SVEUČILIŠTE U ZAGREBU
PRIRODOSLOVNO-MATEMATIČKI FAKULTET
GEOLOŠKI ODSJEK

Mineralogija

Sveučilišni prijediplomski studij Znanosti o okolišu – 1. godina (253566)

Doc. dr. sc. Petra Schneider

akad. god.: 2024./25.

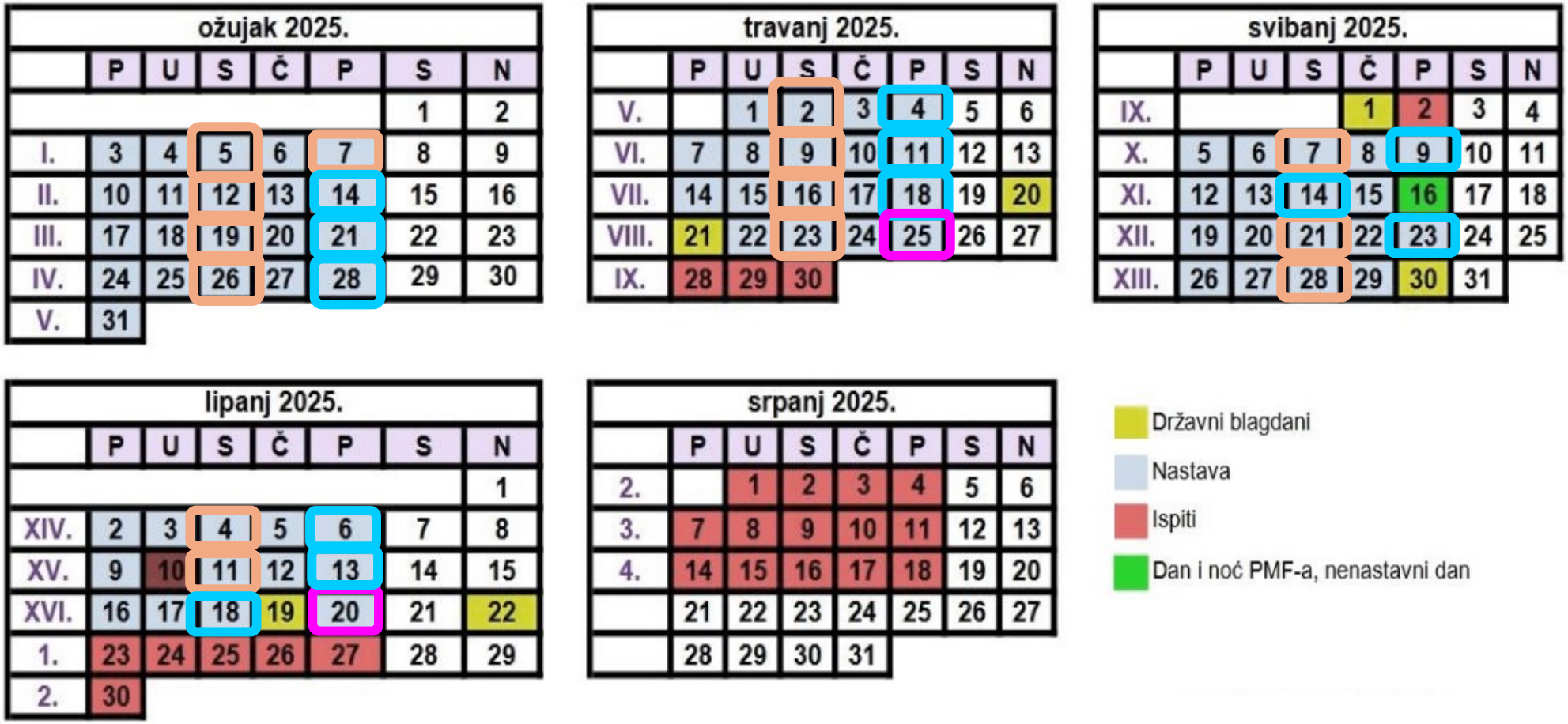
Kalendar nastave

2 kolokvija:

- Kristalografija – Stereografske projekcije
- Sistematska mineralogija

Ispiti: 1. i 3. srijeda u ispitnim rokovima

predavanja
vježbe
kolokvij

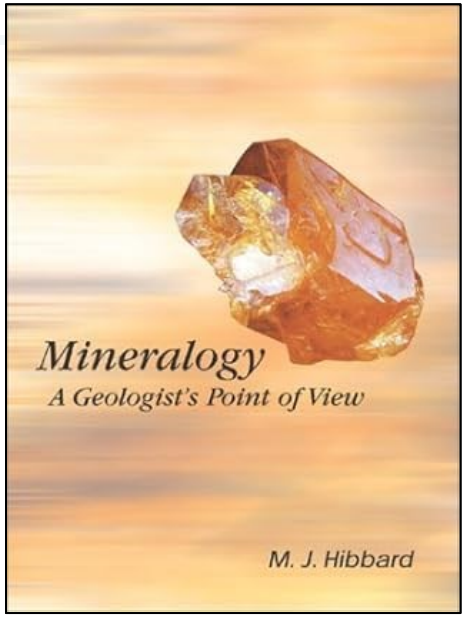


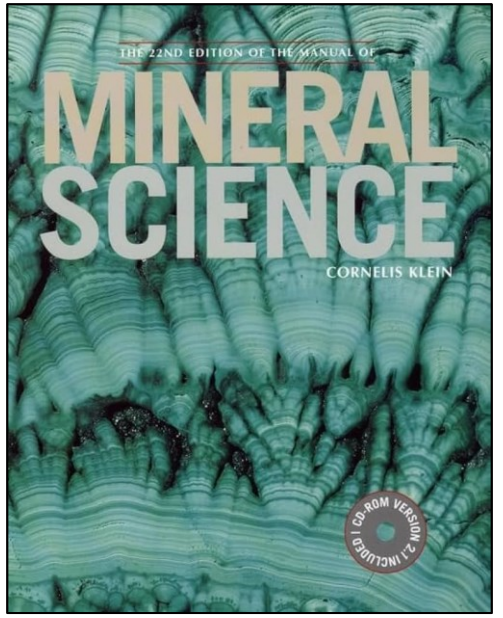

People who like the outdoors and science
Ecologist
Don't listen to that guy. He's trying to lead you down the path of righteousness
@Formorphology
Geologist
I'm gonna lead you down the path that rocks

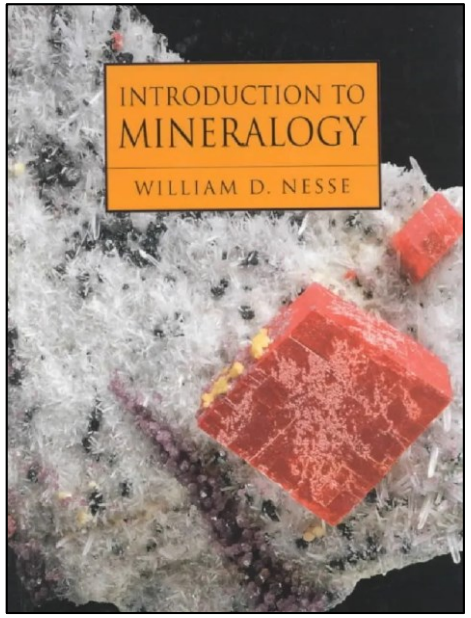
Popis literature

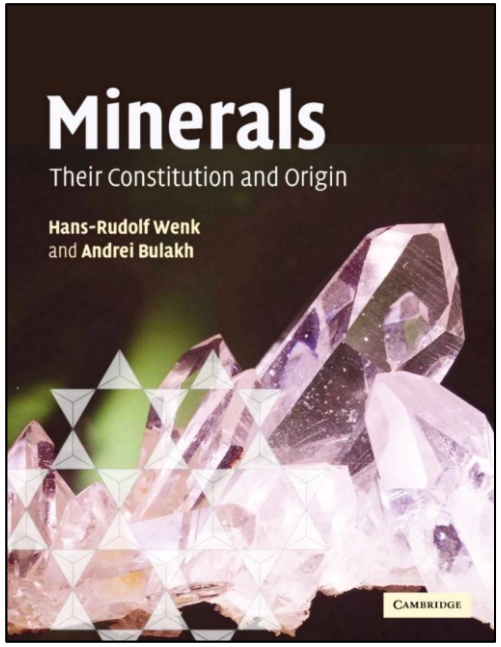
- Klein C. (2002): Mineral Science. John Wiley & Sons, New York, 641 str.
- Nesse W.D. (2000): Introduction to Mineralogy. Oxford University Press, Oxford, 442 str.
- Slovenec D. (2011): Opća mineralogija. Targa, Zagreb, 350 str.
- Klein C. & Philpotts A. (2013): Earth Materials – Introduction to Mineralogy and Petrology. Cambrige University Press, New York, 536 str.

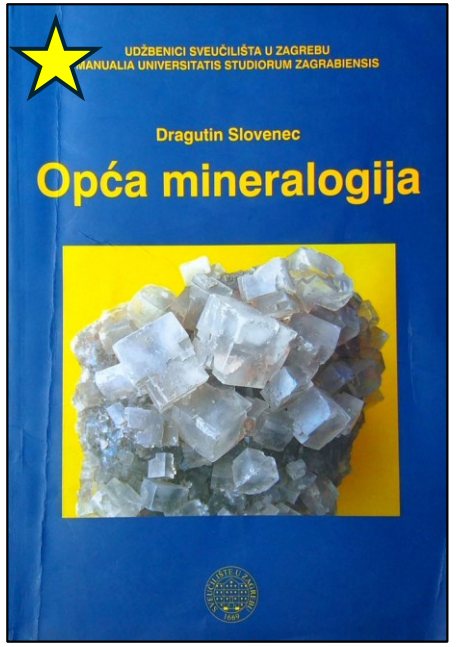
  https://www.geokniga.org/bookfiles/geokniga-earth-materials-introduction-mineralogy-and-petrology.pdf
- Hibbard M.J. (2002): Mineralogy: A Geologist's Point of View. McGraw-Hill Science, New York, 562 str.
- Wenk H.-R. & Bulaks A. (2003):Minerals: their constitution and origin. Cambridge University Press, Cambridge, 646 str.

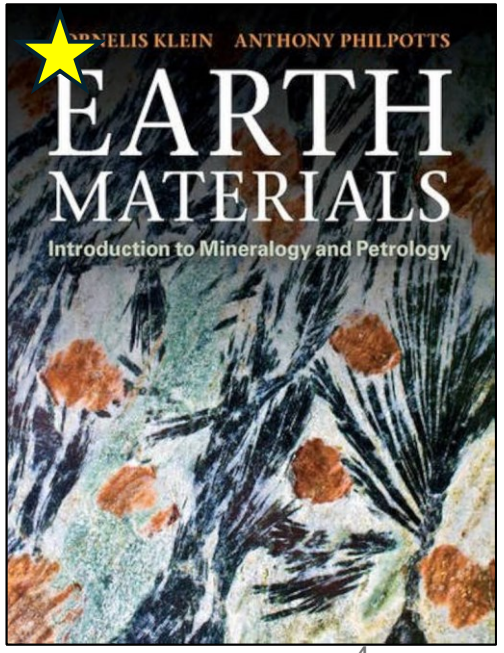












Sadržaj

- Mineralogija kao znanost
- Kratka povijest mineralogije
- Mineral vs. kristal
- Periodičnost
- Prostorna rešetka
- Jedinična ćelija
- Kristalni sustavi
- Morfologija, elementi simetrije
- Forma, habitus
- Zona, 3. kristalografski zakon
- Rast kristala, 1. kristalografski zakon

Mineralogija

- engl. *mineral science, mineralogy*
- lat. *minera* = ruda + grč. *logos* = znanost, nauka

Mineral

Commission on New Minerals and Mineral Names (CNMMN)
of the International Mineralogical Association (IMA):

In general terms, a mineral is an element or chemical compound that is normally crystalline and that has been formed as a result of geological processes. (Nickel, 1995)

A mineral is naturally occurring crystalline solid with a highly ordered atomic arrangement and definite (but not necessarily fixed) chemical composition. (Klein, 2002)

→ kemijska formula (sastav se može mijenjati do određenih granica)
→ pravilna unutrašnja građa (vs. amorfne tvari*)
→ u čvrstom (krutom) agregatnom stanju
→ pojava u prirodi (vs. sintetski minerali)
→ anorganski procesi (vs. organski procesi)

? Koliko ima minerala na Zemlji?

preko 6000 priznatih minerala
https://rruff.info/ima/
https://www.mindat.org/minerals.php
https://mineralogy-ima.org/CNMNC_Strategy.htm

*MINERALOIDI = *mineral-like materials that lack a long-range crystalline structure* (pr. opal, vulkansko staklo, fulgarit, metamiktni minerali)

