Lesson 5:

The Minerals and Rocks of the Earth

Part IIIb: The minerals- special mineralogy continued

The tectosilicates

(from the classical Greek τέκτων {tekton}= builder, mason), i.e. the "framework" silicates.

The tectosilicates are so-called, because in their structure the silica tetrahedra are connected in a three-dimensional infinite lattice.

Let us look at the electrical charges on an isolated SiO_4 tetrahedron again:

The charge of the Si ion is +4, and the O ion is -2, so:

$$Si^{+4}(O^{-2})_4^{-8}$$

This combination has an excess of -4 charges, which means that this unit cannot stay isolated. A +4 charge has to be added to neutralise it. In the tectosilicates we also have $(Si_3Al)O_8^{-1}$ or $(Si_2Al_2)O_8^{-2}$ as basic building blocks.

The tectosilicates make up about 63% of the earth's crust. This determines the deformational characteristics of the earth's crust.

The composition of the earth's crust (after Ronov and Yaroshevsky, 1969; from Klein, 2002)

The crust makes up about 0.03839 of the total earth mass

The tectosilicates comprise four groups of minerals:

Feldspars (these make up about 51 % of the earth's crust)

Quartz (quartz varieties make up about 12% of the earth's crust)

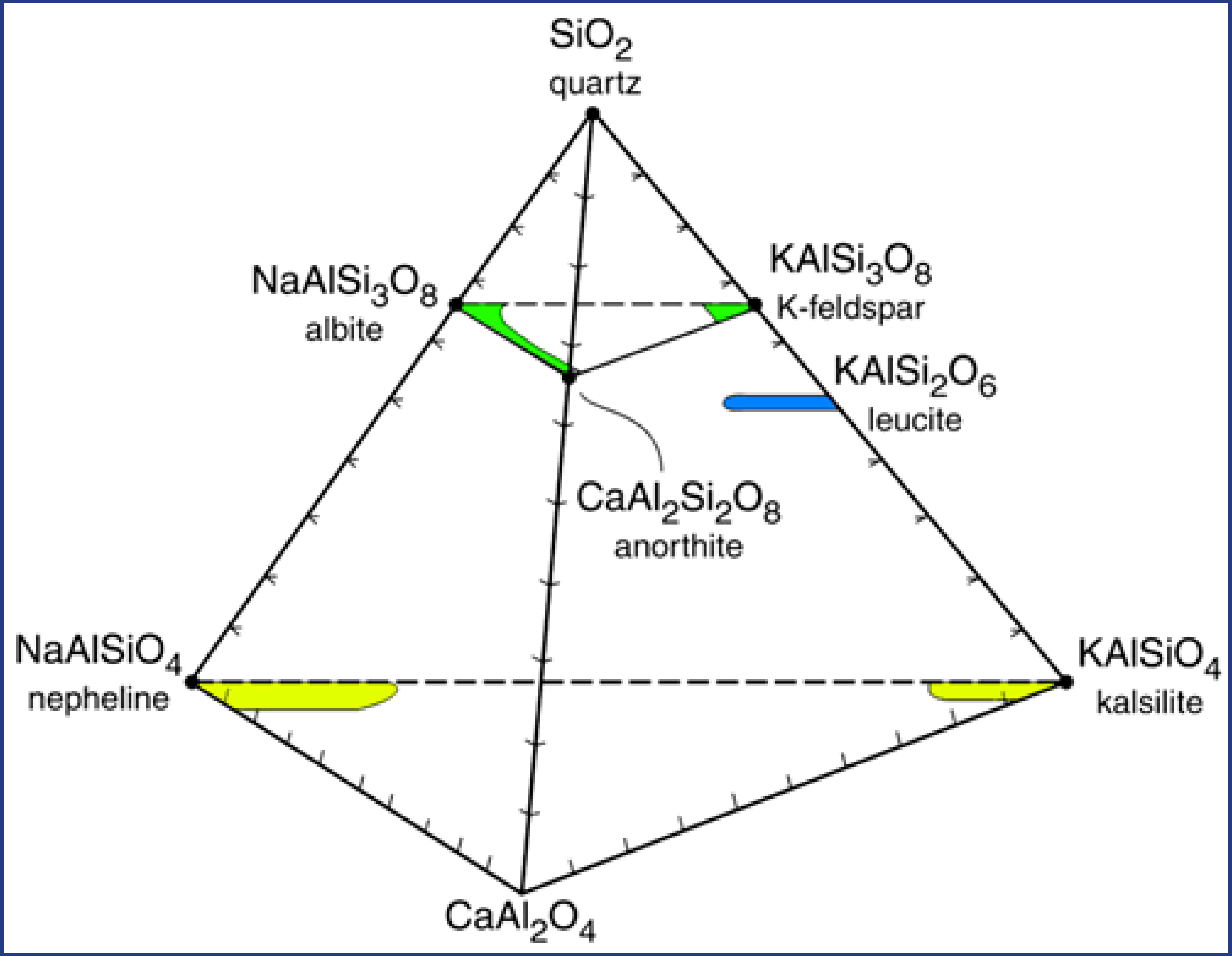
Feldspathoids

Zeolites

Feldspars and quartz make up almost the entire continental crust. If one takes the average crust to be similar to a granite, as taken by some geophysical modellers, then the feldspars would have made up 60% of it. If the crust had a dioritic composition, as assumed by others, then it would have 90% feldspars. For an understanding of the behaviour of the earth's crus it is therefore imperative that we understand the feldspars.

Feldspars, quartz and feldspathoids have a useful relationship: If a rock contains feldspathoids, it cannot have quartz, because feldspathoids form in environments, in which there is not enough silica to make feldspars. Quartz forms in a rock after all the feldspars are made and there is still excess silica. That excess goes to make quartz. Therefore, wherever you see quartz, you know that the environment had plenty of silica to make feldspars and thus there was no need to make feldspathoids.

