Hashemite University

Faculty of Natural Resources and Environment

Department of earth and environmental sciences

Lab1: Mineral Physical Properties

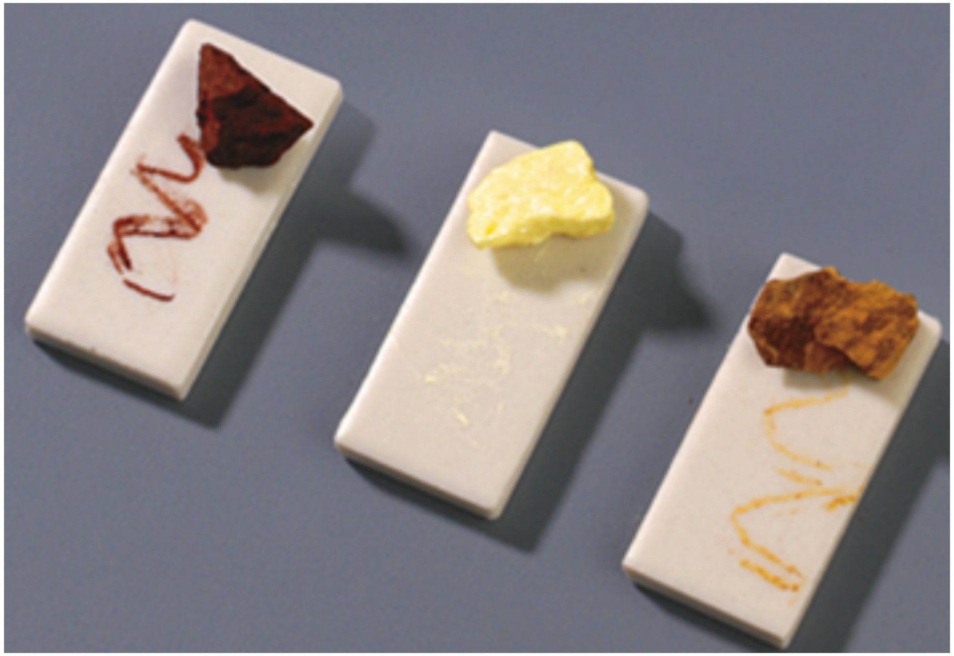
The Physical Properties of Minerals

- Color
- Streak
- Luster
- Hardness
- Cleavage

- Fracture
- Specific Gravity
- External Crystal Form
- Diapheneity
- Other Properties(Chemical Tests, odor, magnetism, reaction with HCl)

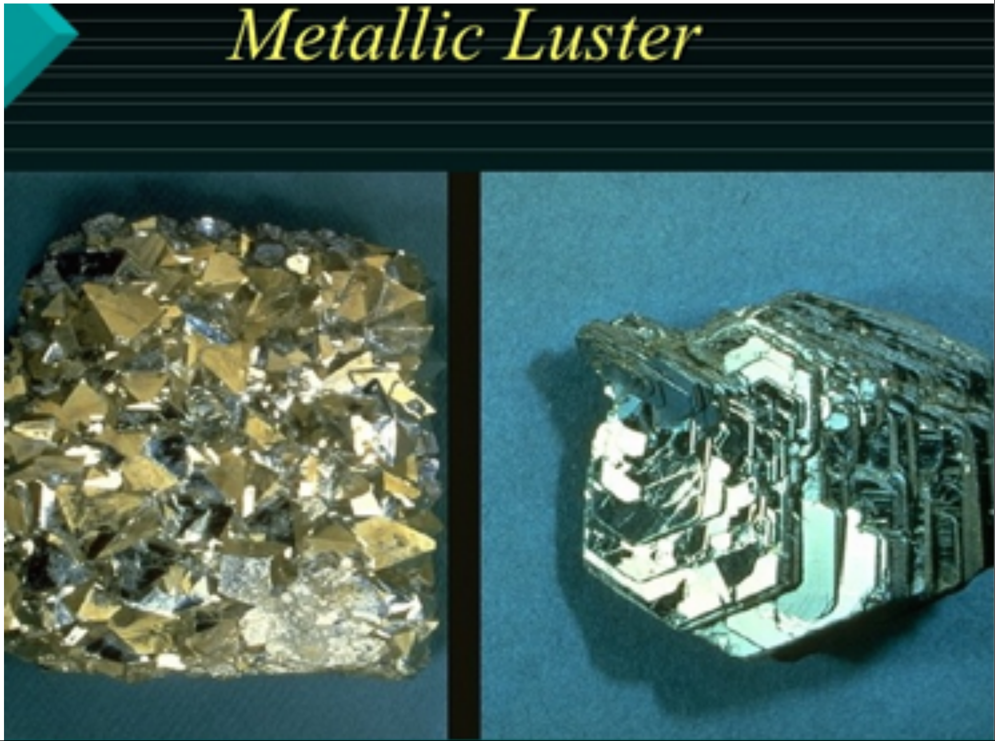
- **Color -** Although an obvious feature, it is often unreliable to use to determine the type of mineral.
  - Color arises due to electronic transitions, often of **trace** constituents, in the visible range of the EM spectrum. For example, quartz is found in a variety of colors.
- Color of a mineral may be quite diagnostic for the trace element and coordination number of its bonding environment.

- **Streak -** The color of a mineral in its powdered form; obtained by rubbing the mineral against an unglazed porcelain plate.
  - Streak is usually less variable than color.
  - Useful for distinguishing between minerals with metallic luster.

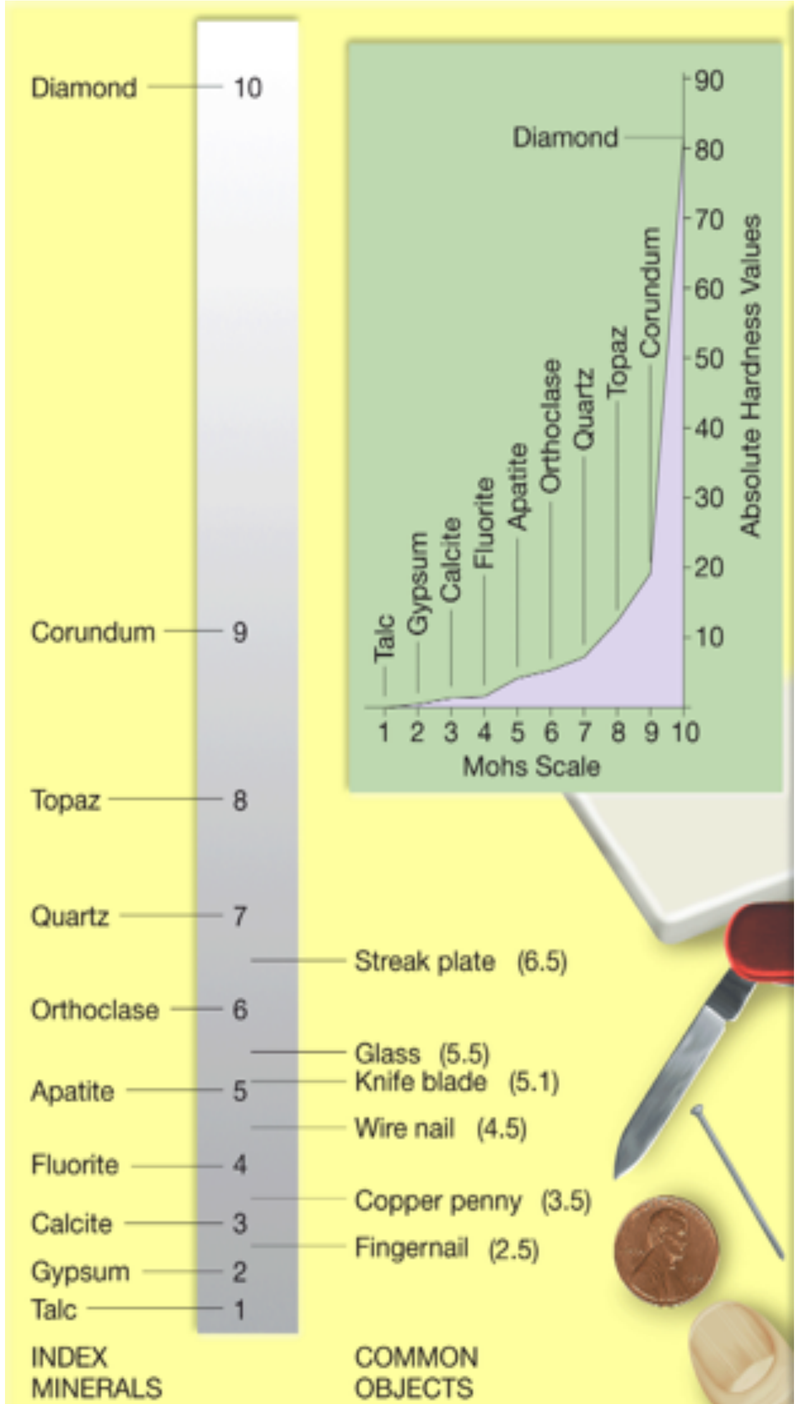


- **Luster -** This property describes the appearance of reflected light from the mineral's surface. Nonmetallic minerals are described using the following terms: vitreous, pearly, silky, resinous, and earthy.


Luster
Metallic
Galena
Greasy-Graphite
Pearly-Talc
Non-Metallic
Earthy-Shale
Photos by Dr. Steve Mattox


Metallic Luster

- **Hardness** - This is the resistance of the mineral to abrasion or scratching. This property doesn't vary greatly from sample to sample of the same mineral, and thus is highly diagnostic. It also is a direct reflection of the bonding type and internal atomic arrangement. A value is obtained by comparing the mineral to a standard scale devised by **Moh**, which is comprised of 10 minerals ranging in hardness from **talc** (softest) to **diamond** (hardest).



Mohs' Hardness Scale

- **Cleavage -** Orientation and number of planes of weakness within a mineral. Directly reflects the orientation of weak bonds within the crystal structure. This feature is also highly diagnostic.

- **Fracture -** This describes how a mineral breaks if it is not along well defined planes. In minerals with low symmetry and highly interconnected atomic networks, irregular fracture is common.

Weak Bonding Yields Planer Cleavage

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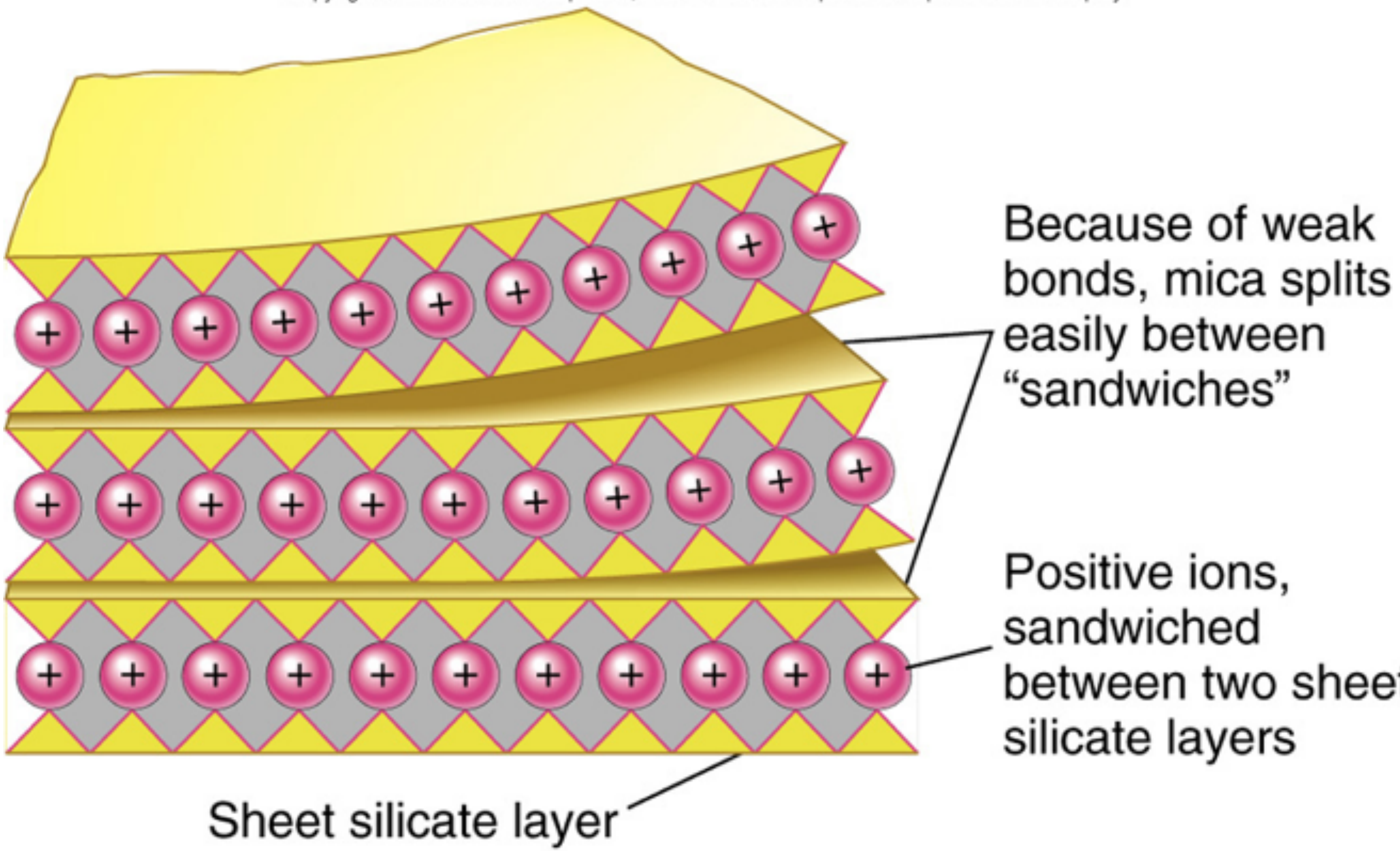

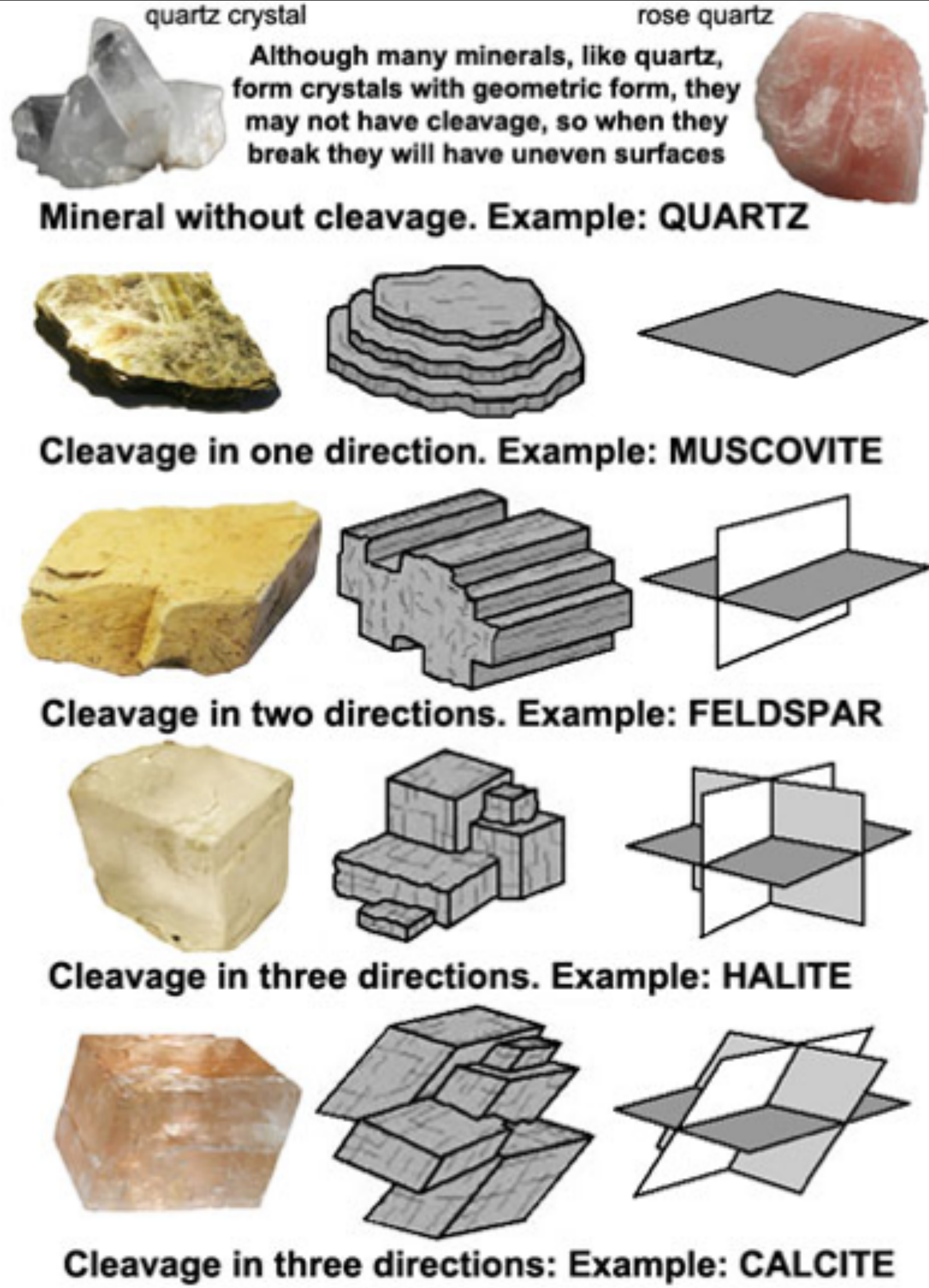
quartz crystal
rose quartz
Although many minerals, like quartz, form crystals with geometric form, they may not have cleavage, so when they break they will have uneven surfaces
Mineral without cleavage. Example: QUARTZ
Cleavage in one direction. Example: MUSCOVITE
Cleavage in two directions. Example: FELDSPAR
Cleavage in three directions. Example: HALITE
Cleavage in three directions: Example: CALCITE

Amphibole Cleavage ~120/60°

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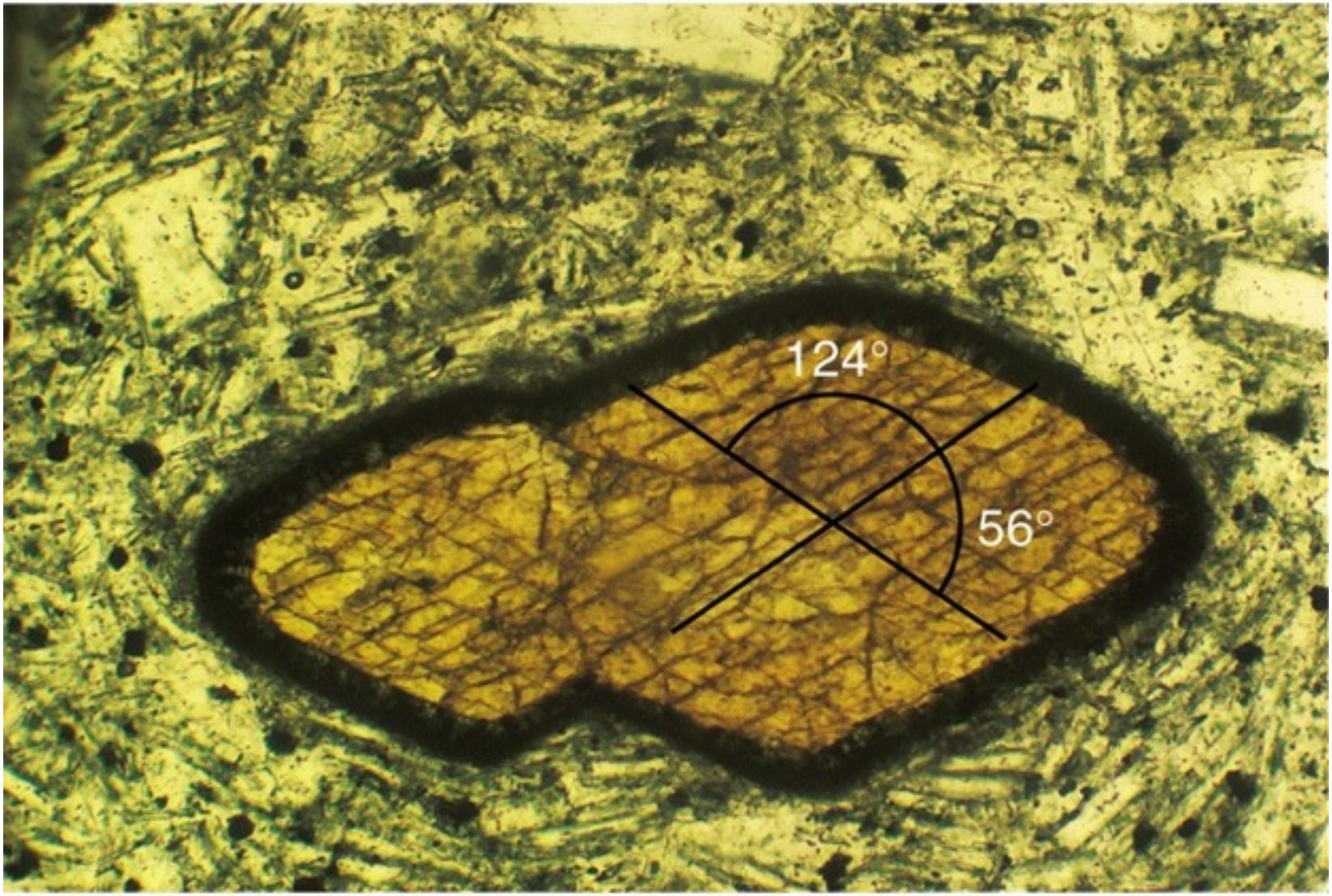

Photo by C. C. Plummer

Rhombohedral Cleavage in Calcite

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Conchoidal Fracture in Glass