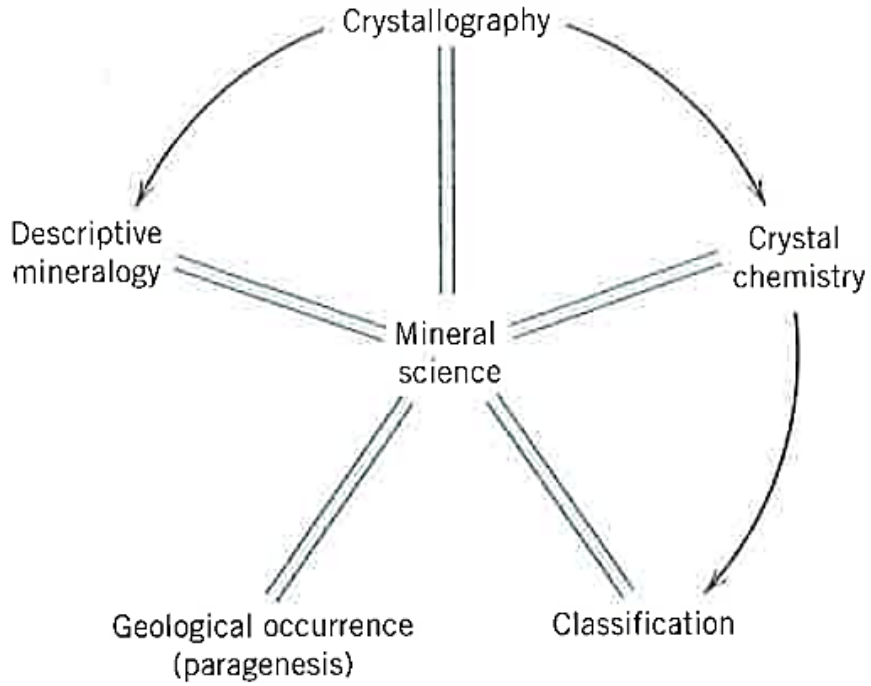
Mineral

! svaki vrijedan materijal koji se vadi iz zemlje, npr. ugljen, nafta, pijesak

! Nutricionisti: svaki element ili spoj koji je važan za prehranu, npr. Ca

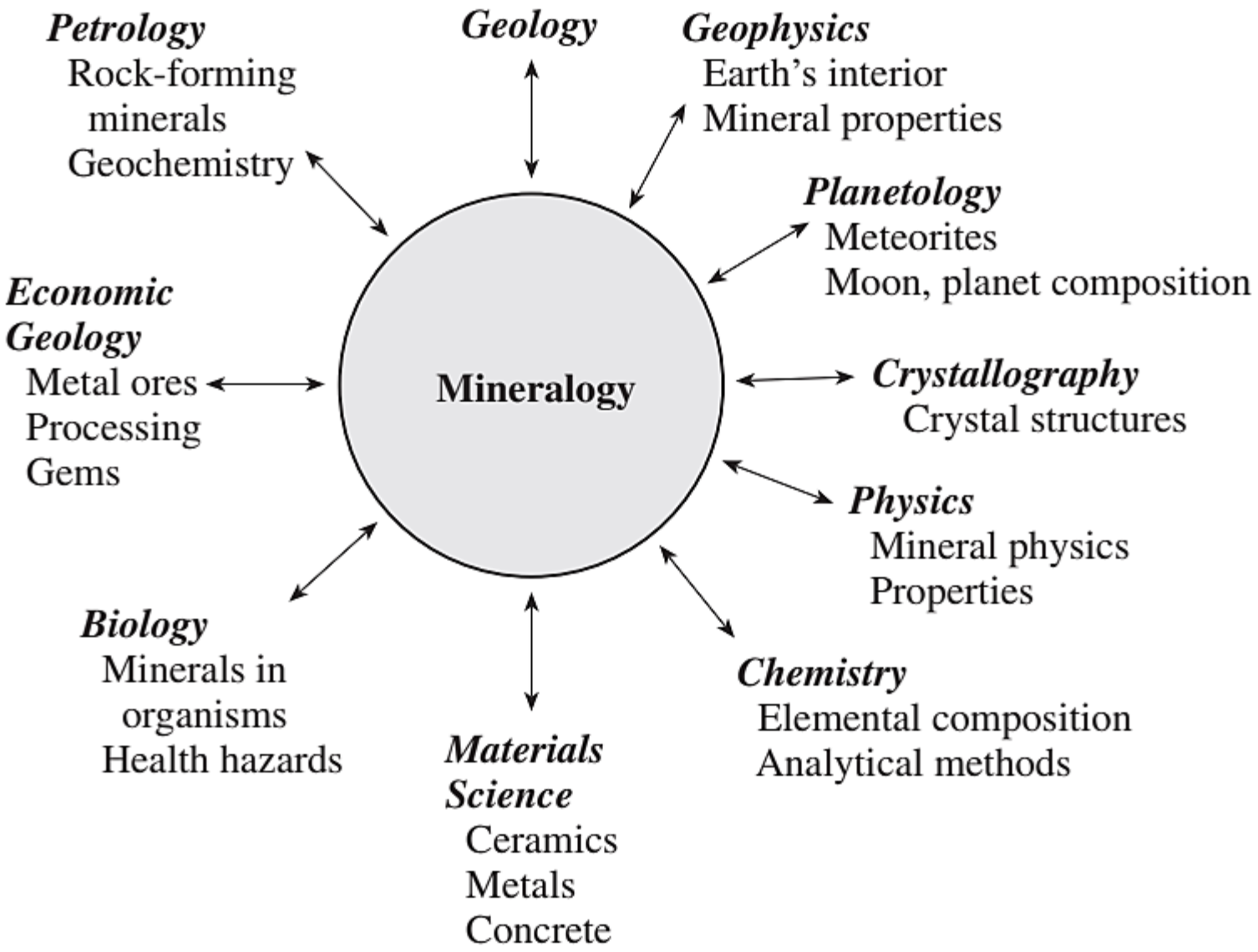
Poddiscipline

- opisna mineralogija
- kristalografija
- kristalokemija
- klasifikacija (sistematika)
- geološka pojavnost (paragenza)



Preuzeto iz Klein (2002).

Mineralogija



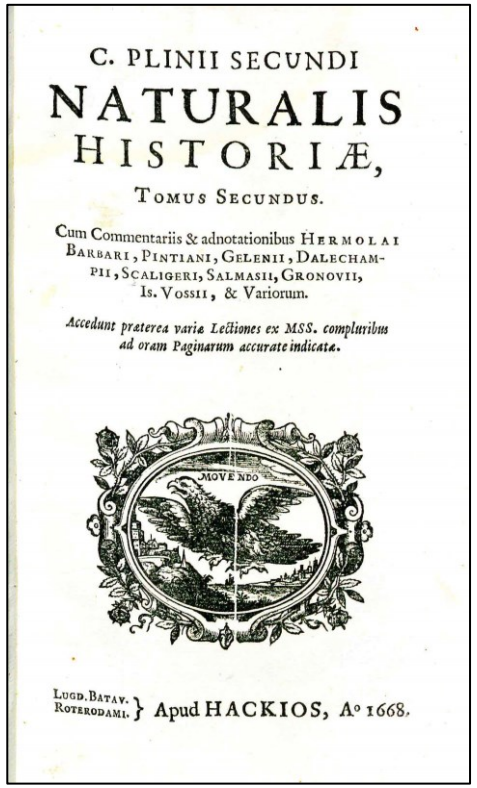
Preuzeto iz Wenk & Bulaks (2006).

Kratka povijest mineralogije

- pretpovijesno doba
- Teofrast (371.-286. pr. K.): *De lapidibus* (*O stijenama)*

  → prvo pisano djelo o mineralima
- Plinije Stariji (23.-79.): *Historia naturalis*

  → enciklopedija tog doba, 37 knjiga (tomova)


C. PLINII SECUNDI
NATURALIS
HISTORIÆ,
TOMUS SECUNDUS.
Cum Commentariis & adnotationibus HERMOLAI BARBARI, PINTIANI, GELENII, DALECHAMPII, SCALIGERI, SALMASII, GRONOVII, Is. VOSSII, & Variorum.
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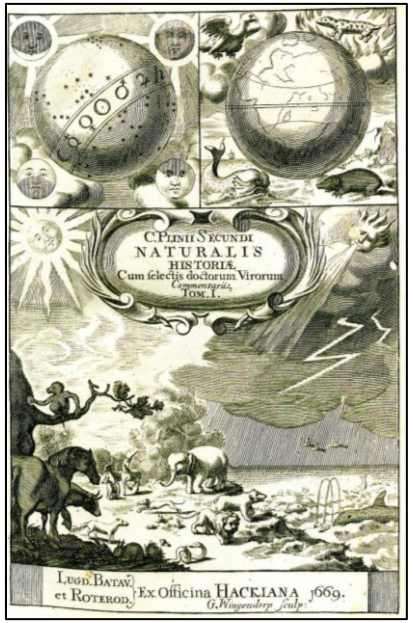
LUGD. BATAV. ROTERODAMI. } Apud HACKIOS, Aº 1668.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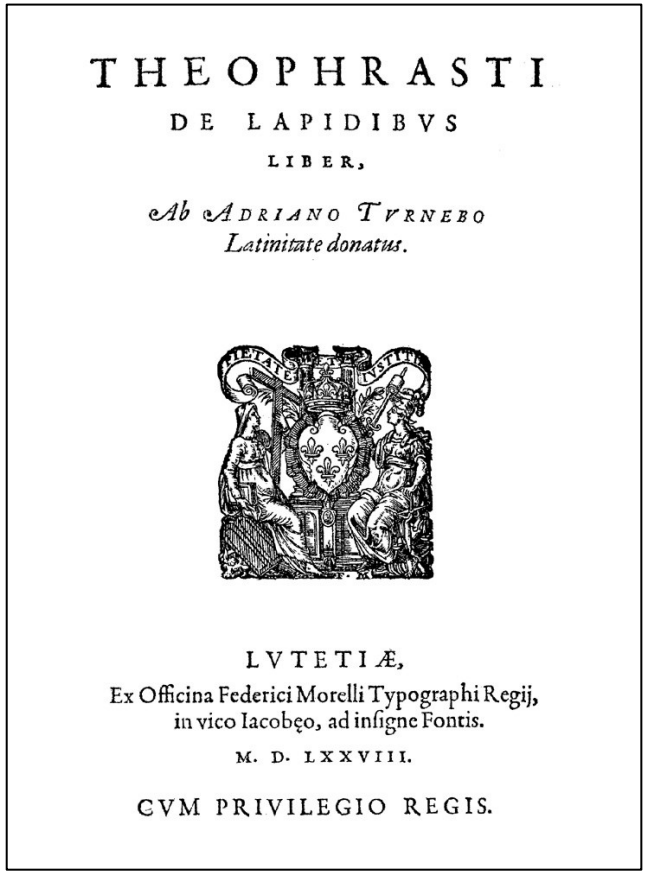
LUGD. BATAV. et ROTEROD. Ex Officina HACKIANA 1669.

https://lawlibrary.wm.edu/wythepedia/index.php/C._Plinii_Secundi_Naturalis_Histori%C3%A6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DE LAPIDIBVS
LIBER,
Ab ADRIANO TVRNEBO
Latinitate donatus.
LVTETIÆ,
Ex Officina Federici Morelli Typographi Regij,
in vico Iacobęo, ad insigne Fontis.
M. D. LXXVIII.
CVM PRIVILEGIO REGIS.

https://mineralogicalrecord.com/new_biobibliography/theophrastus/

Kratka povijest mineralogije

- 1530. Georg Bauer (Georgius Agricola): *De re metalica*

  → opisi fiz. svojstava za identifikaciju minerala

- 1669. Niels Stensen (Nicolaus Steno)

  → pravilnost na kristalima kvarca (kutovi)

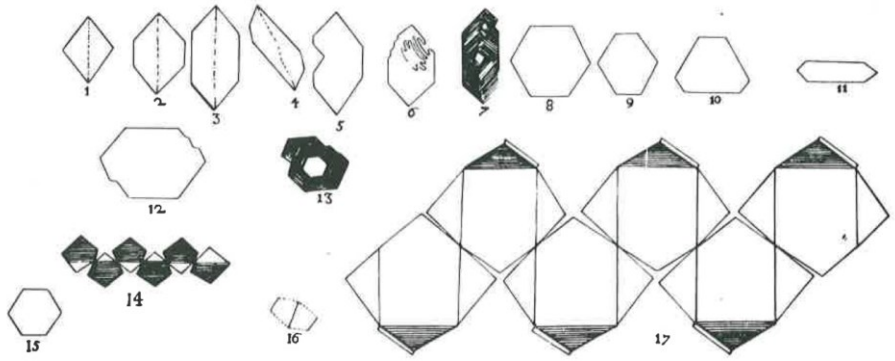
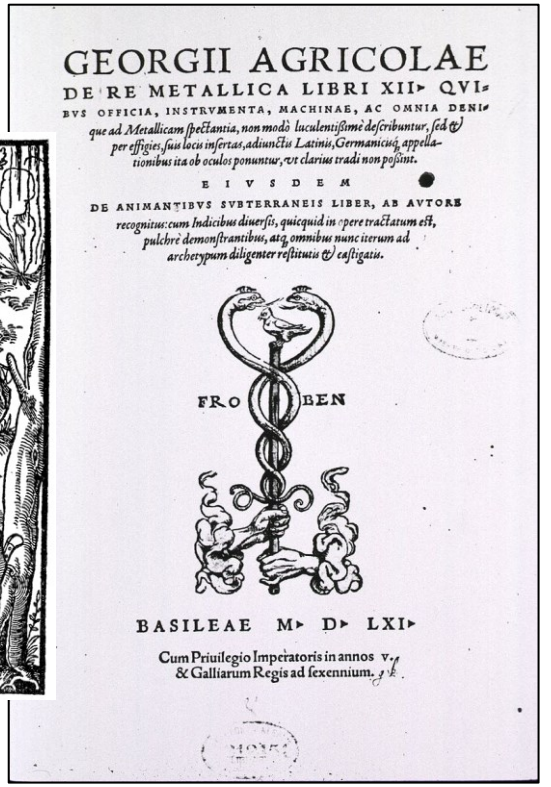


FIG. 1.5. Steno's drawings of various quartz and hematite crystals, illustrating the constancy of angles among crystals of different habits. (From Schafkranovski, J. J., 1971, *Die Kristallographischen Entdeckungen N. Stenens*, in *Steno as Geologist*. Odense University Press.) preuzeto iz Klein (2002)

G. Agricola: *De re metalica*



- 1780. Carangeot

  → kontaktni goniometar

- 1783. Jean-Baptiste Romé de l'Isle

  → **1. kristalografski zakon** (tzv. Zakon o stalnosti kutova)

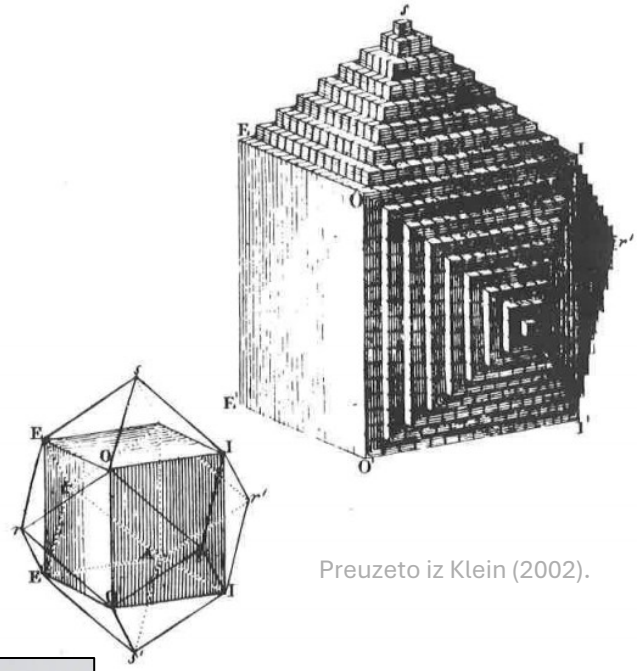
1986. Victor Goldschmidt
dvokružni kontaktni goniometar

1780. Carangeot
kontaktni goniometar

https://mineralogy.eu/gonio/introGONIO.html

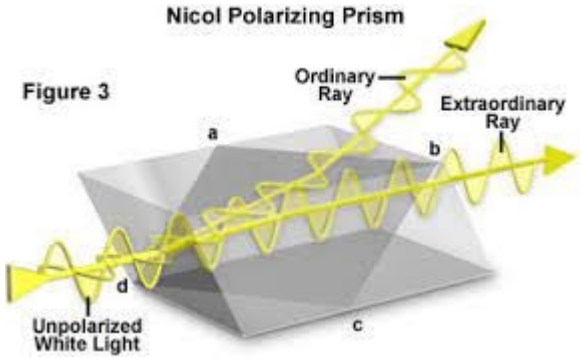
Kratka povijest mineralogije

- 1784. René-Just Haüy = „otac matematičke kristalografije”
  „molekule sastavljačice” (*integral molecules*) → jedinična ćelija
  → 1801. **2. kristalografski zakon** (Zakon o racionalnom odnosu parametara)



Preuzeto iz Klein (2002).

