Isotropy in oxides

two or more substances

- with same crystal structure
- do not form solid solution series
- which form similar crystal shapes

example:

rutile (TiO_2) and cassiterite (SnO_2)

corundum (Al_2O_3) and hematite (Fe_2O_3)

XY_2O_4-bonds: spinel group

- Spinel $MgAl_2O_4$
- Magnetite (loadstone) Fe_3O_4
- Chromite (Chromite iron ore) $FeCr_2O_4$

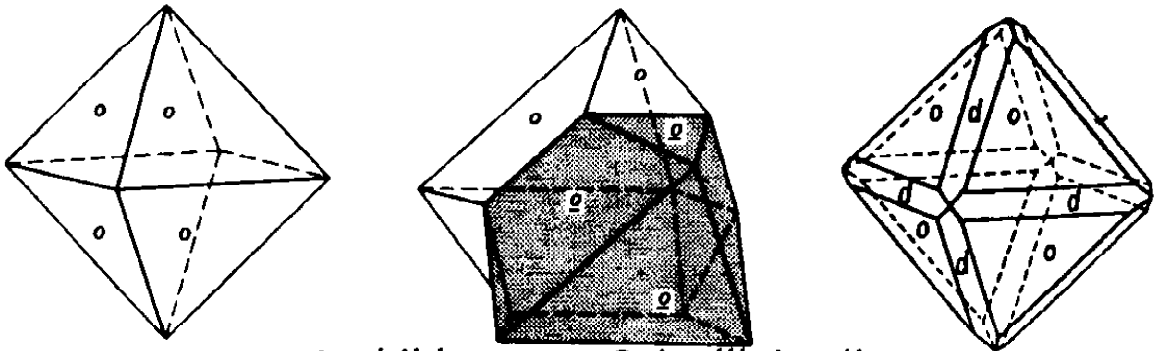
Magnetite

Magnetite from Hargreavis, Brazil

- Fe_3O_4
- cubic
- hardness 6
- density 5.2 g cm^3
- frequently octahedral
- formed magmatic and metamorphic, or accumulated in placers
- it may include Gold or other heavy metals
- it may posses magnetic properties

Magnetite

Spinel: $MgAl_2O_4$ (Spinel) and $Fe^{2+}Al_2O_4$ (hercynite)