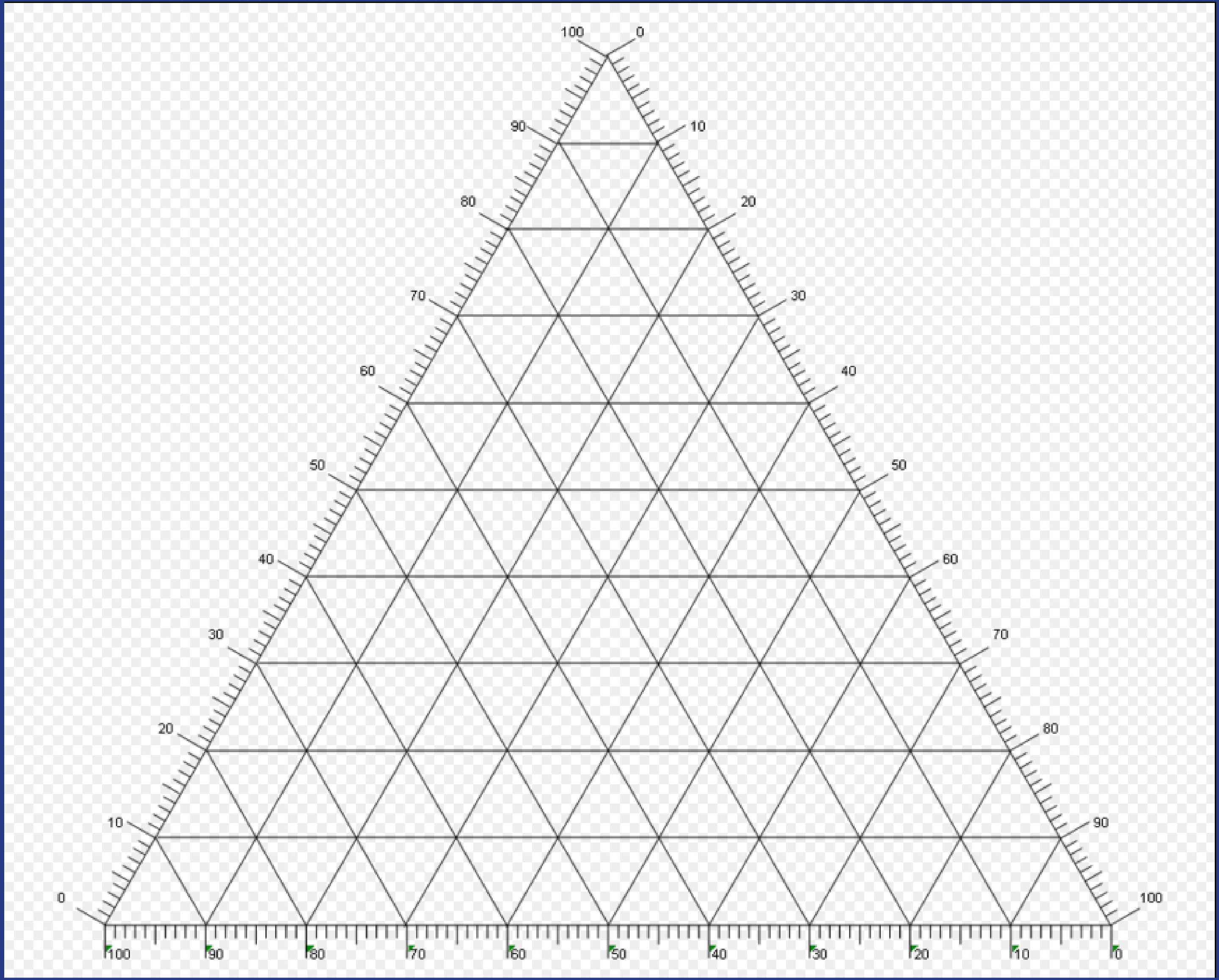
Increasing silica content



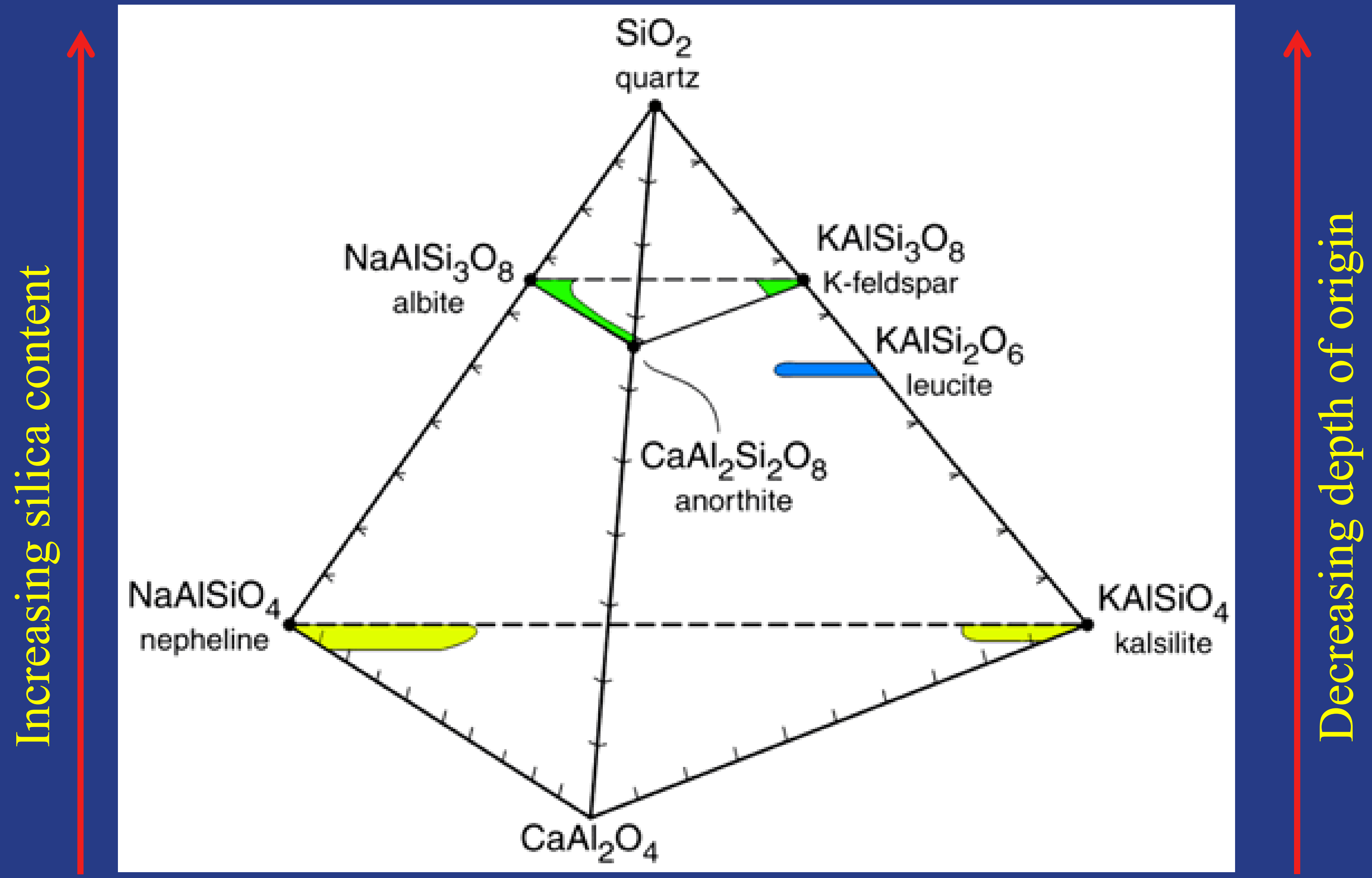
Decreasing depth of origin

FELDSPARS AND FELDSPATHOIDS

(http://www.google.com.tr/imgres?imgurl=http://www4.nau.edu/meteorite/Meteorite/Images/Feldspars.jpg&imgrefurl=http://www4.nau.edu/meteorite/Meteorite/Book-GlossaryF.html&h=451&w=484&sz=35&tbnid=GeFvwJw9yJwjgM:&tbnh=120&tbnw=129&prev=/images%3Fq%3DFeldspars&usg=__47WVVrryq776IXNpz-lUL7kXx-E=&sa=X&ei=FPgOTKPEEKf-0gSfz7WKDg&ved=0CDUQ9QEwAw)



A Ternary diagram. Ternary diagrams are useful for plotting three variables the sum of which is a constant. Every corner is 100 % of one of the components and the corners opposite to it are 0% of the same component.



FELDSPARS AND FELDSPATHOIDS

This is a pyramid made up of four triangular faces making up four ternary diagrams. Thus, one can study the interrelations of four different components here.

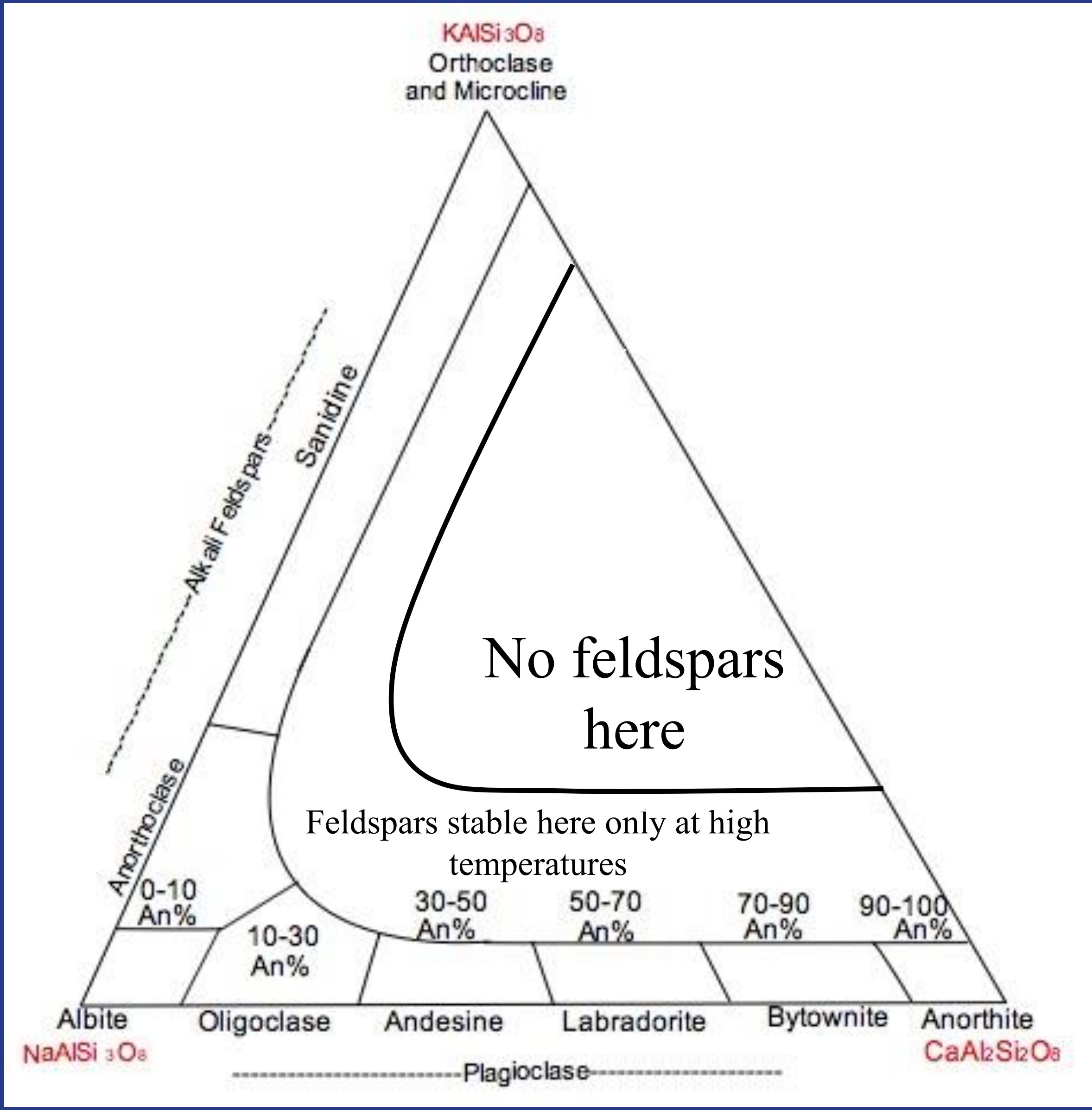
Feldspars

The name feldspar comes from the German word for *Feldspat* consisting of *Feld* meaning field, terrain and *Spar* meaning a mineral that is split along “leaves”. Feldspars are the most abundant minerals in the earth’s crust making up some 51% of it at least.

Feldspars are studied in two main groups:

1. Plagioclases making up 76% of all feldspars

2. Alkali feldspars making up 24 % of all feldspars



FELDSPARS

(http://en.wikipedia.org/wiki/Feldspar)

Plagioclases

The name plagioclase is derived from the Greek πλάγιος (*plagios*= slanting) and κλάσις (klasis= a breaking) referring to the obtuse angle made by its two cleavage planes. This property was first noticed by the German geologist Johann Friedrich Christian Hassel in 1826.

Note the two preferred directions of breakage (cleavage). The sample is an Oligoclase from Evje, Norway)

Anorthite from the Caspar Quarry, Bellerberg volcano, Eifel, Germany (copyright by Stephan Wolfsried)

Anorthite

$(Na_{0.05}Ca_{0.95}Al_{1.95}Si_{2.05}O_8)$

Anorthite was named by the great German mineralogist Gustav Rose in 1823 from the Greek αν (*an*=not) and ορθός (orthos=straight, real), thus meaning not straight, oblique.

Crystal system: triclinic-pinacoidal

Cleavage: [001] perfect, [010] good

Colour: colourless, grey, white, red, reddish grey

Average density: 2.73

Hardness: 6

Streak: white

Luster: vitreous-glassy

Fracture: uneven

Bytownite from Crystal Bay, Hennepin County, Minnesota, USA

Bytownite

$(Na_{0.2}Ca_{0.8}Al_{1.8}Si_{2.2}O_8)$

Bytownite was named in 1835 by T. Thomson, professor of Chemistry in Glasgow, Scotland, after its type locality, Bytown (now Ottawa, Ontario, Canada). It was found by Dr. A. F. Holmes who sent it to Professor Thomson in Glasgow for identification.

Crystal system: triclinic-pinacoidal

Cleavage: [001] perfect, [010] good

Colour: colourless, grey, white, greyish yellow

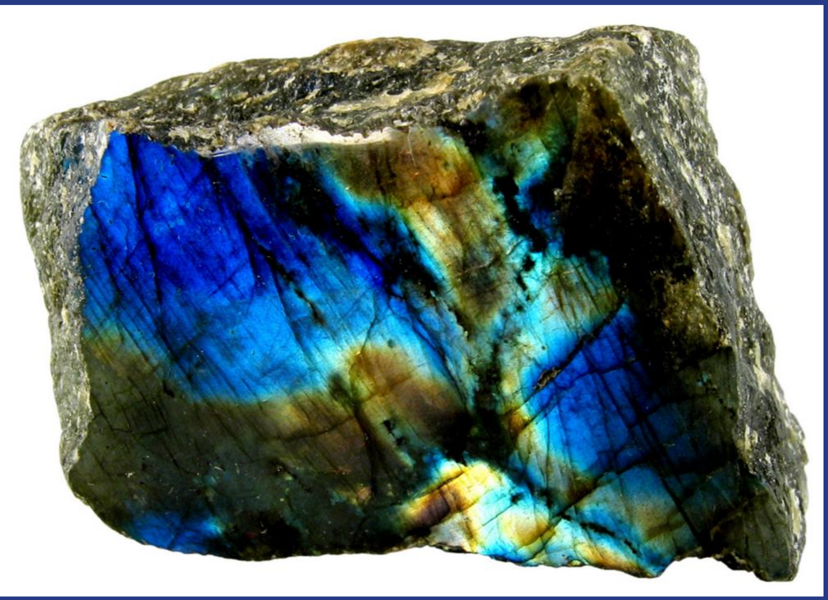
Average density: 2.71

Hardness: 6.5 to 7

Streak: white

Luster: vitreous-glassy

Fracture: uneven, conchoidal



Labradorite from an unknown locality

Labradorite used as gemstone

Labradorite

($Na_{0.4}Ca_{0.6}Al_{1.6}Si_{2.4}O_8$)

Named in 1780 by the great German mineralogist Abraham Gottlob Werner after Ford Harbour, Paul Island, Labrador, Canada.

Crystal system: triclinic-pinacoidal

Cleavage: [001] perfect, [010] good, [110] distinct

Colour: colourless, grey, grey-white, light green bluish

Average density: 2.69

Hardness: 7

Streak: white

Luster: vitreous-glassy

Fracture: uneven

Andesine

($Na_{0.6}Ca_{0.4}Al_{1.4}Si_{2.6}O_8$)

Named in 1841 by the German geologist Otto Wilhelm Hermann von Abich after the Andes Mountains in South America.

Twinned andesine from Maeyama Ueda Shi, Nagano, Japan (copyright Jeff Weissman)

Crystal system: triclinic-pinacoidal

Cleavage: [001] perfect, [010] good

Colour: colourless, grey, yellow-green, white

Average density: 2.67

Hardness: 7

Streak: white

Luster: vitreous-glassy

Fracture: uneven

Oligoclase crystal from Plumtree, Avery County, North Carolina, USA.

Oligoclase

($Na_{0.8}Ca_{0.2}Al_{1.2}Si_{2.8}O_8$)

Named in 1826 by the German geologist August Breithpaupt from the Greek ὀλίγος (*oligos*= few, little) and κλάσις (*klasis*= a breaking) because it had less perfect cleavage than albite. But Berzelius had first recognised it as a distinct mineral species in 1824.

Crystal system: triclinic-pinacoidal

Cleavage: [001] perfect, [010] good

Colour: colourless, brown, greenish, grey, yellowish

Average density: 2.65

Hardness: 7

Streak: white

Luster: vitreous-glassy

Fracture: uneven

Oligoclase from the Hawk Mine, Mitchell County, North Carolina, USA

Oligoclase with sphalerite and pyrite from Potosi, Mexico

Oligoclase from Norway

Albite from Lohning Quarry, Rauris Valley in the High Tauern, Austrian Alps.