- 1809. Wollaston
  → refleksni goniometar
- 1779.–1848. J. J. Berzelius
  → temelji današnje kemijske klasifikacije minerala
- 1815. Cordier
  → obični mikroskop (imerzivne metode)
- 1828. W. Nicol
  → polarizator (Nicolova prizma)
- 1858. H.C. Sorby
  → polarizacijski mikroskop

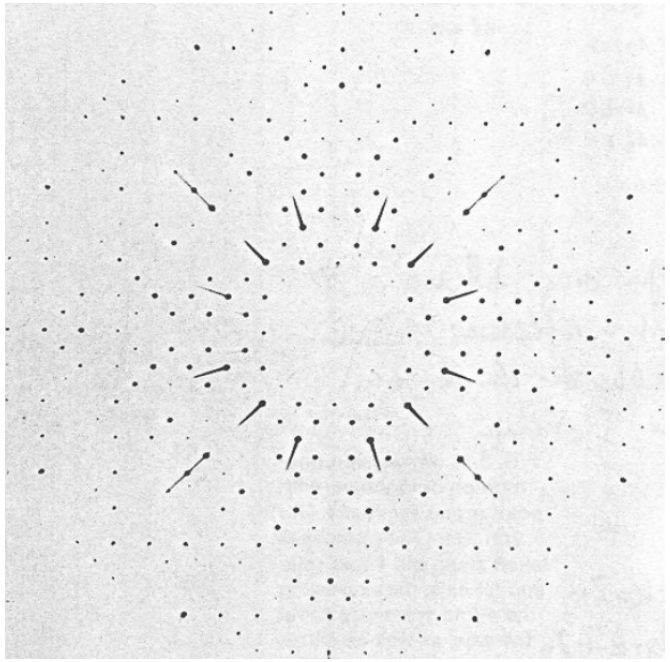


https://www.mineralogy.eu

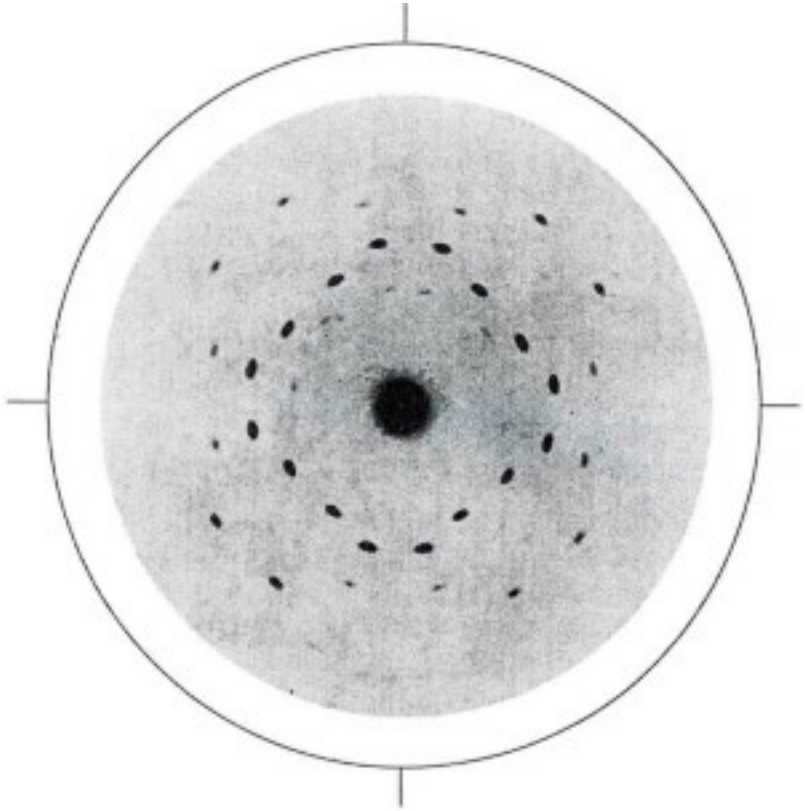
Kratka povijest mineralogije

- 2. pol. 19. st., E.S. Fjodorov, A. Schönflies i W. Barlow
  kristalna struktura izgrađena od pravilno raspoređenih atoma koji sačinjavaju prostornu rešetku → temelji rendgenske kristalografiji
- 1912. Max von Laue (W. Friedrich i P. Knipping)
  kristali difraktiraju X-zrake → pravilna uređena unutrašnja građa
- 1914. W.H. Bragg i sin W.L. Bragg objavljuju prve kristalne strukture

→ najmlađi dobitnik Nobelove nagrade



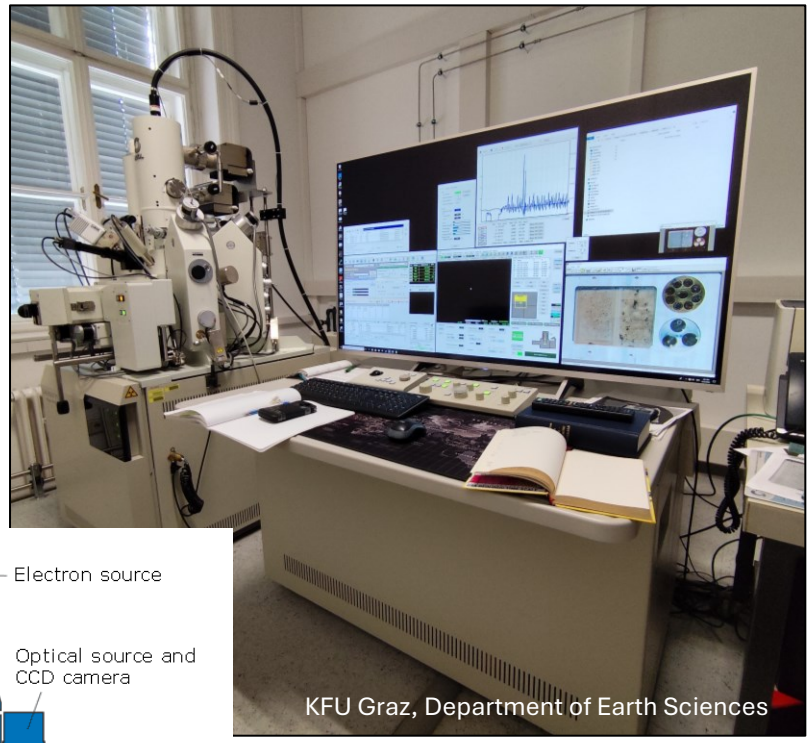
Preuzeto iz Klein (2002)

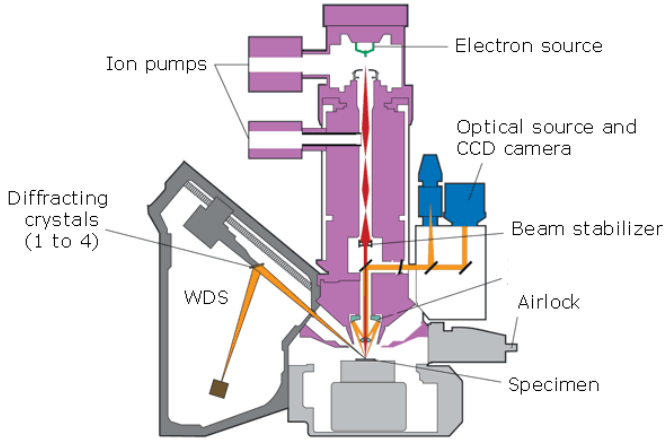


difrakcijski uzorak na kristalu sfalerita (ZnS)
https://www.nature.com/articles/491186a

Kratka povijest mineralogije

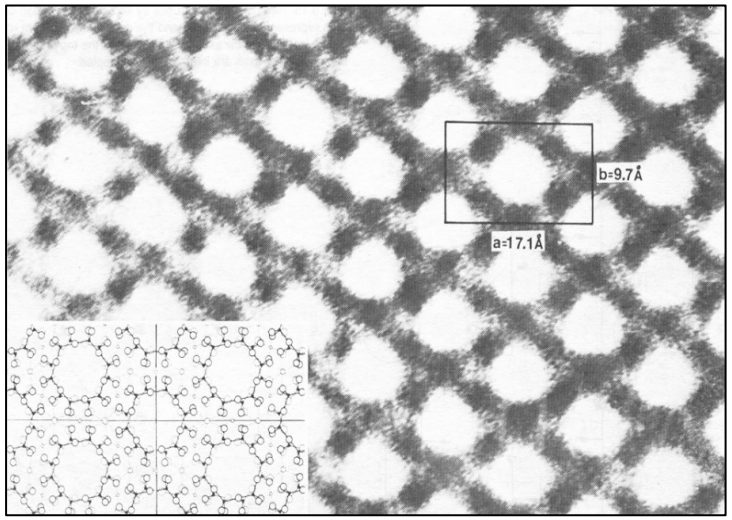
- 1960-ih razvoj elektronskih mikroskopa i elektronske mikrosonde (EPMA, engl. e*lectron-probe microanalyser*)





https://www.cameca.com

- 1970-ih razvoj visokorazlučivog transmisijskog elektronskog mikroskopa (HRTEM): x 1.000.000 puta povećanje → promatranje unutrašnje građe kristala



HRTEM slika minerala cordierita (Klein & Hurlbut, 1999)

Mineralogija u Hrvata?

1875. Katedra mineralogije i geologije Mudroslovnog fakulteta

Klein C. & Hurlbut C.S. (1999): Manual of mineralogy.

Kratka povijest mineralogije

Table 1.1 Some famous mineralogists (not including living mineralogists)

Name, date	Country	Contribution
Georg Bauer (Agricola) 1494–1555	Germany	Detailed description of minerals
Niels Stensen (Nicolaus Steno) 1638–1686	Denmark	Law of interfacial angles
Torbern O. Bergman 1735–1784	Sweden	Cleavage of calcite
René Just Haüy 1743–1822	France	Concept of unit-parallelepipeds
Abraham G. Werner 1750–1817	Germany	Origin and properties of minerals
Lorentz Pansner 1777–1851	Germany/Russia	Hardness and density of minerals
Johan J. Berzelius 1779–1848	Sweden	Chemical mineralogy
Johann A. Breithaupt 1791–1873	Germany	Density of minerals, parageneses
Eilhard Mitscherlich 1794–1863	Germany	Isomorphism and polymorphism
Johann F.C. Hessel 1796–1872	Germany	Point-group symmetry
Auguste Bravais 1811–1863	France	Lattice types
James Dwight Dana 1813–1895	USA	Systematic mineralogy
Nicolai Koksharoff 1818–1892	Russia	Goniometry of crystals
Carl Rosenbusch 1836–1914	Germany	Optical mineralogy
Gustav Tschermak 1836–1927	Austria	Silicate structures
Paul von Groth 1843–1927	Germany	Chemical crystallography
Ephgraph S. Fedorow 1853–1919	Russia	Space-group symmetry
Artur Schoenflies 1853–1928	Germany	Space-group symmetry
Viktor Goldschmidt 1853–1933	Germany	Geometry of crystals
Penti Eskola 1883–1964	Finland	Igneous minerals
Alexander Fersman 1883–1945	Russia	Mineral-forming processes
Norman L. Bowen 1887–1956	USA	Experimental petrology
Paul Niggli 1888–1953	Switzerland	Mineral-forming geologic processes
Viktor M. Goldschmidt 1888–1947	Norway/Germany	Crystal chemistry, geochemistry
William L. Bragg 1890–1971	Great Britain	Crystal structure of minerals
Nicolai Belov 1891–1982	Russia	Mineral structures
Paul Ramdohr 1890–1985	Germany	Ore minerals
Cecil E. Tilley 1894–1973	Great Britain	Igneous and metamorphic minerals
Tom F. W. Barth 1899–1971	Norway	Petrology
Francis J. Turner 1904–1985	New Zealand/USA	Metamorphic minerals and deformation

Box 1.1 Nobel prizes in fields related to crystallography

Year	Field	Awardees	Subject
1901	Physics	W.C. Röntgen	X-rays
1914	Physics	M.T.F. von Laue	X-ray diffraction
1915	Physics	W.H. Bragg and W.L. Bragg	X-ray structure analysis
1918	Physics	C.G. Barkla	Characteristic X-rays
1930	Physics	C.V. Raman	Raman spectroscopy
1937	Physics	C.J. Davisson and G.P. Thomson	Electron diffraction
1946	Physics	P.W. Bridgman	High-pressure physics
1954	Chemistry	L.C. Pauling	Structures of complex substances
1960	Chemistry	W.F. Libby	Carbon-14 dating
1962	Medicine	F.H.C. Crick, J.D. Watson and M.H.F. Wilkins	Crystal structure of DNA
1963	Physics	E.P. Wigner	Symmetry principles
1964	Chemistry	D.C. Hodgkin	X-ray structure of biochemical substances
1982	Physics	K.G. Wilson	Phase transitions
1982	Chemistry	A. Klug	Crystallographic electron microscopy
1985	Chemistry	H.A. Hauptman and J. Karle	Crystal structure analysis
1986	Physics	E. Ruska	Electron microscopy
		G. Binnig and H. Rohrer	Scanning tunneling microscope
1987	Physics	J.G. Bednorz and K.A. Müller	Superconductivity in ceramics
1991	Physics	P.G. de Gennes	Liquid crystals
1994	Physics	B.N. Brockhouse and C.G. Shull	Neutron diffraction

Preuzeto iz Wenk & Bulaks (2006).