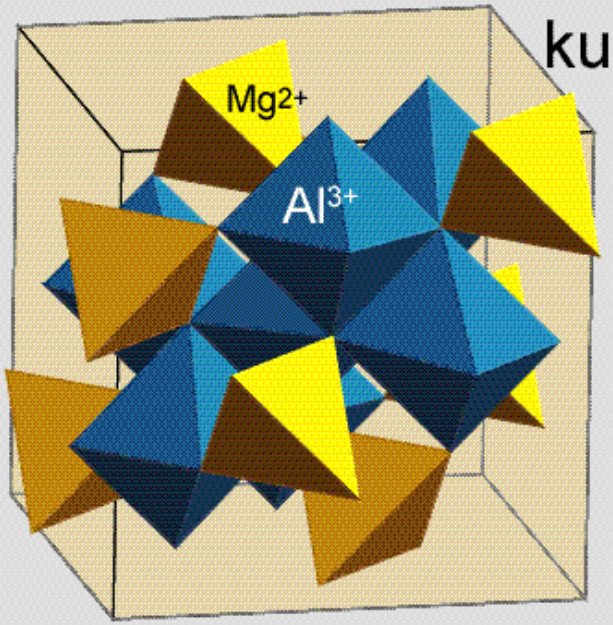


Ausbildung von Spinellkristallen

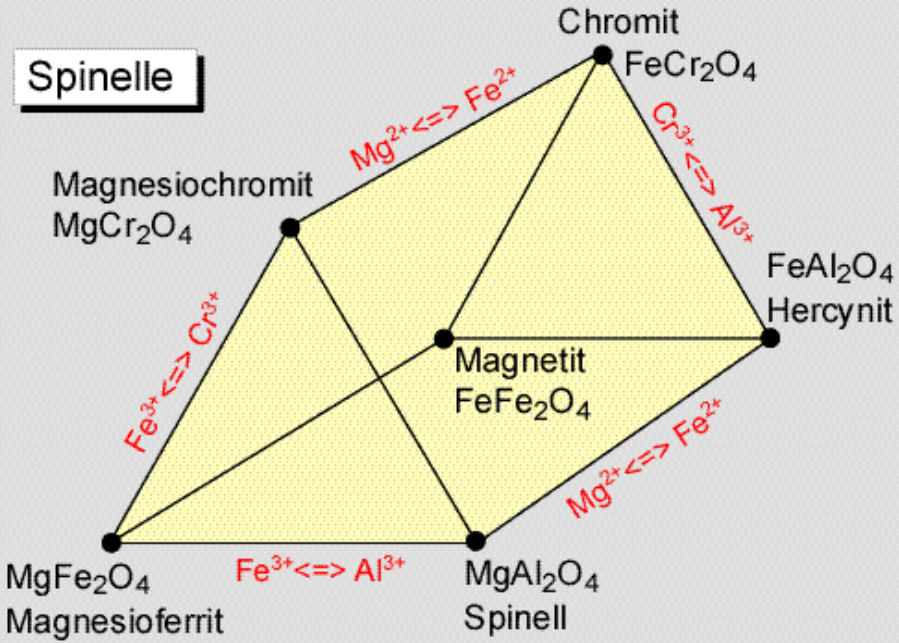
- cubic
- hardness 8
- density 3.5 - 4.1 g cm^3
- formed metamorphic and magmatic
- exsolution between magnetite and spinel due to the different ionic radius of Fe und Al
- a variety of colors: white, green, blue, rose, brown, black
- also placer mineral and gemstone