Albite

($Na_{0.95}Ca_{0.05}Al_{1.05}Si_{2.95}O_8$)

Named in 1815 by the Swedish mineralogist Johan Gottlieb Gahn and the Swedish chemist Jöns Jacob Berzelius from the Latin word *albus* meaning white, because of its usual colour.

Crystal system: triclinic-pinacoidal

Cleavage: [001] perfect, [010] good

Colour: white, greenish-grey, bluish-grey, grey

Average density: 2.62

Hardness: 7

Streak: white

Luster: vitreous-glassy

Fracture: uneven

Increasing amounts of Na, and Si, decreasing amounts of Ca and Al

Albite	$Na_{0.95}\ Ca_{0.05}\ Al_{1.05}Si_{2.95}O_8$	2.62
Oligoclase	$Na_{0.8}\ Ca_{0.2}\ Al_{1.2}\ Si_{2.8}\ O_8$	2.65
Andesine	$Na_{0.6}\ Ca_{0.4}\ Al_{1.4}\ Si_{2.6}\ O_8$	2.67
Labradorite	$Na_{0.4}\ Ca_{0.6}\ Al_{1.6}\ Si_{2.4}\ O_8$	2.69
Bytownite	$Na_{0.2}\ Ca_{0.8}\ Al_{1.8}\ Si_{2.2}\ O_8$	2.71
Anorthite	$Na_{0.05}Ca_{0.95}Al_{1.95}\ Si_{2.05}O_8$	2.73

Decreasing density

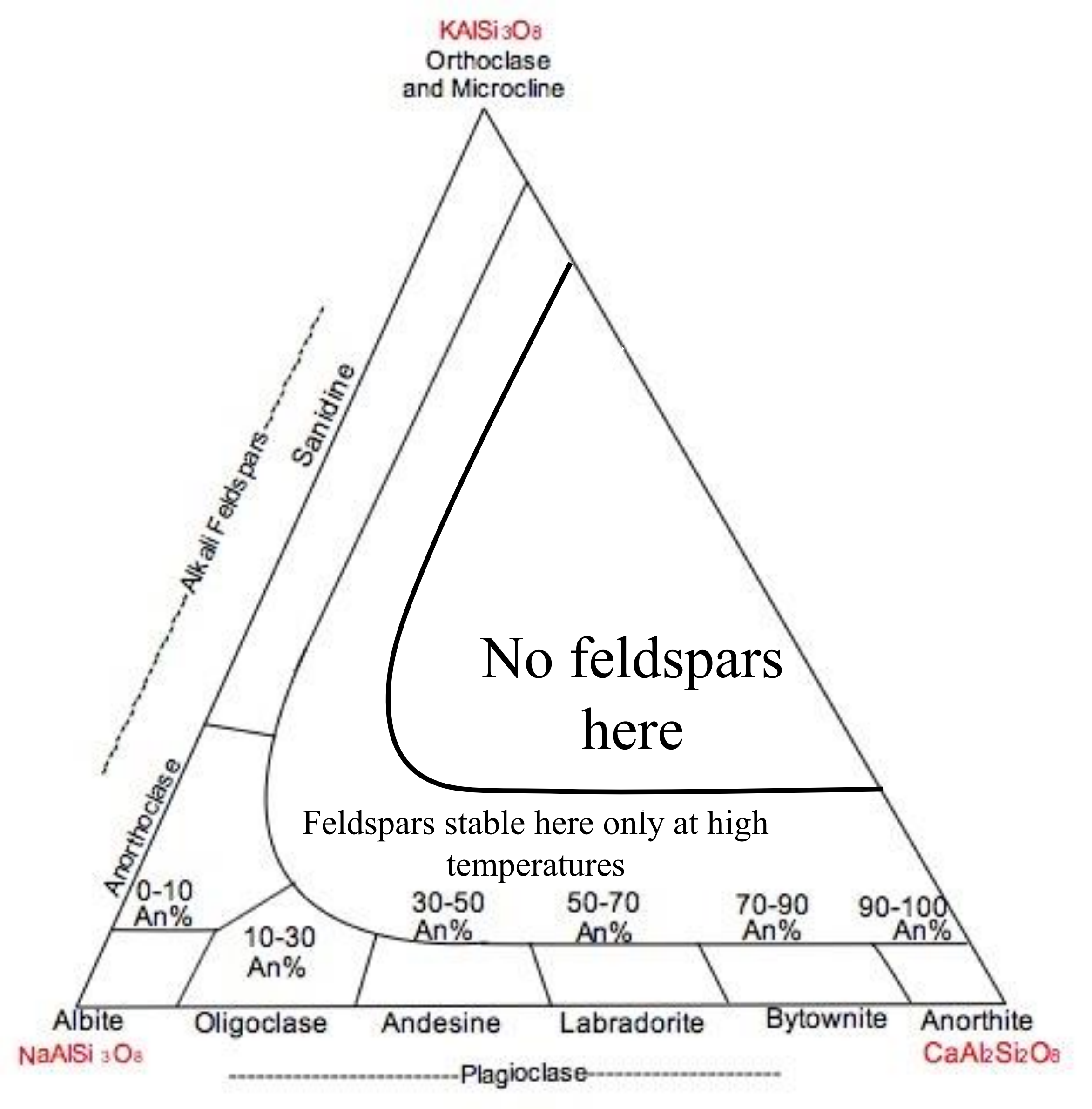
Most commonly associated minerals:

Albite – Quartz (2.62)
Oligoclase-K-feldspar (2.56), quartz (2.62)
Andesine- Pyroxene (3.3-3.5), K-feldspar (2.56)
Labradorite-Pyroxene (3.3-3.5)
Bytownite- Pyroxene (3.3-3.5)
Anorthite- Olivine (3.27), Pyroxene (3.3-3.5)

As the plagioclase solid solution series goes from the calcium-dominated anorthite to sodium-dominated albite, the density of the minerals becomes less. Also their place of origin goes from the lower to middle crust to middle to upper crust.

Parallel with that the minerals go from the smaller ionic radius of the calcium (099 Å) to larger ionic radius of the sodium (1.02Å). As we ascend in the crust, the lower pressures favour larger ionic radii and lower densities. This gives us a clue as to how the continental crust becomes differentiated.

Alkali Feldspars



FELDSPARS

(http://en.wikipedia.org/wiki/Feldspar)

Anorthoclase from the Kinki Region, Honshu Island, Japan

Anorthoclase

$(Na_{0.75}K_{0.25}AlSi_3O_8)$

Named in 1885 by the German mineralogist and petrologist Karl Harry Ferdinand Rosenbusch after the Greek words αν (*an*=not), ορθός (*orthos*=right) and κλάσις (*klasis*= a breaking) "meaning not right cleavage".

Crystal system: triclinic-pinacoidal

Cleavage: [001] perfect, [010] good

Colour: colourless, green, grey, grey-pink, yellow, bluish-grey, grey

Average density: 2.58

Hardness: 6

Streak: white

Luster: vitreous-glassy

Fracture: uneven

Anorthoclase from the Mount Erebus Volcano, Antarctica

Anorthoclase usually occurs as a high-temperature alkali feldspar in shallow intrusions and volcanic rocks.

Sanidine crystals from the Puy de Sancy, Mont-Dore massif, Puy-de-Dôme, Auvergne, France

Sanidine

($K_{0.75}Na_{0.25}AlSi_3O_8$)

Sanidine was named in 1808 by German mineralogist Karl Wilhelm Nose from the Greek words σάνις (*sanis*=board, plank) and εἶδος (*eithos*=shape, form) in reference to its tabular crystals.

Crystal system: monoclinic-prismatic

Cleavage: [001] perfect, [010] good

Colour: colourless, white, grey, yellowish white, reddish white

Average density: 2.52

Hardness: 6

Streak: white

Luster: vitreous-pearly

Fracture: uneven

Orthoclase from Zarzalejo, Madrid, Spain

Orthoclase

($KAlSi_3O_8$)

Named as *orthose* by the Abbot René Just Haüy, one of the farthers of modern mineralogy in 1801 from the Greek word ορθός (*orthos*=straight, real). In 1823, Johann Friedrich August Breithaupt changed the name to orthoclase by adding "*klas*" from the Greek κλάσις (klasis= a breaking)

Crystal system: monoclinic-prismatic

Cleavage: [001] perfect, [010] good

Colour: colourless, greenish, greyish yellow, white, pink

Average density: 2.56

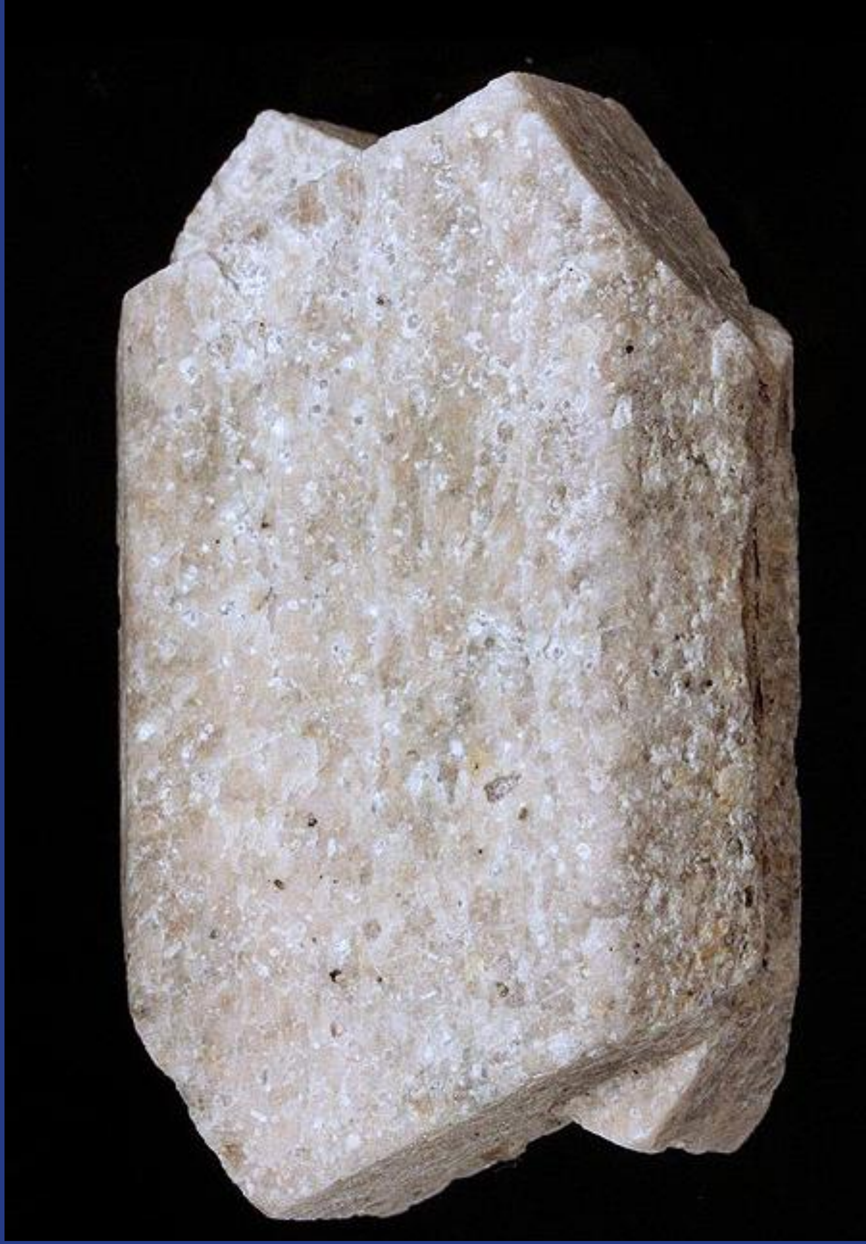
Hardness: 6

Streak: white

Luster: vitreous-glassy

Fracture: uneven

Orthoclase from Vila Real district, Portugal



Orthoclase from Pitkin County, Colorado, USA

Microcline

($KAlSi_3O_8$) (note: same as Orthoclase!)