Mineral ≠ Kristal

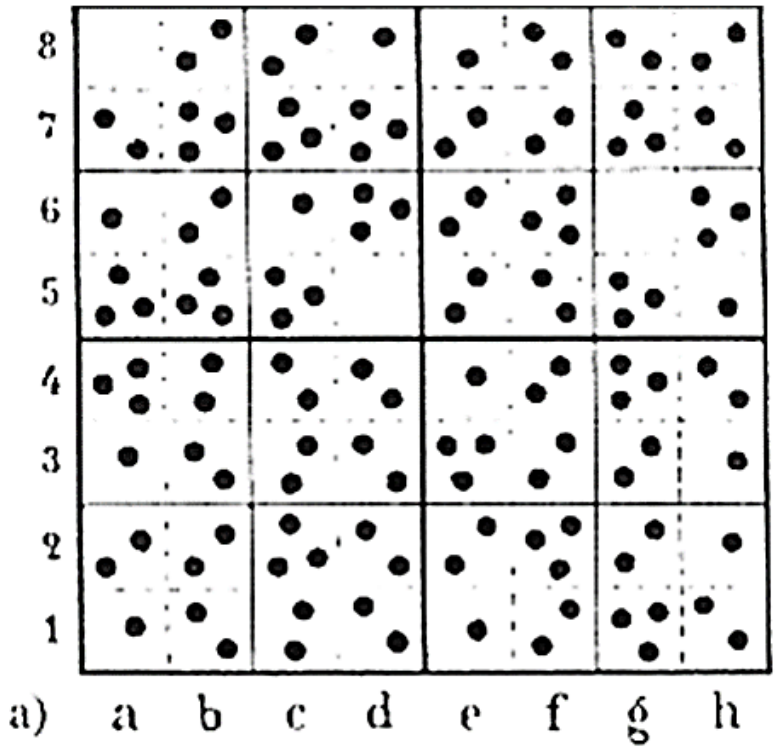
→ pravilna unutrašnja građa → atomi ili ioni su raspoređeni prema pravilnom geometrijskom obrascu → periodičnost → kristalno stanje (kristali)

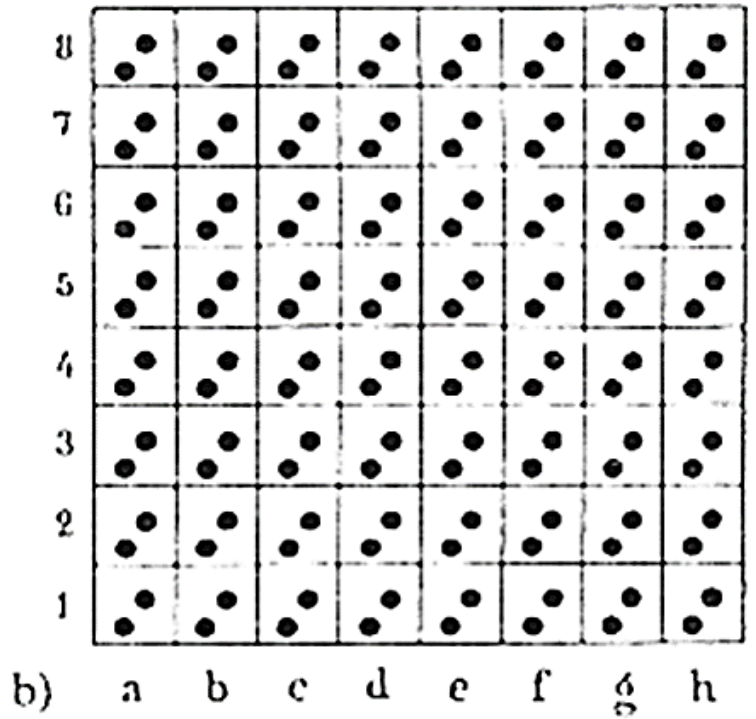
Kristal = kruto anizotropno homogeno tijelo pravilne unutrašnje građe za koju je karakteristična trodimenzionalna periodičnost

= kruto tijelo omeđeno prirodnim plohama nastalim prilikom njegova rasta koje su vanjski odraz njegove pravilne unutrašnje građe.

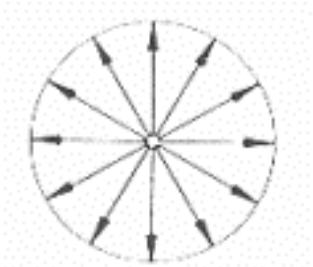
Izvor fotografija: https://www.mindat.org

Raspored materije





- kinetička energija atoma je toliko mala da su oni stalno vezani jedan za drugoga → titranje oko ravnotežnog položaja
- kristalizirano stanje = stanje najniže energije (energetski najstabilnije)



statistička homogenost
slučajan raspored materije
izotropna fizička svojstva

AMORFNE TVARI

vs.

periodična homogenost
pravilan raspored materije
anizotropna fizička svojstva

KRISTALIZIRANE TVARI

Periodičnost

TRODIMENZIONALNA PERIODIČNOST – osnovna građevna jedinica (motiv: atom ili molekula) se ponavlja u tri smjera

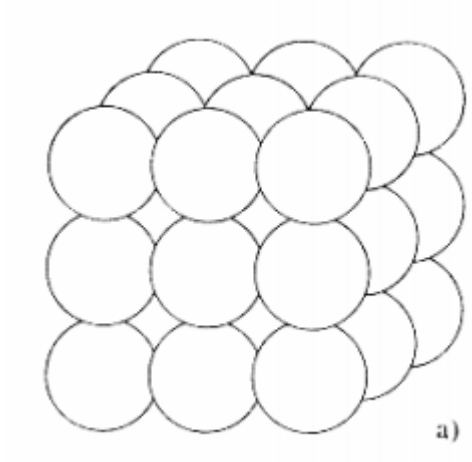
! ali: različit raspored materije u različitim smjerovima → anizotropna svojstva (ovise o smjeru)

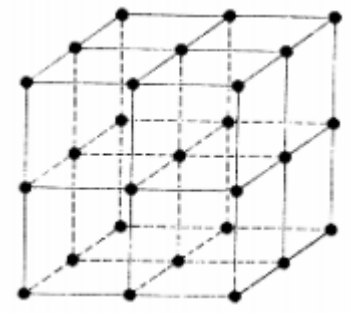
Prostorna rešetka = matematički model

→ zbog jednostavnosti, motiv koji se ponavlja u prostoru zamjenjuje se čvorom

! **kristalna struktura** = nešto realno, definiraju je atomi

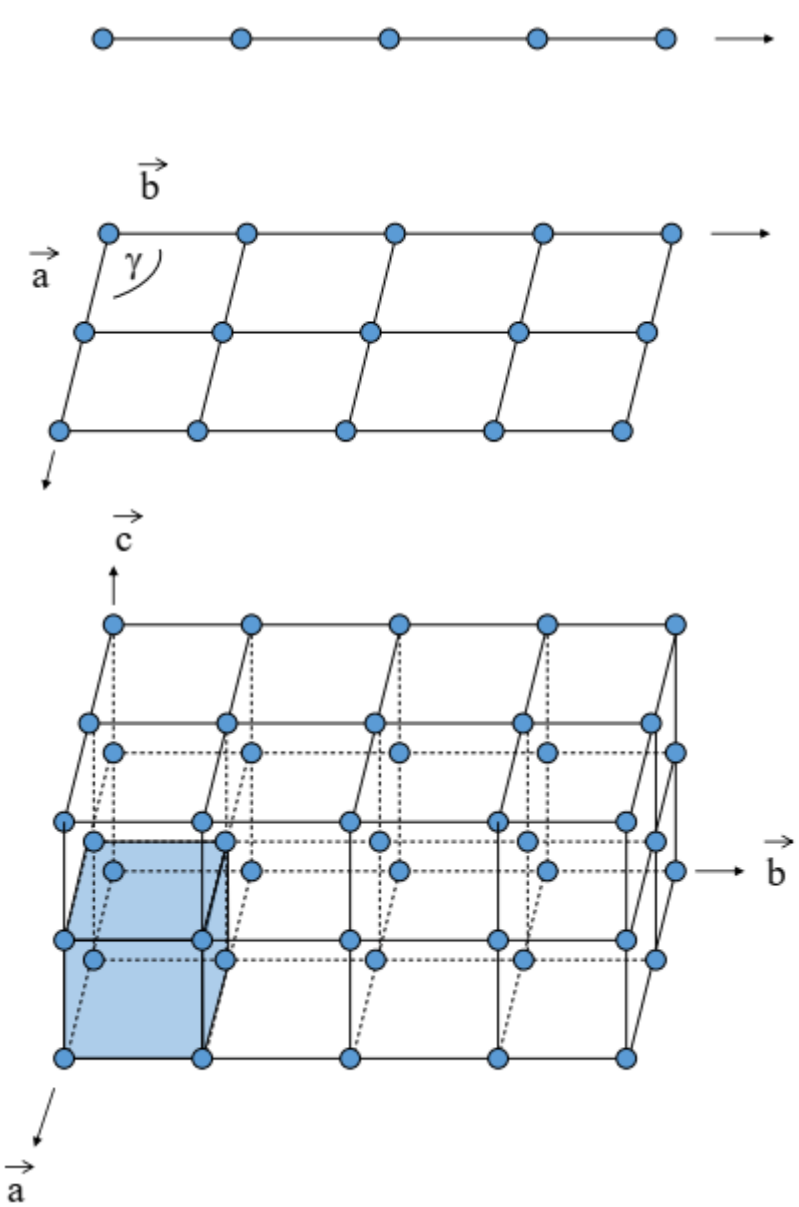
! **prostorna (kristalna) rešetka** = matematički model, definiraju je čvorovi





Preuzeto iz Slovenec (2011)

Prostorna rešetka



1D (linijska) mreža

→ definirana s jednim vektorom translacije ($\vec{a}$)

2D (plošna) mreža

→ definirana s dva osnovna vektora translacije ($\vec{a}, \vec{b}$) i kutom među njima (γ)

3D prostorna mreža

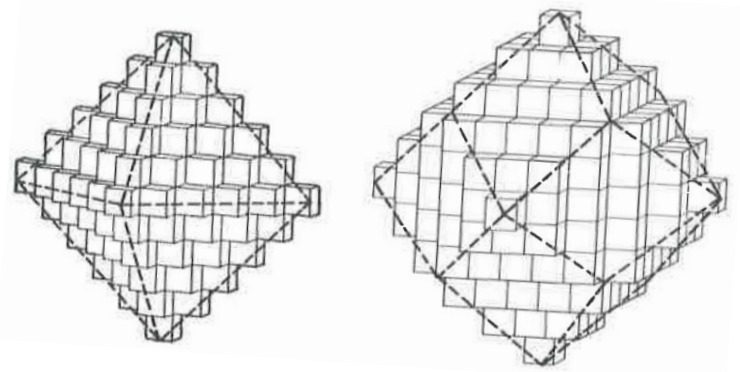
→ definirana s tri osnovna vektora translacije ($\vec{a}, \vec{b}, \vec{c}$) i kutovima među njima (α, β, γ)

6 parametara = dimenzije jedinične ćelije

Jedinična ćelija

→ najmanja strukturna jedinica kojom se može opisati cijela struktura

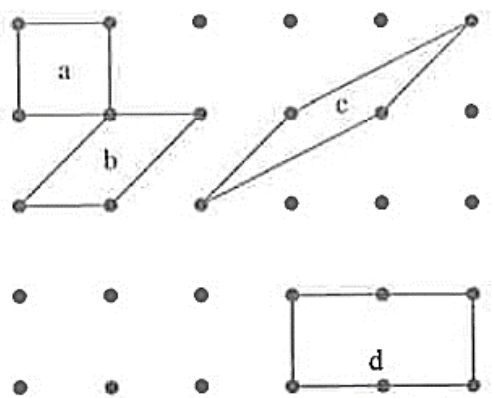
→ najmanji volumen čijim ponavljanjem se može dobiti čitava rešetka



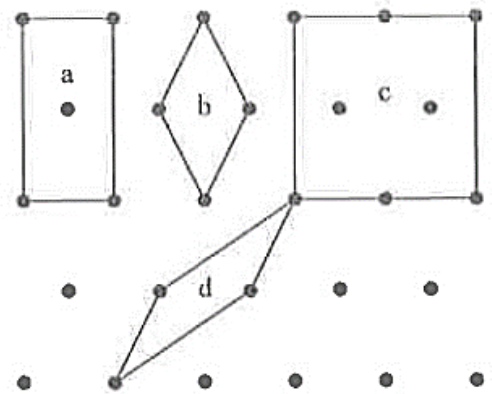
Preuzeto iz Klein (2002)

- svaka jedinična ćelija je paralelopiped te ima 8 vrhova i 6 ploha
- mogućnost odabira → pravila:
  1. simetrija paralelopipeda mora biti jednaka kao simetrija rešetke
  2. br. pravih kutova između bridova paralelopipeda mora uz zadovoljenje 1. uvjeta biti maksimalan
  3. uz zadovoljenje uvjeta 1. i 2., volumen paralelopipeda mora biti minimalan

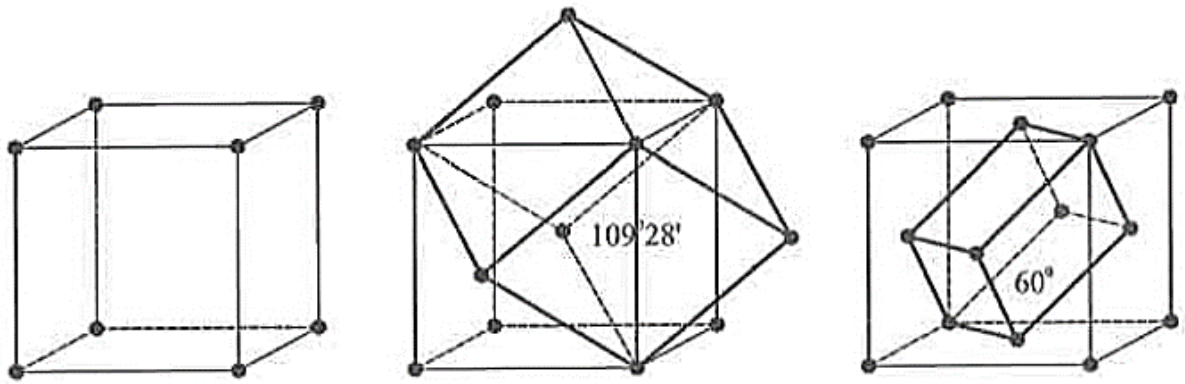
$$V=a_0b_0c_0\,(1-\cos^2\alpha-\cos^2\beta-\cos^2\gamma+2\cos\alpha\,\cos\beta\,\cos\gamma)^{1/2}$$



tetragonska plošna rešetka



rompska plošna rešetka



Preuzeto iz Slovenec (2011)

Kristalni sustavi

Za opis rešetke definira se koordinatni sustav, određen **kristalografskim osima** (paralelne s vektorima koji su definirali jediničnu ćeliju).

