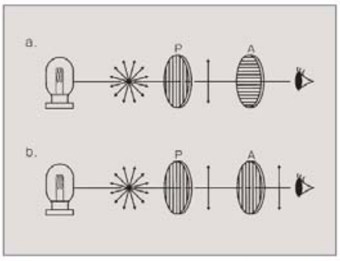
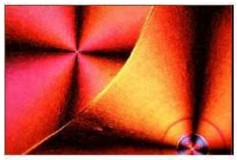


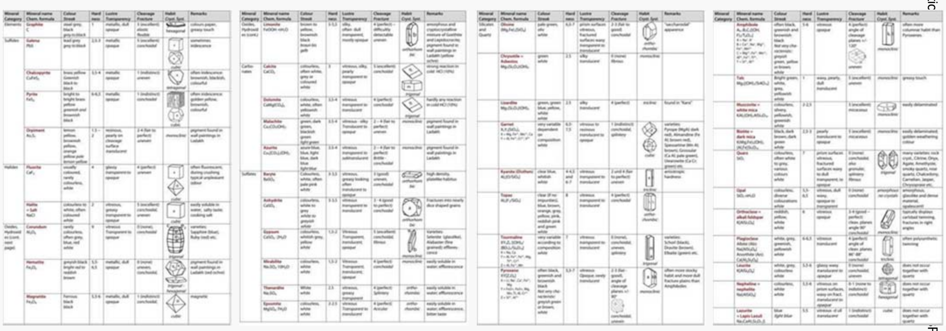
Fig. 1.3 a) crossed nicols and b) parallel nicols
P: polarizer A: analyzer



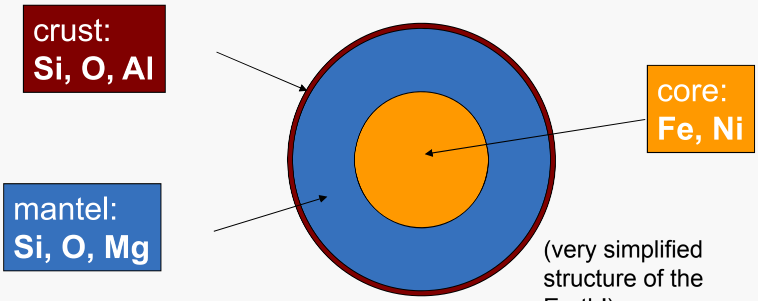
Interference colors

For more details, see for ex.:
http://www.olympusamerica.com/files/seg_polar_basic_theory.pdf (english)
http://www.kasuku.ch/pdf1.php#a_microscope (french)

Additional document on http://www.csc-sarl.ch:
(under the schedule)
Table of minerals (from Dr Jan-Michael Lange of the Senckenberg Natural History Museum in Dresden, adapted by Dr Christine Bläuer of CSC, Fribourg)



Distribution of elements within the earth

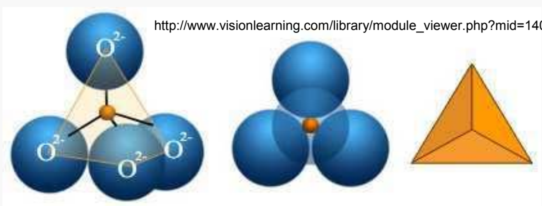


(very simplified structure of the Earth!)

➔ **silicates (& other light minerals) are the most abundant minerals in the earth's surface**

The silicate class

The silicates are the largest, the most interesting and the most complicated class of minerals. ≈ 30% of all minerals are silicates and 90% of the Earth's crust is made up of silicates.

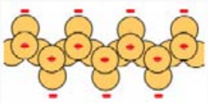


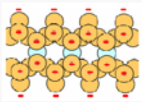
The basic chemical unit of silicates is the (SiO_4) tetrahedron shaped anionic group **with a negative four charge (-4).**
But a mineral must be neutral !!!

