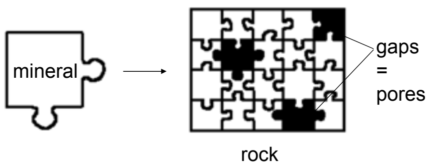
NATURAL STONE

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**)



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)

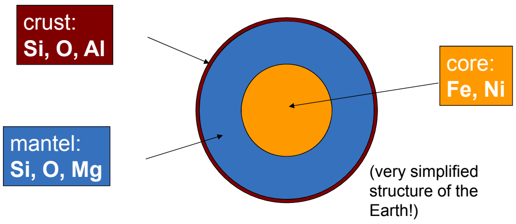
Cristal = **homogeneous solid** composed of atoms, ions or molecules with an **organized arrangement** that is **repeated periodically** in three dimensions of space
(cristal ≠ amorphous compounds)

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...)

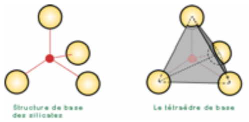
Distribution of elements within the earth



➔ **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.



Le bilan des charges

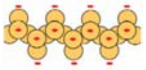
Oxygène (O^{2-}) : $4 \times -2 = -8$
Silicium (Si^{4+}) : $1 \times +4 = +4$
excès -4

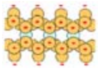
The basic chemical unit of silicates is the (SiO_4) tetrahedron shaped anionic group **with a negative four charge (-4). But a mineral must be neutral !!!**

The silicate class - Neutralization of charges…

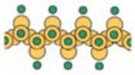
- with cations :

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

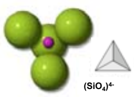
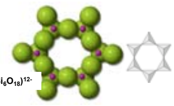
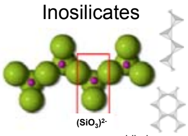
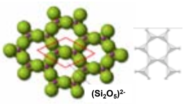




- combining the two previous solutions :



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, amphibole,…	 $(Si_2O_5)^{2-}$ ex.: mica, clay,…	 $(SiO_2)^0$ ex.: quartz, feldspar,…

The silicate class - The clay minerals (phyllosilicates)

Example of 1:1 (or T-O) layer silicate : kaolinite

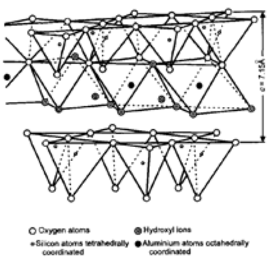


FIG. 1. Kaolinite structure.

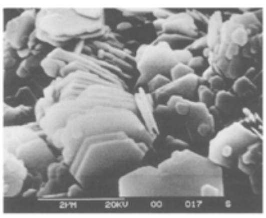


FIG. 2. SEM of kaolinite (Capim River).

H. H. Murray, 1999. Applied clay mineralogy today and tomorrow, Clay Minerals, *V.34, p. 39-49*

Conservation Science Consulting Sàrl

The silicate class - The clay minerals (phyllosilicates)

Example of 2:1 (or T-O-T) layer silicate : smectite
= montmorillonite = bentonite

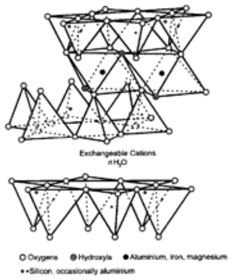


FIG. 4. Smectite structure.

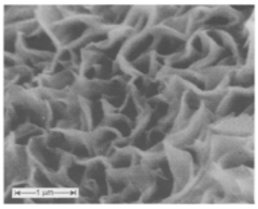


FIG. 5. SEM of Na-montmorillonite (Wyoming).