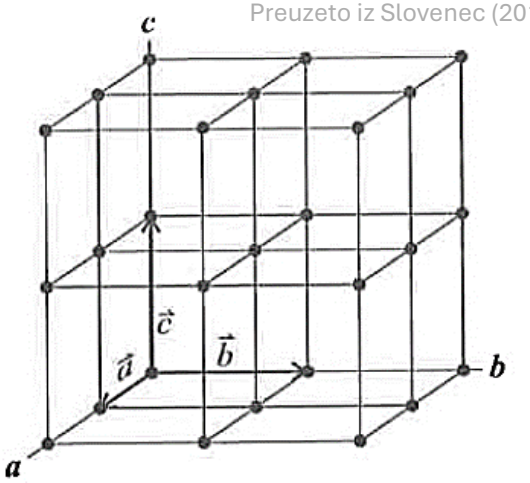
→ 6 (7) različitih koordinatnih sustava = 6 (7) kristalnih sustava*

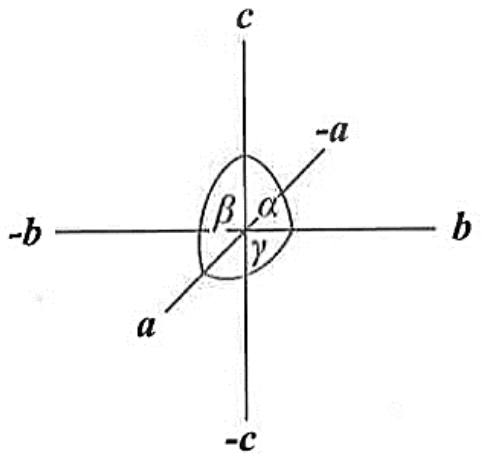
Razlika na temelju:

- veličine kristalografskih osi (jedinica koje su u skladu s dužinama bridova jedinične ćelije)
- kutova među osima
- simetrije

→ kristalografske osi obično se podudaraju s osima simetrije ili okomicama na ravnine simetrije

Preuzeto iz Slovenec (2011)



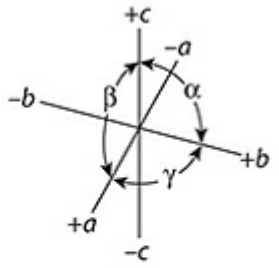


OSNI KRIŽ = središte kristala

* dvije različite rešetke, ali isti osni križ

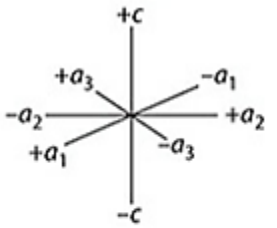
Kristalni sustavi

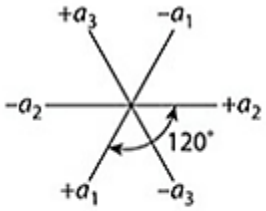
Kristalni sustav	Osni sustav
Triklinski	$a \neq b \neq c$ $\alpha \neq \beta \neq \gamma$
Monoklinski	$a \neq b \neq c$ $\alpha = \gamma = 90°$ $\beta \neq (>) 90°$
Rompski	$a \neq b \neq c$ $\alpha = \beta = \gamma = 90°$
Tetragonski	$a = b \neq c$ $\alpha = \beta = \gamma = 90°$ tj. $a_1 = a_2 \neq c$
Trigonski	$a_1 = a_2 = a_3$ $\alpha = \beta = \gamma \neq 90°$ ili heksagonske osi
Heksagonski	$a = b \neq c$ $\alpha = \beta = 90°$ $\gamma = 120°$ tj. $a_1 = a_2 \neq c$ odnosno $a_1 = a_2 = a_3 \neq c$ $\alpha_1 = \alpha_2 = \alpha_3 = 120°$ $\delta = 90°$
Kubični	$a = b = c$ $\alpha = \beta = \gamma = 90°$ tj $a_1 = a_2 = a_3$ $\alpha_1 = \alpha_2 = \alpha_3$



$a \neq b \neq c$
$\alpha \neq \beta \neq \gamma \neq 90°$

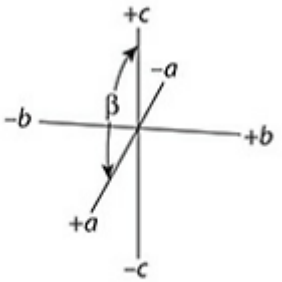
triklinski





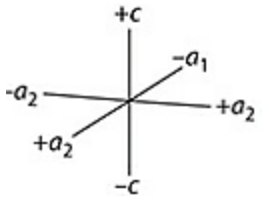
heksagonski

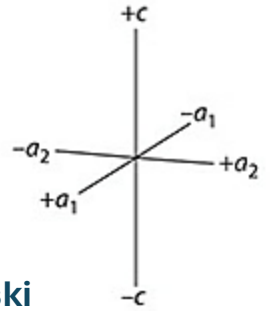
$a_1 = a_2 = a_3$; intersecting at 120°
c perpendicular to plane with a_1, a_2, a_3



$a \neq b \neq c$
$\beta > 90°; \alpha = \gamma = 90°$

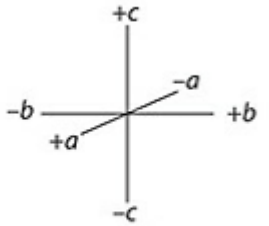
monoklinski





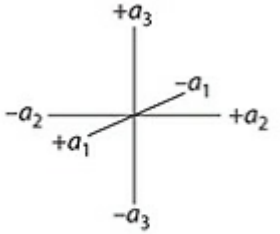
tetragonski

$a = b \neq c; a = a_1; b = a_2;$
all axes at 90° to each other



$a \neq b \neq c;$
all axes at 90° to each other

rompski



$a_1 = a_2 = a_3$; all axes at 90° to each other

kubični

Preuzeto iz Klein & Philpotts (2013)

Morfologija

→ dio mineralogije koji se bavi proučavanjem vanjskog izgleda minerala

Kristal = kruto tijelo omeđeno prirodnim plohama nastalim prilikom njegova rasta koje su vanjski odraz njegove pravilne unutrašnje građe

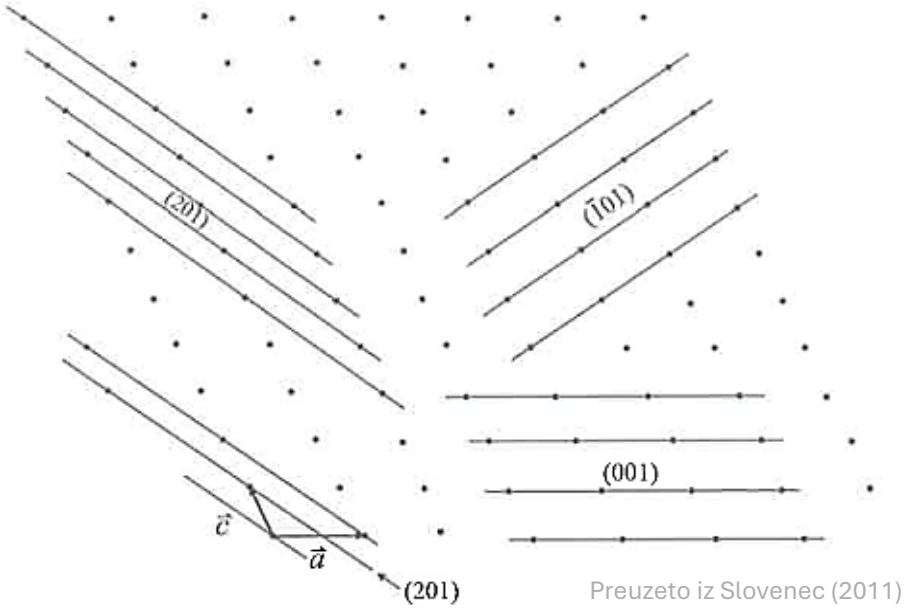
→ **kristalne plohe paralelne su s mrežnim ravninama**


cirkon


apatit


pirit

Izvor fotografija: https://www.mindat.org



Preuzeto iz Slovenec (2011)

mrežne ravnine = zamišljene ravnine u kojima leže čvorovi

! **Bravaisov zakon**: Na kristalu se obično pojavljuju plohe koje su paralelne mrežnim ravninama s najvećom mrežnom gustoćom (najveći broj atoma po jedinici površine).

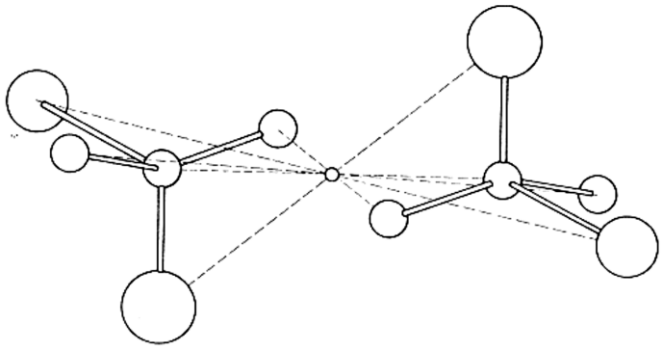
Elementi simetrije

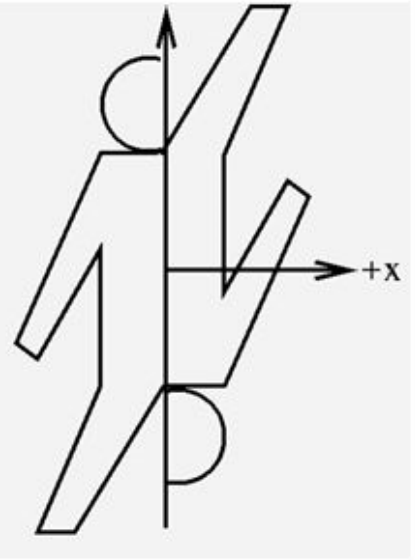
- **Centar simetrije**

  → preslikavanje u točki (inverzija)

  Oznake: klasična **C**

  internacionalna $\overline{1}$



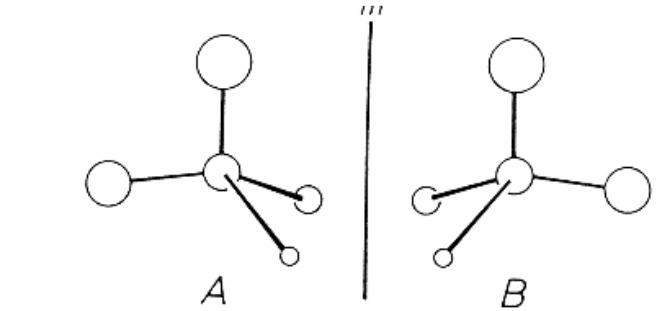


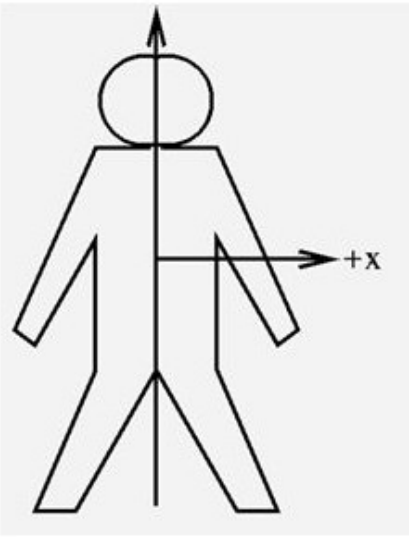
- **Ravnina simetrije**

  → preslikavanje preko ravnine (zrcaljenje, refleksija)