Microcline was named in 1830 by Johann Friedrich August Breithaupt from the Greek words μικρός (*mikros*=small) and κλίνω (*klino*=to slant, to incline) in reference to its small departure from monoclinic symmetry

Crystal system: triclinic-pinacoidal

Cleavage: [001] perfect, [010] good

Colour: bluish green, green, grey, greyish yellow, yellowish

Average density: 2.56

Hardness: 6

Streak: white

Luster: vitreous-glassy

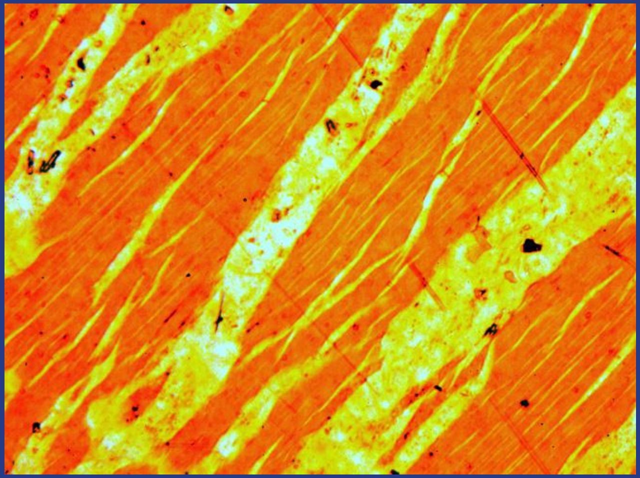
Fracture: uneven

Microcline, Devil's Head, Colorado, USA

Microcline, variety “Amazonite”, from Pike’s Peak, El Paso County, Colorado, USA

Perthitic exsolution lamellae in microcline from Evye, Norway

Perthitic exsolution structure refers to the intergrowth of two kinds of feldspars: the host is usually a microcline and the exsolution lamellae consist of albite. This results from the slow cooling of an alkali feldspar of intermediate composition cooling slowly enough,giving time to the K- and the Na-feldspars to separate into such distinct exsolution lamellae.

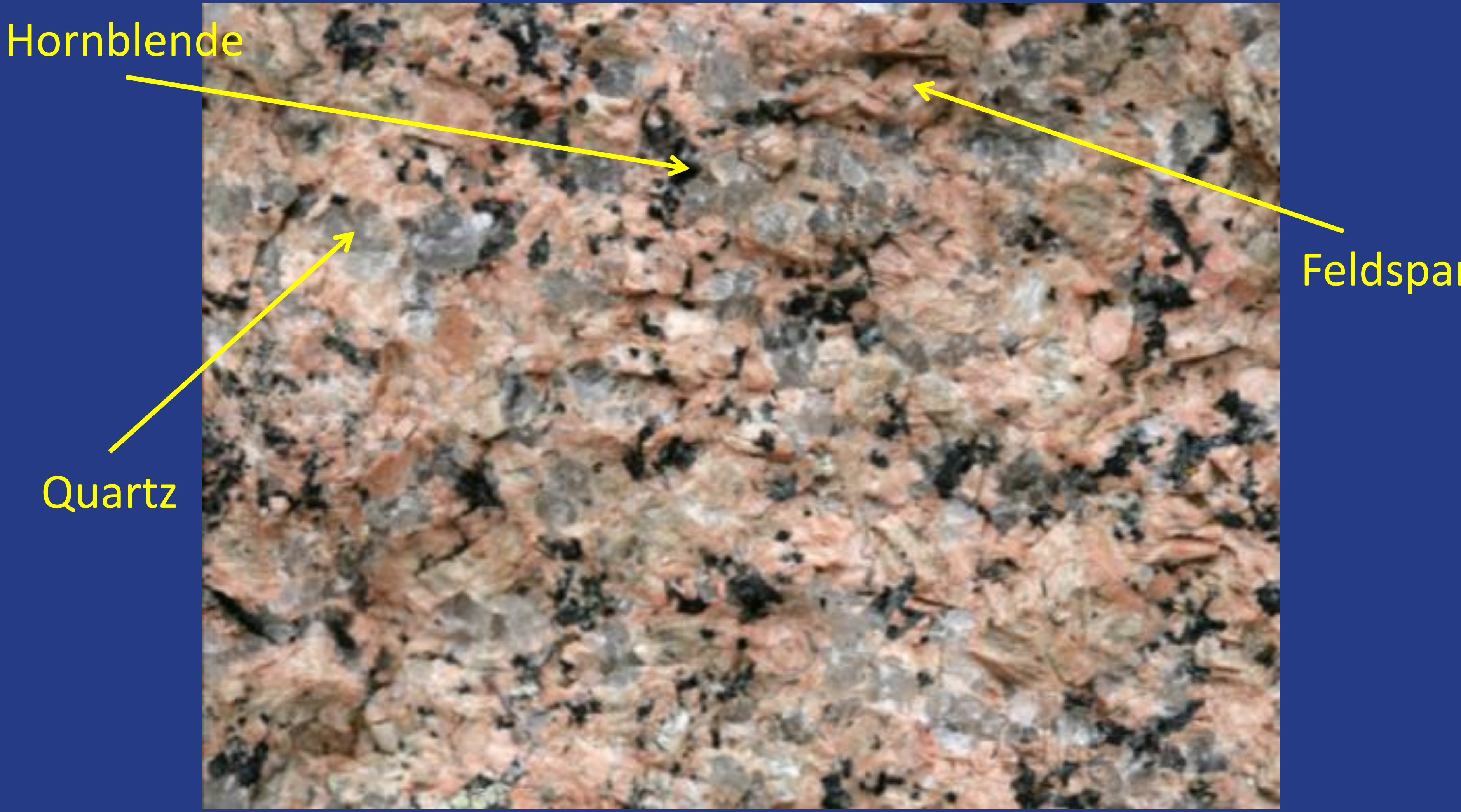


Perthitic exsolution lamellae seen under the miicroscope

Perthitic exsolution in amazonite

Quartz and its polymorphs

In a silicate magma, quartz is the last mineral to crystallise, because it gathers all the left-over SiO_2, not used in making the other silicate minerals. That is why it usually has ahedral crystal shapes in rocks and its beautiful crystals are only found in large late magmatic veins and geodes.



In this granite, the pink is feldspar, black is hornblende and biotite and translucent is quartz. Note the ahedral shape of the quartz crystals, as opposed to the more geometric feldspars and hornblendes.

Beautifully formed quartz crystals in an Alpine crystal vein in the Lötsch Valley, Switzerland. The crystals are 5 to 12 cm long.

An Alpine “Kristallkluft” full of quartz crystals (“Bergkristalle”) in Garstenegg Crystal Museum, Switzerland

A quartz geode

An almost perfect, doubly-terminated quartz crystal from Bergamo in the Italian Alps.

Quartz

(SiO_2)

Quartz has been known to mankind since the earlist times. The word crystal was originally coined for it. The earliest mention of the term quartz is attributed to a German physician from the mining town of Freiberg in Saxony, Ulrich Rülein, who spelled it as querz in 1505.

Crystal system: trigonal-trapezohedral

Cleavage: [0110] indistinct

Colour: colourless, smoky, white, violet, grey, yellow, pink

Average density: 2.62

Hardness: 7

Streak: white

Luster: vitreous-glassy

Fracture: conchoidal

Colourless quartz crystals (=“rock crystal”) passing into white quartz (“milky quartz”) from Brazil

Quartz crystal showing conchoidal fracture

Violet quartz (“amethyst”) from Veracruz, Mexico
(copyright Rob Lavinsky & irocks.com)

Amethyst geode from Uruguay

Rose quartz from Minas Gerais, Brazil (copyright Fabre Minerals)

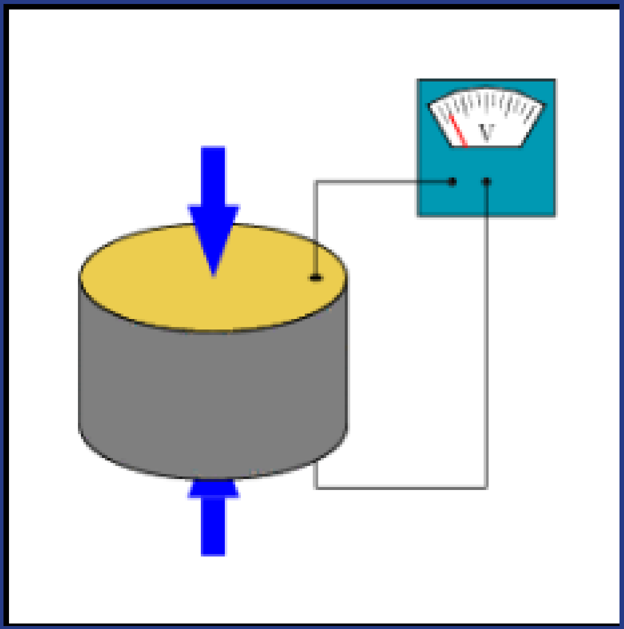
Smoky quartz, Victoria, Australia

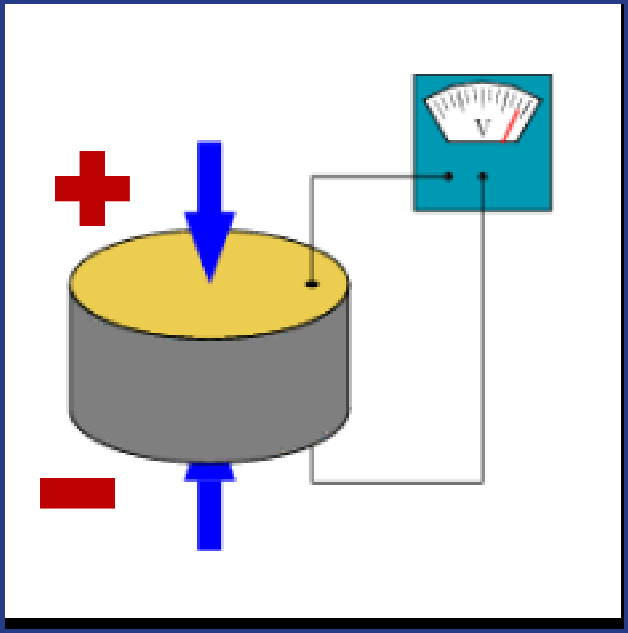
Yellow quartz (“citrine”) from Brazil

Agate is a cryptocrystalline variety of quartz. When white or indistinctly coloured it is known as chalcedony (from Chalcedon=Kadıköy, İstanbul, Turkey)

A Jasper-banded (red bands) ironstone from Minnesota, USA. Jasper is a red cryptocrystalline variety of quartz.

Quartz crystals are piezoelectric. This means that when mechanical stress is applied to them, they generate electrical potential.





Quartz crystals are used in watches and clocks, because they function as oscillators in an electric field and thus keep time. Quartz watches are at least an order of magnitude better time keepers than mechanical clocks or watches.

Quartz has many other industrial uses:

1. In glass industry as a cheap source of SiO_2
2. Used as abrasive (it is harder than all metals)
3. Use as foundry salt (its melting temperature is higher than most metals)
4. Used in petroleum industry to induce hydrofracturing in the reservoir
5. As gemstone (many coloured varieties)

Moganite with Chalcedone from Barranco de los Medios Almudes, Mogan, Gran Canaria. Specimen is 5.5 cm © Volker Betz

Moganite

(SiO_2)

Tridymite was first described in 1868 near Pachua, Mexico by the German geologist Gustav vom Rath and was so named because of its occurrence in triling twinning pattern

Crystal system: monoclinic-prismatic

Colour: grey

Hardness: 6.5-7

Streak: white

Luster: earthy (dull)

Moganite from Mogán, Gran canaria, The Canary Islands, Spain. Copyright by Volker Betz.

High T and high P polymorphs of quartz:

Quartz has two classes of poymorphs: high temperature polymorphs and high pressure polymorphs.