Spinell $MgAl_2O_4$

kubisch



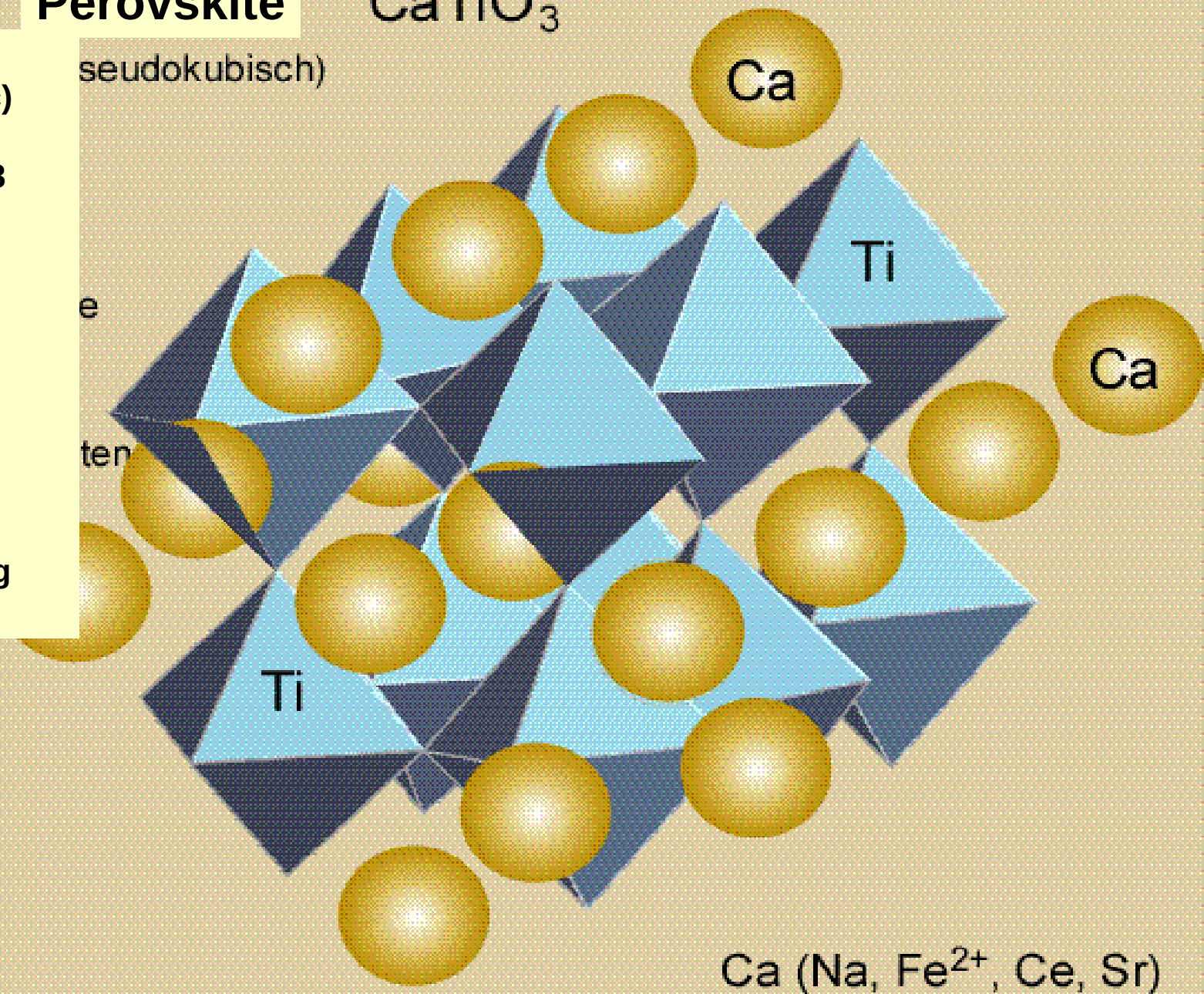
Spinel beside olivine



Perovskite

$CaTiO_3$

Orthorhombic (pseudo cubic)
hardness 5 ½
density 4.0-4.8
high pressure phase
in the earth mantle (400-10000 km depth)
accessory in strong unterkieselten mantle melting