  Oznake: klasična **P**

  internacionalna **m**





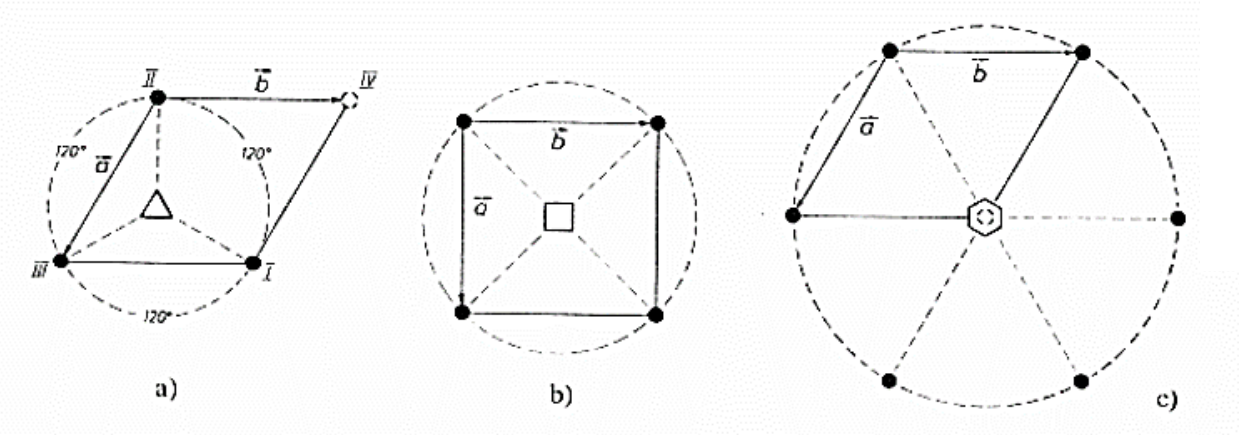
Elementi simetrije

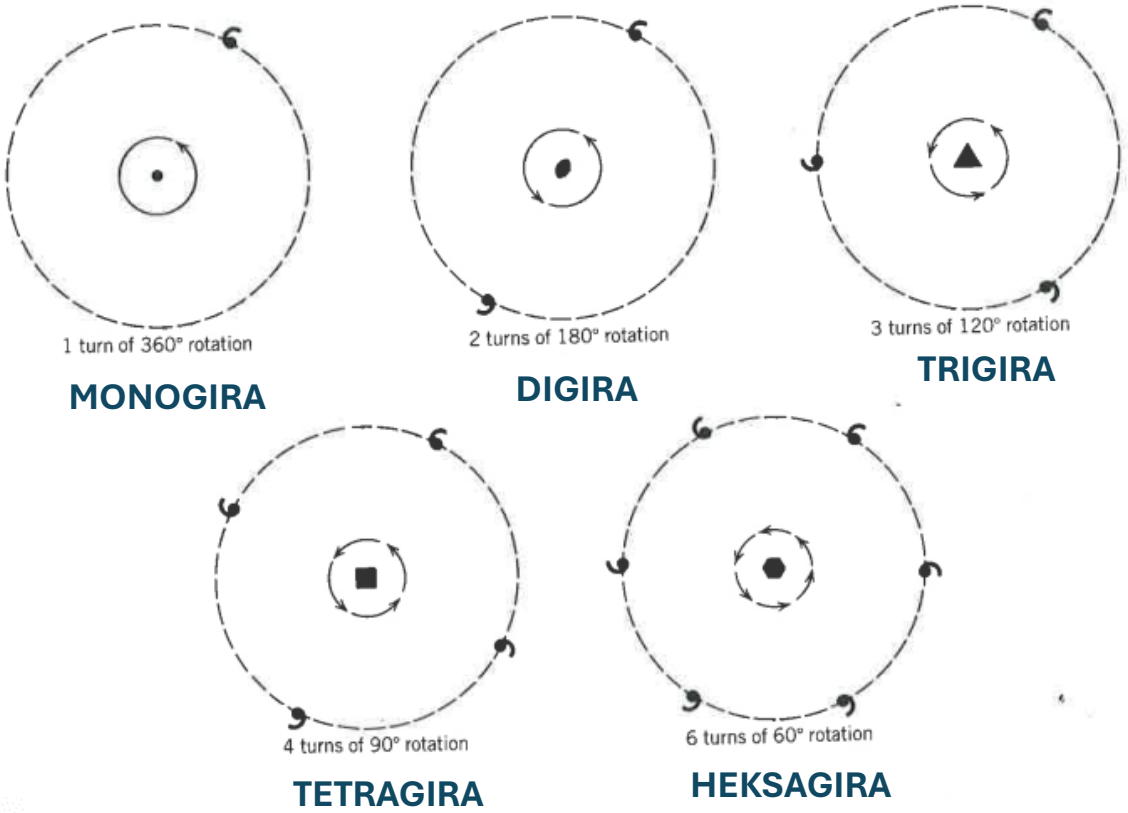
- **Osi simetrije (gire)**

  → rotacija oko osi za 360°, 180°, 120°, 90°, 60°

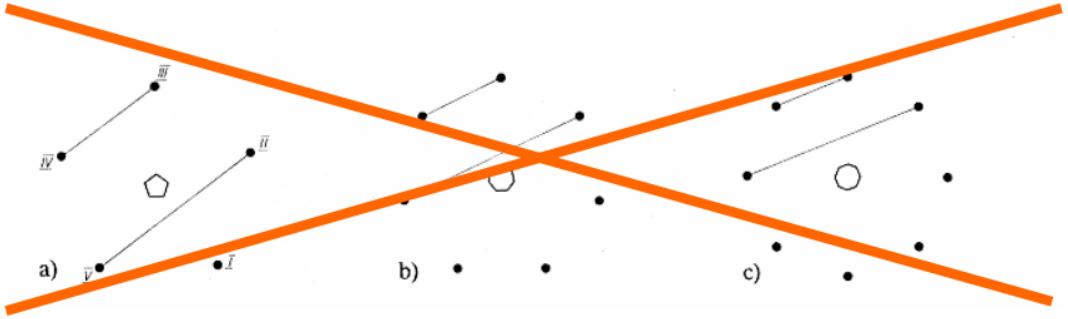
Oznake: klasične: L^1, L^2, L^3, L^4, L^6

internacionalne: 1, 2, 3, 4, 6





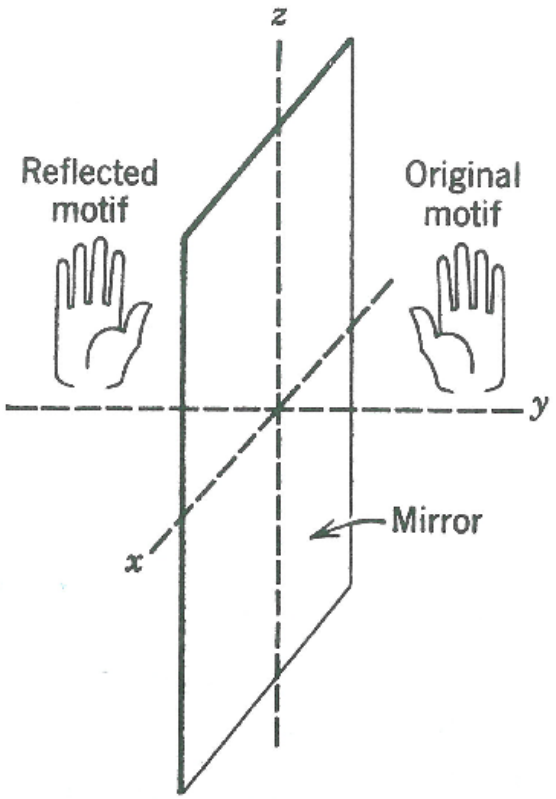
Preuzeto iz Klein (2002)



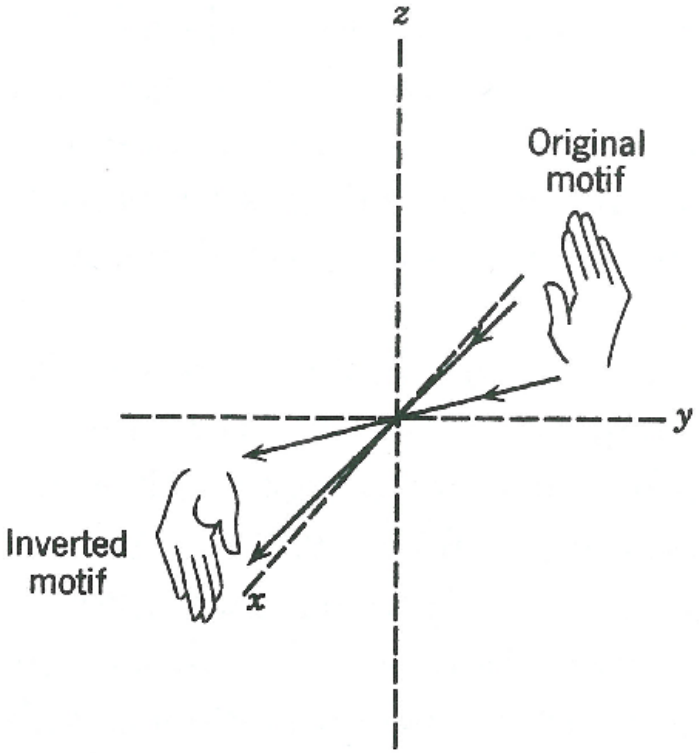
! Moguće su samo osi koje su u skladu s periodičnom građom kristala.

Elementi simetrije

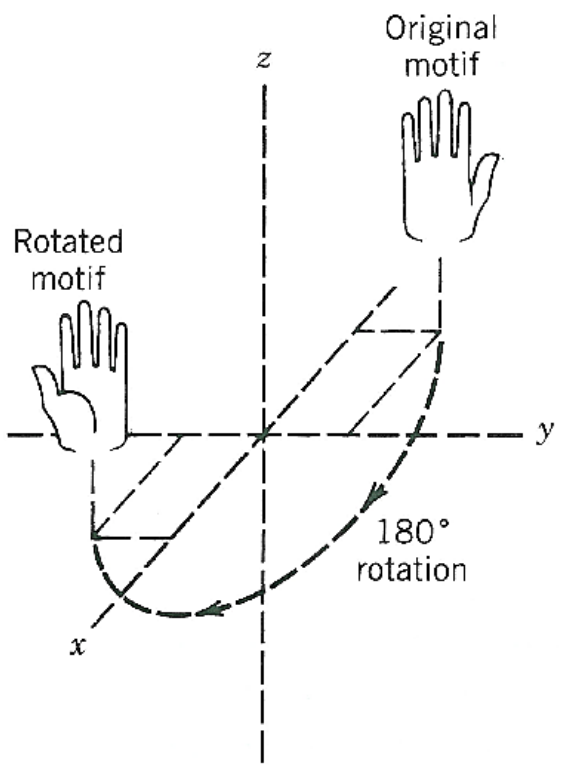
ravnina simetrije (m)



centar simetrije ($\bar{1}$)



digira (2)



Preuzeto iz Klein (2002).

Elementi simetrije

Simetrijska operacija	Element simetrije	Oznake	
		Klasične	Internacionalne
Preslikavanje u točki, inverzija	Centar simetrije	C	$\bar{1}$
Preslikavanje u ravnini, zrcaljenje ili refleksija	Ravnina simetrije, zrcalo	P	m
Rotacija oko pravca	Os simetrije, gira	L^1, L^2, L^3, L^4, L^6	1, 2, 3, 4, 6

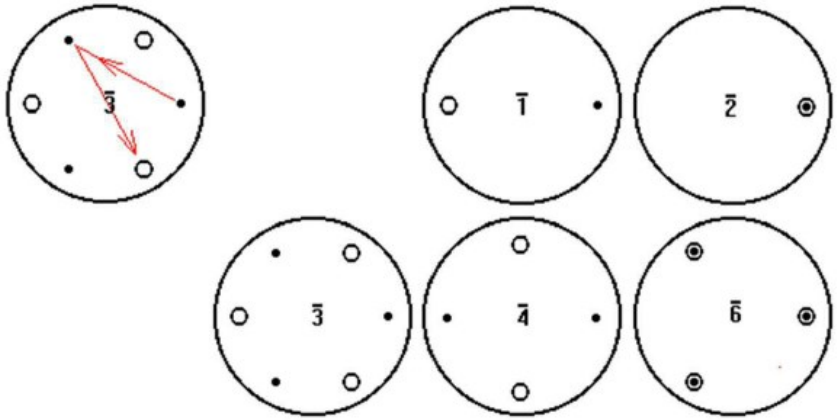
Elementi simetrije

Složene osi simetrije

a) **Rotoinverzne gire**

Rotacija oko osi za 360°, 180°, 120°, 90°, 30°
+
preslikavanje preko centra simetrije koji se nalazi na toj osi (**inverzija**)

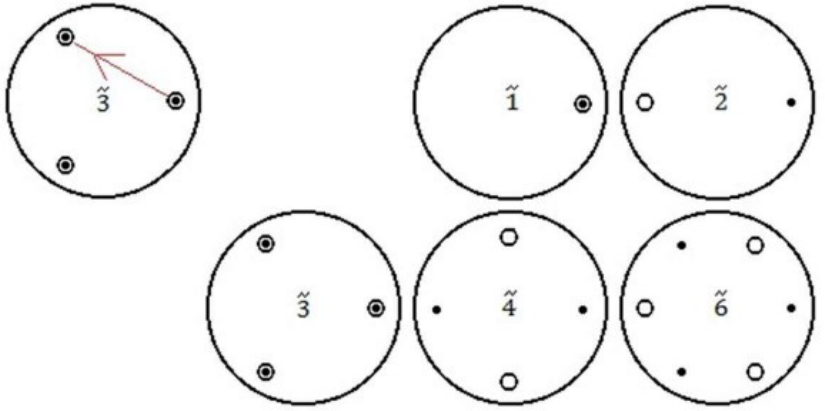
Oznake: $\bar{1}$, $\bar{2}$, $\bar{3}$, $\bar{4}$, $\bar{6}$



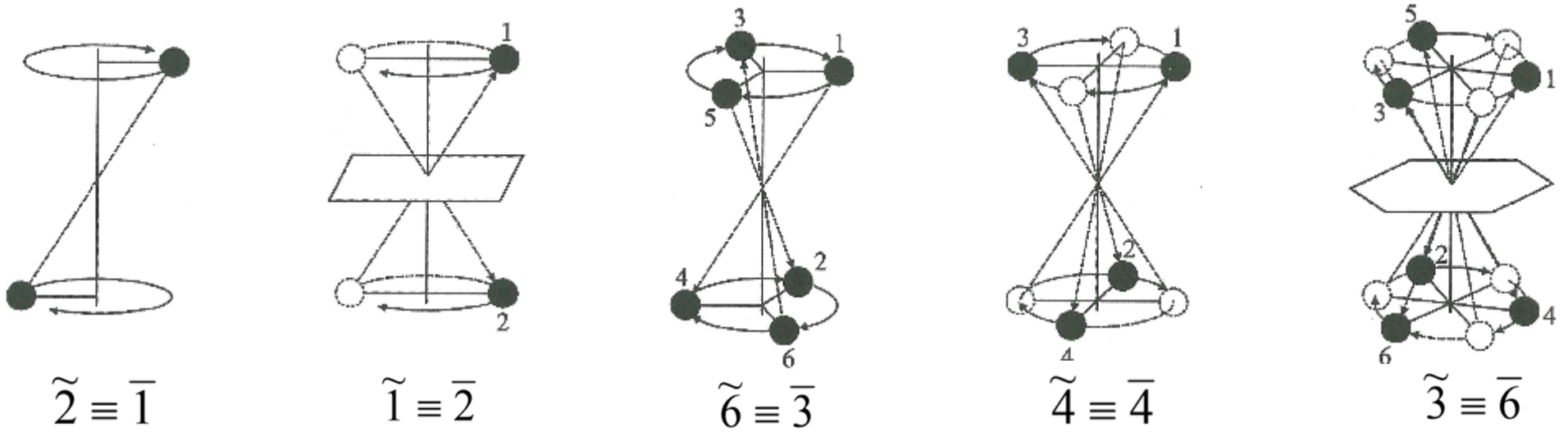
b) **Rotorefleksne gire**

Rotacija oko osi za 360°, 180°, 120°, 90°, 30°
+
preslikavanje preko ravnine simetrije koja je okomita na tu os (**refleksija**)