The silicate class - Neutralization of charges…

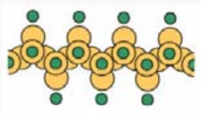
- with cations :

- polymerization with sharing the O^{2-} anions :

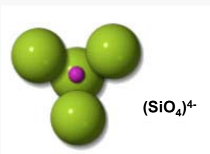
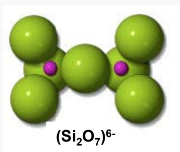
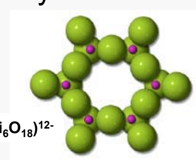
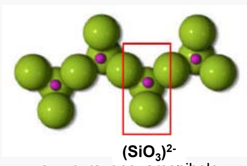




- combining the two previous solutions :

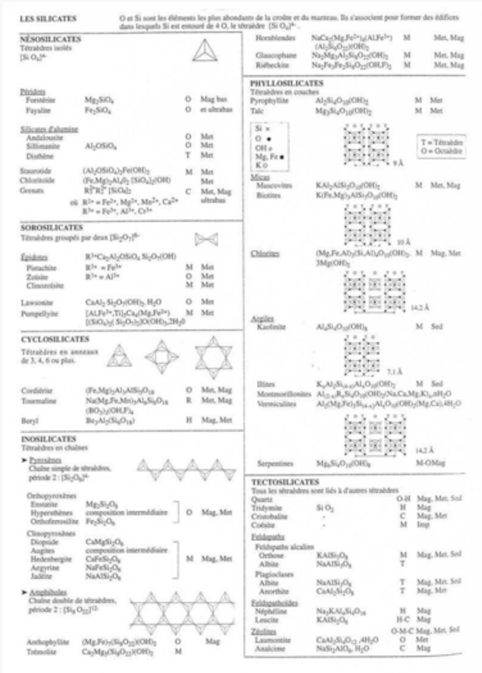


The silicate class - The 6 groups of silicate minerals

Nesosilicates	Sorosilicates	Cyclosilicates
 $(SiO_4)^{4-}$ ex.: olivine, garnet, zircon,…	 $(Si_2O_7)^{6-}$ ex.: epidote,…	$(Si_6O_{18})^{12-}$  ex.: beryl, tourmaline,…
Inosilicates	**Phyllosilicates**	**Tectosilicates**
 $(SiO_3)^{2-}$ ex.: pyroxene, ampnibole,…	 $(Si_2O_5)^{2-}$ ex.: mica, clay,…	$(SiO_2)^0$  ex.: quartz, feldspar,…

Conservation Science Consulting Sàrl

Additional document on http://www.csc-sarl.ch:
(under the schedule)
Structure of a few silicate minerals


LES SILICATES

NÉSOSILICATES

SOROSILICATES

CYCLOSILICATES

INOSILICATES

PHYLLOSILICATES

TECTOSILICATES

Conservation Science Consulting Sàrl

Minerals and rocks

Cardinal minerals:

60 to 70% of the rock (usually white or slightly colored)
quartz, feldspars, feldspathoids, calcite

Essential minerals:

20 to 25% of the rock (often dark)
micas, amphiboles, pyroxenes, olivine,...

Accessory minerals:

5 to 10% of the rock
oxides, sulfides,...