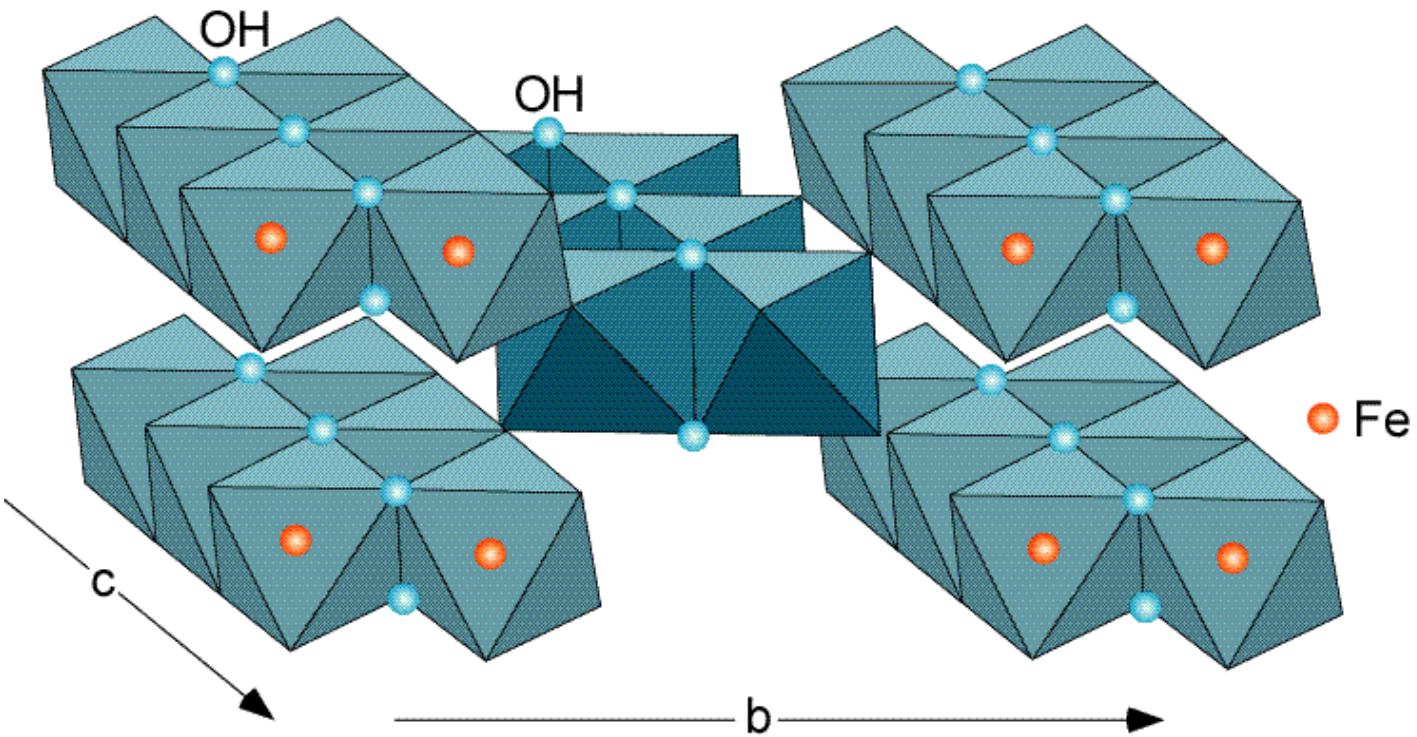


Limonite orthorhombic α-$Fe^{3+}OOH$

Goethite „ “ γ-$Fe^{3+}OOH$

The structure of diaspore (α-AlOOH)

or goethite (α-FeOOH)



Lepidocrocite

Limonite occurs during the weathering of Fe-minerals.
➔ Oxidation zone sulfidic mineralization (“iron hat")

Most fine-grained to coarse and occurs as a coating to magnetite, hematite or pyrite, but also fibrous (variety brown iron ore).

hardness (5 - $5^1/_2$) intermediary.

Goethite (limonite) from Minas Gerais, Brazil.

V. Group: carbonate, borate, nitrate

- most carbonates are colorless or white.
- hardness 3-4
- they possess a good cleavage after rhombohedral cleavage.
- carbonate are salts of carbonic acid H_2CO_3, analogue applies to the nitrates and borates.

- carbonates with small cations (e.g. Mg^{2+}, Zn^{2+}, Fe^{2+},Mn^{2+}) crystallize in the calcite structure.

- while carbonates with big cations (e.g. Sr^{2+}, Pb^{2+}, Ba^{2+}) crystallize in the aragonite structure.

- the carbonates of the dolomite series are structured analogous to the calcite structure, whit alternated layers of $CaCO_3$ and $MgCO_3$.

Chemical and isotopic tracer for paleoenvironment reconstruction:

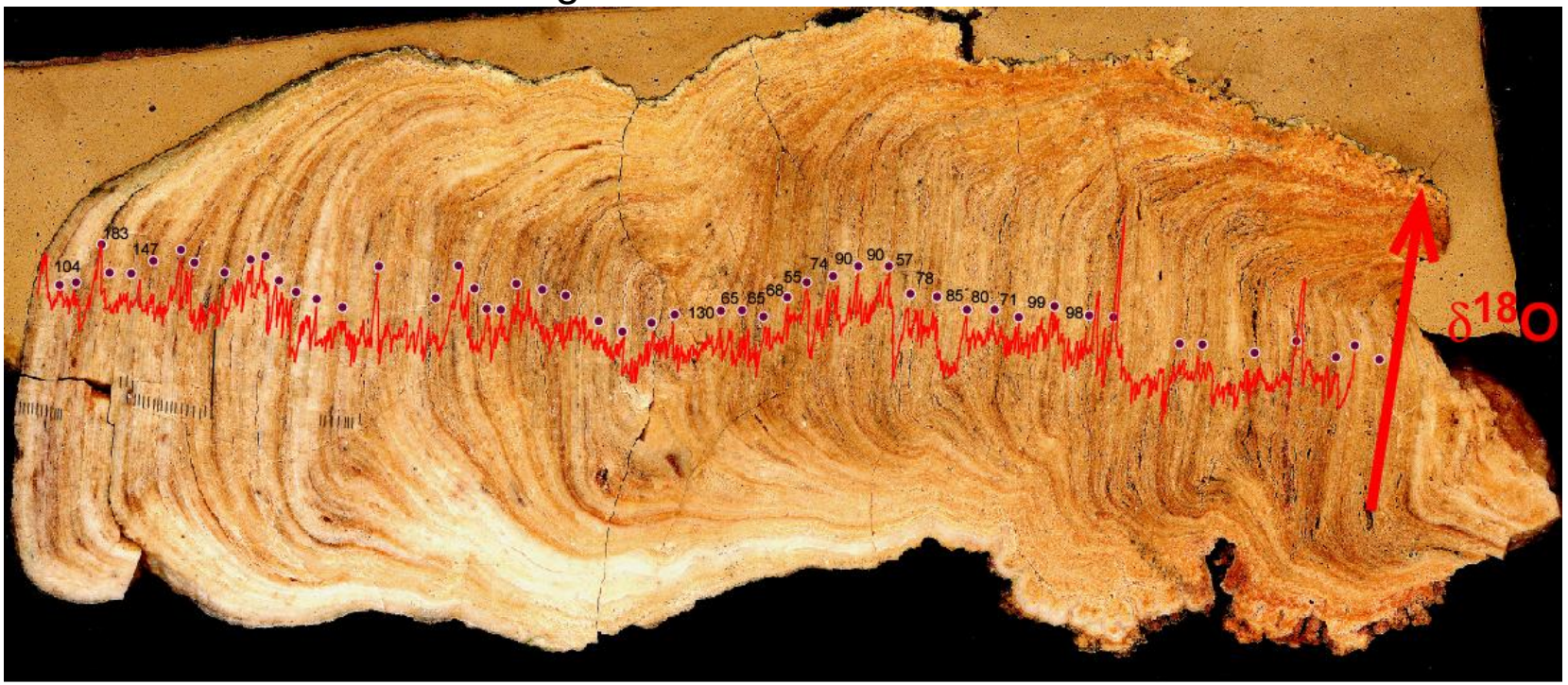
$\delta^{18}O$-values (relative ratio of ^{18}O to ^{16}O about a standard normalized)