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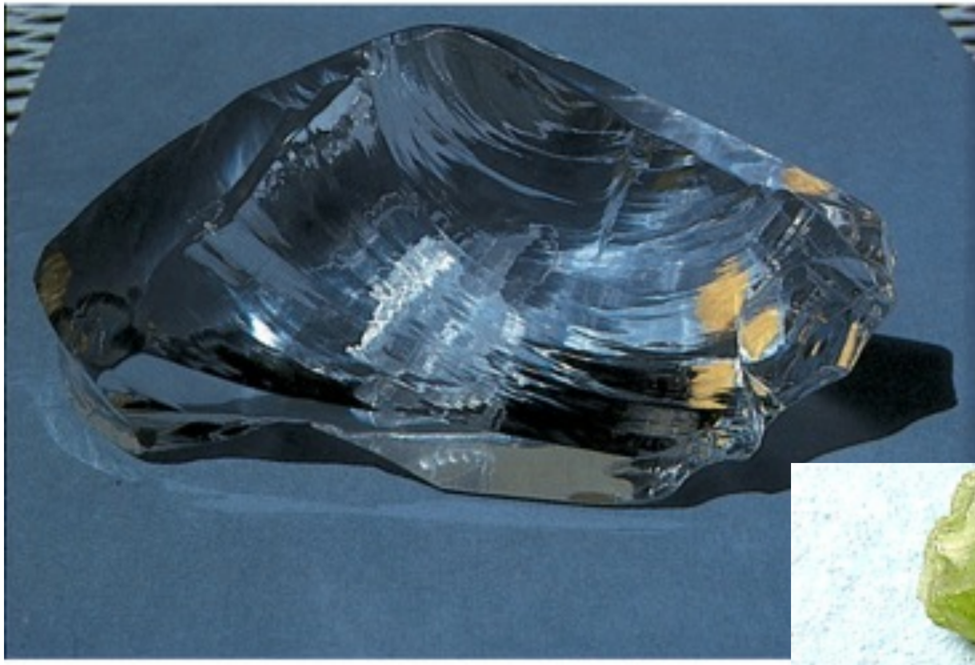
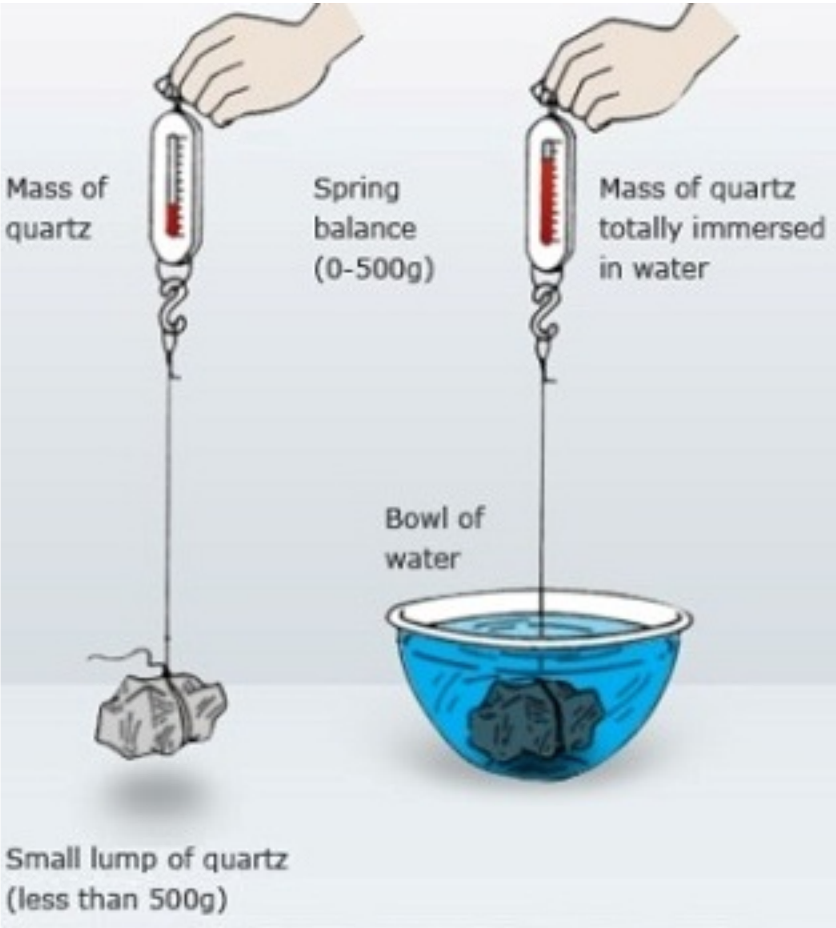


Photo by C. C. Plummer

Specific Gravity

- **Specific Gravity** - Ratio of the mass of a substance to the mass of an equal volume of water. Note that $r_{water} = 1$ g cm^{-3}. S.G. is unitless.

- **Examples** - quartz (SiO_2) has a S.G. of 2.65 while galena (PbS) has a S.G. of 7.5 and gold (Au) has a S.G. of 19.3.



Color and Density

- **Two broad categories are ferromagnesian and nonferromagnesian silicates**, which simply means iron and magnesian bearing or not. The presence or absence of Fe and Mg strongly affects the external appearance (color) and density of the minerals.

- **Ferromagnesian silicates -** dark color, density range from 3.2 - 3.6 g/cc
  - **Olivine -** high T, low silica rocks; comprises over 50% of upper mantle
  - **Pyroxenes -** high T, low silica rocks
  - **Amphiboles -** esp. hornblende; moderate T, higher silica rocks
  - **Mica -** esp. biotite; moderate T, higher silica rocks
  - **Garnet -** common metamorphic mineral

- **Nonferromagnesian silicates -** light color, density close to 2.7 g/cc
  - **Mica** - exp. muscovite; moderate T, higher silica rocks
  - **Feldspars** - plagioclase and orthoclase; most common mineral in crust; form over a wide range of temperatures and melt compositions
  - **Quartz -** low T, high silica rocks; extremely stable at surface, hence it tends to be a major component in sedimentary rocks.
  - **Clay** - esp. kaolinite; different types found in different soils

- **Crystal form or habit:** The external morphology of crystals generally reflect the internal arrangement of their constituent atoms. This can be obscured, however, if the mineral crystallized in an environment that did not allow it to grow without significant interaction with other crystals (even of the same mineral).


granular, as in marble
lamellar, foliated, micaceous, as in mica
bladed, as in actinolite
fibrous, as in asbestos
acicular (needlelike), radiating, as in millerite
radiating and globular, as in wavellite
dendritic, as in pyrolusite
mammillated, botryoidal, as in hematite
colloform, stalactitic, as in cave deposits
large crystals
chalcedony
opening
geode
oöid
quartz and hematite cement
oölitic, as in oölitic limestone

Diapheneity is the amount of light transmitted or absorbed by a solid. It is used strictly for hand specimens because most minerals that are opaque as hand specimen becomes transparent when very thin.

1. **Transparent**: object behind it can be seen clearly, Eg., **Qua, Cal, Flu**.
2. **Translucent**: light transmitted but the object cannot be seen
3. **Opaque**: light is wholly absorbed, Eg., **Mat, Hem**.


Some *Transparent* Examples:
TRANSPARENT
TRANSLUCENT
OPAQUE

Mineralogy
Dr.Faten Slaty
G.Wafa Arqan

Lab sheet #1
Physical properties of minerals

Student name:
Section:

Mineral Name / No.	Mineral Class	Color	Streak	Luster	Cleavage	Fracture	Hardness	Sp.G	Habit	Diapheneity	Other

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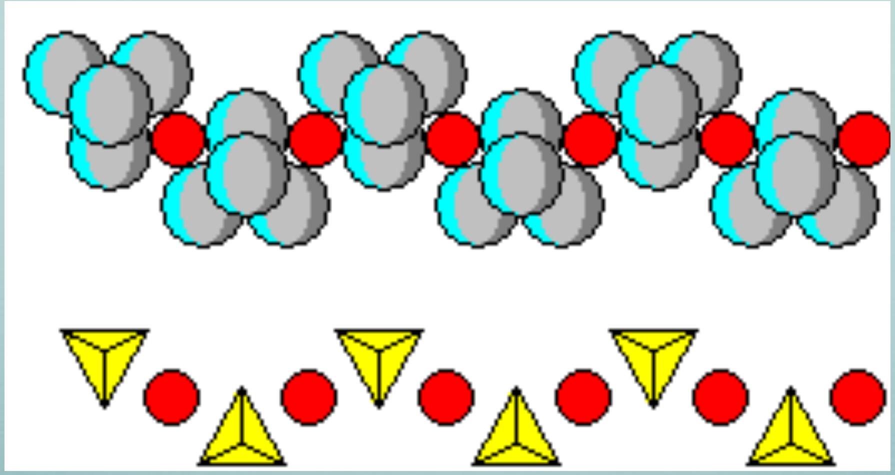
Lab 2: Crystal System



Crystallography

Science study the crystalline solids and the principles that govern their growth, external shape (Geometry), and internal structure.

A crystal is a solid object with a geometric shape that reflects a regular internal structure.

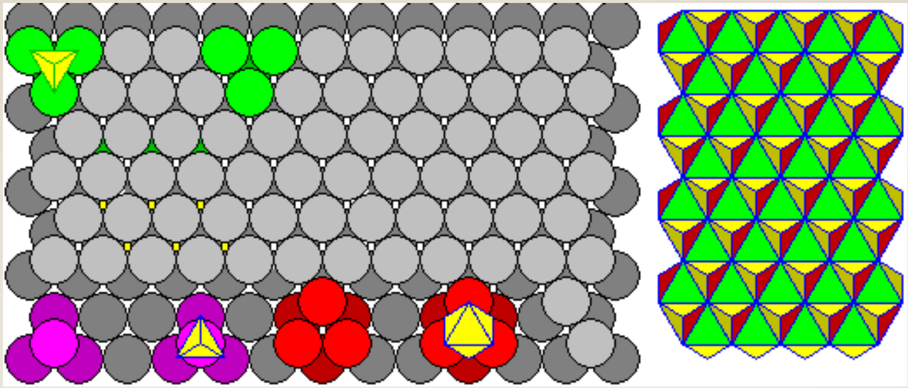
Crystallization Processes

- different media (liquid, solid, gas) have ions in random case
- change in conditions needed (T,P,X)
- repetition of unit (atoms, anionic group, molecules, ions, combination) in 3D must be

Very slow cooling of a liquid allows atoms to arrange themselves into an ordered pattern, which may extend of a long range (millions of atoms).

This kind of solid is called crystalline.

Space lattices: is "a 3–Dimensional array of points in space that can be repeated indefinitely".

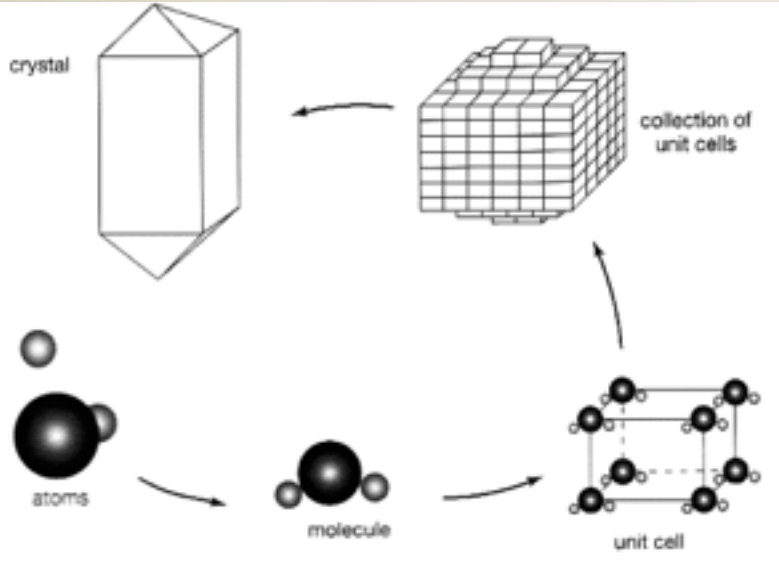


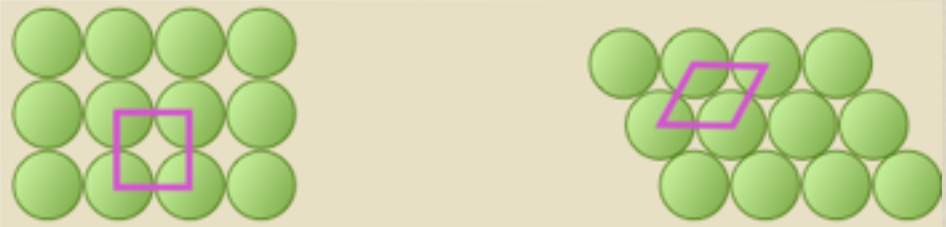
- All "points" in a lattice have identical environments these "points" known as **motifs** or **unit cells** may be considered atoms, ions, or groups of atoms / ions.

- The repetition of those unit cells in a space lattice is performed by certain **operations** which build the space lattice.

Building a space lattice: from motifs to lattices:

Motif → Line lattice → Plane lattice → Space Lattice





Crystal Morphology

Crystal Faces: the regular internal structure of a mineral is manifested by the development of surfaces that define the shape of the crystal, and which may be related to one another by certain elements of symmetry.

- **Bravais Law**: states that the frequency by which a face is observed in a crystal is directly proportional to the number of "points" it intersects in a lattice.

- **Factors affecting the morphology of a crystal (conditions of growth):**

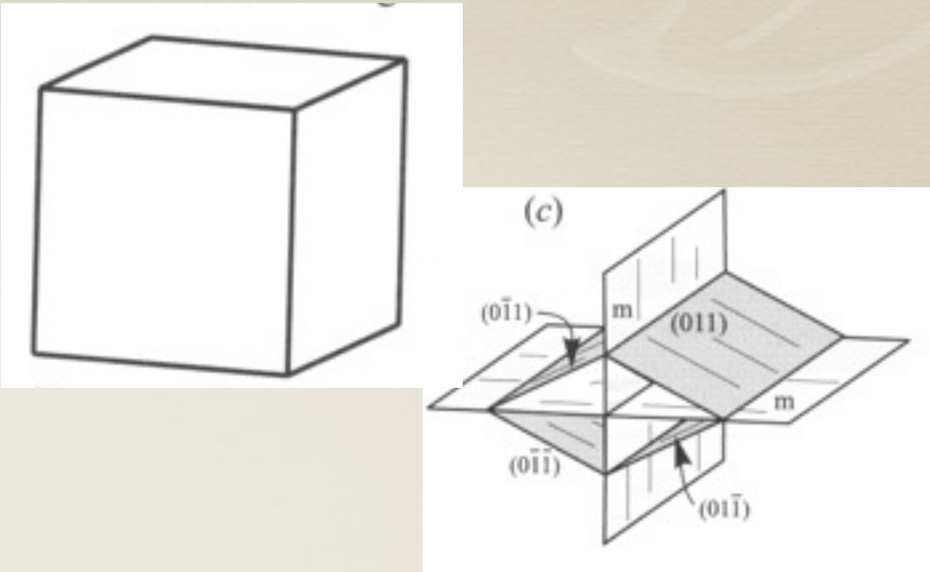
1. T
2. P
3. solutions available
4. direction of solution flow
5. availability of open space.

- **Steno's Law**: The angles between these faces (known as the **interfacial angles**) are always constant for the same mineral (at the same temperature).

Crystal Forms:

Two or more faces having the same geometric relations to the crystallographic axes, and the same shape, and which are related to each other by some element of symmetry in a crystal.

Distribution of minerals among the different crystal systems:



1. 26% cubic,
2. 21% monoclinic,
3. 20% Orthorhombic.

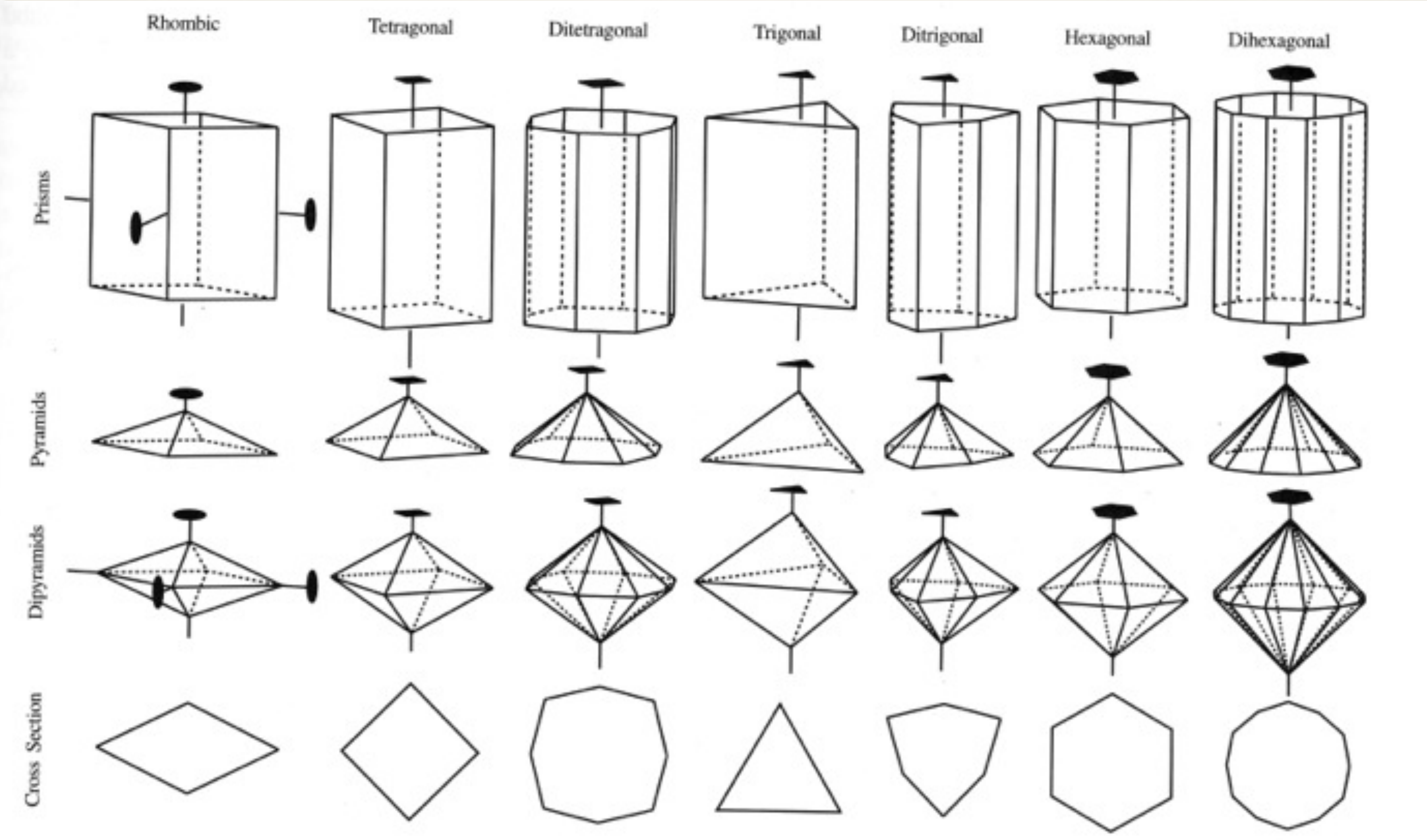
Two types of forms:

- Open form – one or more faces that do not completely enclose space

- Closed form – faces that completely enclose space

There are 32 forms in the **nonisometric** (noncubic) crystal systems and another 15 forms in the **isometric** (cubic) system.

Three types – seven modifiers – total of 21 forms



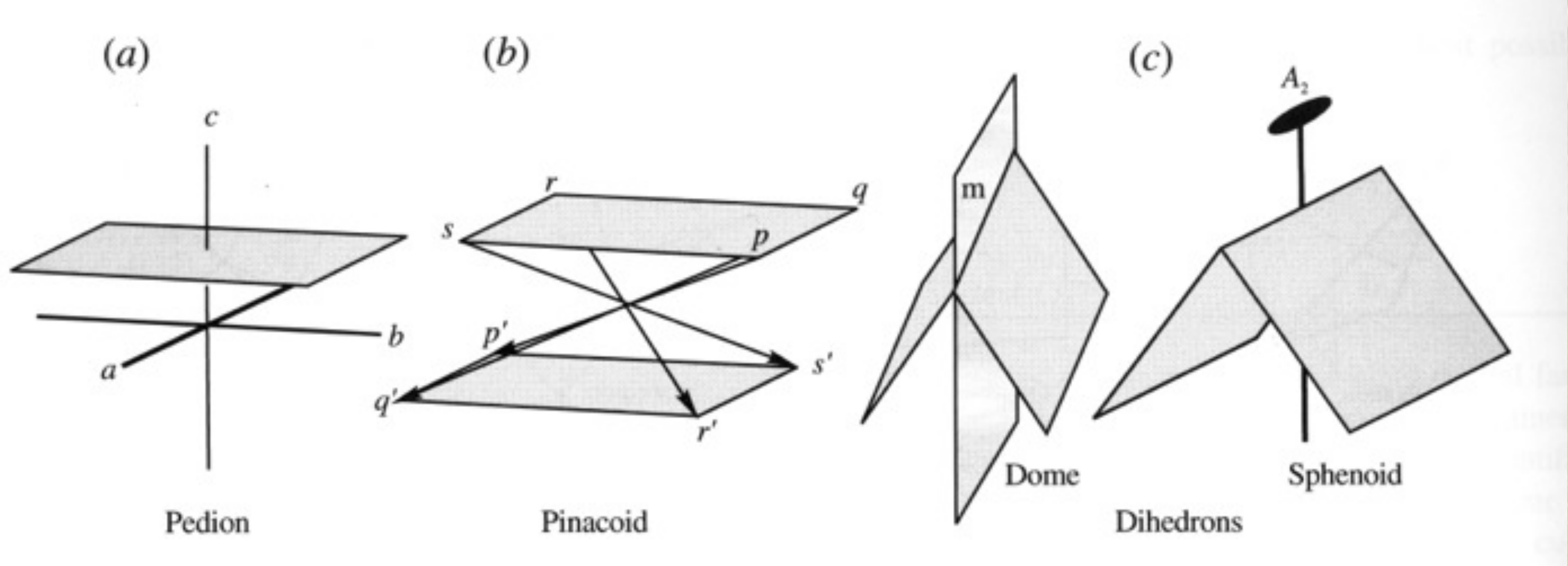
Isometric Crystal Forms

Name	Number of Faces	Name	Number of Faces
 (1) Cube	6	 9)Tristetrahedron	12
 (2) Octahedron	8	 (10) Hextetrahedron	24
 (3) Dodecahedron	12	 (11) Deltoid dodecahedron	24
 (4) Tetrahexahedron	24	 (12) Gyroid	24
 (5) Trapezohedron	24	 (13) Pyritohedron	12
 (6) Trisoctahedron	24	 (14) Diploid	24
 (7) Hexoctahedron	48	 (15) Tetartoid	12
 (8) Tetrahedron	4		