High temperature polymorphs:

α-quartz (ordinary quartz)	stable stable above	573°C
β-quartz (high quartz)	“	875°C
Tridymite	“	1453°C
Cristobalite	“	1700°C
Lechateliérite	“	around 30,273.15°C (five times hotter than the Sun’s surface

More heating will result in a silica melt

High pressure polymorphs:

Coesite	“	30 kb
Keatite	“	≈ 40 kb
Stishovite	“	>100 kb
Seifertite	“	>780 kb

β-Quartz (=high quartz)

(SiO_2)

Crystal system: hexagonal-trapezohedral

Average density: 2.53

Tridymite from the Eifel volcanic region, Germany

Tridymite mostly occurs in volcanic rocks. The best-known locality is in the Obsidian Cliff, in the Yellowstone National Park

Tridymite

(SiO_2)

Tridymite was first described in 1868 near Pachua, Mexico by the German geologist Gustav vom Rath and was so named because of its occurrence in triling twinning pattern

Crystal system: triclinic-pedial

Cleavage: [0001] indistinct, [1010] imperfect

Colour: colourless, white, grey, yellowish white

Average density: 2.3

Hardness: 6.5-7

Streak: white

Luster: vitreous-glassy

Fracture: brittle-conchoidal

Cristobalite from an unknown locality

Cristobalite

(SiO_2)

Cristobalite was first described in 1887 in San Cristobal, Pachua, Mexico by the German geologist Gustav vom Rath after its type locality near San Cristobal, Pachua, Mexico

Crystal system: tetragonal-trapezohedral (?) (pseudo-isometric)

Cleavage: [0001] indistinct, [1010] imperfect

Colour: blue-grey, brown, grey, yellow, white

Average density: 2.27

Hardness: 6.5

Streak: white

Luster: vitreous-glassy

Fracture: brittle

Actually, there are low and high pseudmorphs of cristobalite. The high form was discovered by the French mineralogist Ernest-François Mallard in 1890 and crystallises in isometric crystals. Its density is 2.20. Its range of stability reaches 1625°C.

Lechateliérite has no crystal form.
It is amorphous and therefore is not a mineral. Such substances are called mineraloids. It was discovered in 1915 by the famous French mineralogist and petrologist Alfred Lacroix.

Fulgurites are formed commonly from Lachatelierite upon a lightening hitting a moist silica sand area or a moist silica-rich soil.

Various shapes of fulgurites

Coesite from the Dora Maira
Massif, Pennine Zone, Italian Alps

Coesite

(SiO_2)

Named after the American chemist Loring Coes, Jr., who first synthesised it, by Robert B. Sosman in 1954.

Crystal system: Monoclinic-prismatic

Cleavage: none

Colour: colourless

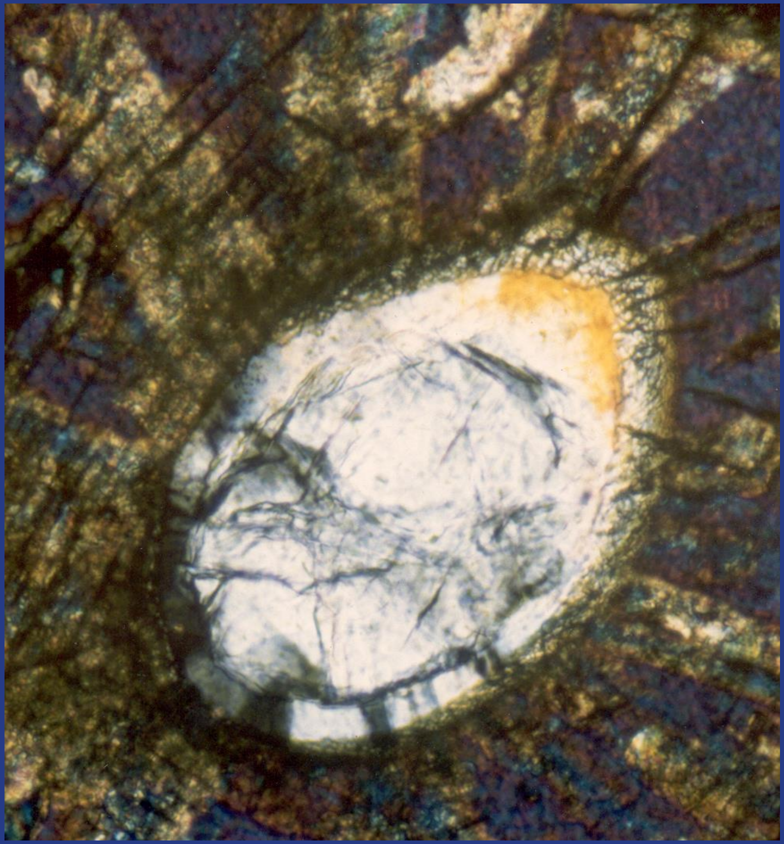
Average density: 2.93

Hardness: 7.5

Streak: white

Luster: vitreous-glassy

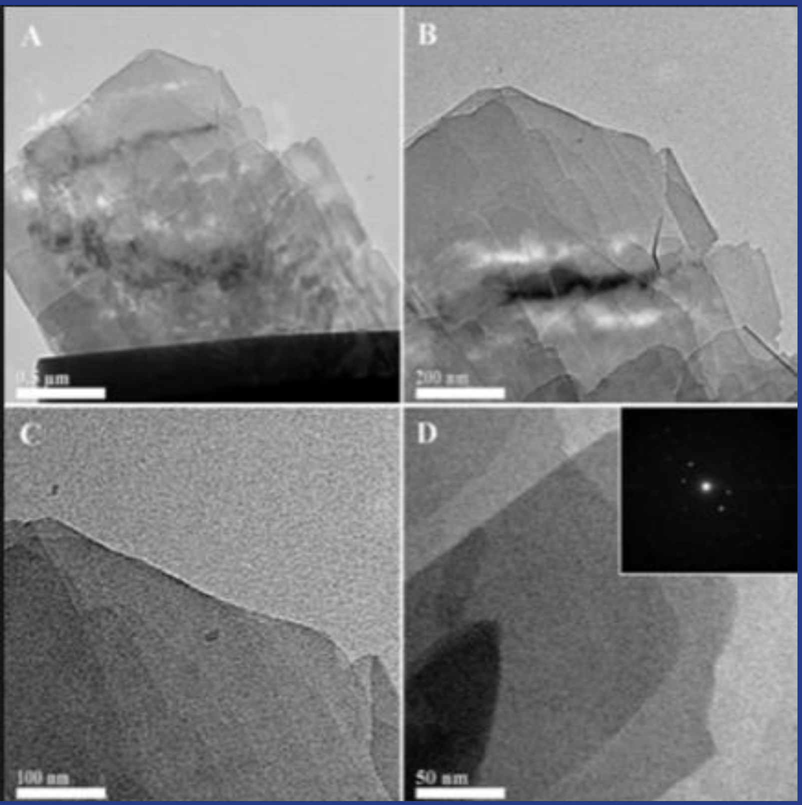
Fracture: conchoidal



Coesite discovered by Professor Aral İ. Okay in the Dabie Shan mountains, PRC

Okay A. I., Xu, S.-T. and Şengör, A. M. C., 1989, Coesite from the Dabie Shan eclogites, central China: *European Journal of Mineralogy,* v. 1, pp. 595-598.

1988: Aral Okay, in front of the Dabie Shan gneisses containing eclogites in which he discovered the first coesite in China. This was the first time that it was proven that an entire mountain range was subducted to depths nearly 30 km!



Keatite

(SiO_2)

Discovered in 2013 by Hill et al. in Kökchetav Massif, Altaids, Kazakhstan

No further mineralogical data are as yet available.

Keatite from Ren et al., 2013

Hill, T. R., Konishi, H., Xu, H, 2013, Natural occurrence of keatite precipitates in UHP clinopyroxene from the Kokchetav Massif: A TEM investigation: *American Mineralogist* v. v . 98, pp.187-196.

Stishovite (synthetic?)

Stishovite

(SiO_2)

Named after the Russian high pressure physicist Sergei Mikhailovich Stishov who first synthesised it in 1961

Crystal system: tetragonal-ditetragonal dipyramidal

Cleavage: none

Colour: colourless

Average density: 4. 35

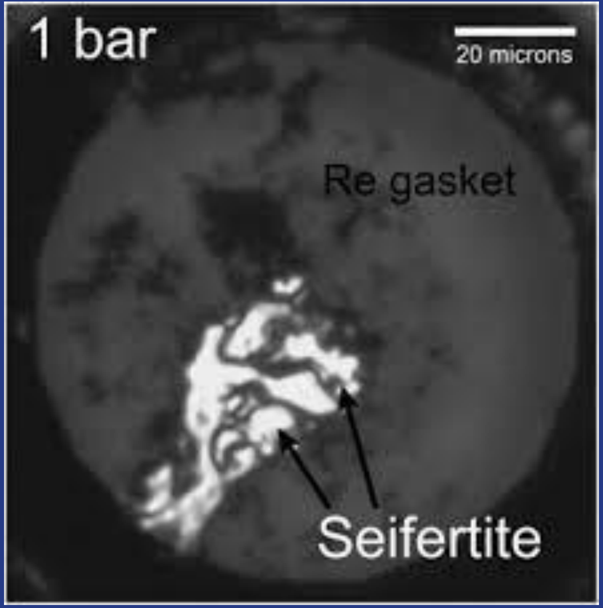
Hardness: 7.5-8

Streak: white

Luster: vitreous-glassy

Fracture: ?

Stishovite was first discovered in a natural state here in the Arizona meteor Crater by Edward Ching-Te Chao in 1962



Seifertite from Grocholski et al 2013

Seifertite

(SiO_2)

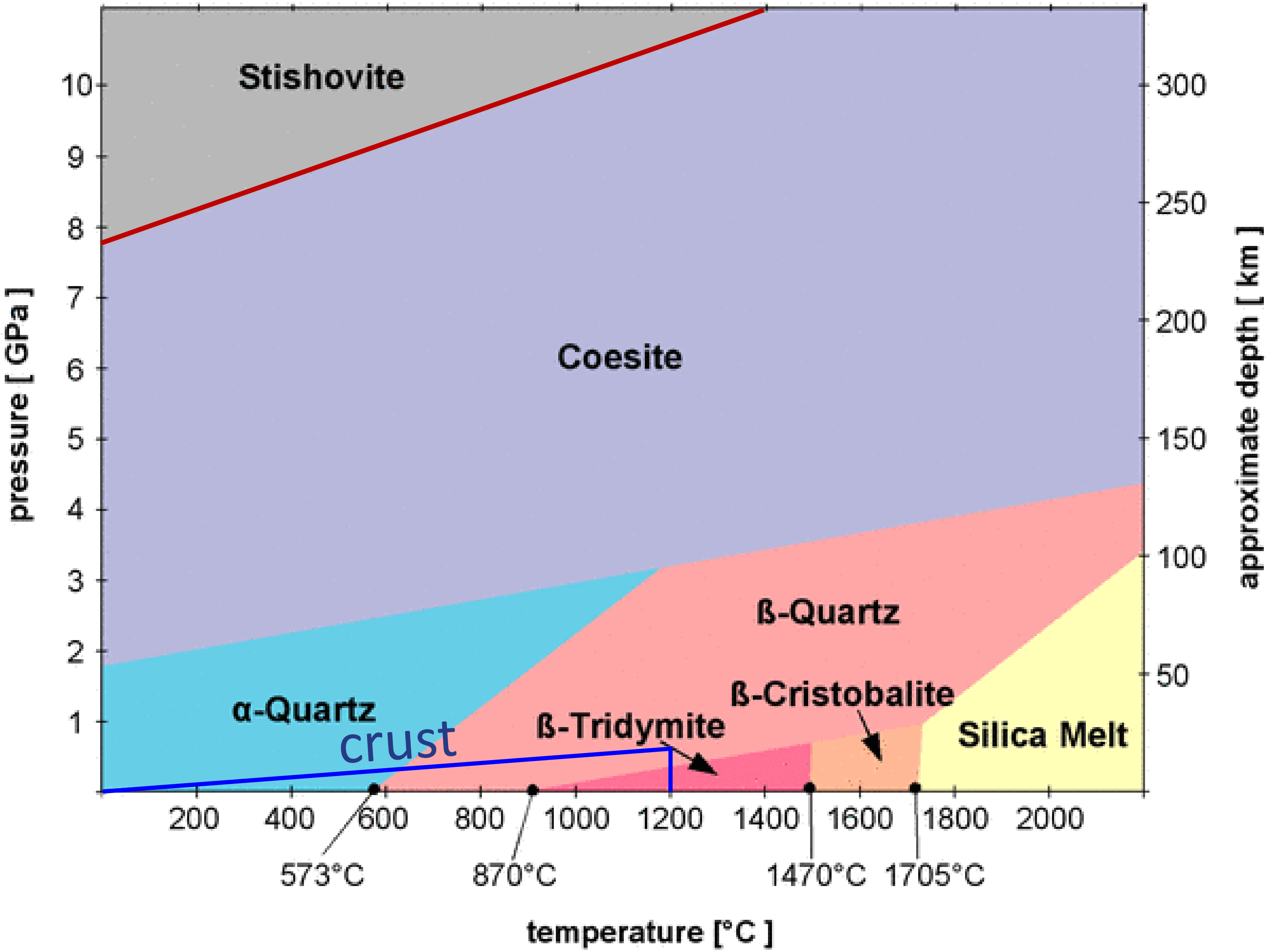
Seifertite was first discovered in the Martian (SNC) meteorite of Shergotty, India by Ahmed el Gorasy Przemyslaw Dera, Thomas G. Sharp , Charles T. Prewitt, Ming Chen, Leonid Dubrovinsky, Brigitte Wopenka, Nabil Z. Boctor, Russell J. Hemley, in 2008. The name is in honour of Friedrich Seifert, the founder of the Bavarian Geoinstitute in Germany.