$\delta^{13}C$-values (relative ratio of ^{13}O to ^{16}O about a standard normalized)

Mg/Ca-ratios in calcite or aragonite

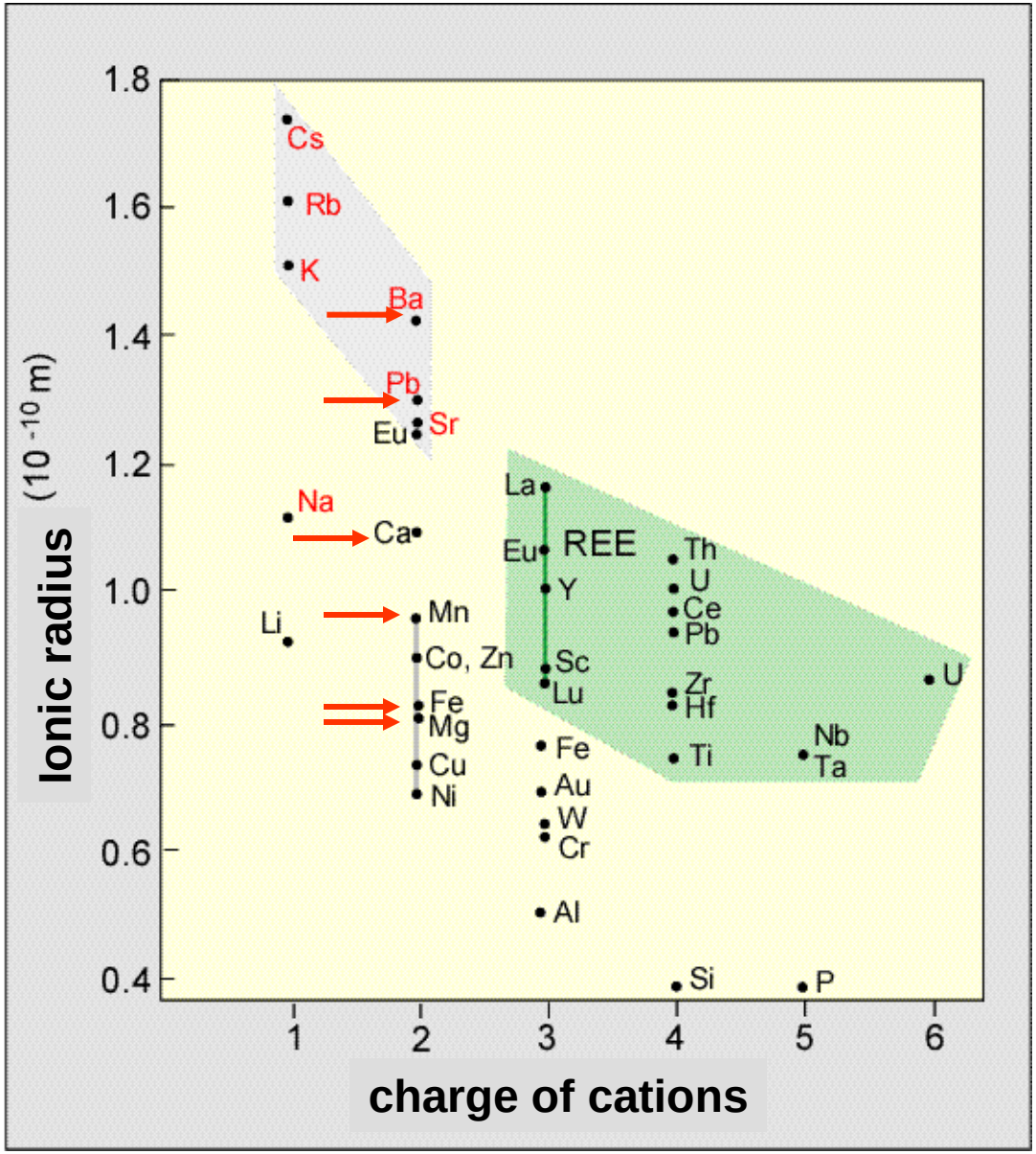
U/Ca-ratios in calcite or aragonite

Sr/Ca-ratios in calcite or aragonite



Stalagmite with variations of $\delta^{18}O$, which reflect high-resolution changes