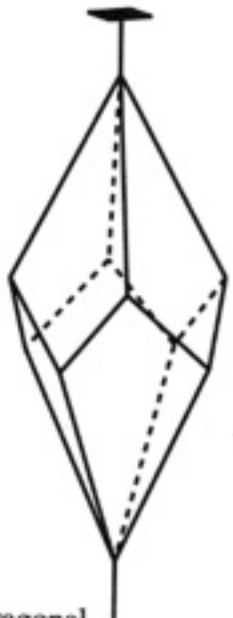
Non-isometric form

10 types of forms

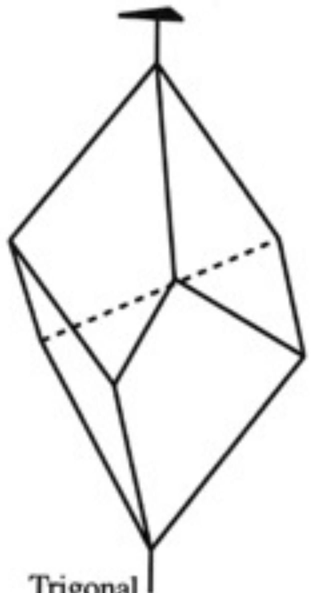
- Pedion (open): Single face
- Pinacoid (open): Two parallel faces
- Dihedron (open): Two non-parallel face



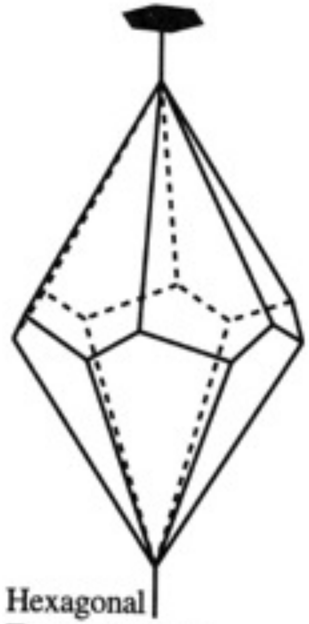
- Trapezohedrons (closed)
  - 6, 8, 12 faces
- Scalenohedron (closed)
  - 8 or 12 faces
  - Each a scalene triangle (no two angles are equal)
- Rhombohedrons (closed)
  - 6 faces, each rhomb shaped (4 equal sides, no 90 angles)
- Tetrahedron (closed)
  - 4 triangular faces



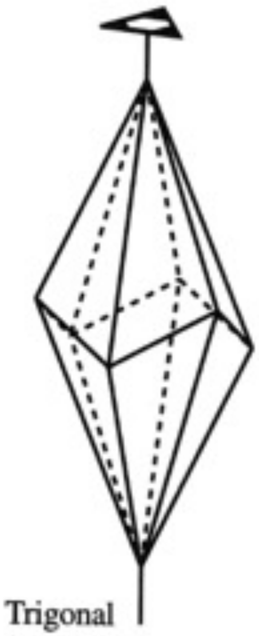
Tetragonal Trapezohedron



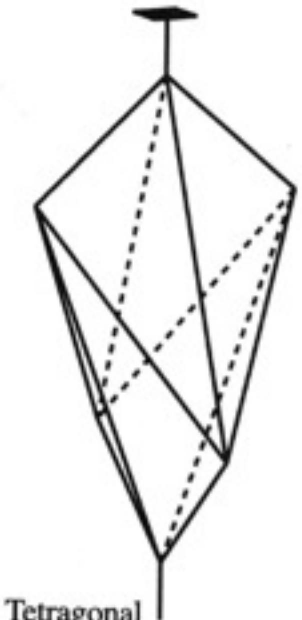
Trigonal Trapezohedron



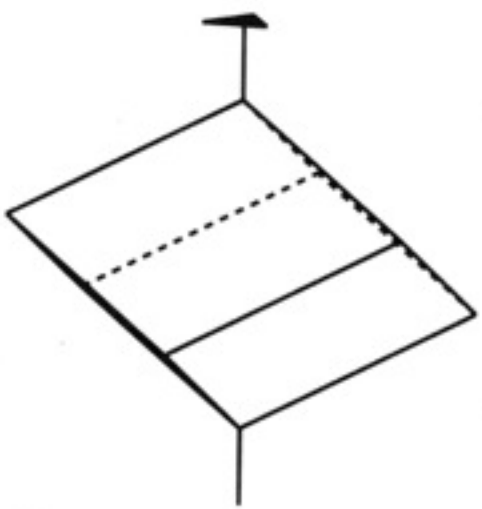
Hexagonal Trapezohedron



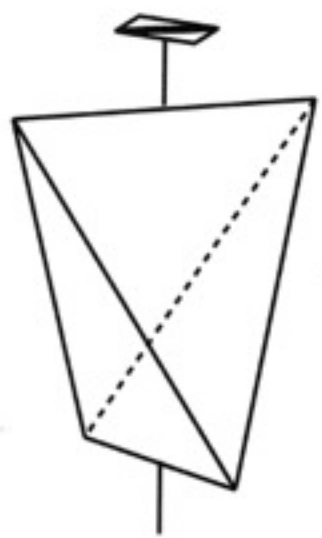
Trigonal Scalenohedron



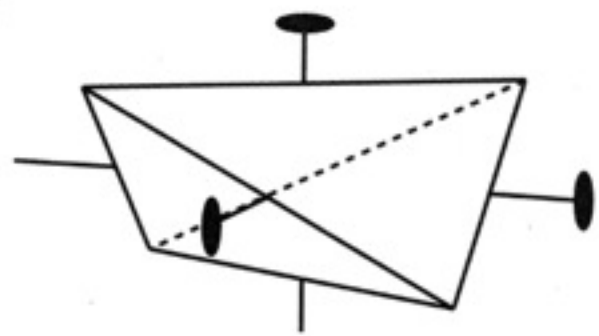
Tetragonal Scalenohedron



Rhombohedron



Tetragonal Tetrahedron
(Tetragonal Disphenoid)

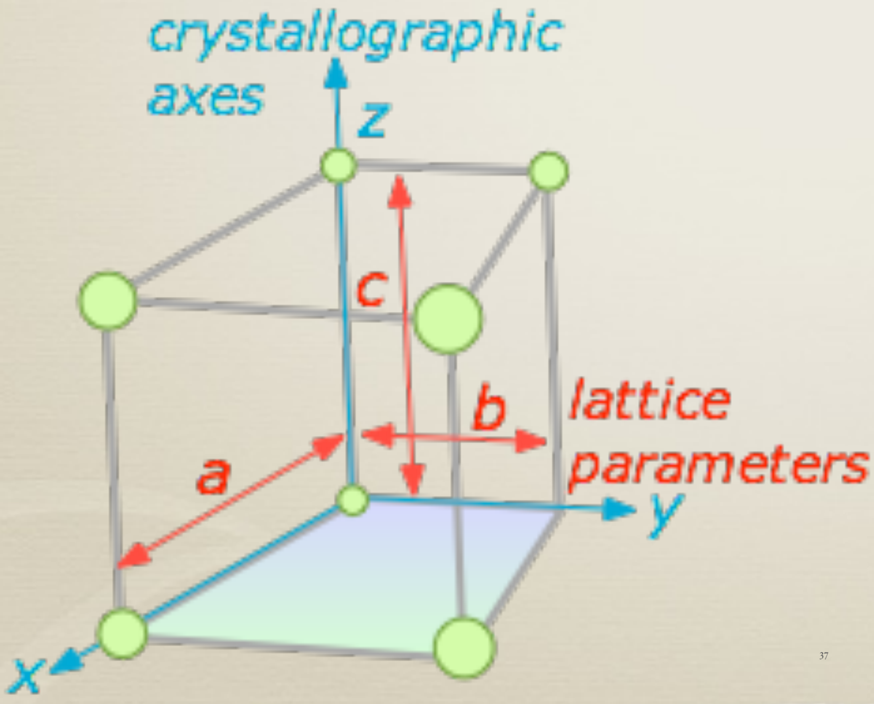


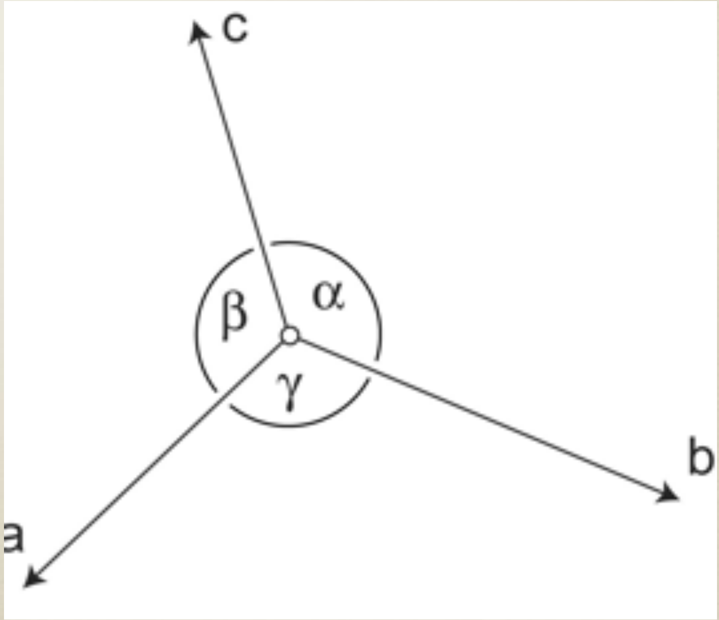
Rhombic Tetrahedron
(Rhombic Disphenoid)

Crystal parts:

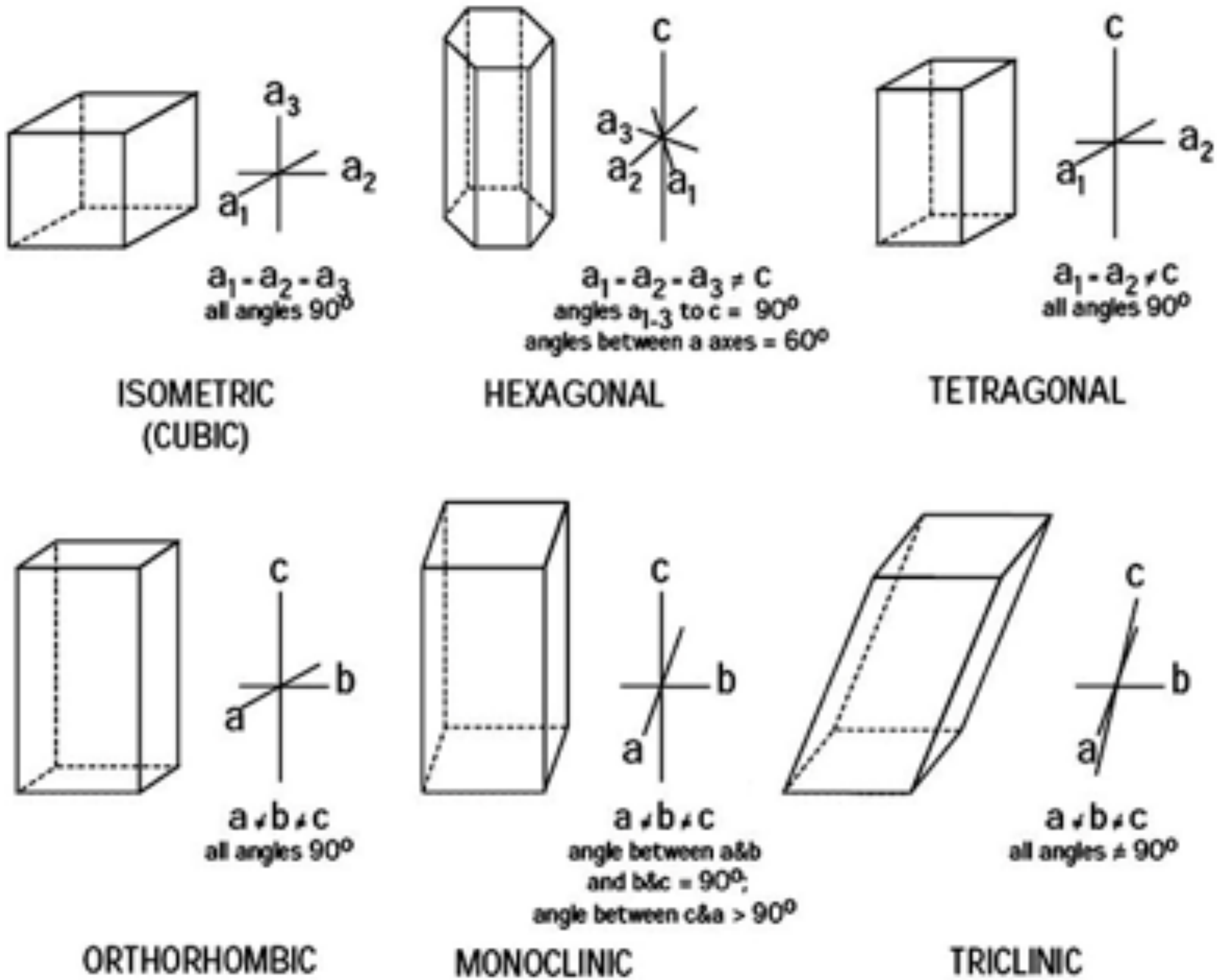
1. **Crystal axes** are imaginary lines of reference inside a crystal that intersect at a crystal centre. Any crystal has either 3 or 4 axes (a, b and c or a1,a2,a3,c).

2. **Interaxial angles** :The angles between these axes are known as the(alpha, beta and gama).

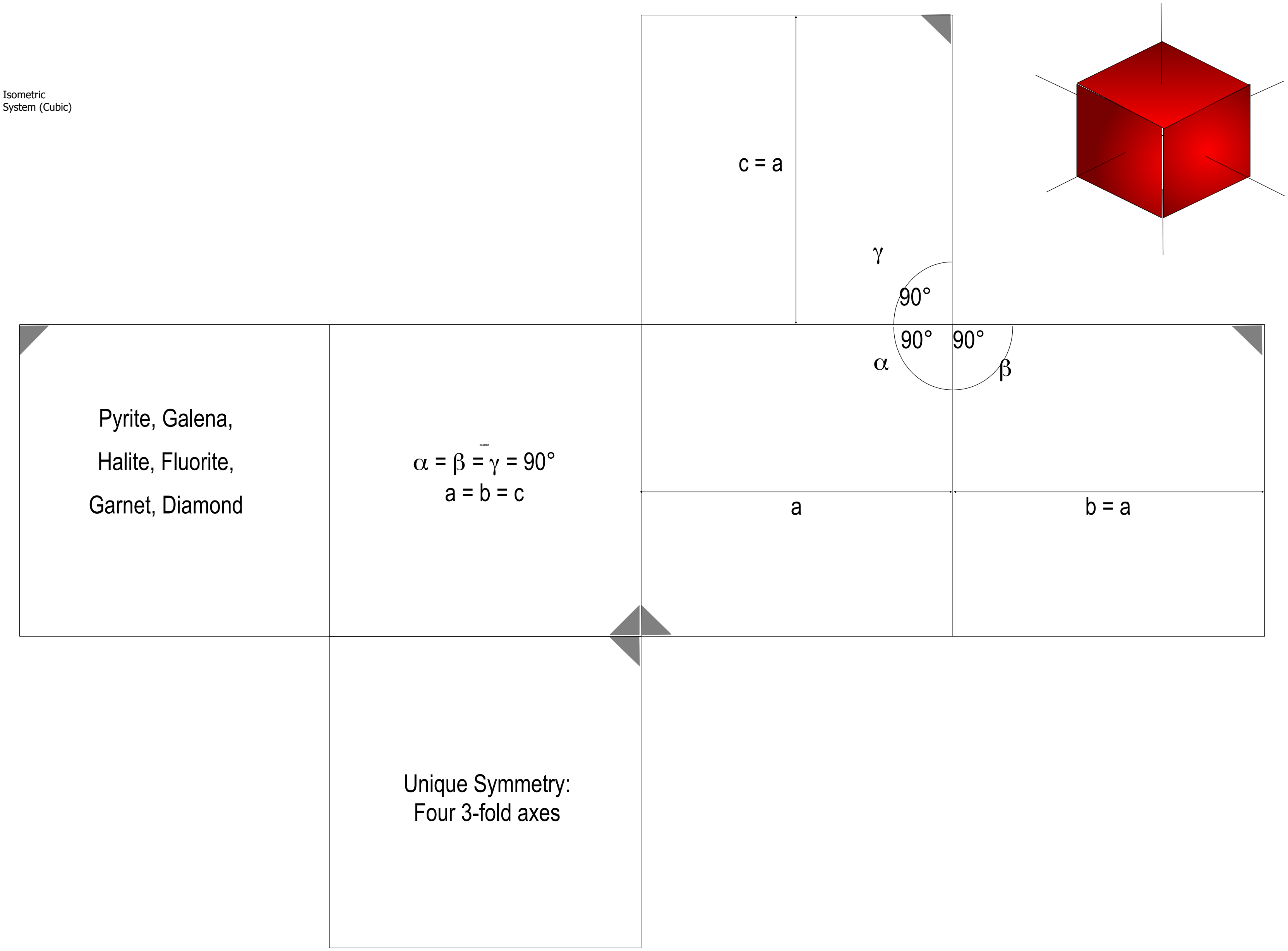




Crystal system:



Isometric
System (Cubic)