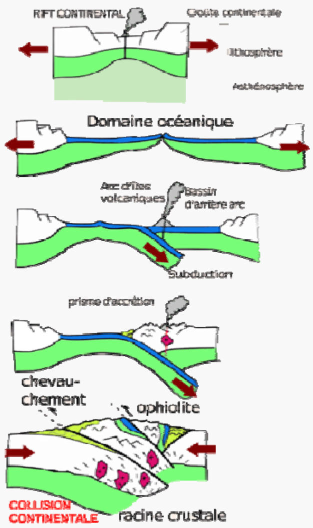
Genesis of minerals and rocks

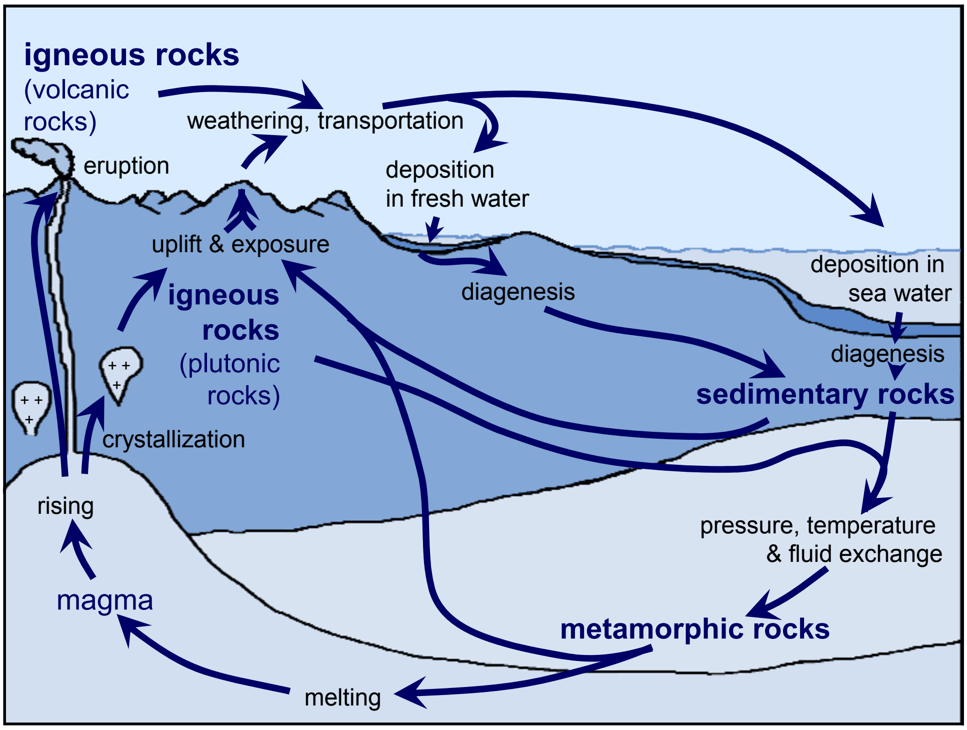
Endogenous genesis (in depth)

- **magmatic process:** coming from a magma
- **metamorphic process:** transformation of pre-existent mineral materials

Exogenic genesis (at the surface)

- **sedimentary process:** pre-existent mineral materials transformation and/or neo-formation





A few silicate minerals

Nesosilicates / Garnets ($X_3^{2+}Y_2^{3+}[SiO_4]_3$)

Use: gemstone, abrasive

Inosilicates / Amphiboles

Bleu asbestos: Crocidolite ($Na_2(Fe,Mg)_5Si_8O_{22}(OH)_2$)

Inosilicates / Amphiboles

Brown asbestos: Amosite ($Fe_7Si_8O_{22}(OH)_2$)

Inosilicates / Amphiboles

Green asbestos. ex. : Actinolite $(Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2)$

Phyllosilicates / Micas

Muscovite $(KAl_2[(OH,F)_2|AlSi_3O_{10}])$ white mica,
Biotite $(K(Mg,Fe^{2+},Mn^{2+})_3[(OH,F)_2(Al,Fe^{3+},Ti^{3+})Si_3O_{10}])$ black/brown mica

Use: Heat, acoustic and electric insulator, paints

Phyllosilicates / Clay minerals

Kaolinite $(Al_2Si_2O_5(OH)_4)$

Use:
porcelain manufacture,
filler in papers

Phyllosilicates / Clay minerals

Montmorillonite $((Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2.nH_2O)$

Swelling clay mineral exchanger of ions

Use: gastric plaster, cleaner of greases (Terre de Sommières), bentonite, container for the nuclear waste

Phyllosilicates / Clay minerals

Talc ($Mg_3Si_4O_{10}(OH)_2$)

Use of talc: cosmetic, lubricant, manufacture of paper, excipient and lubricant in the pharmaceutical industry, tailor's chalk

Phyllosilicates / Chlorites

($(Mg,Fe,Mn,Al)_6((Si,Al)_4O_{10})(OH)_8$)

Use: decorative stone

Phyllosilicates / Serpentinites

White asbestos: Chrysotile ($Mg_3Si_2O_5(OH)_4$)

Use: reinforced cement, machine parts under friction, joints for high temperature machines… because non flammable, imputrescible, flexible, resistant to the majority of chemicals and with a high breaking stress => majority of the world market of asbestos

http://www.ec.gc.ca/nopp/docs/consult/Rotterdam/ca/fr/chrysotileBG.cfm

Tectosilicates / Quartz

(SiO_2)

Use: Piezoelectric (clock industry, …) and…

gemstones (amethyst, citrine)… cryptocristalline varieties: flint, agate, onyx, carnelian, jasper, opal