of drop rates and precipitations during the last 5000 years (Kilian et al. in prep.)

- Cations, which to be incorporated in carbonates:



Water-free carbonates

Rhodochrosite $MnCO_3$

Calcite series

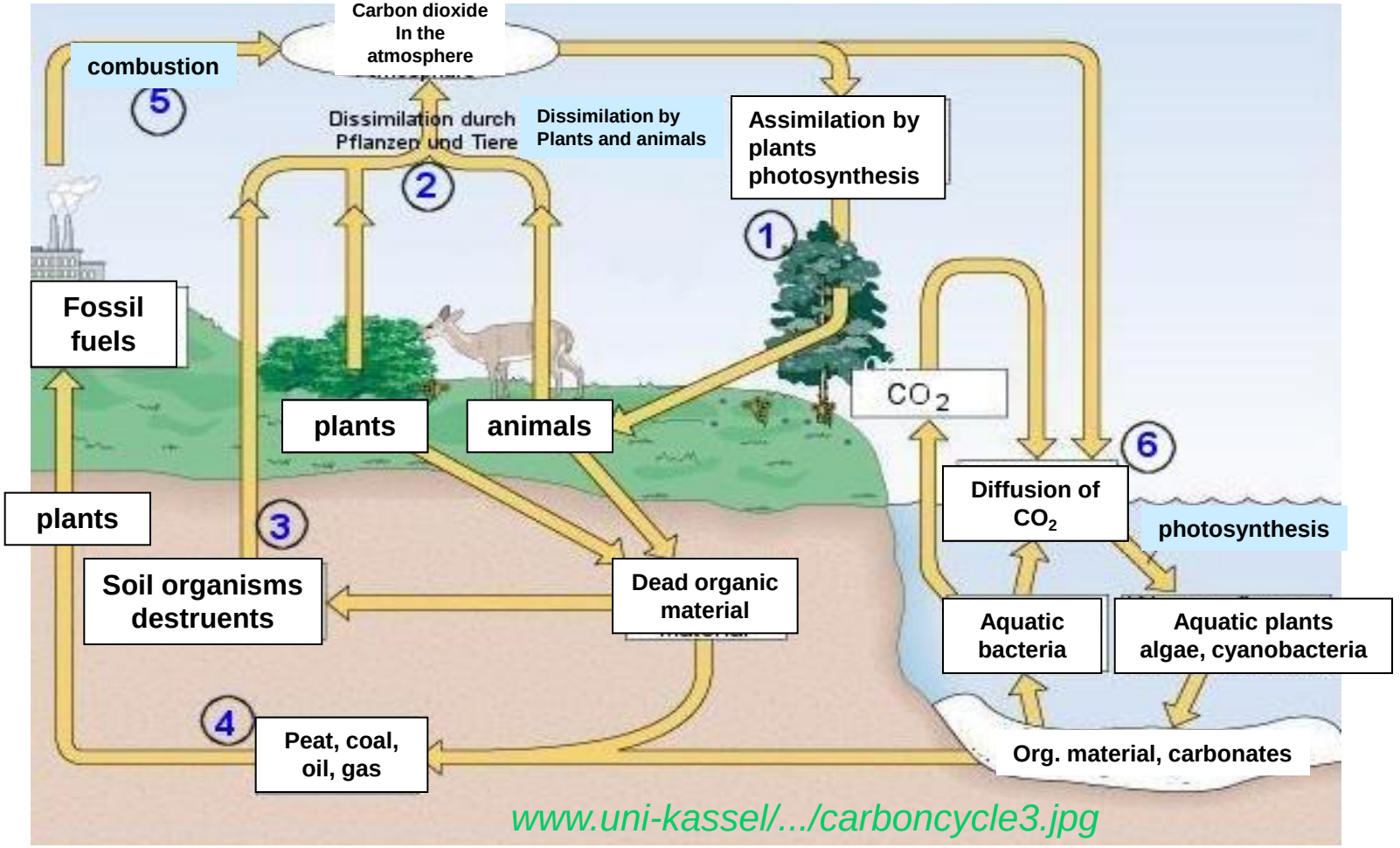
- Calcite $CaCO_3$
- Siderite $FeCO_3$
- Smithsonite $ZnCO_3$
- Magnesite $MgCO_3$