Crystal system: orthorhombic

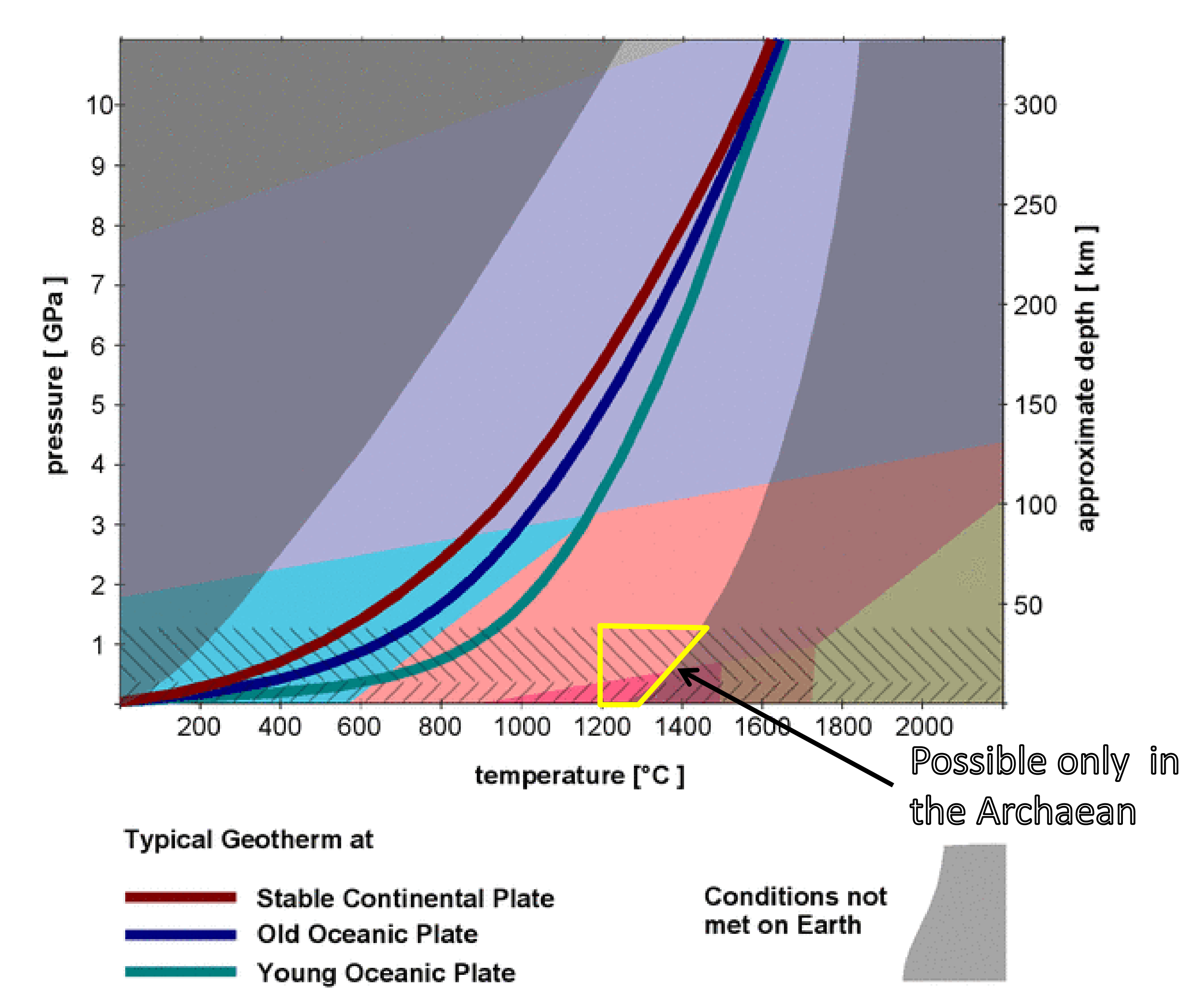
Average density: 4.294

The Shergotti meteorite. It fell on 1st January 1865 in Bihar, India. It is an achondritic meteorite. We know that it came from Mars, because the gas found in it matches the composition of the atmosphere of Mars.

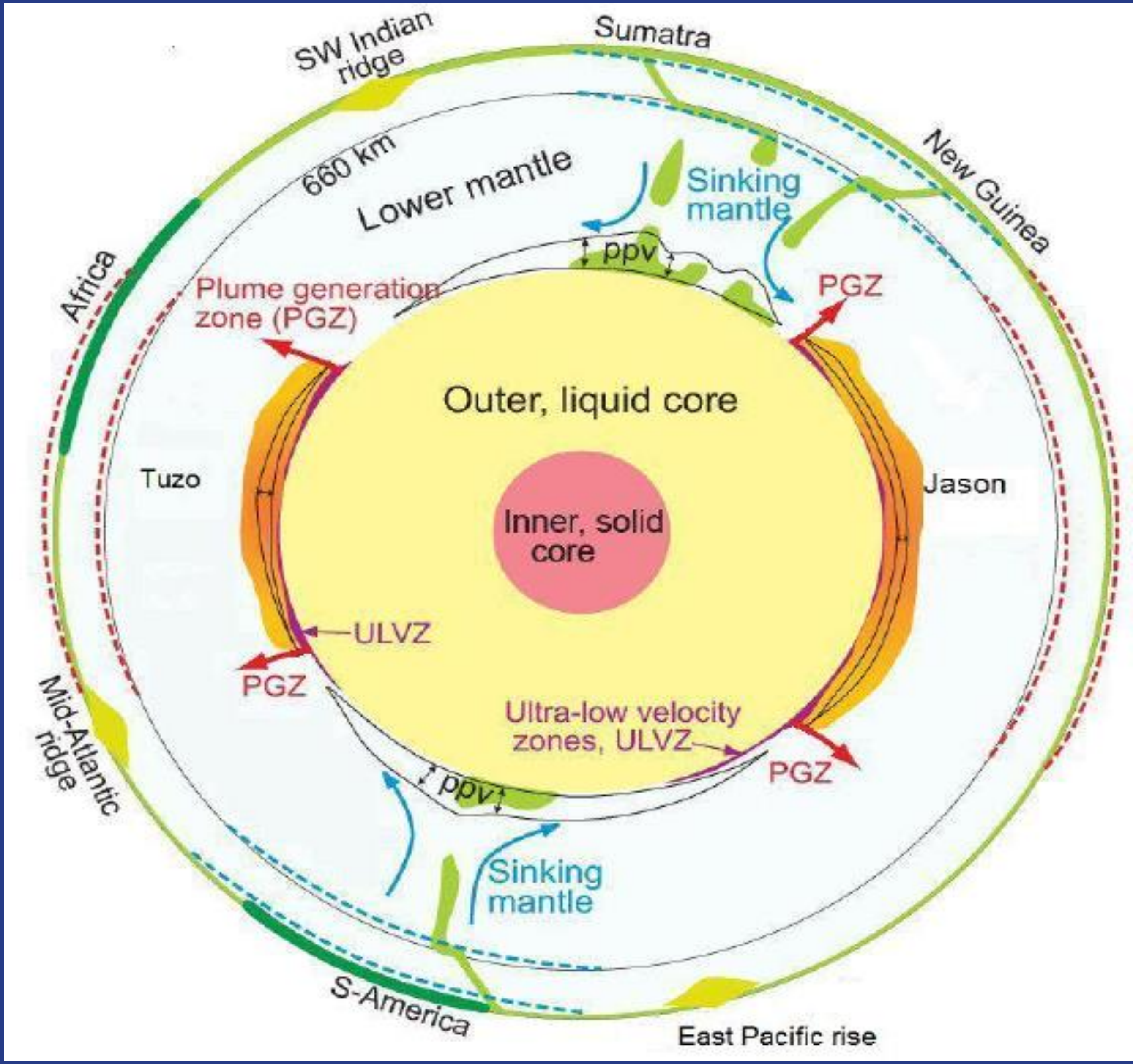
Nothing above the red line has been discovered on earth as a product of endogenous processes



Phase diagram of SiO_2 polymorphs from www.quartzpage.de/gen_mod.html#



Geotherms down to 325 km depth in the earth superimposed on the silica phase diagram
from www.quartzpage.de/gen_mod.html#