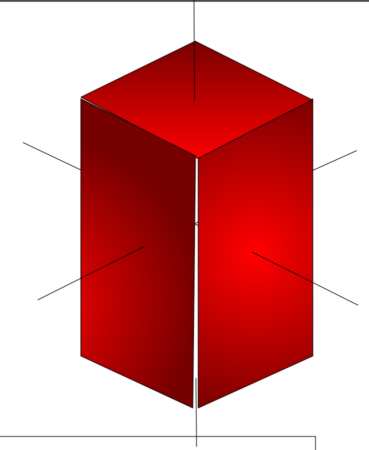
Tetragonal
System

Wulfenite, Zircon,

Chalcopyrite, Rutile

γ 90°

α 90° 90° β



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

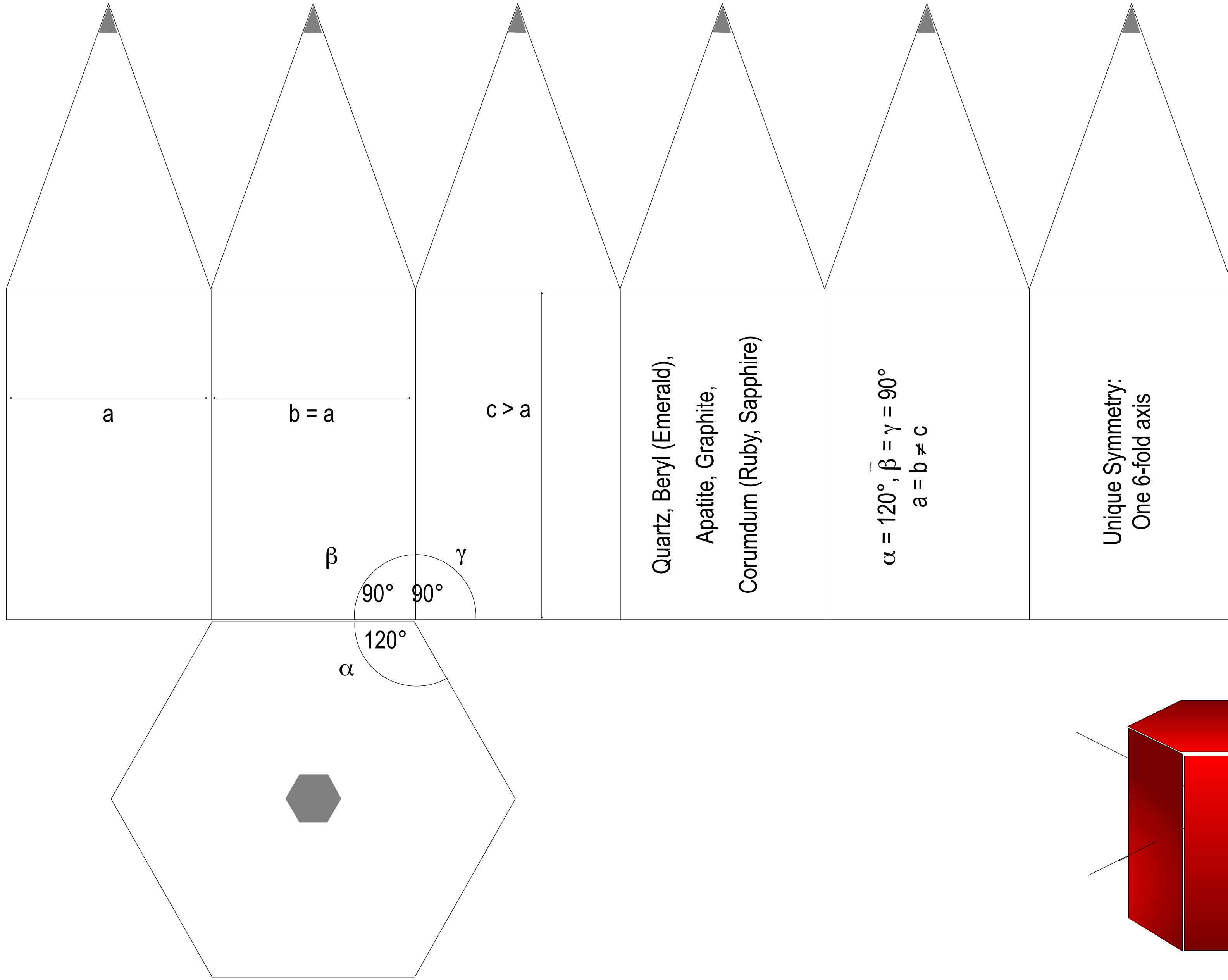
$c \neq a$

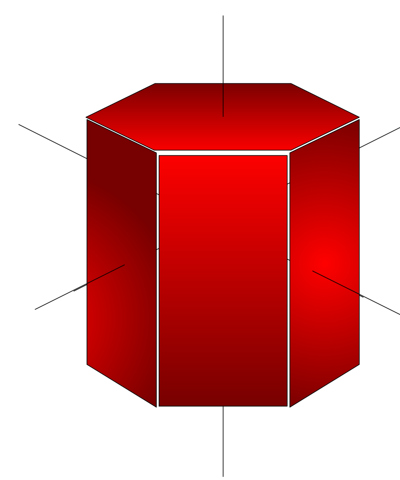
a

b = a

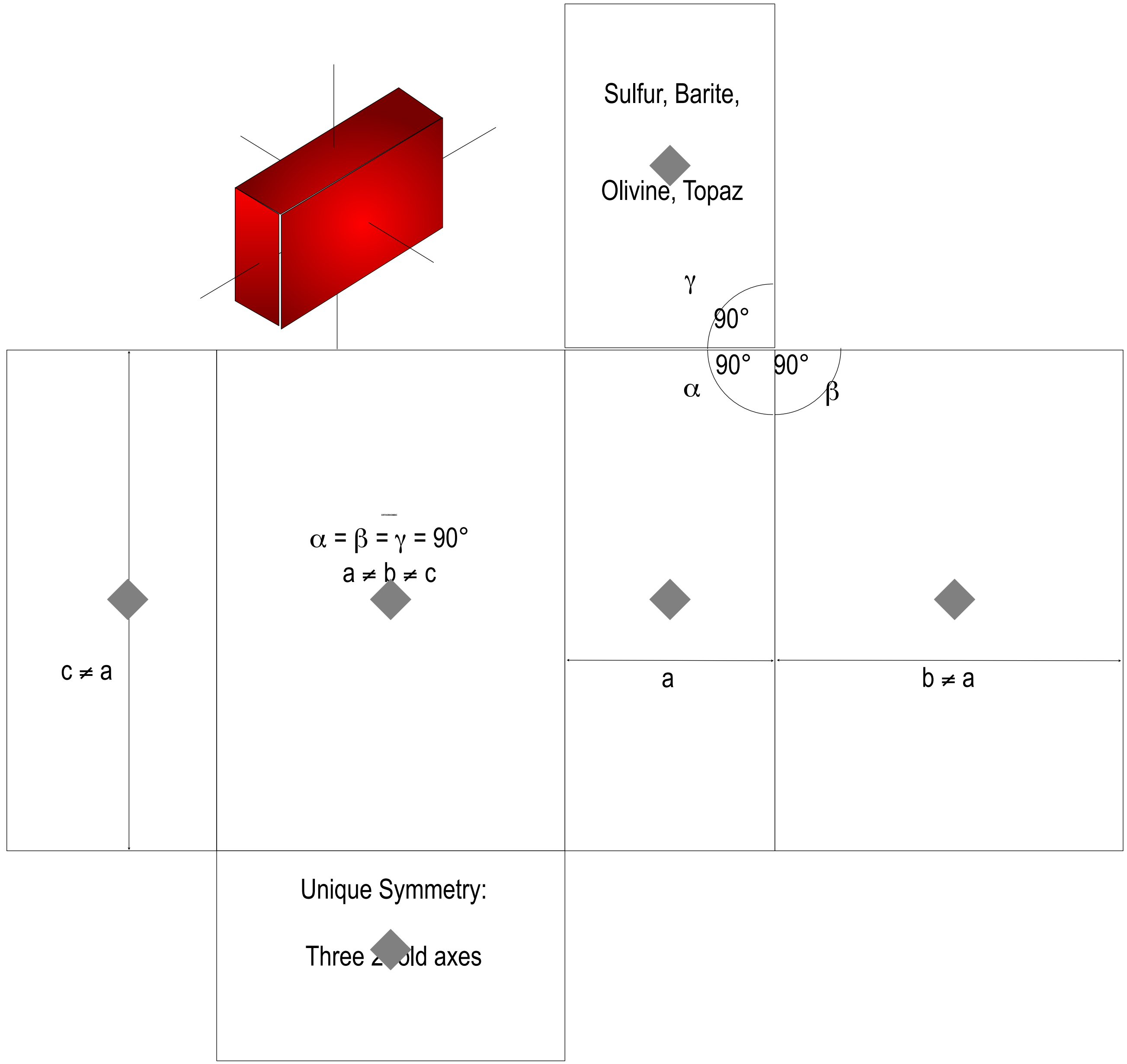
Unique Symmetry:
One 4-fold axis

Hexagonal System

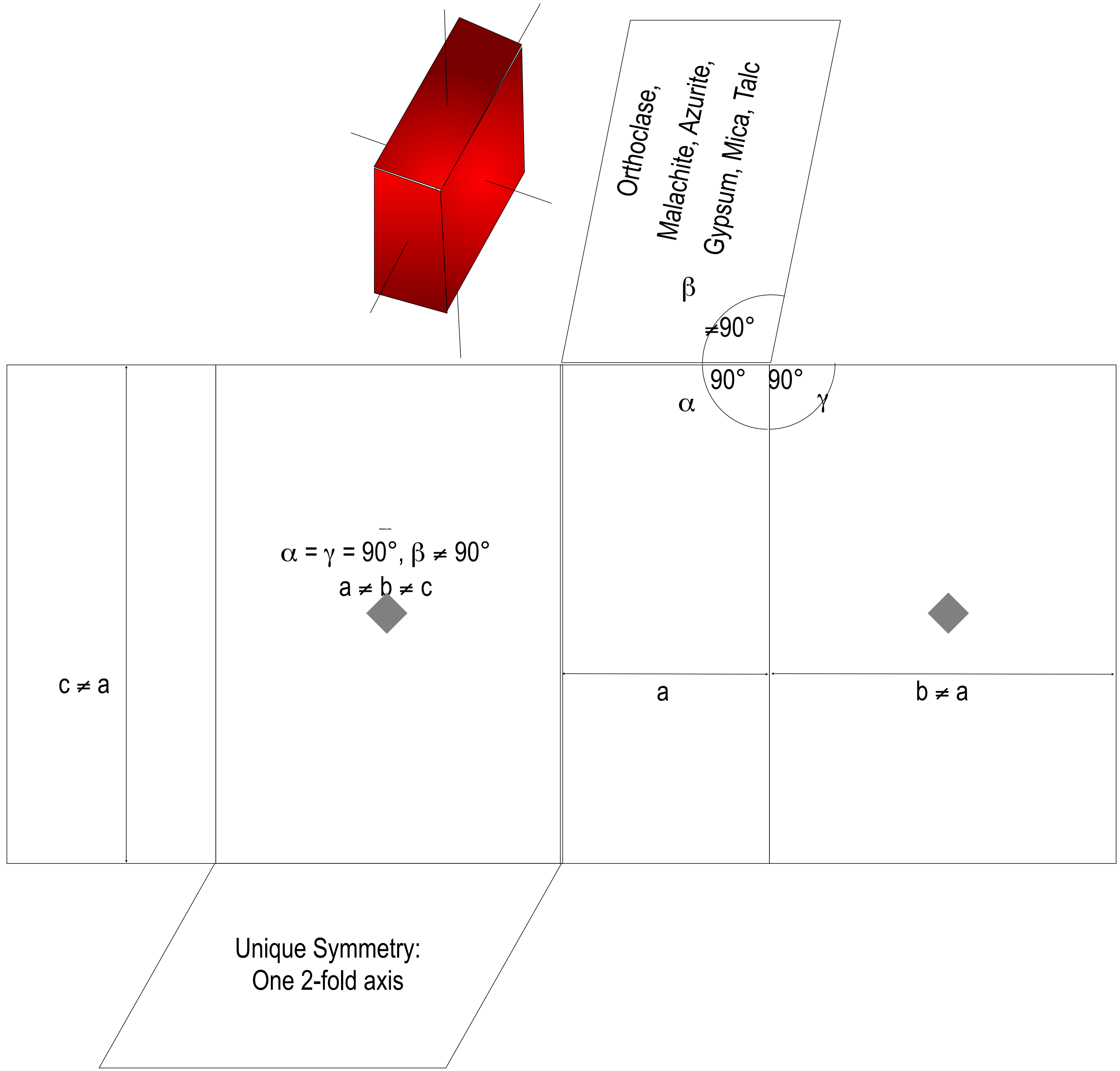




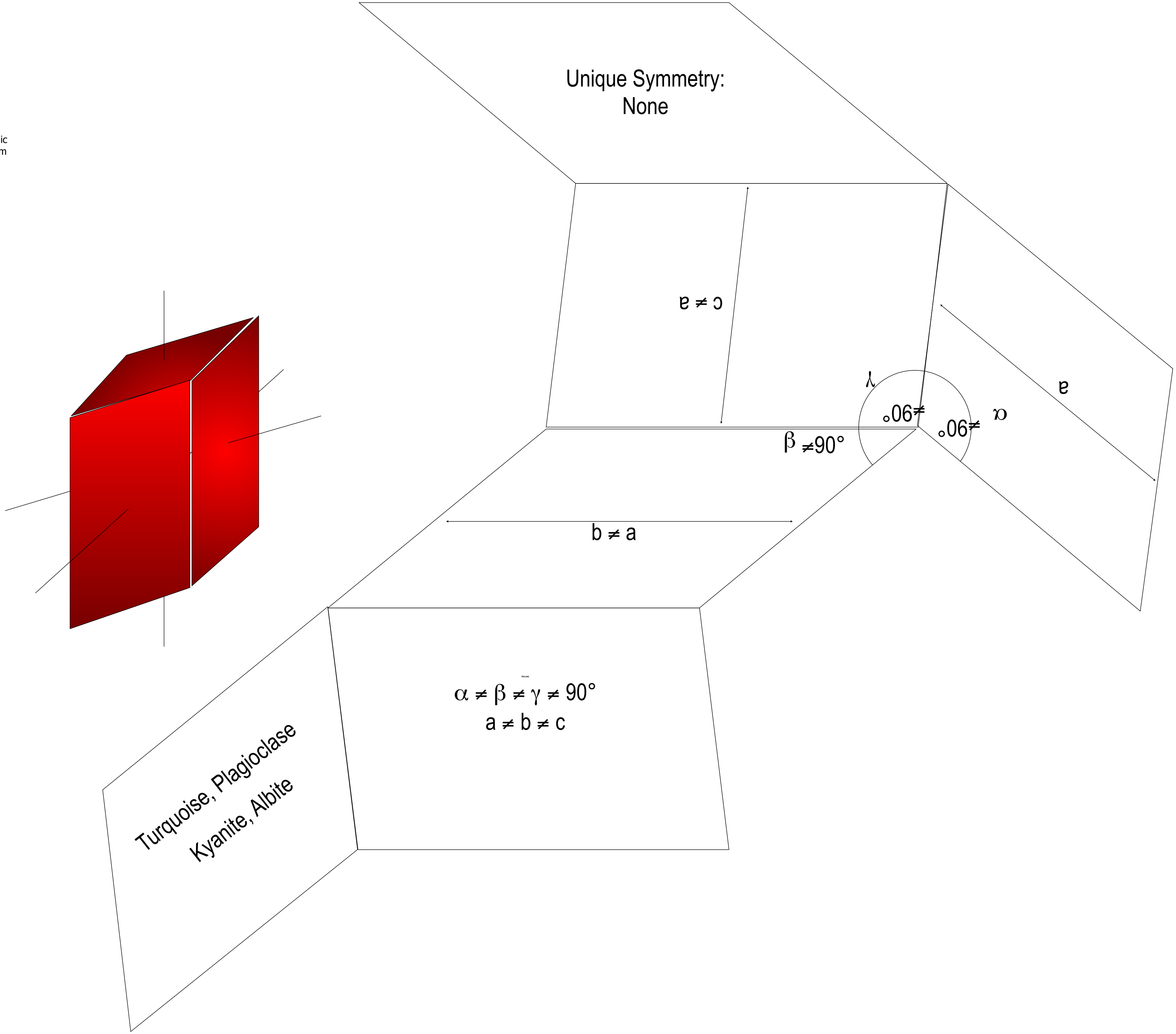
Orthorhombic
System



Monoclinic
System

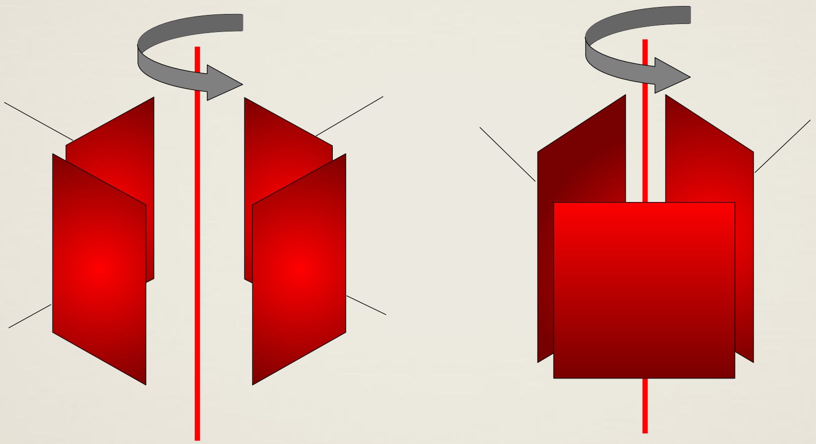


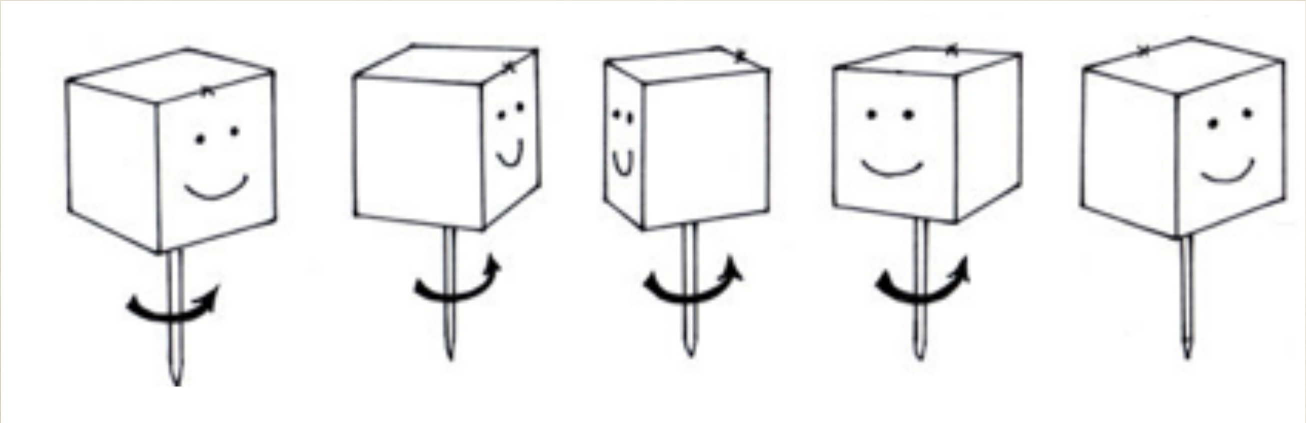
Triclinic
System



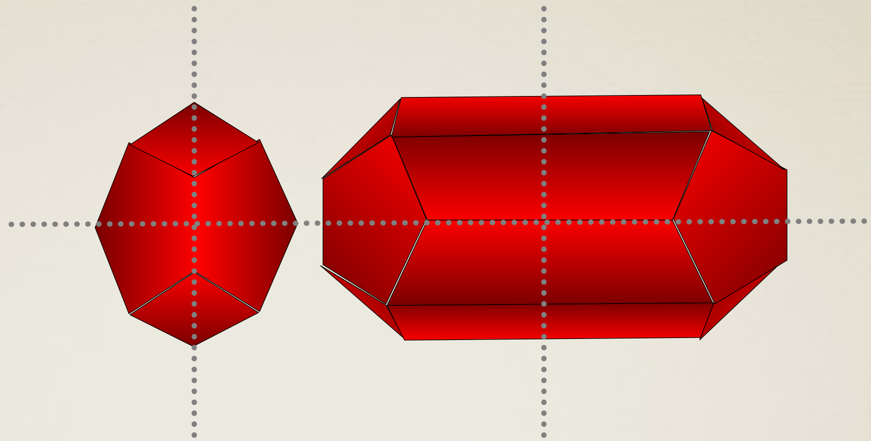
Elements of symmetry:

i- Axes of rotation (1, 2, 3, 4 or 6): If during the rotation of a crystal around an axis one of the faces repeats itself two or more times, the crystal is said to have an axis of symmetry.

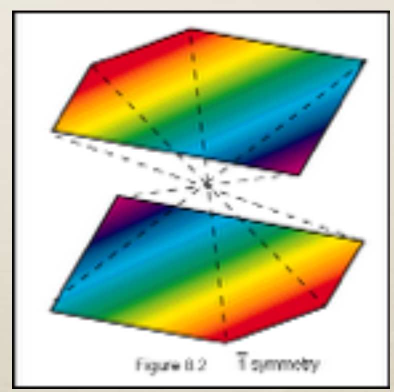


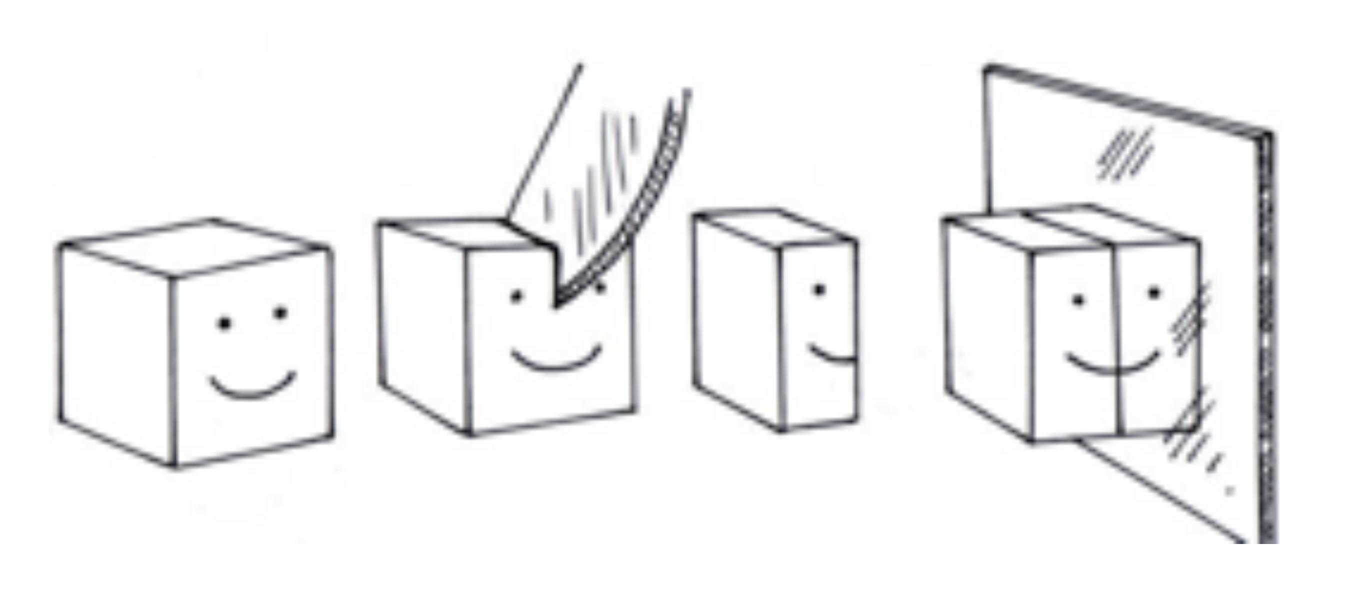


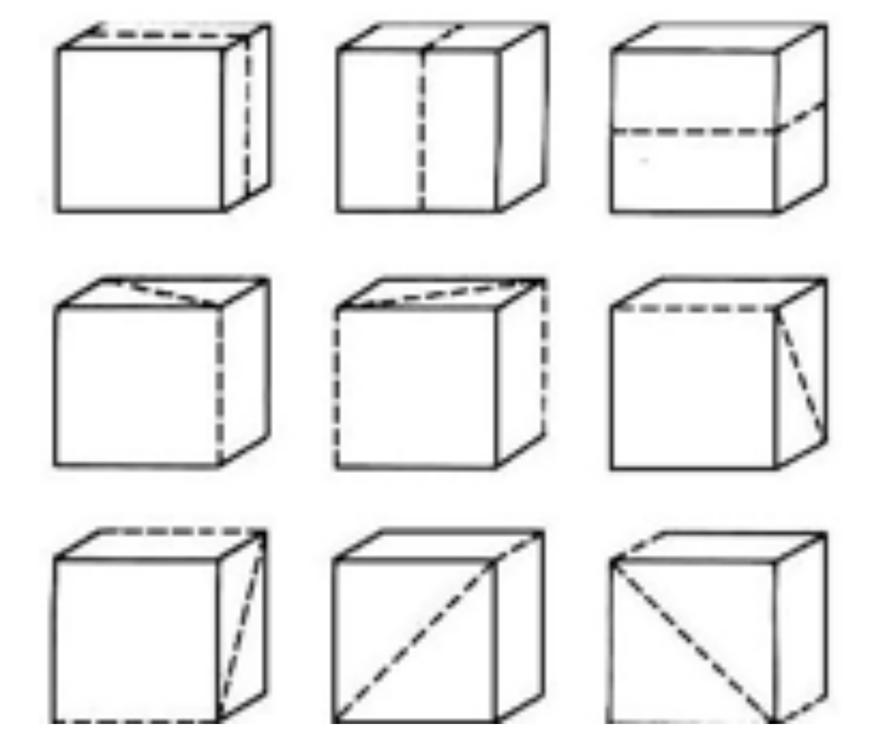
ii- Planes (m): When one or more faces are the mirror images of each other, the crystal is said to have a plane of symmetry.



ii- Center (n or i): If two similar faces lie at equal distances from a central point, the crystal is said to have a centre of symmetry.