H. H. Murray, 1999. Applied clay mineralogy today and tomorrow, Clay Minerals, *V.34, p. 39-49*

Conservation Science Consulting Sàrl

The silicate class - The clay minerals (phyllosilicates)

T-O or 1:1 type

T-O-T or 2:1 type

T-O-T or 2:1 type

T-O-T O or 2:1:1 type

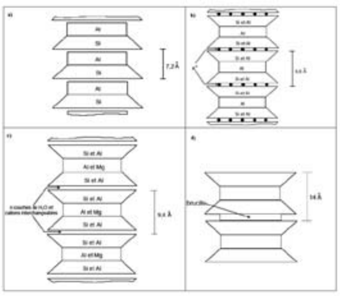


Figure II-9: Schéma de la particule de a) kaolinite, b) illite, c) smectite et d) chlorite

Truche, C., 2010. Caractérisation et quantification des minéraux argileux dans les sols expansifs par spectroscopie infrarouge aux échelles du laboratoire et du terrain. Thèse de doctorat, Université Paul Sabatier, Toulouse, 226 p.

Conservation Science Consulting Sàrl

The silicate class - The clay minerals (phyllosilicates)

name	type	particule diameter (µm)	specific surface area (m^2/g)	CEC (meq/100g)
Kaolinite	1:1	0.1 - 4	10 - 30	3 - 15
Illite	2:1	0.1 - 1	100 - 175	25 - 40
Smectite (montmorillonite)	2:1	0.1	700 - 840	80 - 100
Vermiculite	2 :1	0.1	760	100 - 150
Chlorite	2:1:1	0.1	20	5 - 15

Tableau 6: Caractéristiques des différentes familles d'argile.

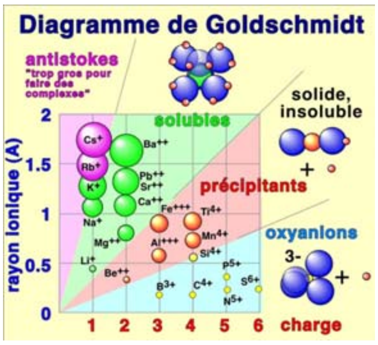
CEC = cation exchange capacity

Truche, C., 2010. Caractérisation et quantification des minéraux argileux dans les sols expansifs par spectroscopie infrarouge aux échelles du laboratoire et du terrain. Thèse de doctorat, Université Paul Sabatier, Toulouse, 226 p.

Conservation Science Consulting Sàrl

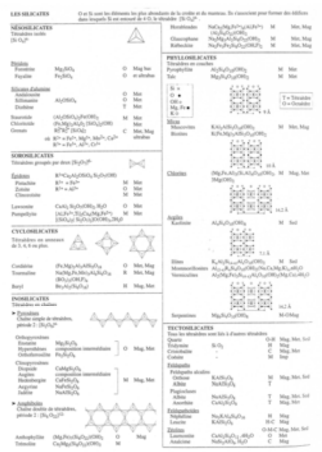
The silicate class - The clay minerals (phyllosilicates)

Ionic radius & cation exchange capacity



Conservation Science Consulting Sàrl

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



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,...

Conservation Science Consulting Sàrl

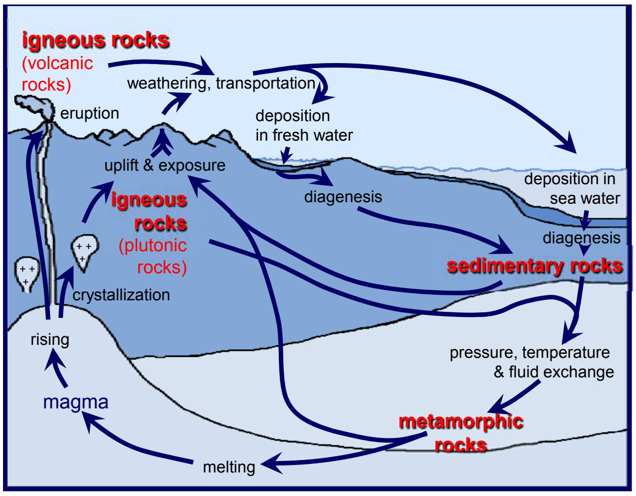
Genesis of minerals and rocks

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



Conservation Science Consulting Sàrl

A few examples of minerals

Additional document on http://www.csc-sarl.ch:
(under the schedule)
Mineral examples

Silicate minerals:	**Non silicate minerals:**
Garnets (nesosilicates)	Carbonates
Asbetos (inosilicates)	Sulfates
Micas (phyllosilicates)	Halides
Clay minerals (phyllosilicates)	Oxides
Serpentinites (phyllosilicates)	Sulfides
Quartz (tectosilicate)	Phosphates
Feldspars (tectosilicates)	Native element minerals