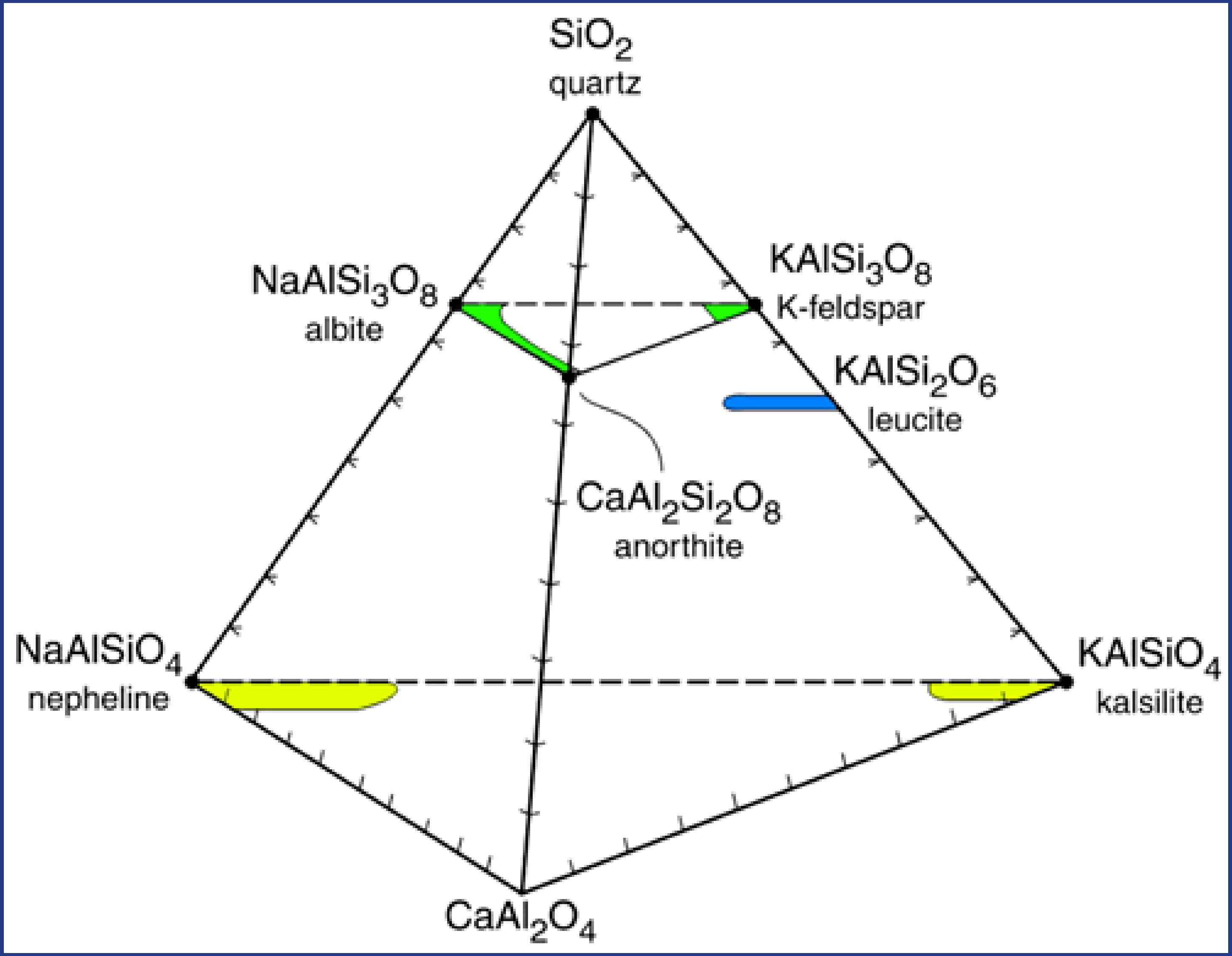
From Kevin Burke written comm.

Coesite and keatite can only form in subduction zones

Feldspathoids

Feldspathoids are the silicate minerals that take the place of feldspars in low silica rocks. These are mostly alkalic igneous rocks that form in the mantle, i.e., below the earth's crust. *Rocks that contain feldspathoids cannot have quartz or any other* SiO_2 *poymorph*.

Increasing silica content



Decreasing depth of origin

FELDSPARS AND FELDSPATHOIDS

This is a pyramid made up of four triangular faces making up four ternary diagrams. Thus, one can study the interrelations of four different components here.

Feldspathoids:

Nepheline Group:

Afghanite (hydrous sodium, calcium, potassium silicate carbonate)

Analcime (hydrous sodium aluminium silicate)

Kalsilite (potassium aluminium silicate)

Leucite (potasium aluminium silicate)

Nepheline (sodium potasium aluminium silicate)

Cancrinite (sodium calcium aluminium silicate carbonate)

Sodalite Group:

Hauyne (sodium calcium aluminium silicate sulfate)

Lazurite (sodium calcium aluminium silicate sulfate (sulfide chloride))

Nosean (sodium aluminum silicate sulfate)

Sodalite (sodium aluminum silicate chloride)

Tugtupite (sodium, aluminium, beryillium, silicate with chlorine)

Petalite (lithium, aluminium silicate)

Analcime from New Jersey, USA

Analcime is also considered a zeolite, but structurally it is much closer to the feldspathoids

Analcime

($NaAl(Si_2O_6)\cdot(H_2O)$)

Named in 1770 by the Abbot René Just Haüy from the Greek ανάλκιμος (*analkimos*=weak) alluding to the weak electricity it produces when rubbed

Crystal system: triclinic-pedial

Cleavage: [001] indistinct, [010] indistinct, [100] indistinct

Colour: white, greyish white, greenish white, yellowish white, reddish whie

Average density: 2.3

Hardness: 5

Streak: white

Luster: vitreous-glassy

Fracture: subconchoidal

Nepheline Group

Kalsilite

($KAlSiO_4$)

The name kalsilite was coined by Bannister and Hey in 1942 northwest of the Nyungu crater, East Africa, to reflect its composition from the Latin words kalium (=potassium), aluminium and silicium

Crystal system: trigonal-ditrigonal pyramidal

Cleavage: [1010] indistinct, [0001] indistinct

Colour: colourless, grey, grey-white, white

Average density: 2.6

Hardness: 6

Streak: white

Luster: vitreous-greasy

Fracture: brittle conchoidal

Kalsilite from San Venanzo, Italy.

Leucite from Karlovy Vary in the Czech Republic.

Leucite (called *amphigène* in the older French literature)

($KAlSi_2O_6$)

Named by the German mineralogist Abraham Gottlob Werner in 1791 from its white colour (Greek λευκός {*loykos*=bright, white}).

Crystal system: tetragonal-dipyramidal

Cleavage: [110] indistinct

Colour: colourless, grey, yellow-grey, white

Average density: 2.47

Hardness: 6

Streak: white

Luster: vitreous-glassy

Fracture: brittle conchoidal

Leucite from the alkalic lavas of the Eifel volcanic region, Germany (© S. Wolfsried)

Leucite from the alkalic lavas of Mt. Vesuvius, Naples, Italy

Nepheline from an unknown locality

Nepheline

$(Na_{0.75}K_{0.25}Al(SiO_4))$

Named in 1801 by René Just Haüy after the Greek word for clud (νεφέλη {nefele} because of its cloudy appearance

Crystal system: hexagonal-pyramidal

Cleavage: [1010] poor

Colour: grey, white, brown, brownish grey, reddish white

Average density: 2.59

Hardness: 6

Streak: white

Luster: vitreous-greasy

Fracture: subconchoidal

Nepheline from the High Atlas Mountains, Morocco

Sodalite Group

Lazurite from Badakhshan, Afghanistan

Lazurite

($Na_3CaAl_3Si_3O_{12}S$)

Named after the Arabic word ***lajuward*** meaning dark blue. In fact the Paropamisus Mountains, the type locality of lazurite is known as Lajuwardi in classic Arabic geographical literature

Crystal system: isometric-hextetrahedral

Cleavage: [010] imperfect

Colour: Blue, azure blue, violet blue, greenish blue

Average density: 2.4

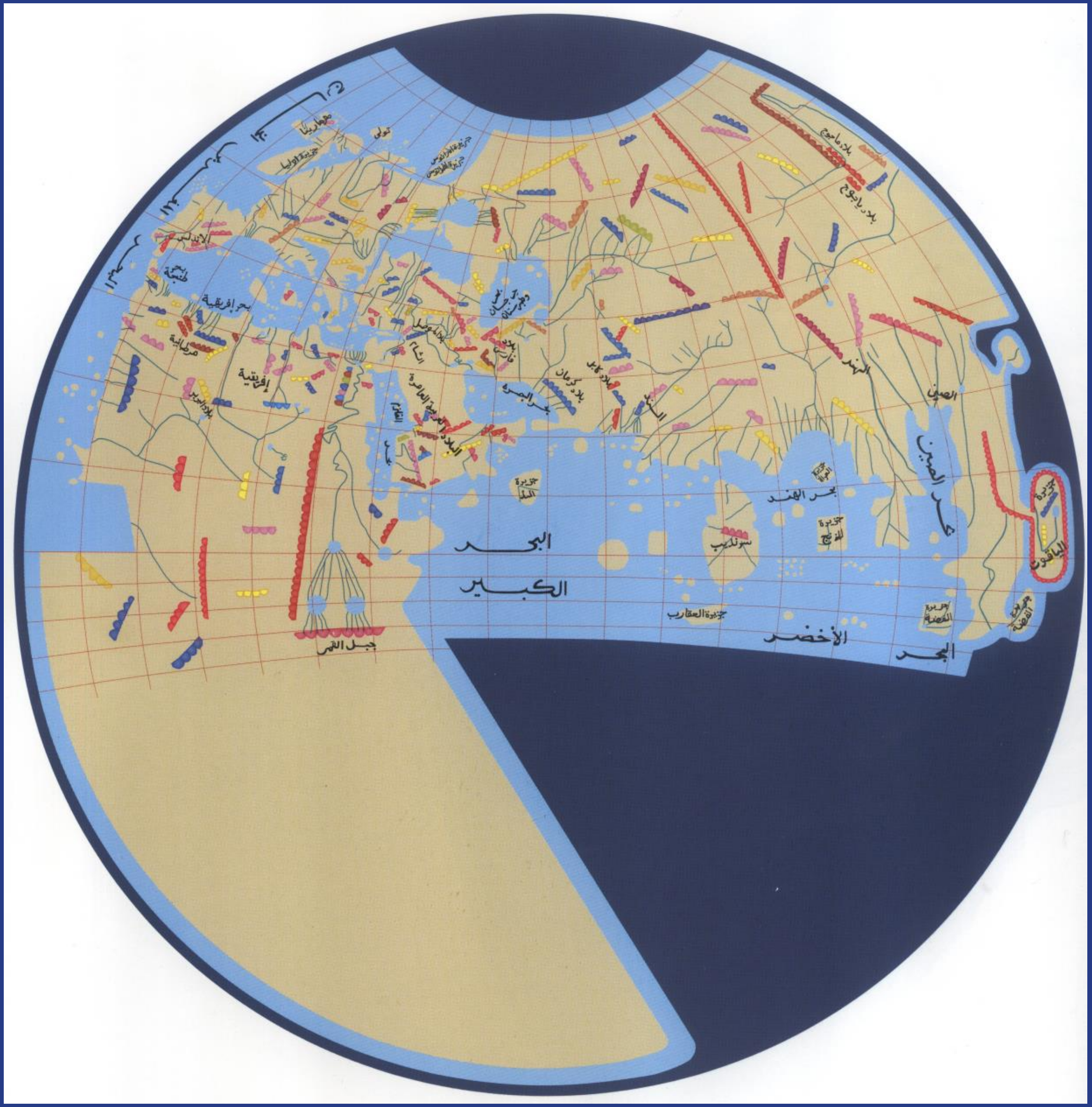
Hardness: 5.5

Streak: light blue

Luster: vitreous-dull

Fracture: conchoidal

Lazurite surrounded by calcite:
Badakhshan, Afghanistan



The world map by the geographers of the Abbasid Khalif Al-Ma'mun showing the location of the Paropamisus (*Lajuwardi*) mountains (first half of the 9th century) (reconstruction by Fuad Sezgin)

A poor later copy of the Ma’munic map from Ibn Fadl’allah al Umari’s *Masalik al Abshar wal Mamalik al Afshar* (Topkapı Palace Museum Library, İstanbul)

The place of the Lajuwardi Mountains on a present-day geographical map

Sodalite, Badakhshan, Afghanistan

Sodalite
($Na_8Al_6Si_6O_{24}Cl_2$)

Named in 1811 by the Glasgow professor of chemistry Thomas Thomson because of its high soda content .

Crystal system: isometric-hextetrahedral

Cleavage: [110] poor

Colour: Azure blue, white, pink grey green

Average density: 2.29

Hardness: 6

Streak: white

Luster: vitreous-greasy

Fracture: very brittle, conchoidal

Zeolites are tectosilicates with highly absorbent qualities and as such are very important in the industry as absorbants and catalysts of certain chemical reactions. Geologically they are important in very low-grade metamorphic rocks.

Zeolite facies is the lowest grade metamorphic facies, considered transitional from diagenesis (≈induration) to prehnite-pumpellyite facies. The temperature range is 50 to 150 °C and, depending on the local geotherm, the burial depth may range from a km to some 5 km.

The following are the more common zeolite minerals:

Chabazite, clinoptilolite, heulandite, natrolite, phillipsite, and stilbite. Let us not forget that analcime is also considered by some a zeolite.

In the following I shall only describe the stilbite as it is the most commonly encountered zeolite in the geological literature.