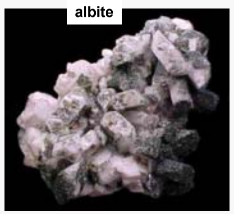
Tectosilicates / Feldspars

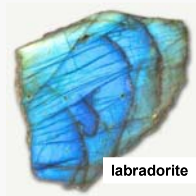
K- feldspars ($KAlSi_3O_8$)

Use: ceramics, porcelain, glass, bricks, soaps, scouring powders, gemstones

Tectosilicates / Feldspars

Plagioclases ($AlSi_3O_8$)(Ca,Na)





Use: ceramics, porcelain, glass, bricks, soaps, scouring powders, gemstones

Tectosilicates / Feldspathoids

Lazurite ($(Na, Ca)_8(Al, Si)_{12}O_{24}S_2$ FeS- $CaCO_3$)

Use: gemstone, blue pigment

A few non silicate minerals

Carbonates / Calcite ($CaCO_3$)

Use: white pigment (calcite as chalk used since prehistory), raw material of lime

Carbonates / Azurite ($2CuCO_3,Cu(OH)_2$)

Use: blue pigment, gemstone

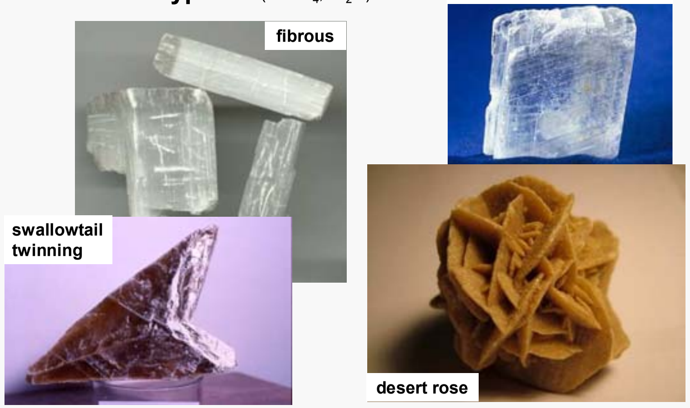
Carbonates / Malachite ($CuCO_3,Cu(OH)_3$)

Use: green pigment, gemstone

Carbonates / Cerussite ($PbCO_3$)

Use: cosmetic (in the past since antiquity); white pigment (= white lead)

Sulfates / Gypsum ($CaSO_4,2H_2O$)



Sulfates / Gypsum ($CaSO_4,2H_2O$)

Use: raw material of plaster; fertilizer and soil conditioner, Tofu coagulant, blackboard chalk

Sulfates / Gypsum alabaster ($CaSO_4,2H_2O$)

Use: decorative stone

Sulfates / Gypsum ($CaSO_4,2H_2O$)

Danger: coming from the air pollution, the stone itself or from cements => degrading stones

Sulfates / Barite ($BaSO_4$)

Use: major source of barium, white pigment (blanc fixe), used in paper or paint manufacturing, radiography, heavy filler

Halides / Halite (NaCl)

Use: table salt, road salt

Danger for building stones:
crystallisation
damp patches

Halides / Sylvite (KCl)

Use: fertilizer, substitute for table salt, lethal injection

Danger for building stones:
crystallisation,
damp patches

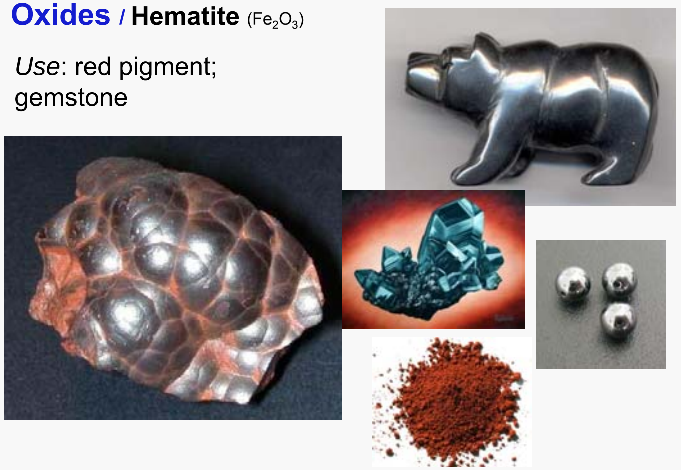
Halides / Fluorite (CaF_2)

Use:
manufacture of hydrofluoric acid, enamels, glass fibre;
used as camera lens;
purple pigment;
gemstone