The identification criteria of minerals, simple tests that sometimes can be also used for stones …

The identification criteria of minerals

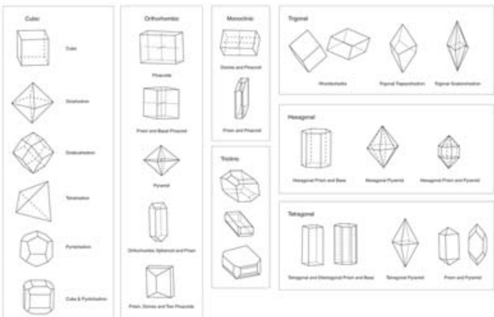
Cleavage / fracture: in some minerals, bonds between layers of atoms aligned in certain directions are weaker than bonds between different layers. In these cases, breakage occurs along smooth, flat surfaces parallel to those zones of weakness

≠

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

Conservation Science Consulting Sàrl

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,...

Conservation Science Consulting Sàrl

The identification criteria of minerals

Optical properties:

Polarizing microscope

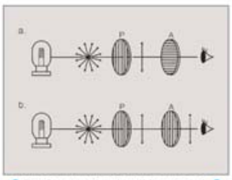
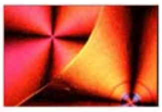


Fig. 1.3 a) crossed nicols and b) parallel nicols
P: polarizer A: analyzer



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)

Conservation Science Consulting Sàrl

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)

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/

Access to the planning, and exercices: http://www.cscsarl.ch

CSC Sàrl
Route de Beaumont 13
CH-1700 Fribourg
Tél. +41 26 422 12 44
csc@conservation-science.ch

Newsletter:
inscription/désinscription

Date	Sujet	Description	Enseignant
23.9.16	Introduction La pierre naturelle - Minéralogie	Buts du cours - Notion d'éthique de la conservation Minéraux silicatés et non silicatés Exercice à faire pour le 30.09	B. Rousset
30.9.16	La pierre naturelle - Minéralogie / Pétrologie	Minéraux silicatés et non silicatés, manipulation d'échantillons / Classification des roches	B. Rousset
7.10.16	La pierre naturelle - Pétrologie	Classification des roches, manipulation d'échantillons	B. Rousset
14.10.16	Mortiers	Mortiers anciens et mortiers de restauration	C. Bläuer
21.10.16	Excursion : les matériaux pierreux sur les bâtiments	Identification des 3 grandes familles de roches et de quelques mortiers sur les façades des bâtiments lausannois	B. Rousset
28.10.16	Pétrophysique	Propriétés physiques et mécaniques des pierres	B. Rousset
4.11.16	Journée des classes		
11.11.16	Pétrophysique - sels solubles	Propriétés physiques et mécaniques des pierres, le problème des sels solubles	B. Rousset
18.11.16	Altération des pierres	Comment et pourquoi les pierres s'altèrent	B. Rousset
25.11.16	Altération des pierres	Comment et pourquoi les pierres s'altèrent	B. Rousset
2.12.16	Excursion : altération des pierres sur le terrain	Identification des formes d'altération sur les façades lausannoises, approche d'un tailleur de pierre	O. Fawer & B. Rousset
9.12.16	Méthodes et matériaux de conservation de la pierre	Méthodes et produits de traitement utilisés pour la consolidation, l'hydrofugation, la protection de la pierre	B. Rousset
16.12.16	Méthodes et matériaux de conservation de la pierre	Méthodes et produits de traitement utilisés pour la consolidation, l'hydrofugation, la protection de la pierre	B. Rousset
23.12.16	Examen oral	Étude de cas. Sujet	B. Rousset

Documents complémentaires au cours de minéralogie:
- Tableau des minéraux (d'après Dr Jan-Michael Lange du Musée d'Histoire Naturelle Senckenberg à Dresden, adapté par Dr Christine Bläuer de CSC, Fribourg)
- Structure de quelques silicates

Documents complémentaires au cours de pétrologie:
- tableau synoptique simplifié pour l'identification des roches