Mineralogy lab
Dr.Faten Slaty / G.Wafa Al-Argan

Lab sheet #2: Crystal system

Student name:
Section:

Sample No.	Crystal system	Length of crystal axes	Angle of crystal axes	No. plane of symmetry	No. and type rotation axes	Center of symmetry	Diagram

Hashemite University

Faculty of Natural Resources and Environment

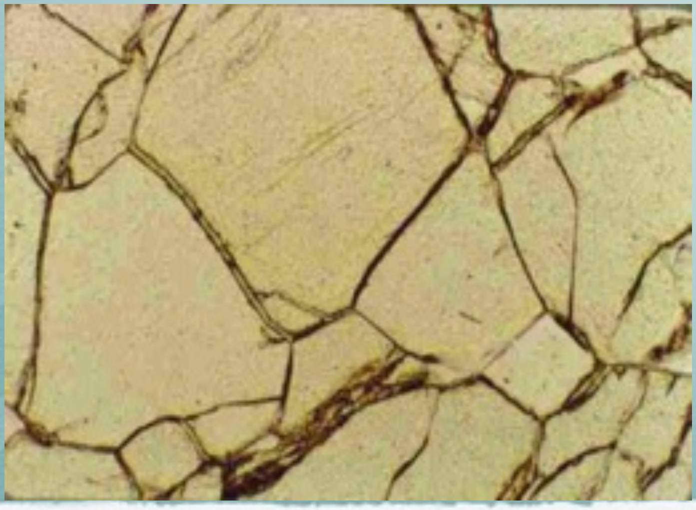
Department of earth and environmental sciences

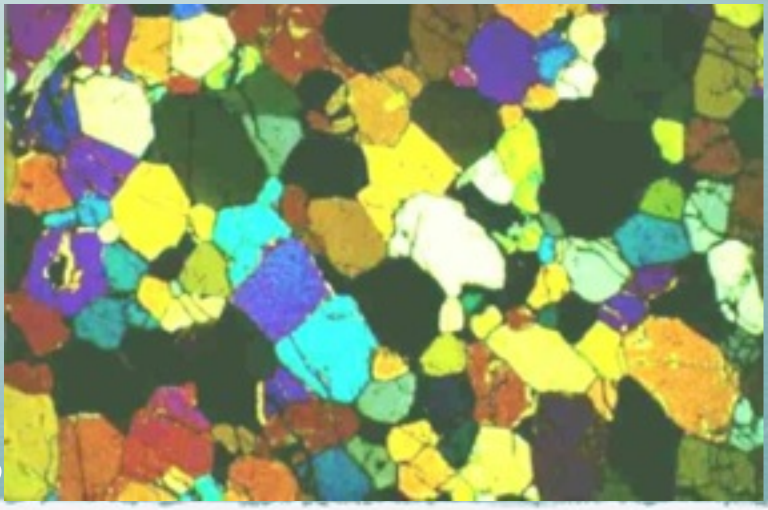
Mineralogy lab

Optical Mineralogy

Dr. Faten Al-Slaty

First Semester 2015/2016

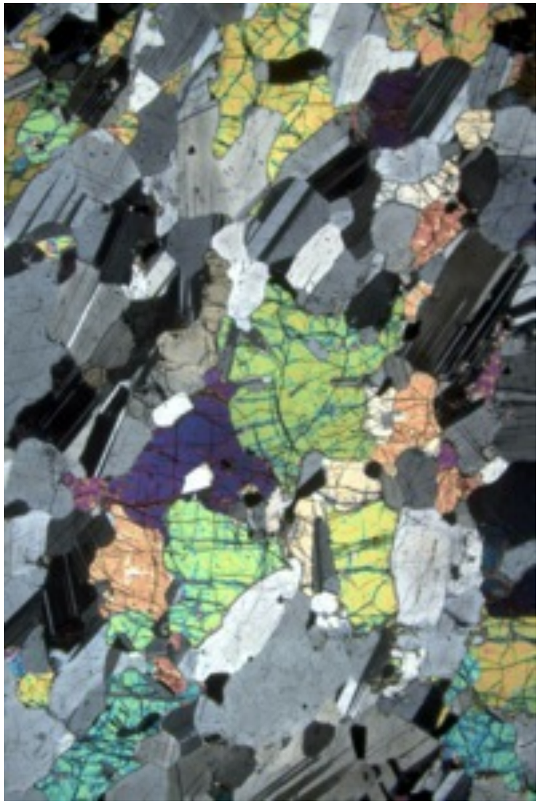




Optical Microscopy

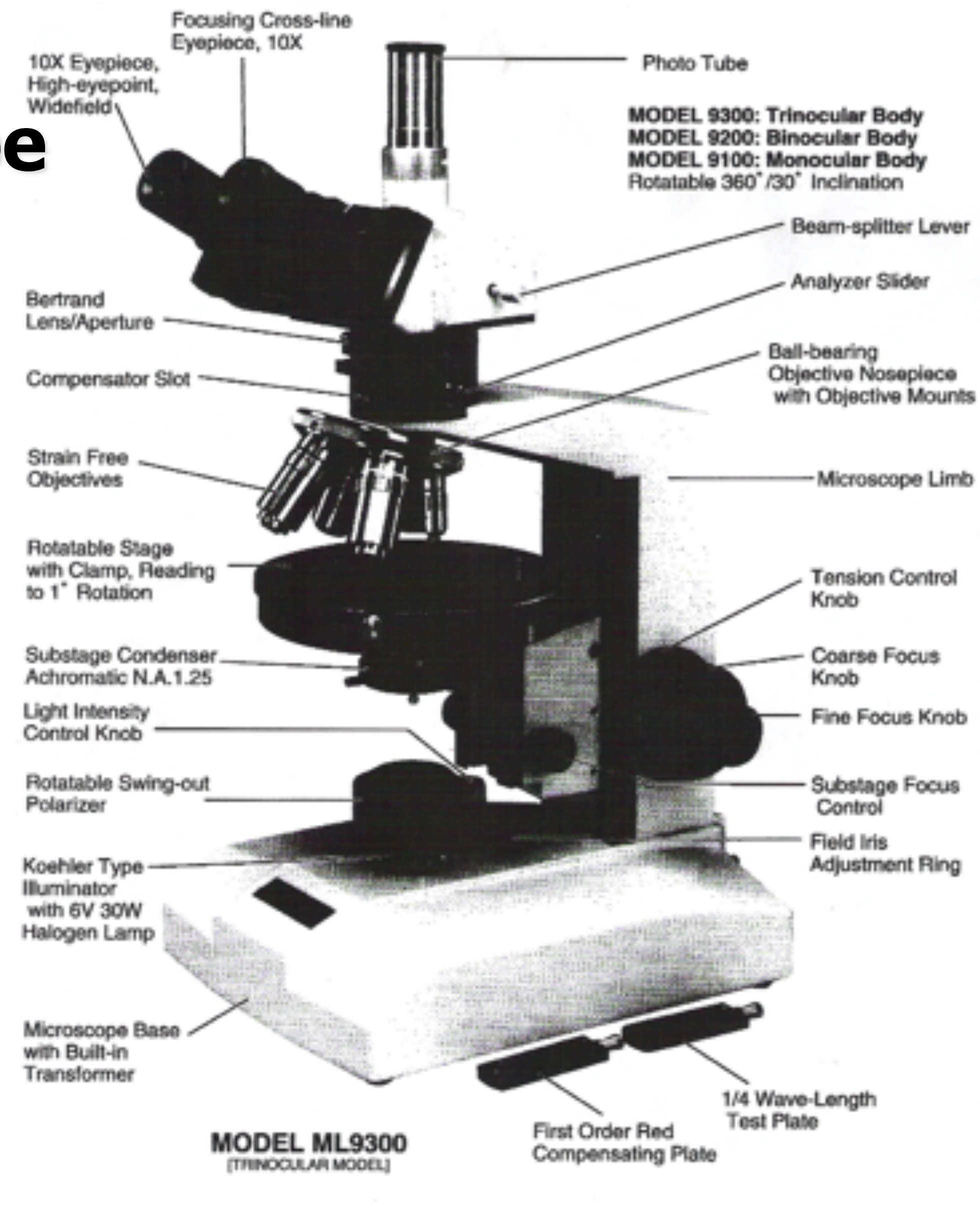
- Study of how light passes through thin sections(rock cut and polished to about 0.3 mm thickness)
- Microscopic determine

mineralogy
textural relationships
rock composition



Polarizing microscope

Parts of a Microscope



Parts and Functions of a Polarizing Microscope

I. Base

Part	Function
a) Light source – with Halogen lamp (illuminator) housing bulb Line cord sliding control, lever, voltmeter	source of light
b) Collector lens system	concentrates light
c) Field iris diaphragm with field iris diaphragm ring	controls light ray bundle at the source field
d) Filter mount with blue filter	approximates daylight

II. Sub stage Assembly

Part	Function
a) Polarizer (lower polar) With Polarizer scale, polarizer rotation ring, screw	polarizes light in one direction
b) Condenser with clamping screw, condenser centering screw, fixed back lens movable top and front lens with swing out knob	controls and illuminates light coming from the source field directed to the object field
c) Aperture Iris Diaphragm with lever and numerical aperture scale	controls cone of light catering the objective (useful for R. I. determination)

III. Stage Assembly

Part	Function
a) **Stage** with stage clamping screw verniers	platform for specimen
b) **Stage Clips**	fix specimen on stage
c) **Mechanical Stage** with vernier scale click stops, stage centering screw	for point locations and systematic traverse in a species along mutually perpendicular directions

IV. Microscope Stand / Tube

1. Coarse Adjustment Knob 2. Fine Adjustment Knob	For Focusing Image

V. Objective Assembly

Part	Function
a) Revolving Nosepiece with objective centering screw	holds objectives
b) Objectives initial magnifications 4x, 10x, 20x, 40x	essential lenses of microscope for magnification and resolution

VI. Intermediate Polarizing Assembly

Part	Function
a) **Test plate** insertion slot (accessory opening)	for insertion of microscopic accessory plate
b) **Analyzer** (upper polar)	polarizes light
c) **Bertrand lens** with focusing ring	for observing interference figure

VII. Ocular Assembly

Part	Function
a) Observation tube with clamping screw and light	holds eyepieces
b) Path selector knob	
c) Eyepieces with cross hair	essential lenses of microscope for magnification or resolution conform with objectives
d) Diopter adjustment ring	for focusing eyepieces
e) Photo Tube	for camera attachment in photomicrography

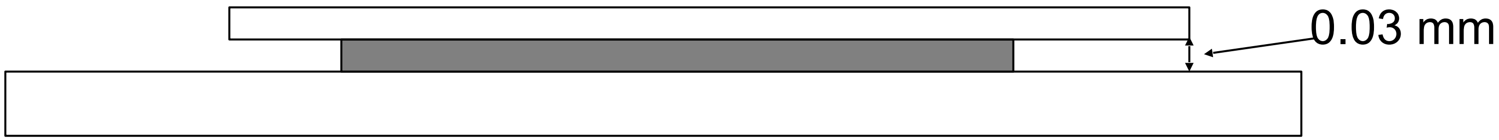
Thin section

Thin rectangular slice of rock that light can pass through.

One side is polished smooth and then stuck to a glass slide with epoxy resin

The other side is ground to 0.03 mm thickness, and then polished smooth.

May be covered with a thin glass cover slip



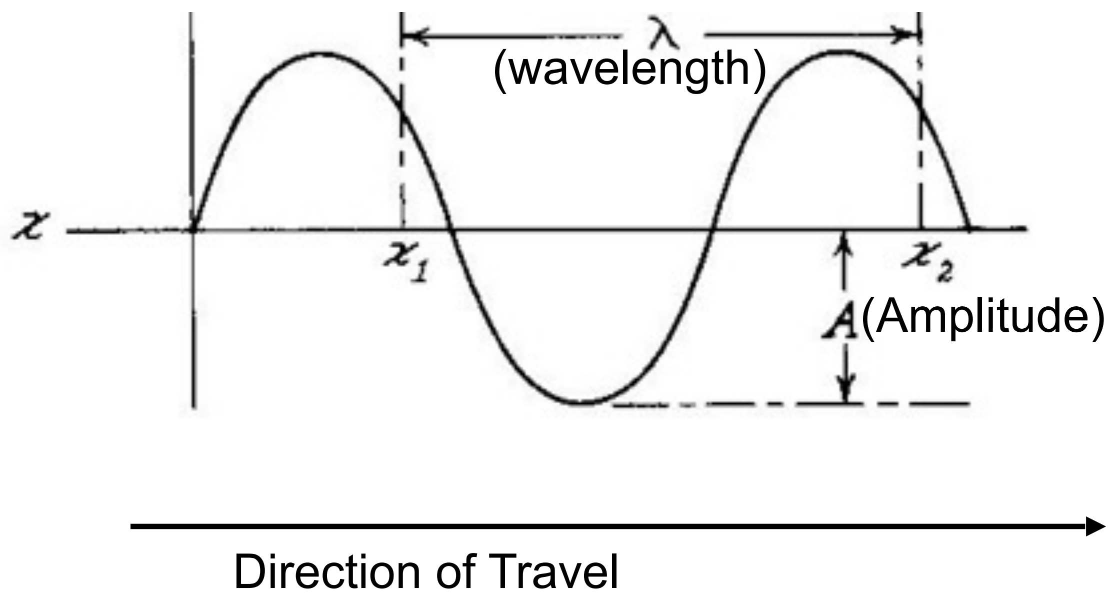
Basic Steps in Preparation of thin section

1. Cutting - at least 1″x 2″ size using the cutting machine
2. Grinding – to a 240 mesh abrasive them to 800 mesh.
3. Heating – both the thin section and the sample in a hot plate put Canada Balsam in thin section and heat it for about 30 minutes.
4. Mounting - put the sample in thin section
5. Cutting – using the diamond saw cutter
6. Grinding – to a 300 mesh abrasive up to at least 0.03 mm thickness
7. Covering – cover the thin section with the sample using the cover slip.
8. Washing – clean the thin section using the xylol solution.

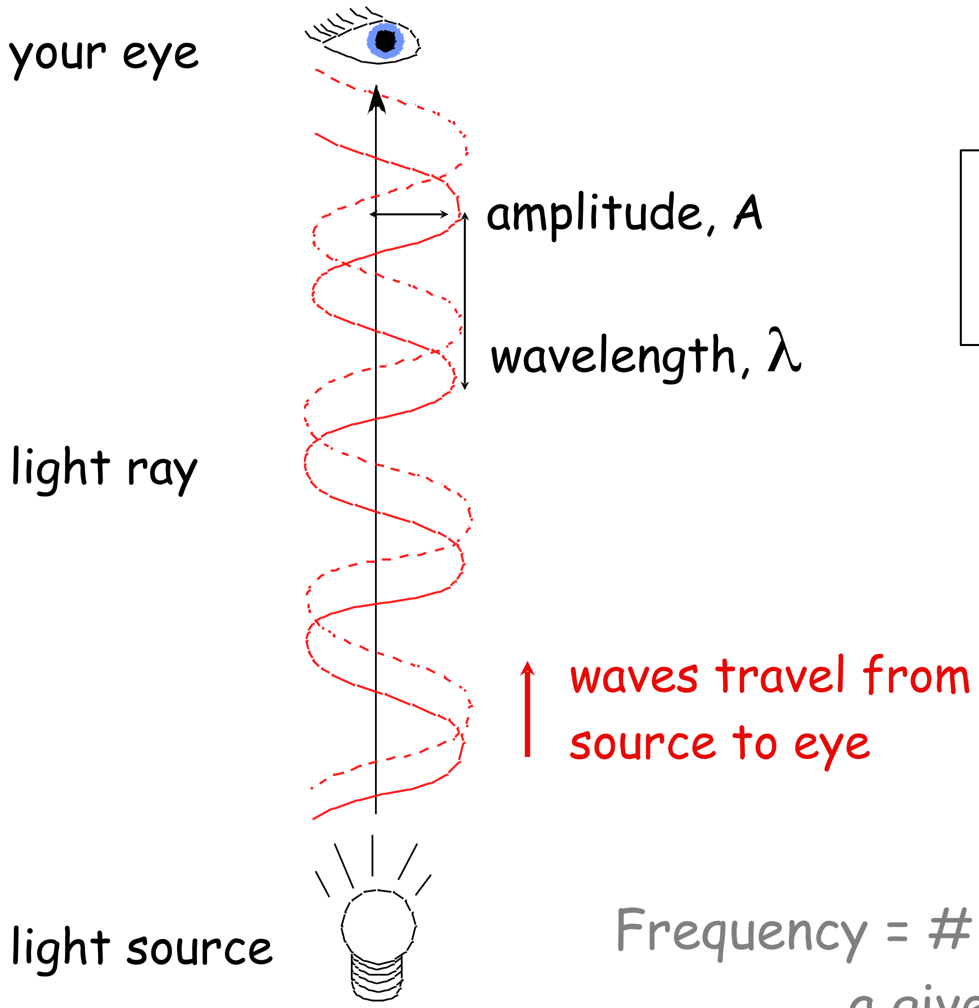
Properties of Light

Light travels as an electromagnetic wave

In a solid, liquid or gaseous medium the electromagnetic light waves interact with the electrons of the atom.



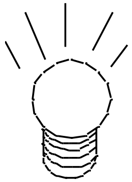
What happens as light moves through the scope?



light travels as waves

Frequency = # of waves/sec to pass a given point (hz)

$f = v/\lambda$ v = velocity

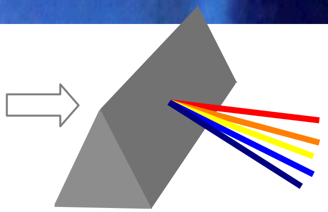


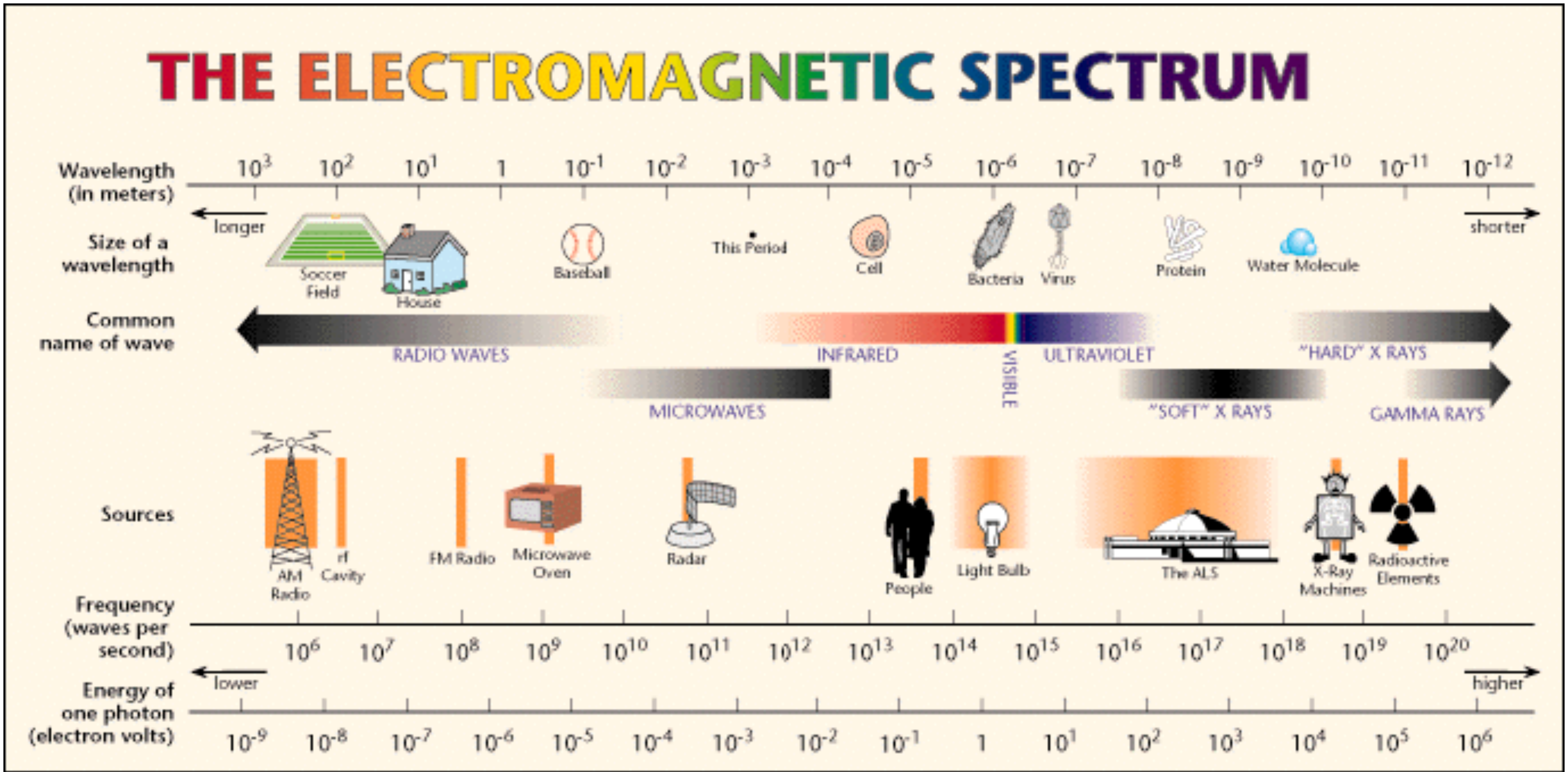
We are dealing with white light in microscopy:

Violet (400 nm) → Red (700 nm)

White = ROYGBV

(can be separated by dispersion in a prism)



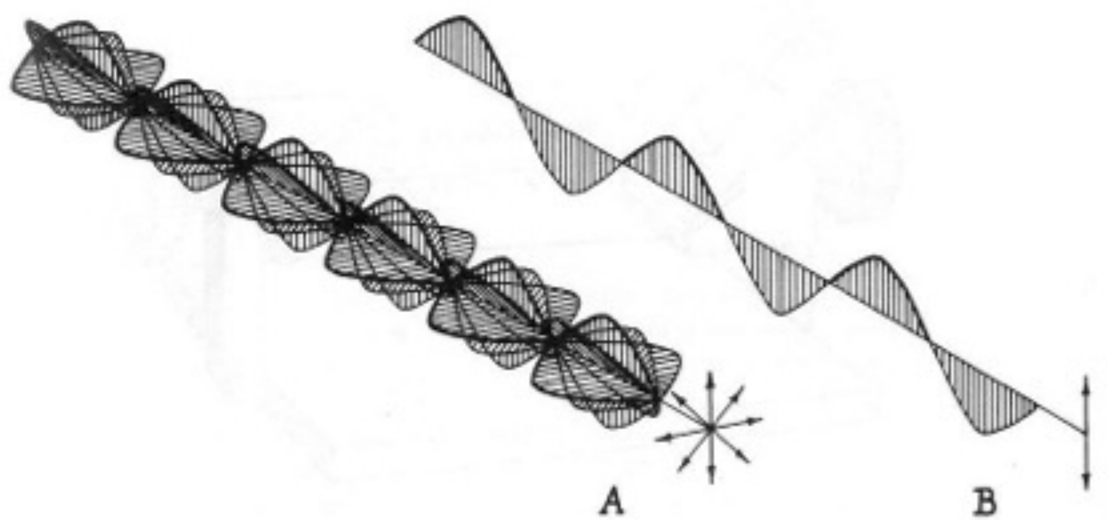


Plane Polarized light (PPL)