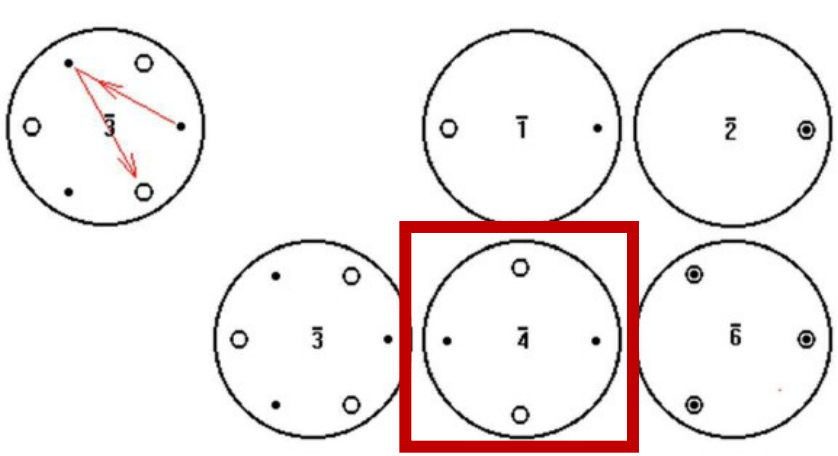
Oznake: $\tilde{1}$, $\tilde{2}$, $\tilde{3}$, $\tilde{4}$, $\tilde{6}$



Elementi simetrije

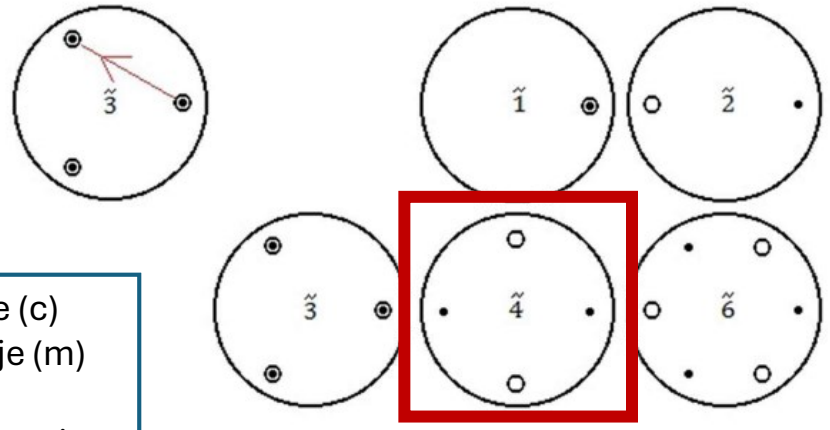


Preuzeto iz Slovenec (2011)



ROTOINVERZNE GIRE

$\bar{1}$ = centar simetrije (c)
$\bar{2}$ = ravnina simetrije (m)
$\bar{3} = 3 + \bar{1} = 3 + c$
$\bar{4}$ = rotoinverzna tetragira
$\bar{6} = 3 \perp \bar{2} = 3 \perp m$



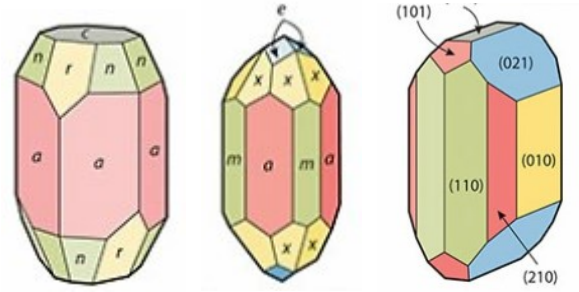
ROTOREFLEKSNE GIRE

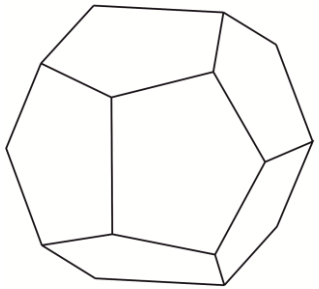
Forma

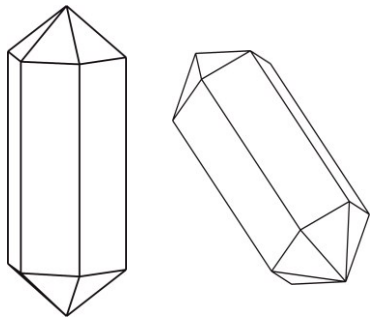
→ skup simetrijski identičnih ploha

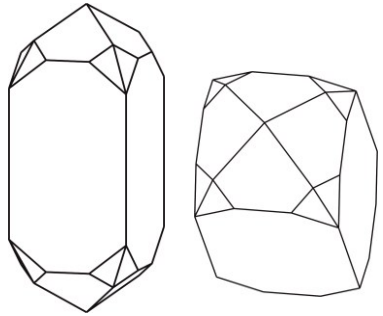
→ skup ploha koje su međusobno povezane elementima simetrije

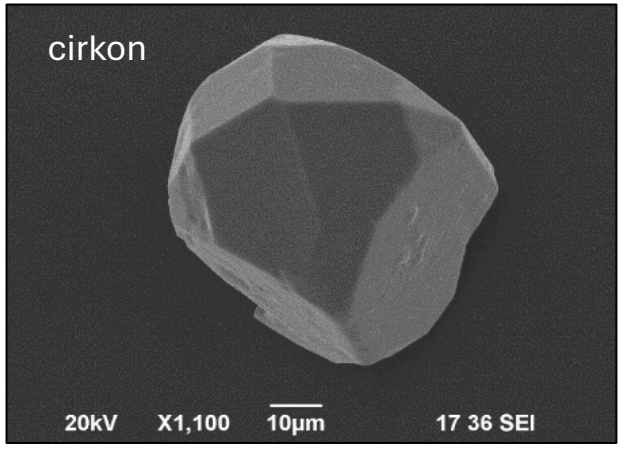
! Sve plohe neke forme imaju isti odnos prema elementima simetrije







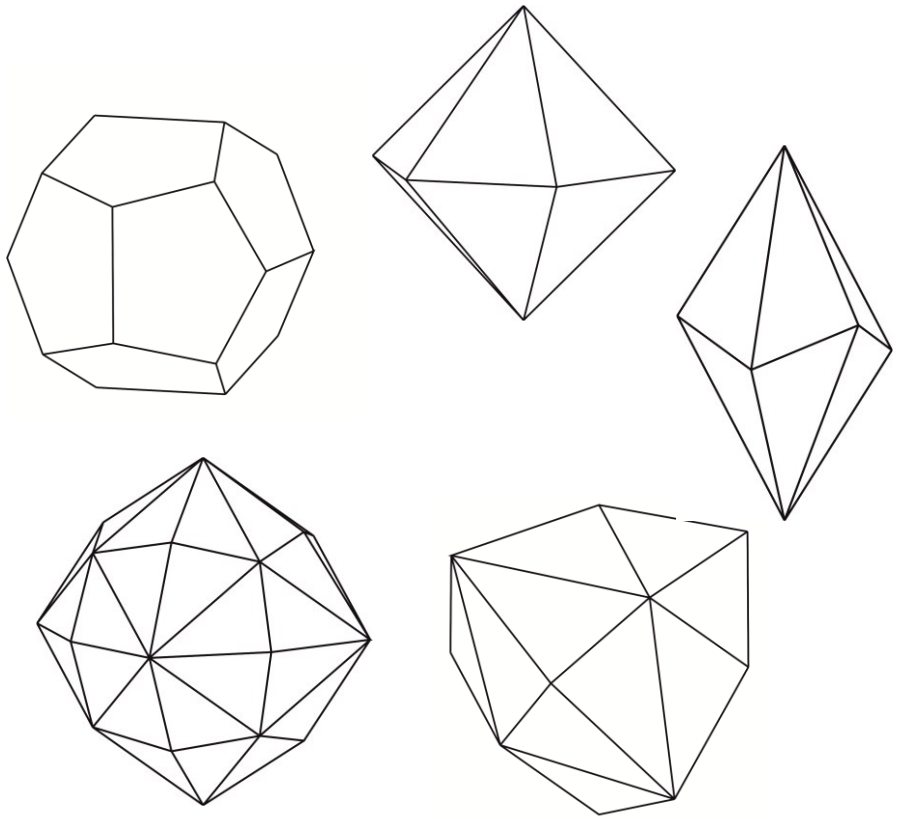




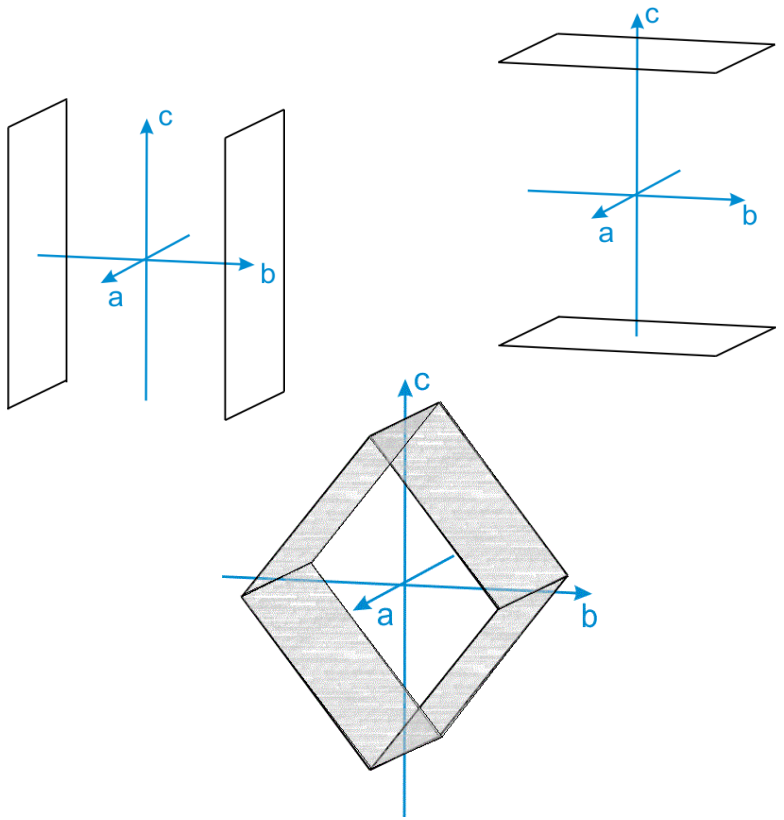
Izvor fotografija: https://www.mindat.org

Forma

Zatvorene
→ forme čije plohe same za sebe zatvaraju određeni volumen



Otvorene
→ forme čije plohe, bez obzira koliko ih produljili, nikada ne mogu same za sebe zatvoriti neki volumen



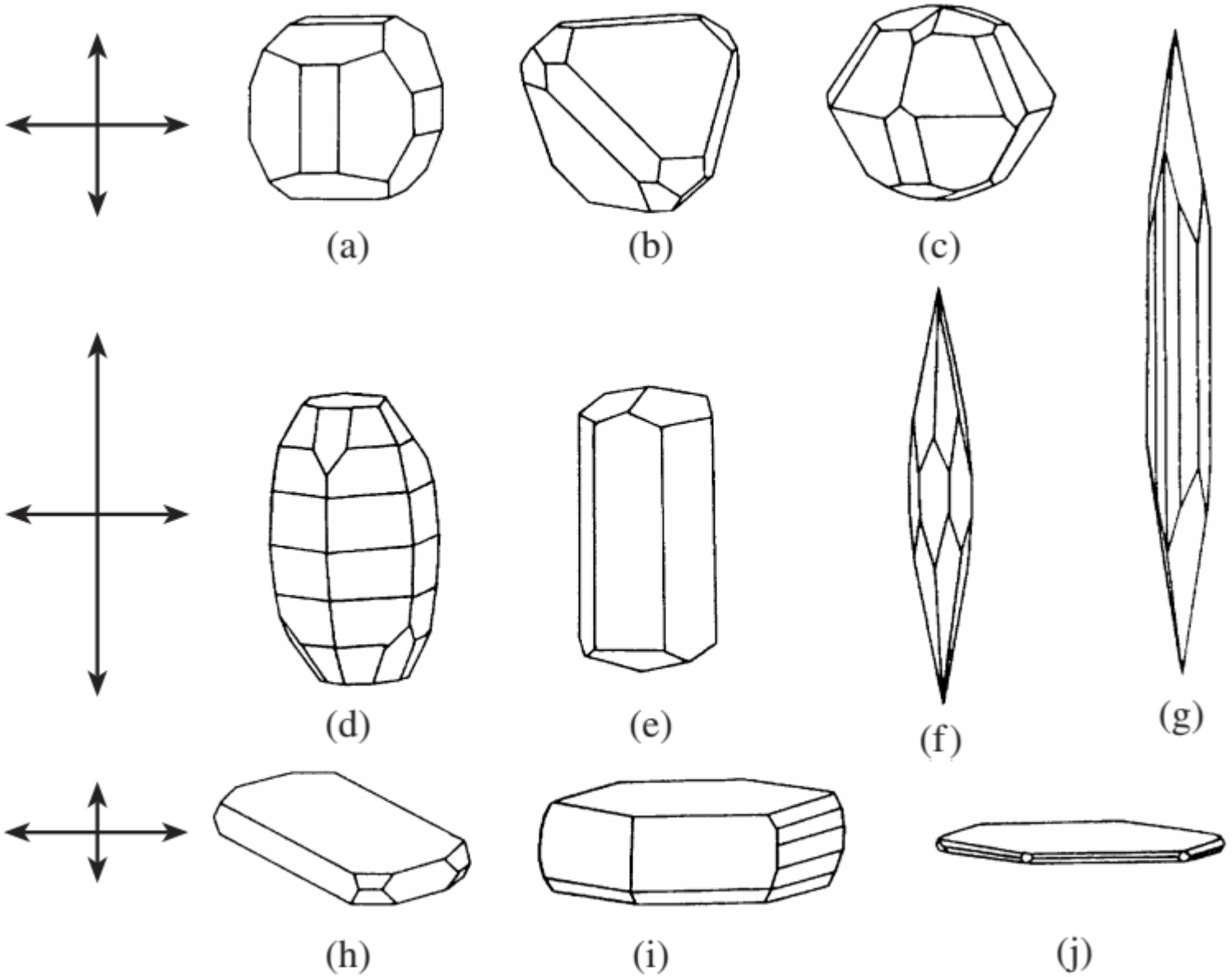
Habitus

→ definira relativne veličine pojedinih ploha, tj. <u>opći oblik kristala</u>

→ posljedica vanjskih utjecaja na rast kristala

Primjer:

- ekvidimenzionalni/izometričan
- pločasti
- prizmatski
- igličast

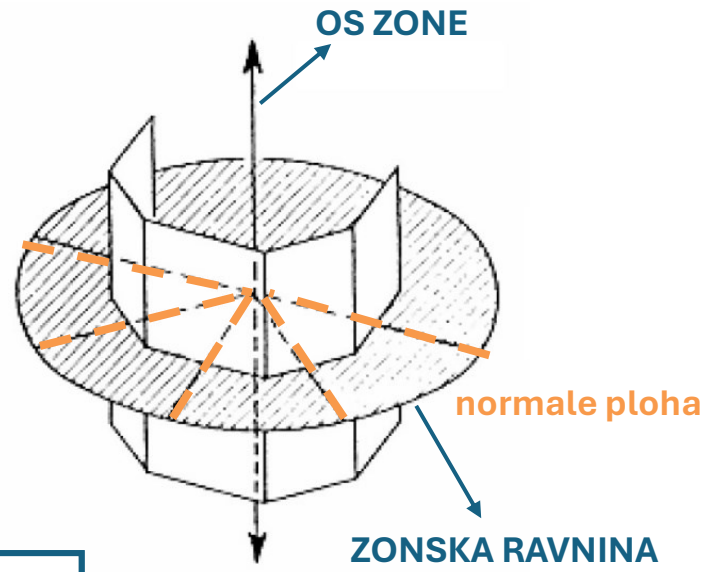


Preuzeto iz Wenk & Bulaks (2006).