Stilbite from Sardinia, Italy
(Copyright by Di Domenico Dario)

Stilbite

(since 1997, Stilbite-Ca)
$(NaCa_4Al_8Si_{28}O_{72} \cdot 30(H_2O))$

Crystal system: monoclinic-prismatic

Cleavage: [010] perfect

Colour: White, red, yellow, brown, cream

Average density: 2.15

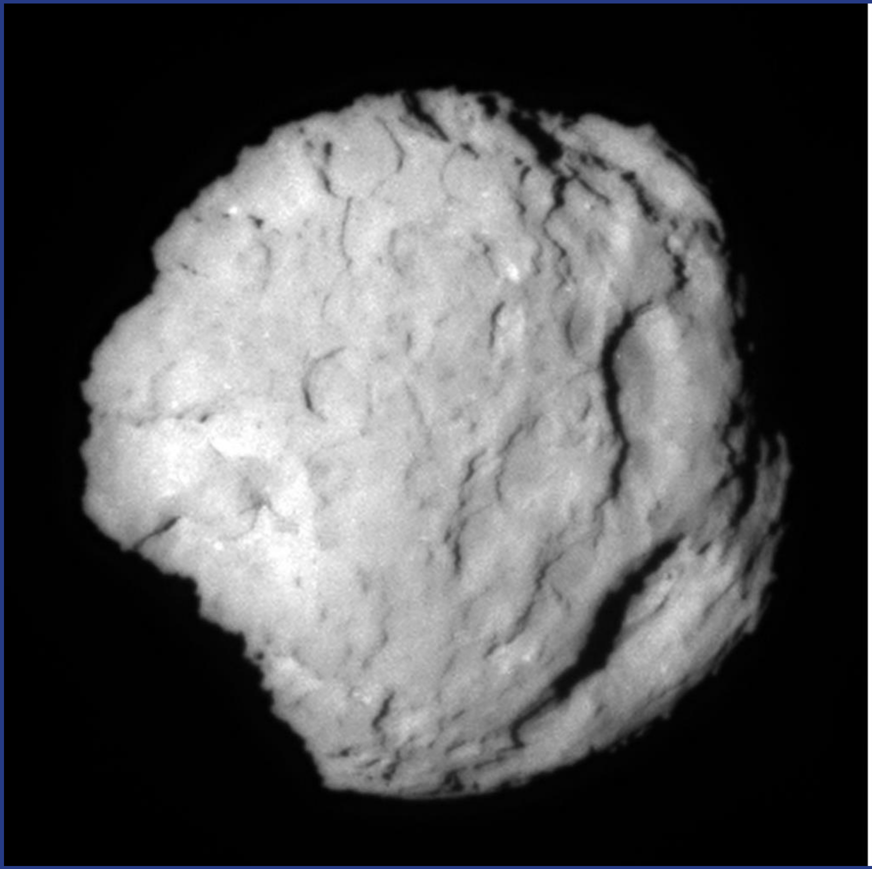
Hardness: 3.5-4

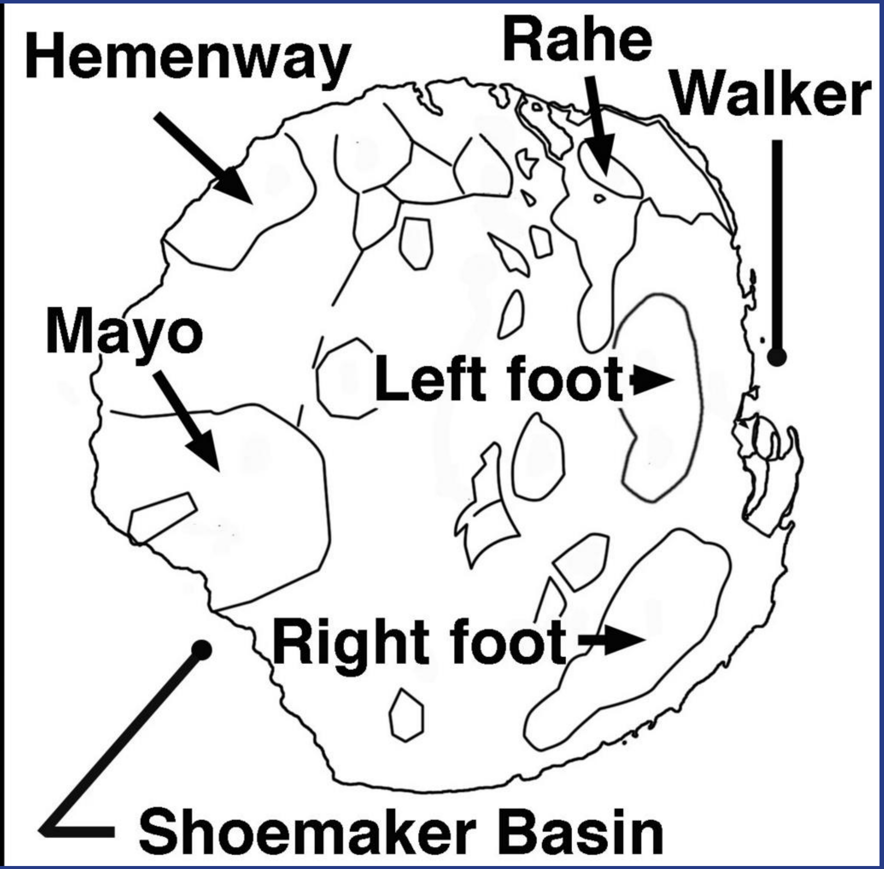
Streak: white

Luster: vitreous-pearly

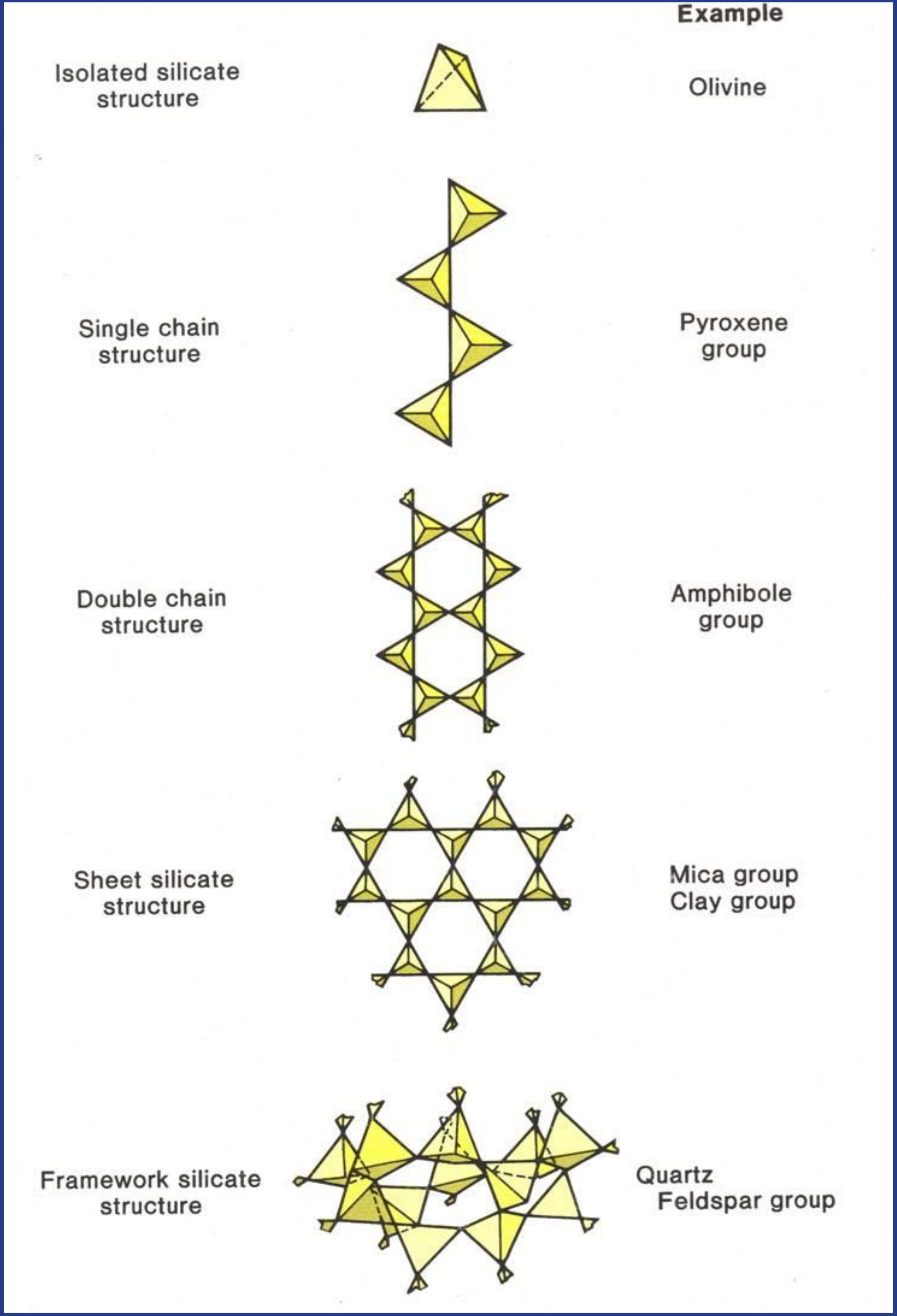
Fracture: very brittle, conchoidal

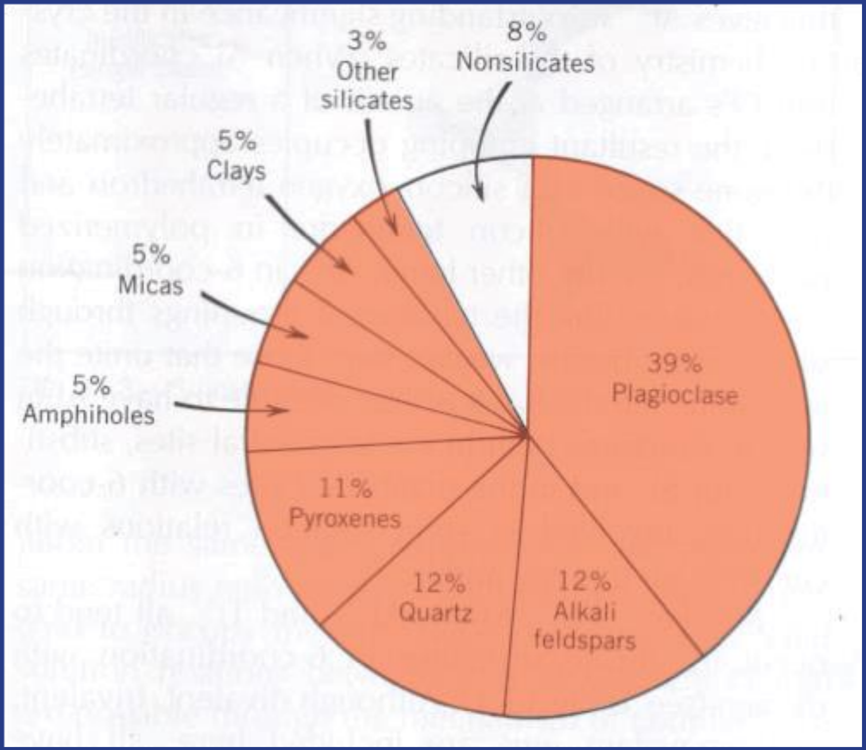
Stilbite concludes our survey of the silicate minerals. I have shown you only the most important ones, i.e., the most commonly encountered ones on our planet. Their distribution is more or less the same on all rocky planets, with the exception that Mercury, Venus and Mars do not have continental crusts. On them we therefore would not expect the same abundance of the sodic plagioclases or the alkali feldspars. No quartz has yet been reported from these planets. So far only NASA's Stardust mission found tridymite minerals in the comet 81P/Wild, also known as Wild 2. Some SiO_2 dust has been detected from distant planetary dusts but their origin is unknown.





One view of the comet Wild 2
(named after the Swiss astronomer Paul Wild).
Its dimensions are 5.5 km x 4.0 km x 3.3 km





Silicates make up at least 92% of the earth's crust. If you know them well, you essentially know the crust! Since the earth's mantle is essentially all silicates, they inform you of the 85% of the entire planet!