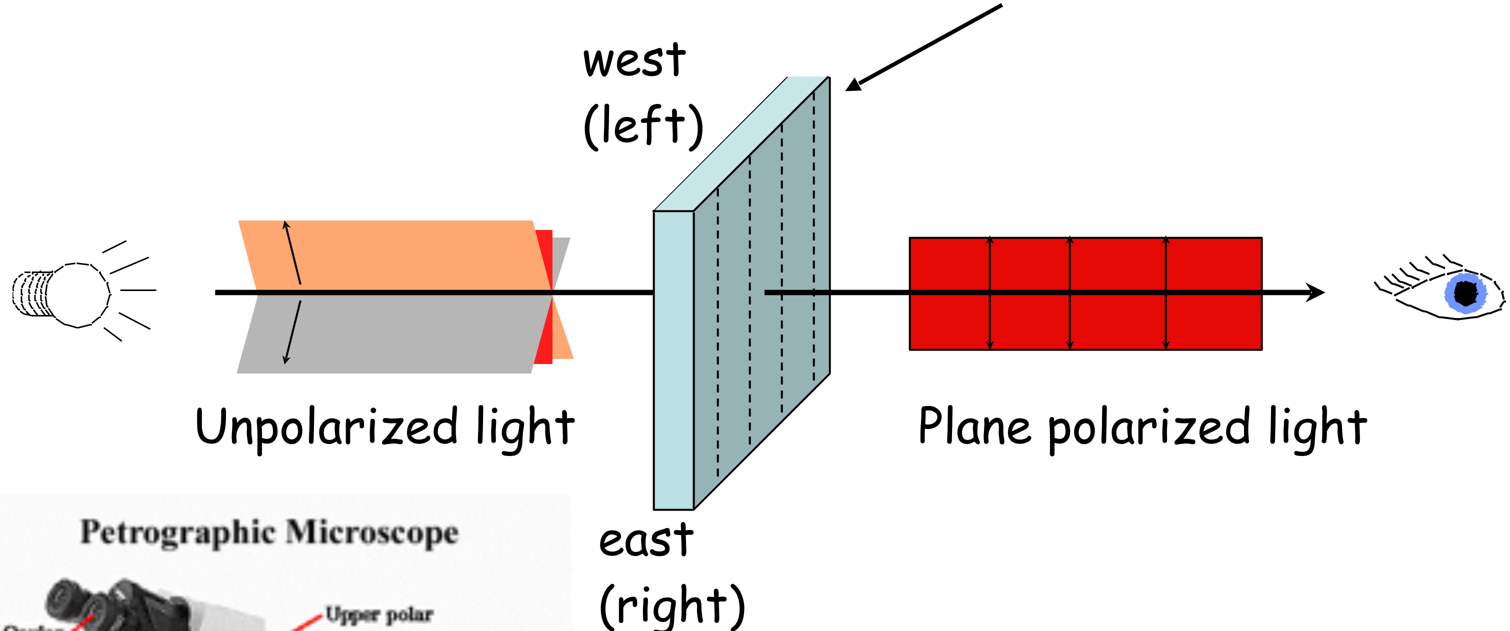
In air, light normally vibrates in all possible directions perpendicular to the direction of travel (A)

Plane Polarized Light vibrates in one plane (B)

PPL is produced by substage polarizer which stops all other vibration directions



1) Light passes through the **lower polarizer**

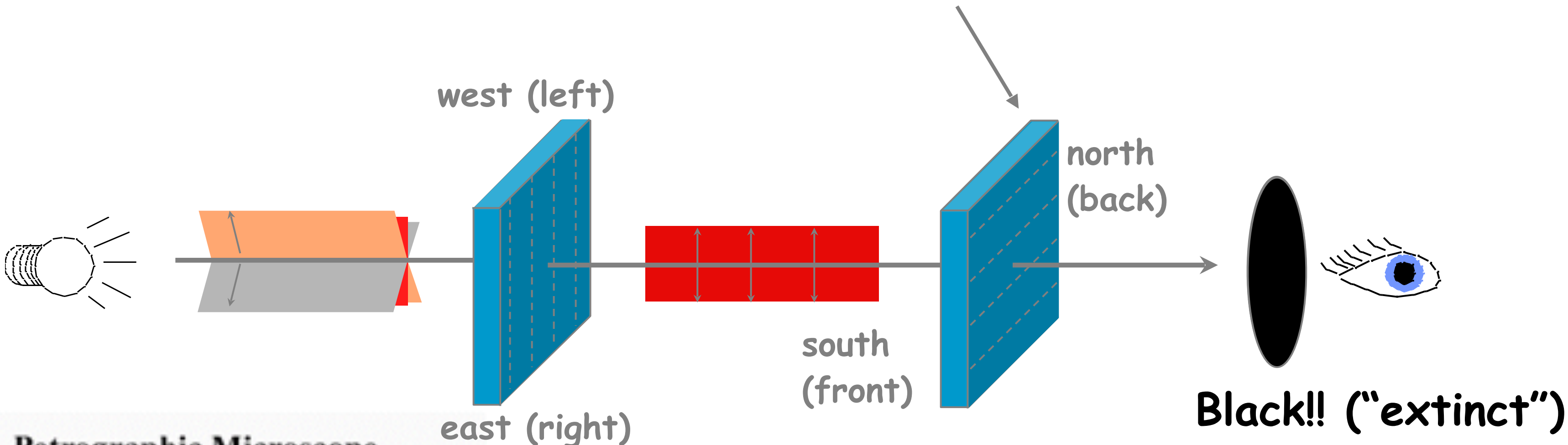


Only the component of light vibrating in E-W direction can pass through lower polarizer – **light intensity decreases**

Though polarized, still white light!

PPL=plane polarized light

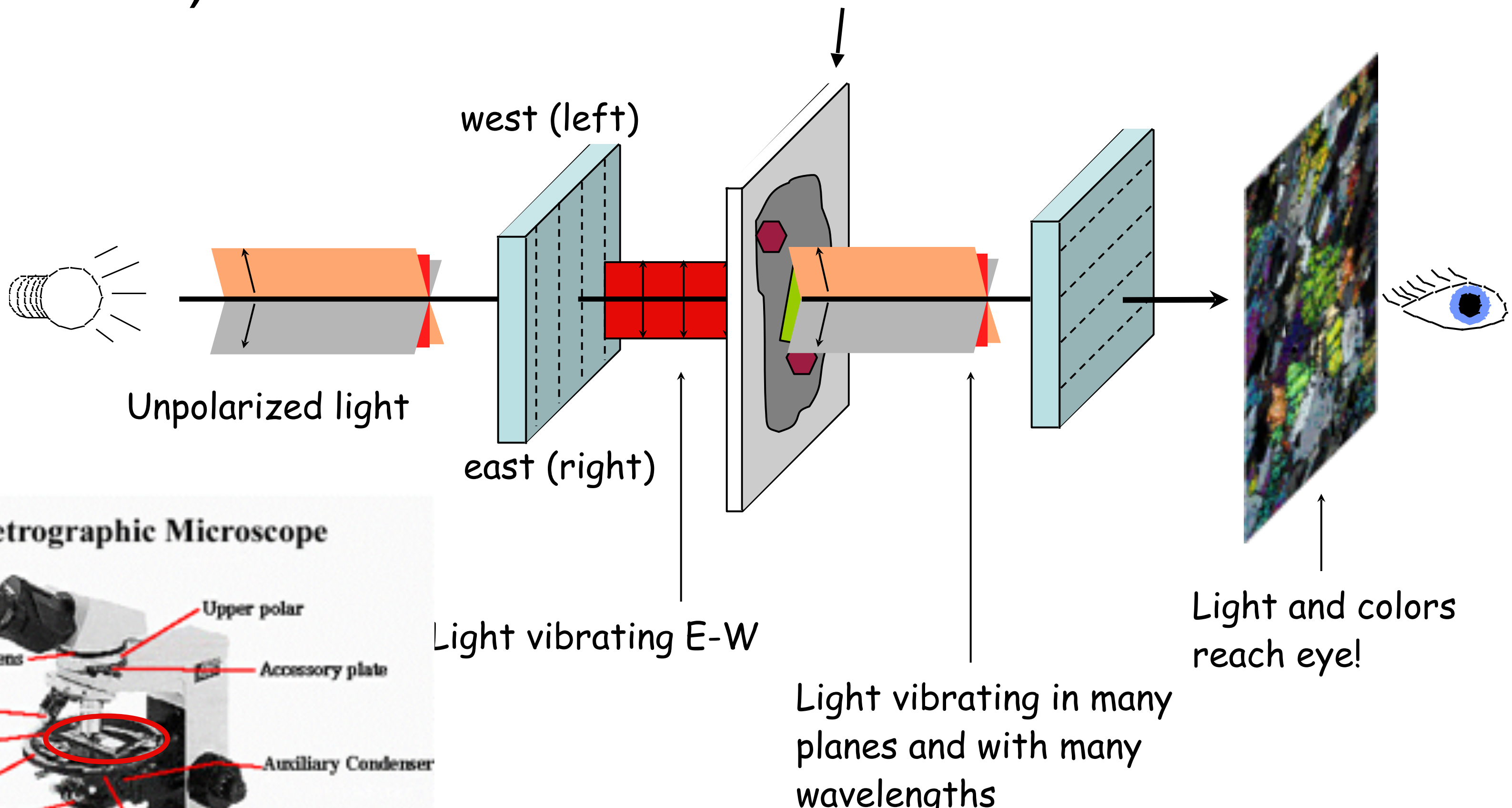
2) Insert the **upper polarizer**



XPL=crossed nicols
(crossed polars)

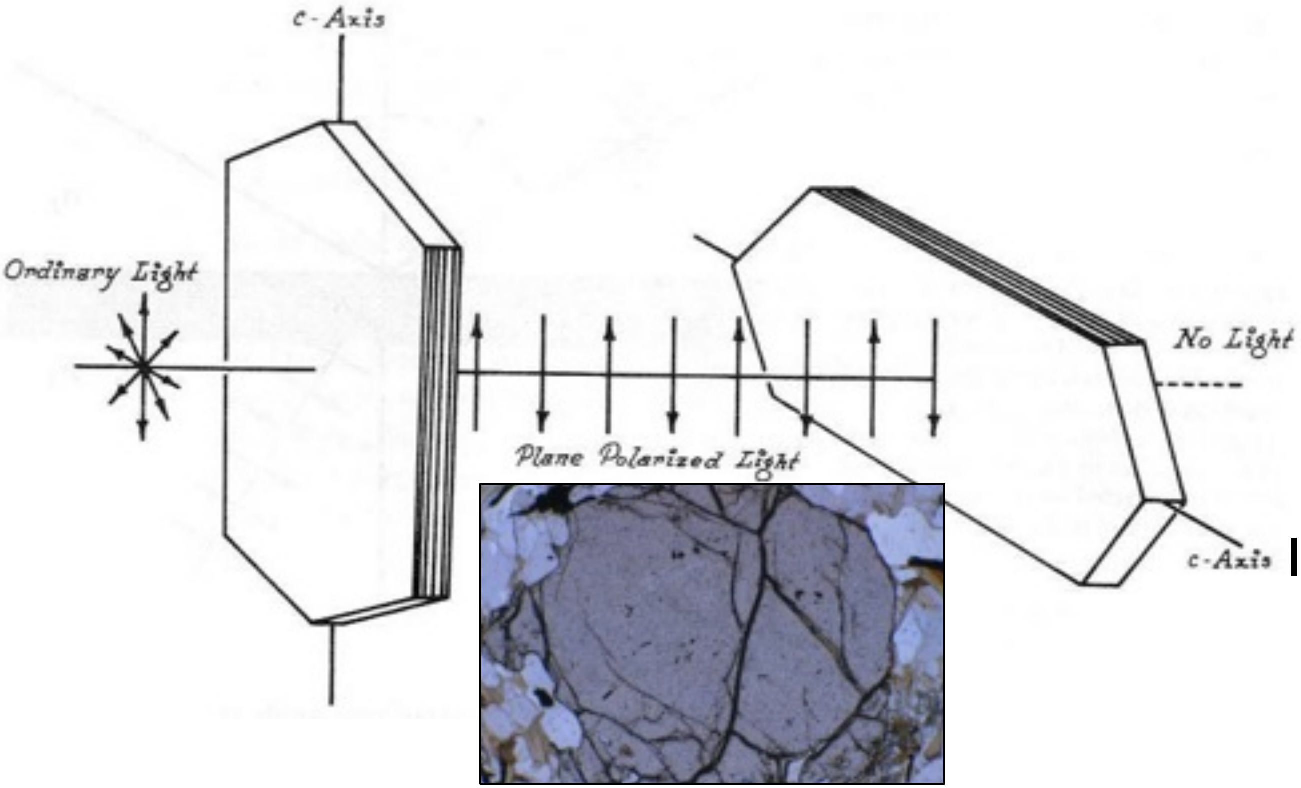
© Jane Selverstone, University of New Mexico, 2003

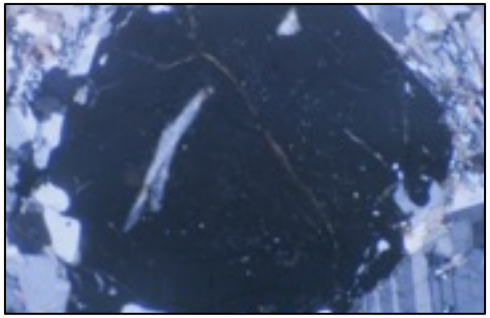
3) Now insert a **thin section** of a rock



Crossed Polars

A second polarizer can be inserted above the stage, perpendicular to the substage polarizer.

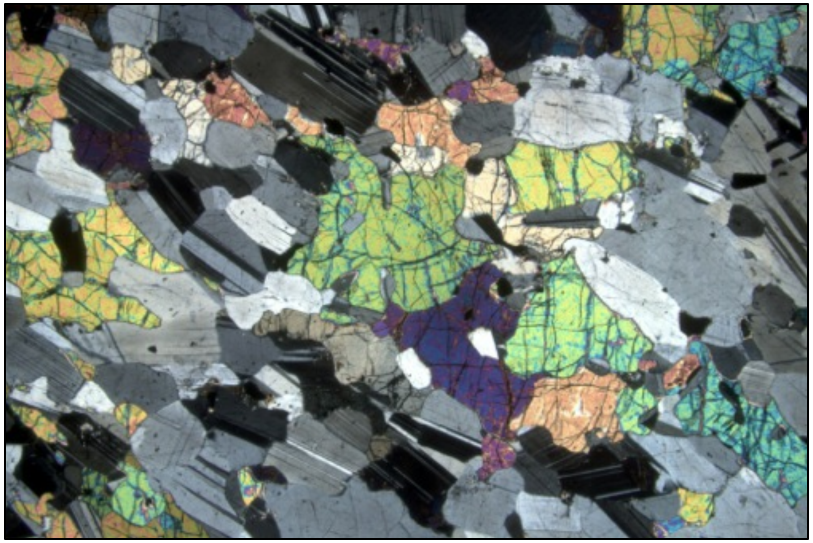




Isotropic garnet in XPL

Isotropic garnet in PPL

Conclusion has to be that minerals somehow **reorient** the planes in which light is vibrating; some light passes through the upper polarizer



Optical mineral properties

A. Optical mineral properties ONLY visible in PPL:

1. **Color** – not an interference color! (for that, see below)
2. **Pleochroism** – is there a color change while rotating stage?
3. **Relief** – low, intermediate, high, very high?

B. Optical mineral properties visible in PPL or XPL:

1. **Cleavage** – number and orientation of cleavage planes (may need higher magnification and at different grains)
2. **Habit** – characteristic form of mineral (sometimes better in XPL)

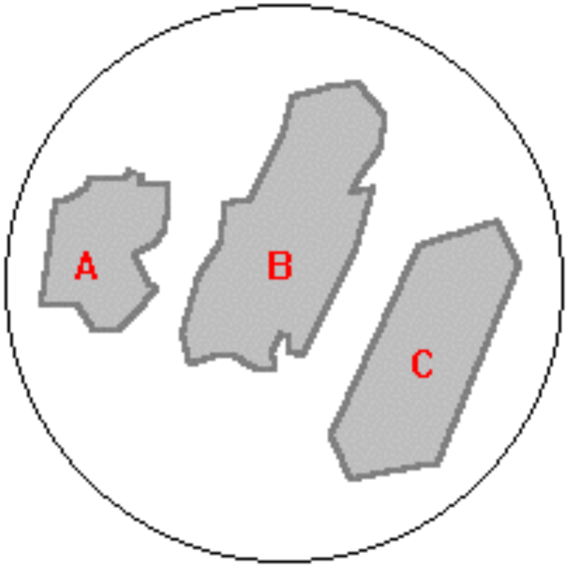
C. Optical mineral properties ONLY visible in XPL:

1. **Birefringence / Interference Colors** – use highest order interference color to describe
2. **Twinning** – type of twinning, orientation
3. **Extinction angle** – parallel or inclined? Angle?
4. **Isotropic vs. anisotropic minerals** – 100% extinct in XPL

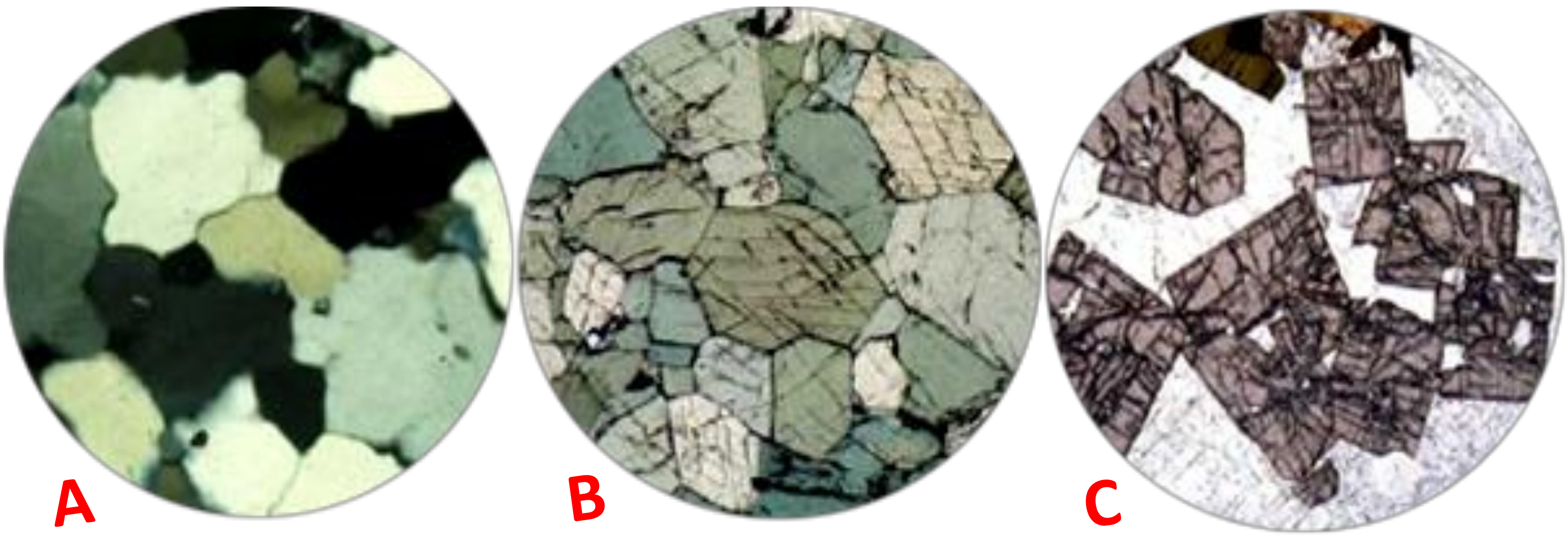
1. Crystal shape / form / habit

How well defined the crystal shape is

- **Euhedral** – sharp edges, well– defined crystal shape
- **Anhedral** – rounded edges, poorly defined shape
- **Subhedral** – in between anhedral and euhedral



Grains that show no recognizable crystal form are said to be **anhedral** (A).
Grains that show imperfect but recognizable crystal form are said to be subhedral (B).
Grains that show sharp and clear crystal form are said to be **euhedral** (C).



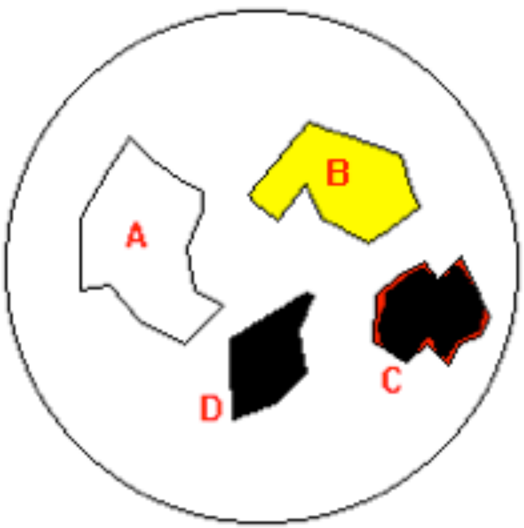
A: Anhedral crystal: Quartz

B: Subhedral crystal: Hornblende

C: Euhedral crystal: Zircon

2. Color

- Colorless (quartz)or transperent
- Distinctly colored (hornblende); absorbs certain wavelength, transmit others.
- Opaque minerals (Sulphides and oxides)



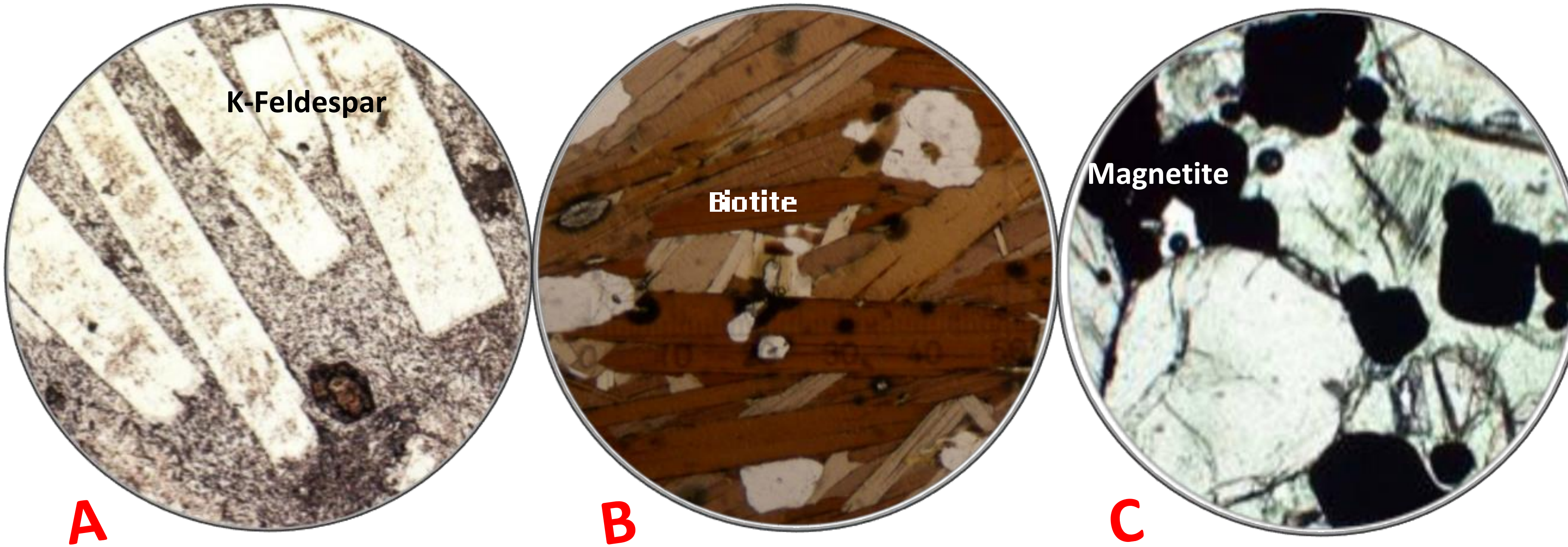
Most major rock forming minerals are **colorless** (A).

– Some have **distinctive colors** (B).

– Some minerals like hematite (C) which appear **opaque with transparent on thin edges** in thin section.