Calcite (calc-spar)

Calc-spar from St. Andreasberg, Harz

- $CaCO_3$
- trigonal
- hardness 3
- stark reaction with hydrochloric acid
- can have a variety of arrays
- widespread mineral in sediments and in metamorphic rocks
- occurs also in carbonatites of continental rift zones

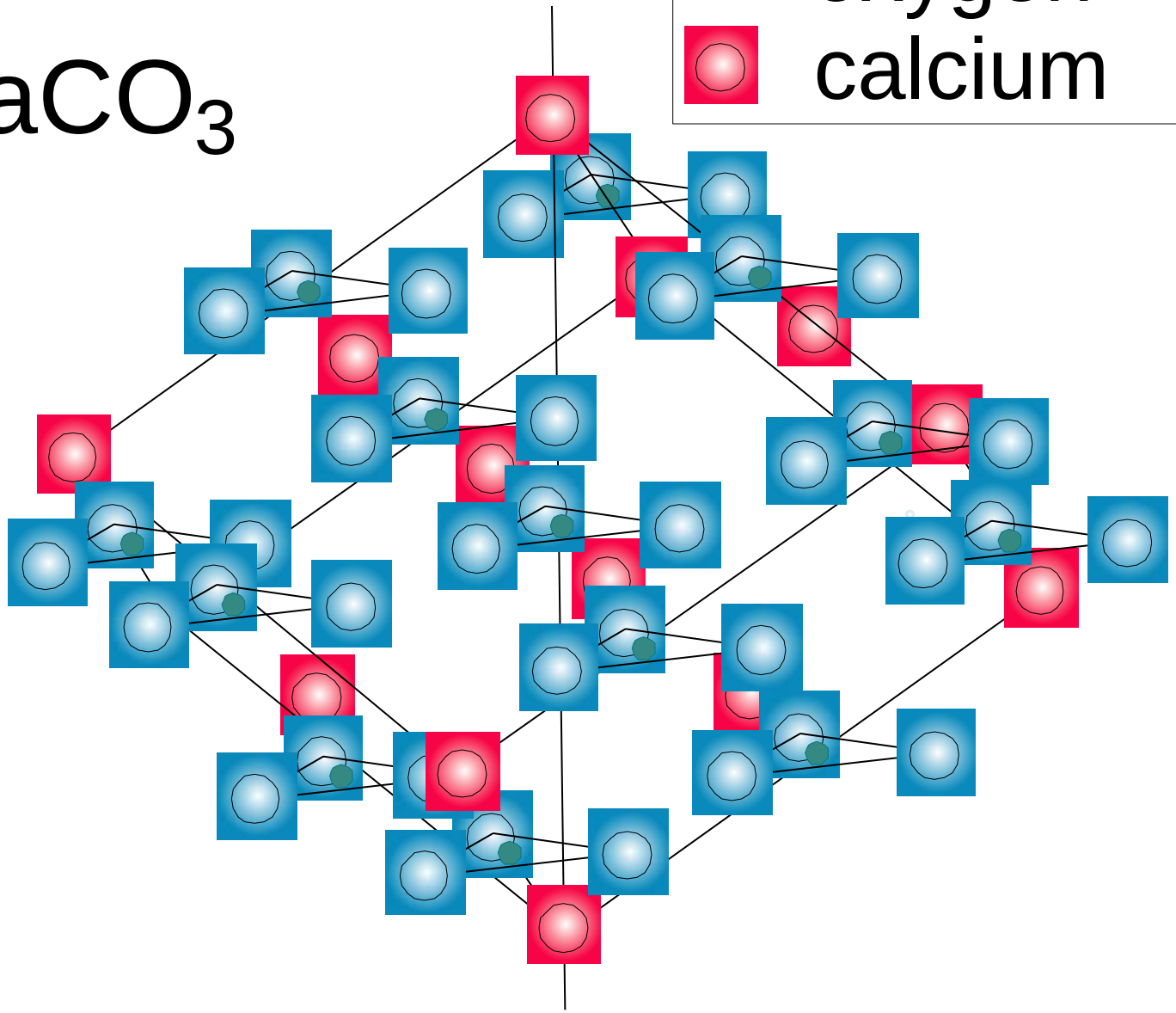
carbonates ➔ important part of the carbon cycle