Zona

→ skup ploha koje se sijeku (ili bi se sjekle) u paralelnim bridovima

→ sve plohe koje su paralelne s nekim pravcem (= **os zone)**



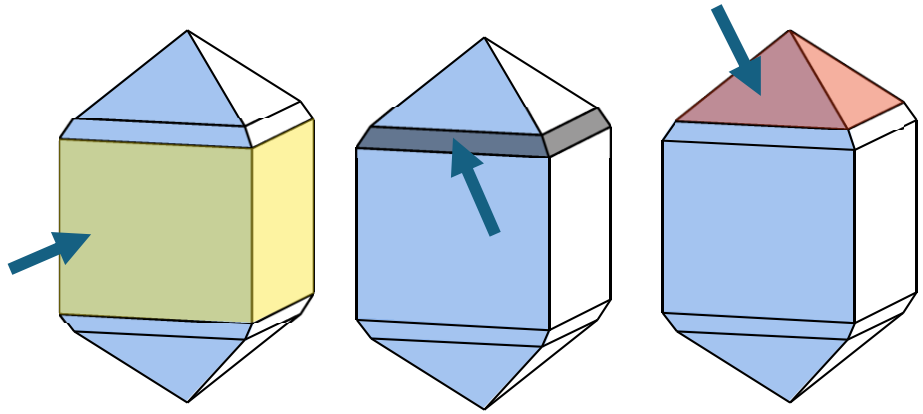
! Os zone je paralelna sa bridovima u kojima se plohe iz te zone sijeku.

Zonska ravnina = ravnina okomita na os zone i na svaku od ploha iz te zone

! Zonu definiraju bilo koje dvije neparalelne plohe, jer postoji samo jedan pravac s kojim su obje paralelne, a on je paralelan s bridom u kojem se te plohe sijeku.

! NORMALE (okomice) ploha koje leže u istoj zoni nalaze u zonskoj ravnini te zone.

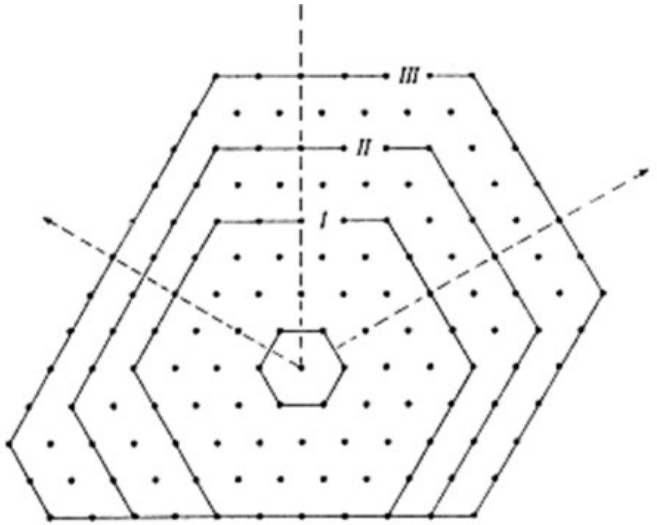
! 3. kristalografski zakon (zakon zona):
Svaka ploha u kristalu leži u presjecištu dvije (ili više) zona.



* broj zona u kojoj se nalazi jedna ploha = broj neparalelnih bridova te plohe

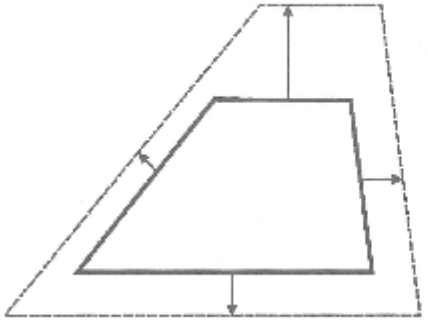
Nastanak kristala

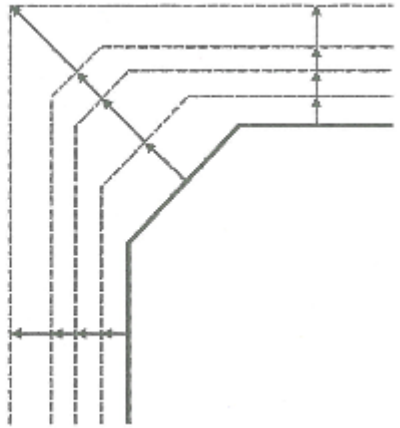
→ proces KRISTALIZACIJE iz otopina, taljevina ili para: neuređeno stanje sa slučajnim rasporedom atoma → promjena T, p, c → atomi se udružuju u uređeni raspored → kristalno stanje



- Nukleacija = nastanak jezgre kristalizacije
- Rast jezgre u kristal – jezgra privlači druge slobodne ione, koji zauzimaju svoja mjesta na njezinim plohama

Kristalne plohe pomiču se pri rastu uvijek paralelno svom prvotnom položaju i uvijek su paralelne s mrežnim ravninama, koje imaju uvijek isti položaj određen parametrima jedinične ćelije karakterističnim za pojedine minerale.

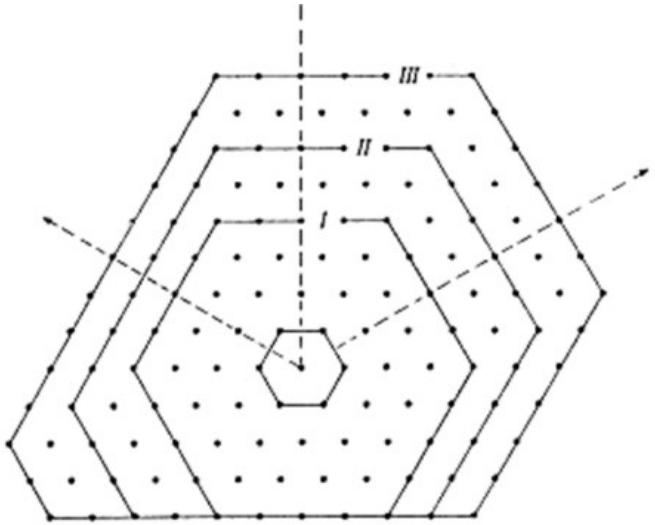


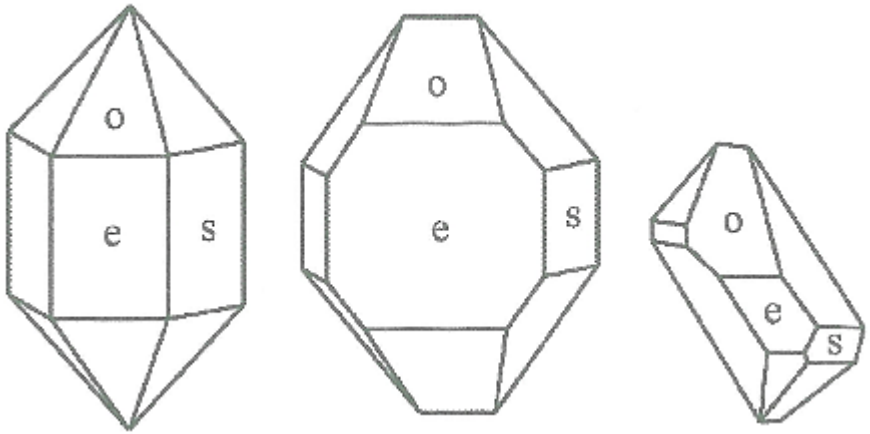


Preuzeto iz Slovenec (2011)

Nastanak kristala

! 1. kristalografski zakon (zakon o stalnosti kutova):
U različitim uzorcima istog minerala, kutovi između odgovarajućih ploha su isti pri konstantnoj temperaturi i tlaku.

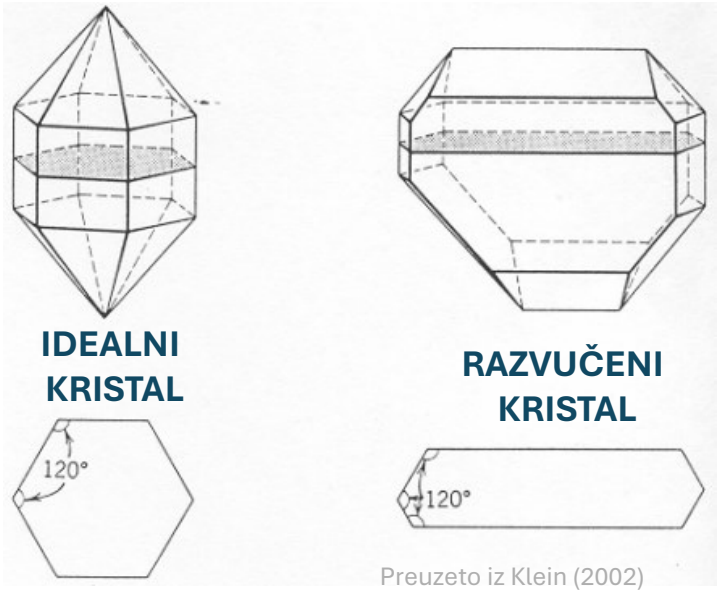




IDEALNI KRISTAL

RAZVUČENI KRISTALI
simetrijski identične plohe
nisu geometrijski jednake

Preuzeto iz Slovenec (2011)



Preuzeto iz Klein (2002)

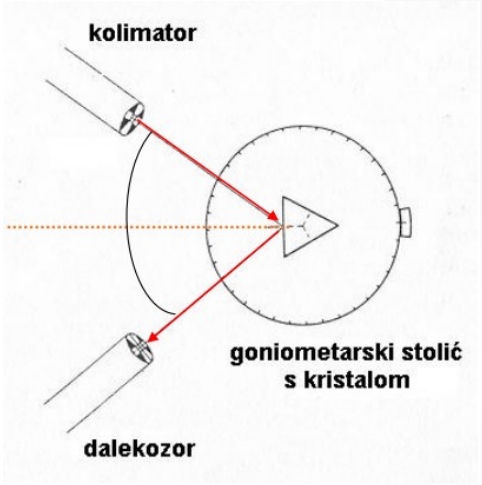
! Kutovi među plohama karakteriziraju kristal.

→ mogu definirati simetriju

→ mogu se koristiti pri identifikaciji minerala

GONIOMETAR

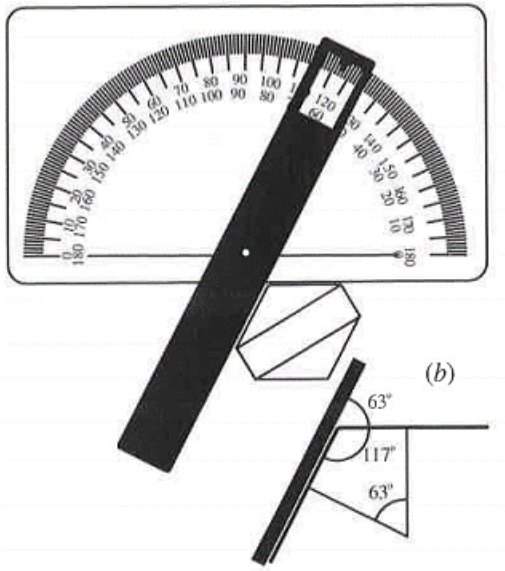
- kontaktni
- refleksni

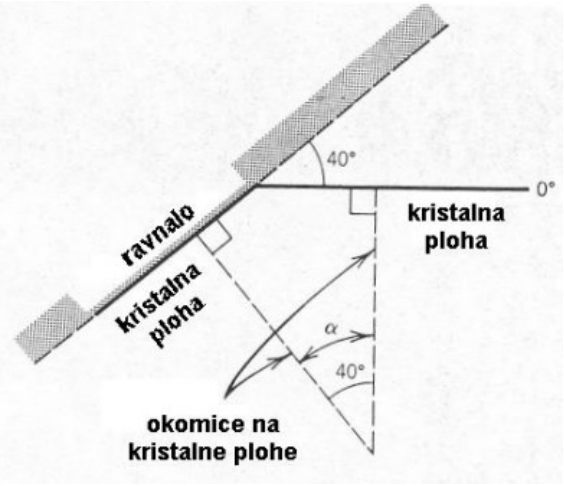


1780. Carangeot
Contact gonimeter

1986. Victor Goldschmidt
two-circle contact goniometer

Preuzeto iz Klein (2002)





Izvor fotografija: https://mineralogy.eu/gonio/introGONIO.html