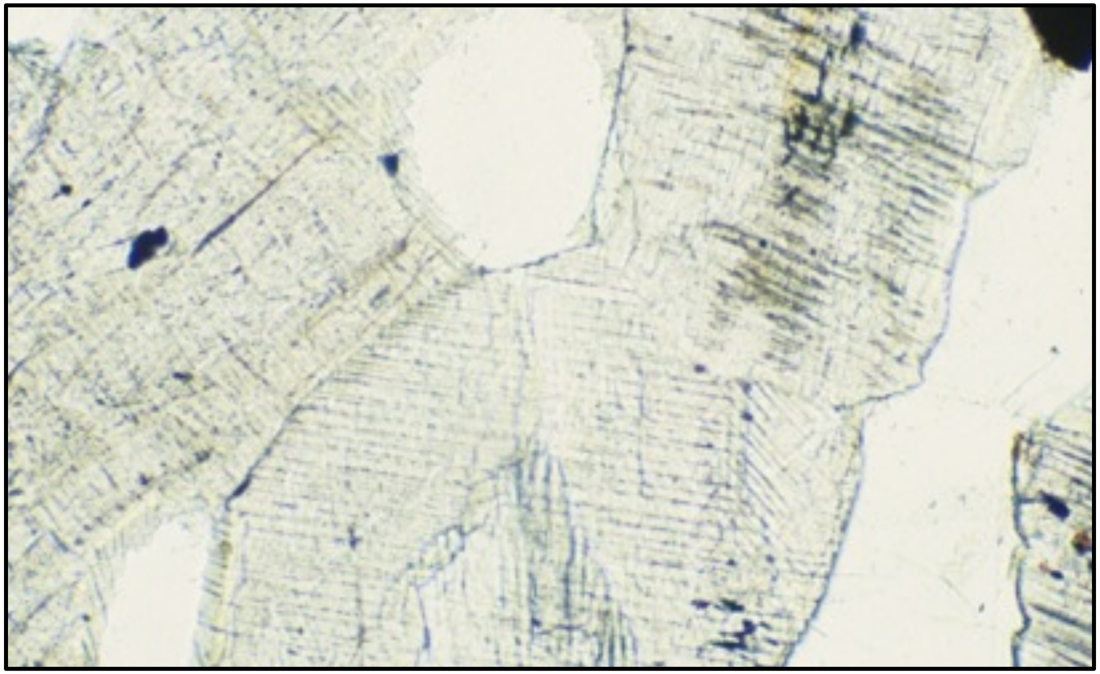
– The most common **truly opaque** minerals (D) are metallic oxides (magnetite, ilmenite) and sulfides (pyrite).

pyrite.



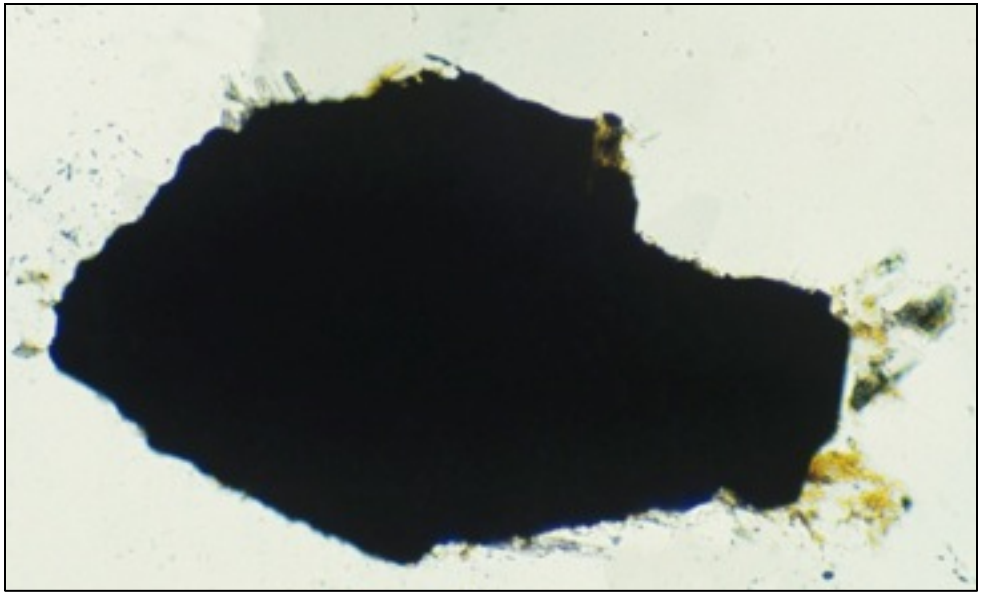
A: Colorless: K-Feldspar. B: Colored: Brown Biotite. C: Opaque: Magnetite.

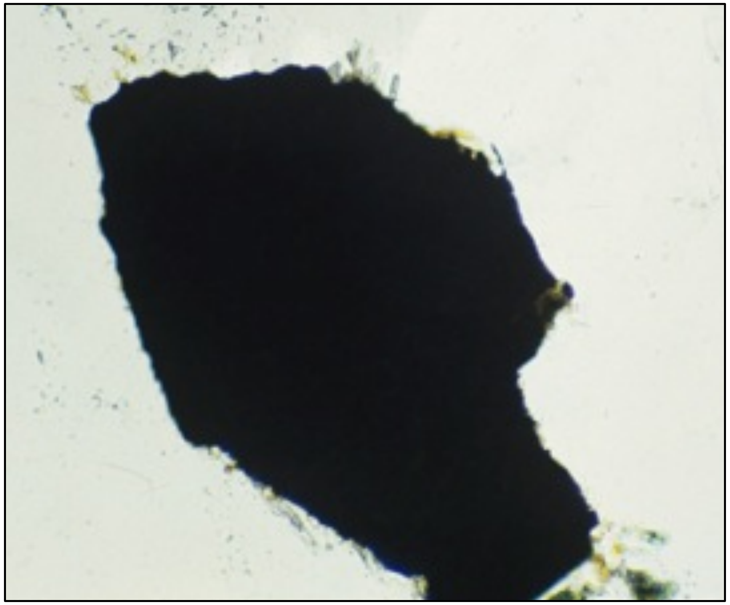
Transparent mineral



pyroxene in gabbro
PPL

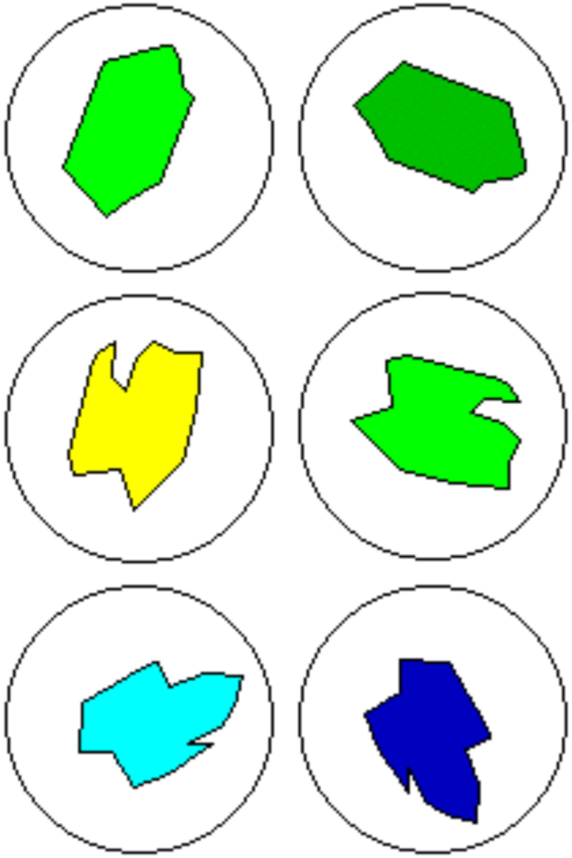
Opaque Mineral





Opaque mineral in granite
Rotated 45^{o} in PPL

3. Pleochroism - change in color of a mineral in varying degrees as the stage is rotated due to differences in light absorption



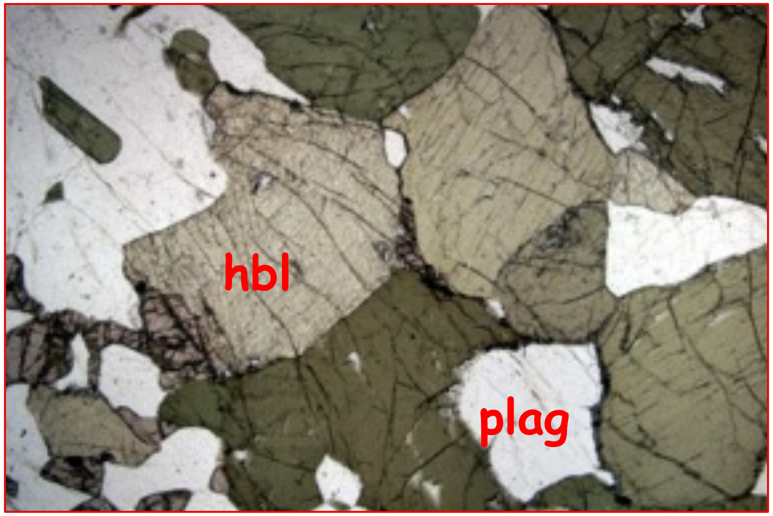
1. **Top**: Most minerals change from lighter to darker as the stage is rotated.
2. **Middle**: Some minerals change color entirely as the grain is rotated.
3. **Bottom**: In a few cases the color change is so extreme that the mineral is, in effect, a natural polarizer.

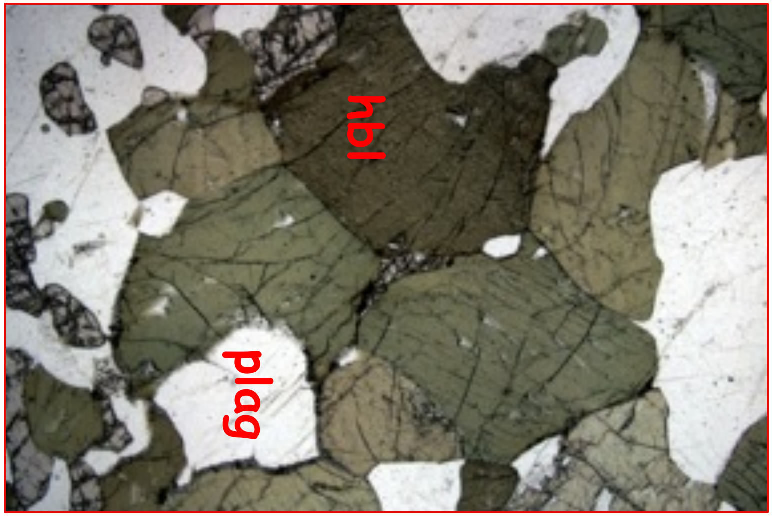
Plechroism in biotite.

Mineral properties: color & pleochroism (PPL)

- Color is observed only in PPL
- Not an inherent property – changes with light type / intensity
- Results from selective absorption of certain λ of light
- Pleochroism results when different λ are absorbed

differently by different crystallographic directions rotate stage to observe





-Plagioclase is colorless
-Hornblende is pleochroic

4. **Relief** – degree of visibility of a transparent mineral in an immersion medium

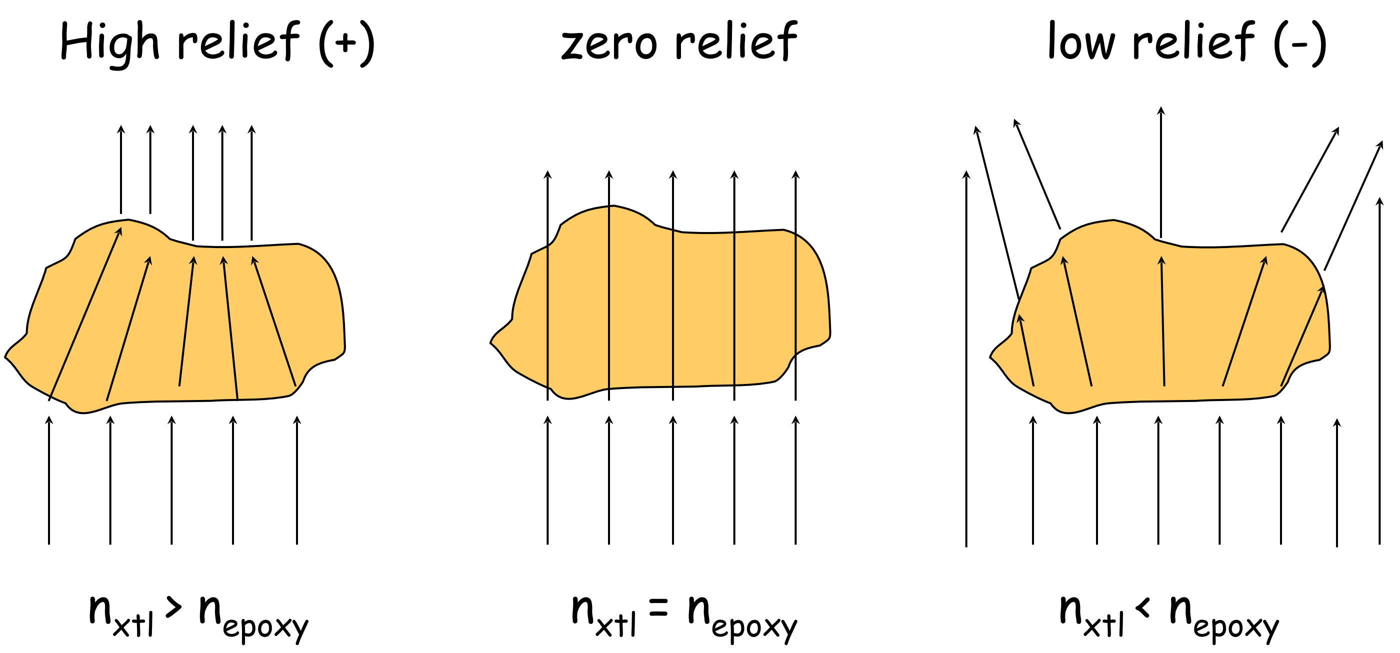
– a function of the difference between n mineral and n medium

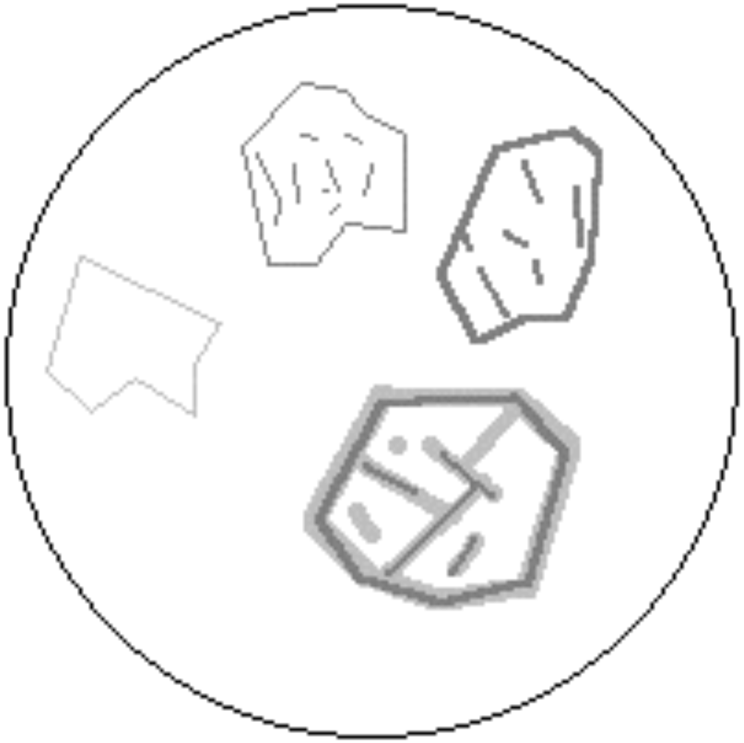
Note: R.I of Canada balsam = 1.53

1. **High Relef** (+ relief): index of refraction (R.I) of the mineral is Higher than the medium
2. **Low Relief** (– relief): R.I of the mineral is lower than the medium
3. **Zero Relief**: almost the same with the medium
4. **Change Of Relief**: varies as the stage is rotated, takes place if one n mineral is near n balsam, and the other n mineral

What causes relief?

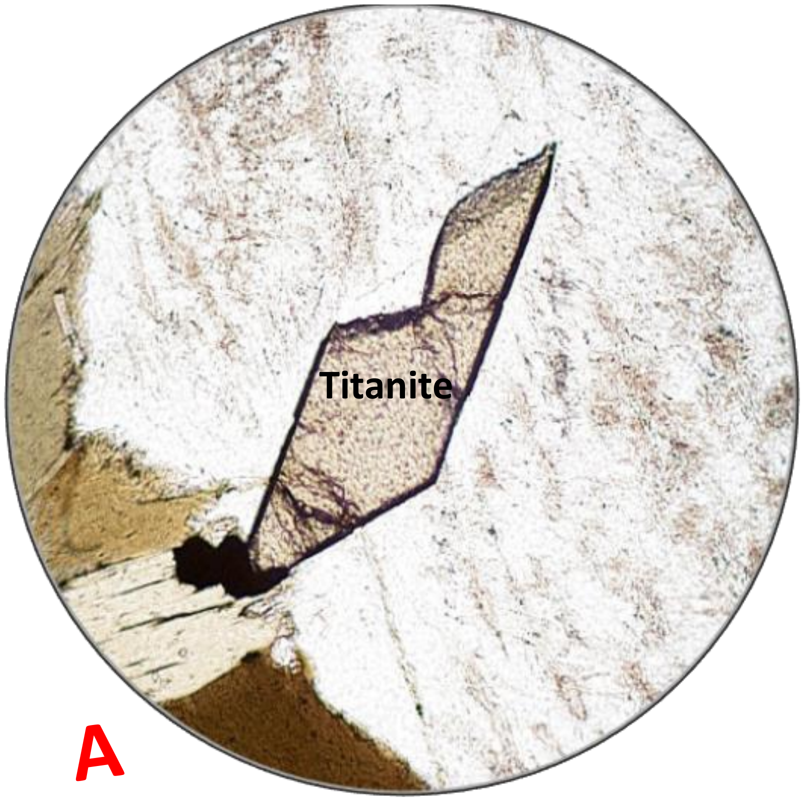
Difference in speed of light (n) in different materials causes refraction of light rays, which can lead to focusing or defocusing of grain edges relative to their surroundings

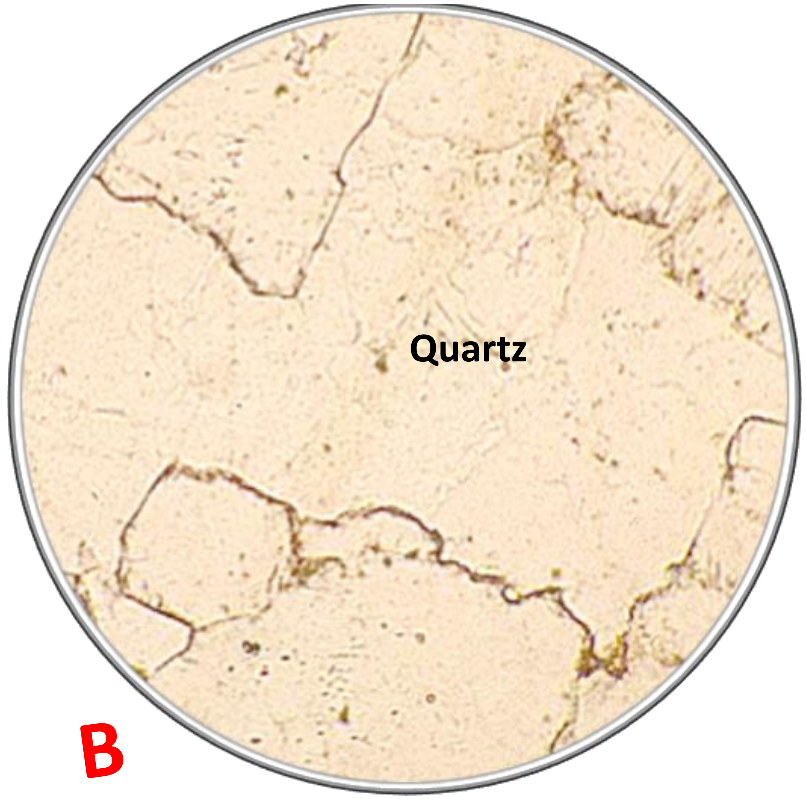




Relief is the contrast between a mineral and its surroundings due to difference in refractive index.

Relief is positive when the grain has higher refractive index than its surroundings, negative if lower.

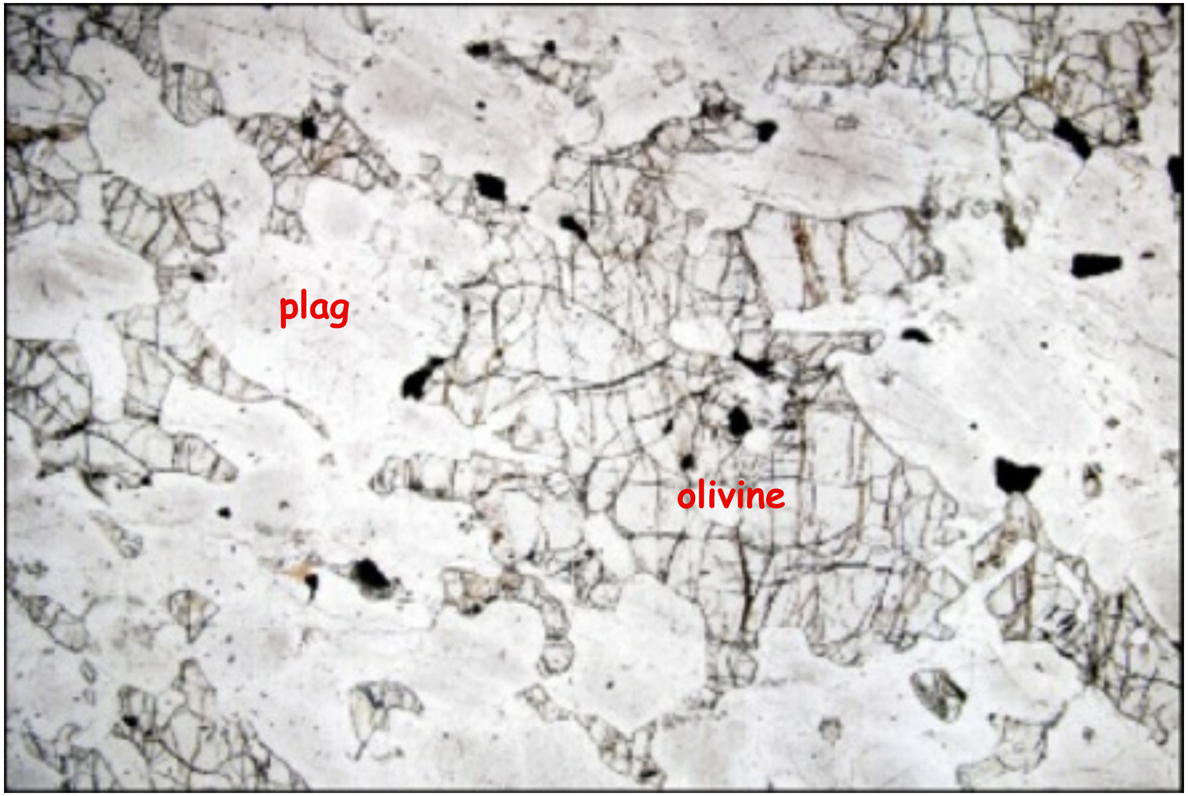




A: Titanite\ High relief.