Conservation Science Consulting Sàrl

Oxides / Hematite (Fe_2O_3)

Use: red pigment; gemstone



Conservation Science Consulting Sàrl

Oxides / Goethite (FeO(OH))

Use: yellow pigment

Conservation Science Consulting Sàrl

Oxides / Rutile (TiO_2)

Use: white pigment (artificial); manufacture of paints; +/- in gemstones

Conservation Science Consulting Sàrl

Oxides / Corundum (Al_2O_3)

Use:
abrasive;
gemstones

Conservation Science Consulting Sàrl

Oxides / Minium (Pb_3O_4)

Use: red pigment, manufacture of glass, protecting paint against the corrosion of metals

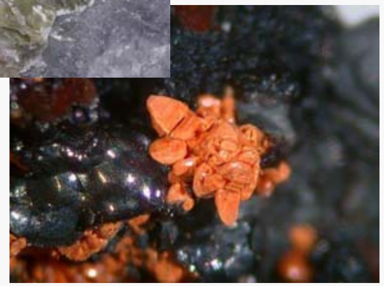



Conservation Science Consulting Sàrl

Oxides / Massicot (or litharge) (PbO)

Use: yellow pigment, manufacture of glass, of oils and varnishes (desiccant), production of insecticides





Conservation Science Consulting Sàrl

Sulfides / Galena (PbS)

Use: black pigment, cosmetic (khol), semiconductor in old wireless systems



Conservation Science Consulting Sàrl

Sulfides / Pyrite (FeS_2) (= fool's gold)

Use: production of sulfur dioxide for paper industry or manufacturing of sulfuric acid

"Dangers" in building oxidation makes it dangerous in aggregates of concrete; rost patches on stones (marble, sandstones,...)



Conservation Science Consulting Sàrl

Sulfides / Realgar (AsS)

Use: red pigment; fireworks

Problems: unstable with light (=> yellow pararealgar)



Conservation Science Consulting Sàrl

Sulfides / Orpiment (As_2S_3)

Use: yellow pigment; production of semiconductors and photoconductors, fireworks

Problems: incompatible with pigments like lead and copper-based; it blackens in contact with the air



Conservation Science Consulting Sàrl

Sulfides / Cinnabar (HgS)

Use: red pigment; medicine, drug, food dye

Problems: it blackens in contact with the air



Conservation Science Consulting Sàrl

Phosphates / Apatite ($Ca_5(PO_4)_3(OH, F, Cl)$)

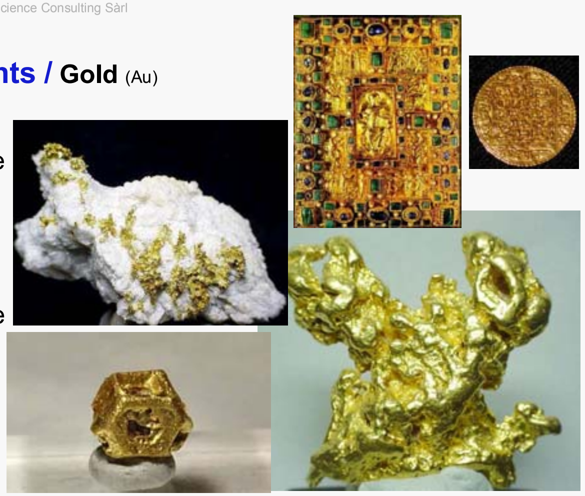
Use: fertilizer; gemstone; new stone consolidant




Conservation Science Consulting Sàrl

Elements / **Gold** (Au)

Use: noble metal, decorative metal, gilding; conductive coating, money



Stony materials and conservation of the built heritage – Natural Stone _Mineralogy_ BR /61

Conservation Science Consulting Sàrl

Elements / **Silver** (Ag)

Use: noble metal; decorative metal; printed circuits; electrical contacts; dental alloys; antibacterial; money

Stony materials and conservation of the built heritage – Natural Stone _Mineralogy_ BR /62

Conservation Science Consulting Sàrl

French bibliography

• Schumann W., 1990 - Guide des pierres et minéraux - Ed. Delachaux et Niestlé

• http://www.kasuku.ch/

English bibliography

• http://webmineral.com/

Stony materials and conservation of the built heritage – Natural Stone _Mineralogy_ BR /63