www.uni-kassel/.../carboncycle3.jpg

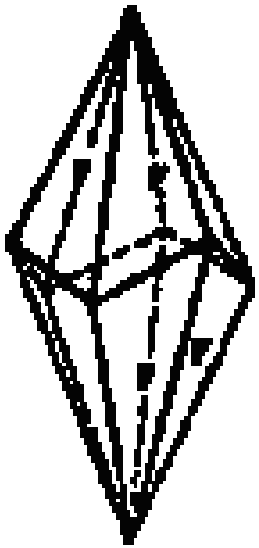
Calcite structure

$CaCO_3$

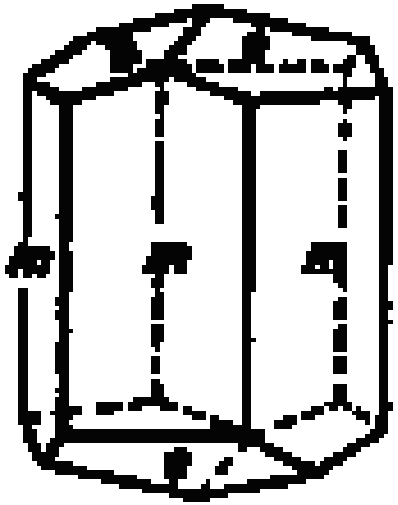


Rhomboeder

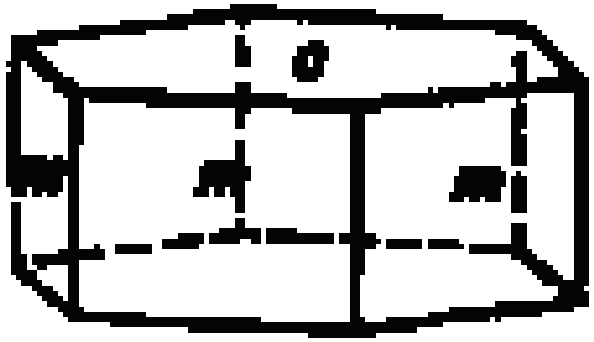
Formation of minerals of the calcite group



Ditrigonal scalenohedron



Hexagonal prism combined with rhombohedron



Basis pinacoid


Siderite and sphalerite

Magnesium and iron carbonates (magnesite, siderite and dolomite)

- hardness $3^1/_2$ – 4
- crystallize trigonal
- show perfect cleavage after rhombohedric cleavage ;
- sedimentary and metamorphic formed.