B: Quartz \ low relief.

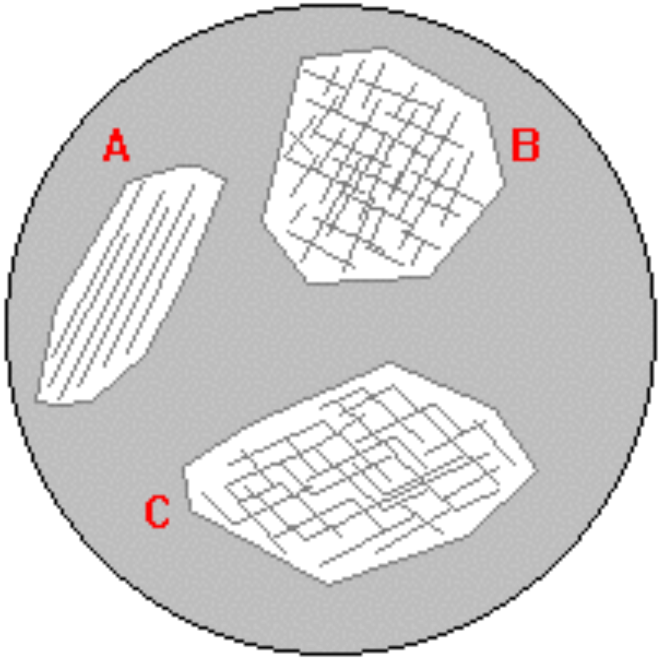
relief (PPL)



- Olivine has high relief
- Plag has low relief

olivine:	n=1.64-1.88
plag:	n=1.53-1.57
epoxy:	n=1.54

5. **Cleavage / Fracture**: the ability of a mineral to separate into smaller particles bounded of faces of possible crystal form.

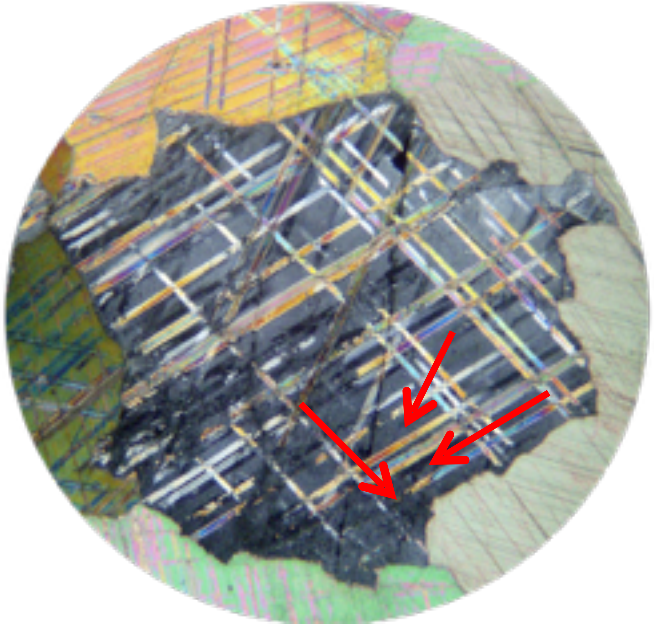


Cleavage will appear as sets of parallel lines in thin sections.

Sheet silicates (e.g. micas; muscovite and biotite) tend to have **one excellent cleavage,**

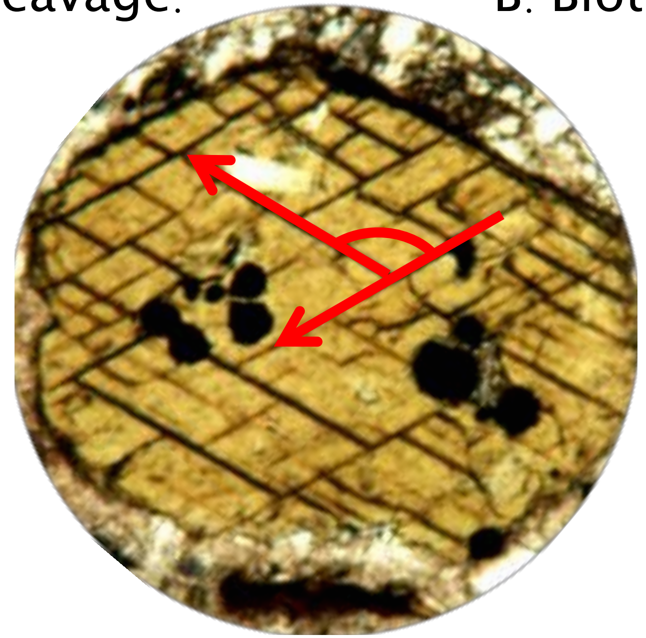
chain silicates (e.g. amphiboles and pyroxenes) have **two cleavages** and

framework silicates (e.g. feldspars; plagioclase and K-Feldspar) and carbonate



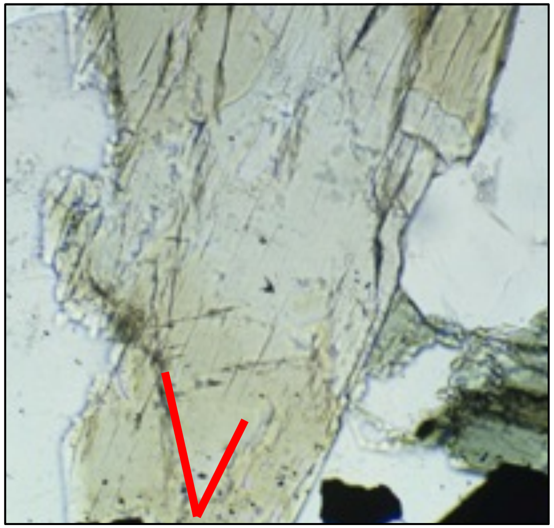
A: Calcite \ 3 set cleavage.

B: Biotite\ 1set cleavage.

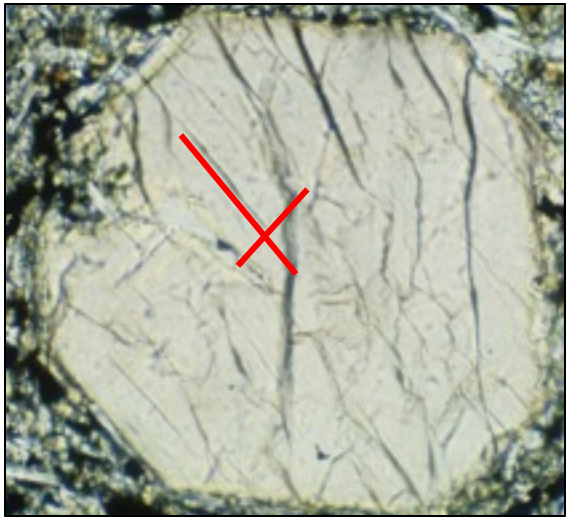


C: Amphimple / 2 set cleavage.

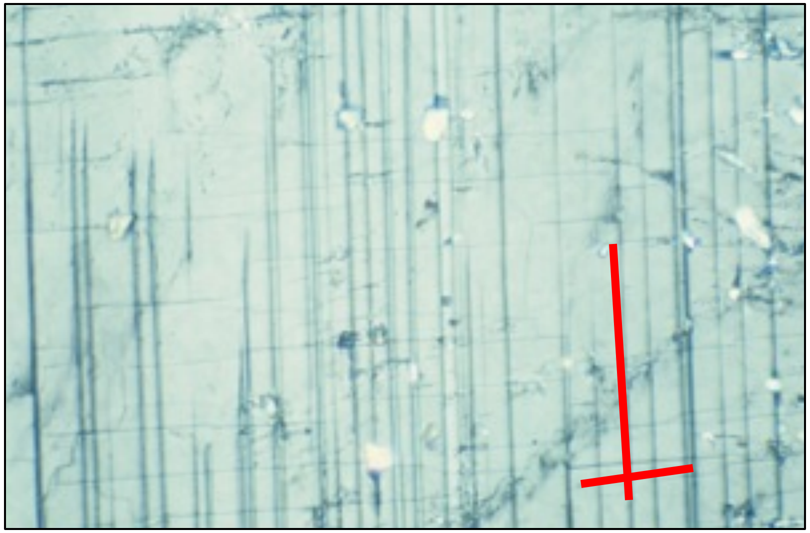
Cleavage



Amphiboles
e.g. hornblende ~ $54^o/126^o$



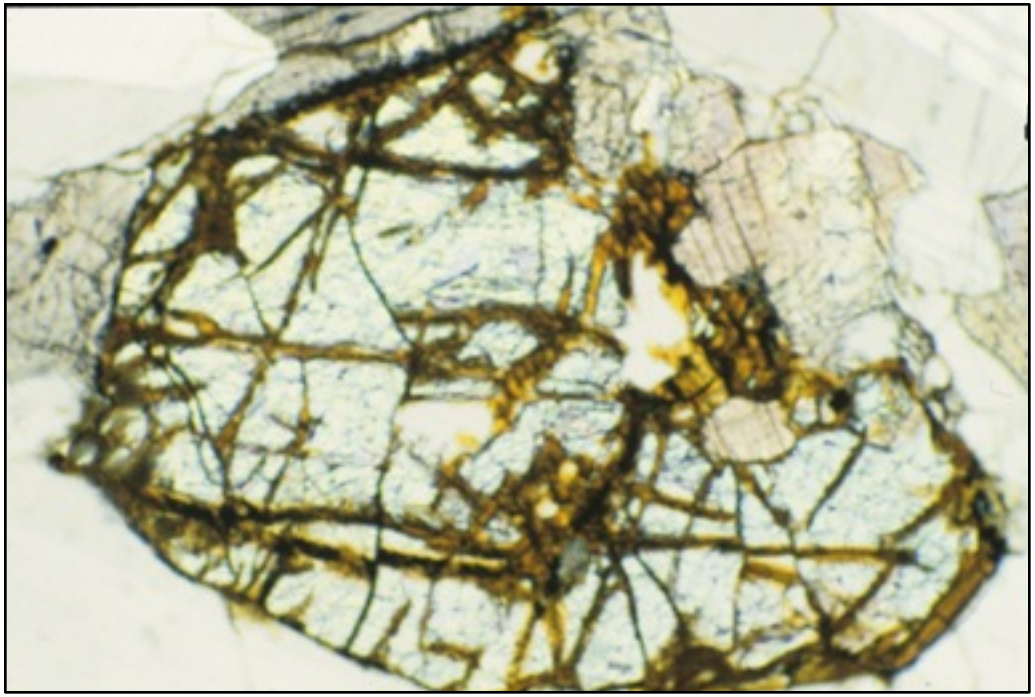
Pyroxene e.g. augite ~ 90^o;



Plagioclase: ~90^o

Fracture

Irregular cracks not related to atomic structure e.g. olivine

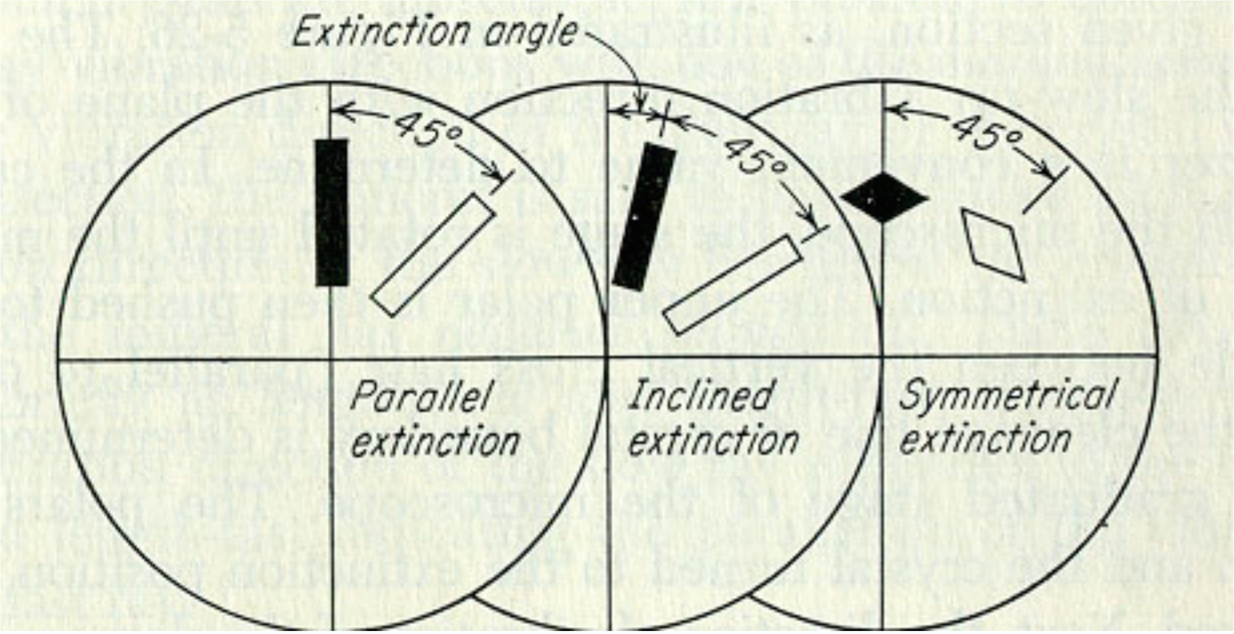


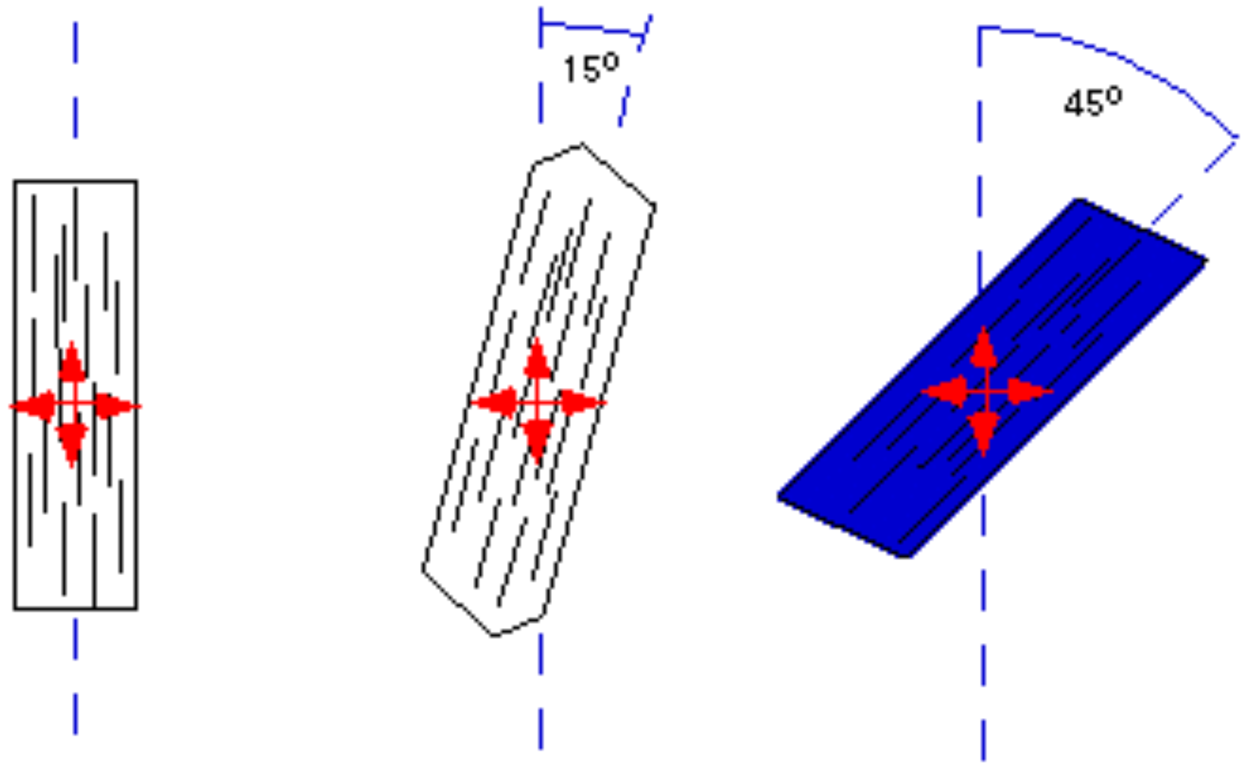
Olivine in gabbro (PPL)

6. Extinction & Extinction Angle

Types of Extinction:

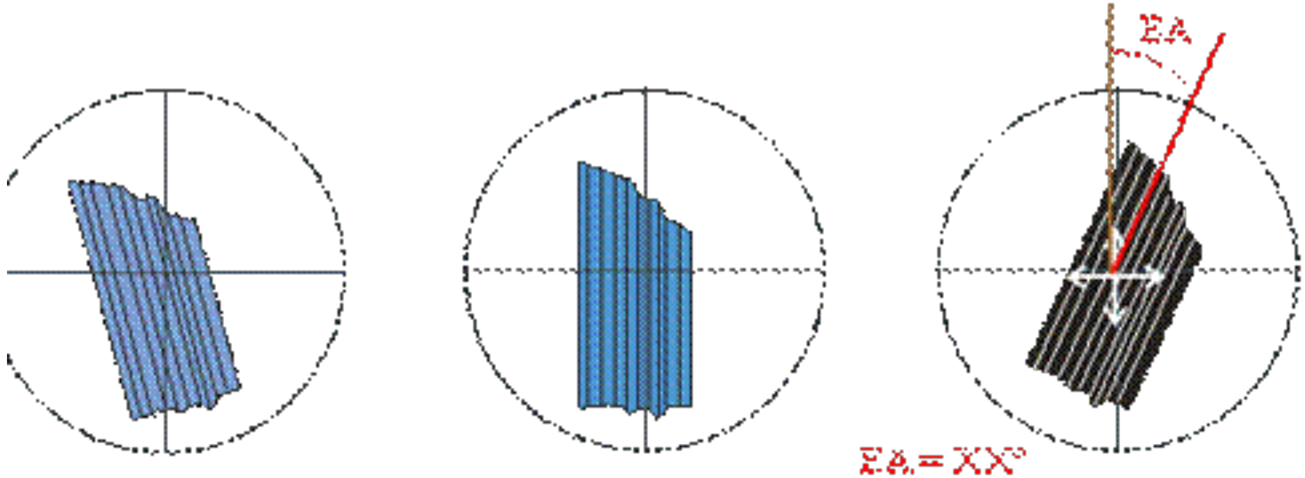
1. **Parallel Extinction**: when a mineral becomes dark parallel to the crosshairs. crystal face is oriented either N–S or E–W
2. **Inclined**: at an angle with the direction of polars.

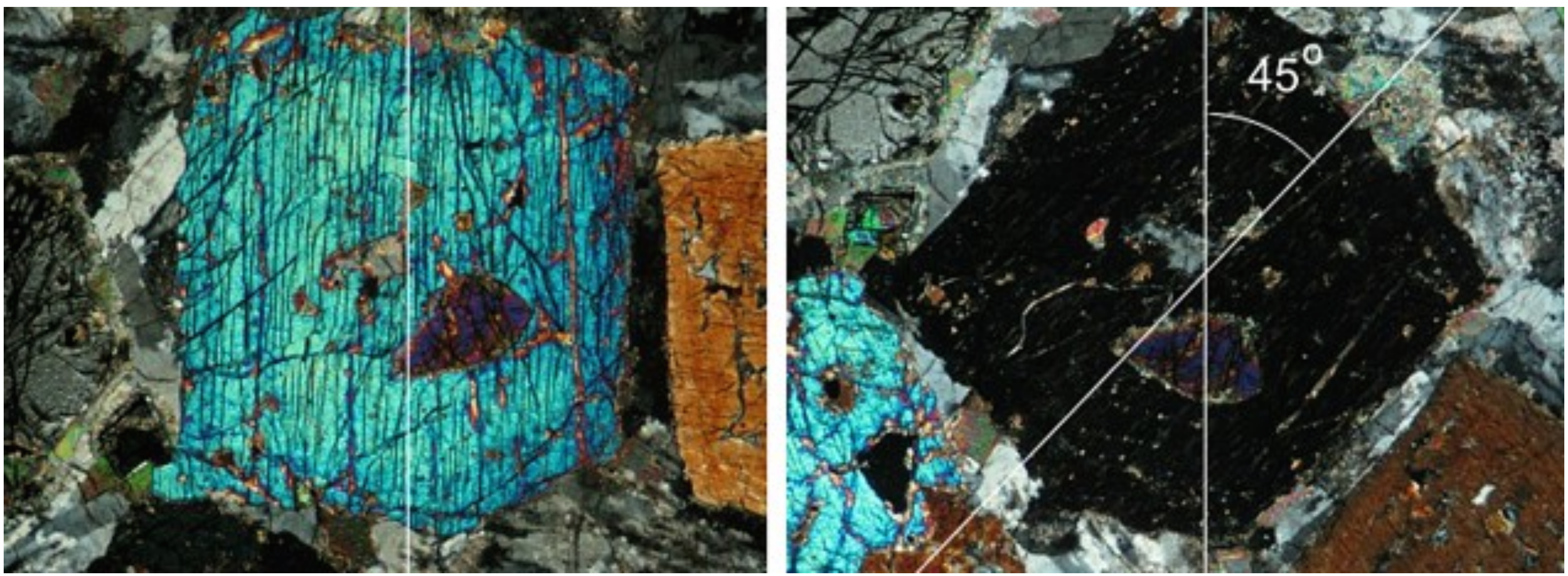




Inclined: at an angle with the direction of polars.

- inclined extinction: Amphiboles and Clinopyroxene .


EA
EA = XX°


45°

7. Interference Colors (Birefringence)

The colors that a mineral shows in thin section with the analyzer in are called interference colors.

These vary according to orientation of the crystal and the thickness of the thin section.

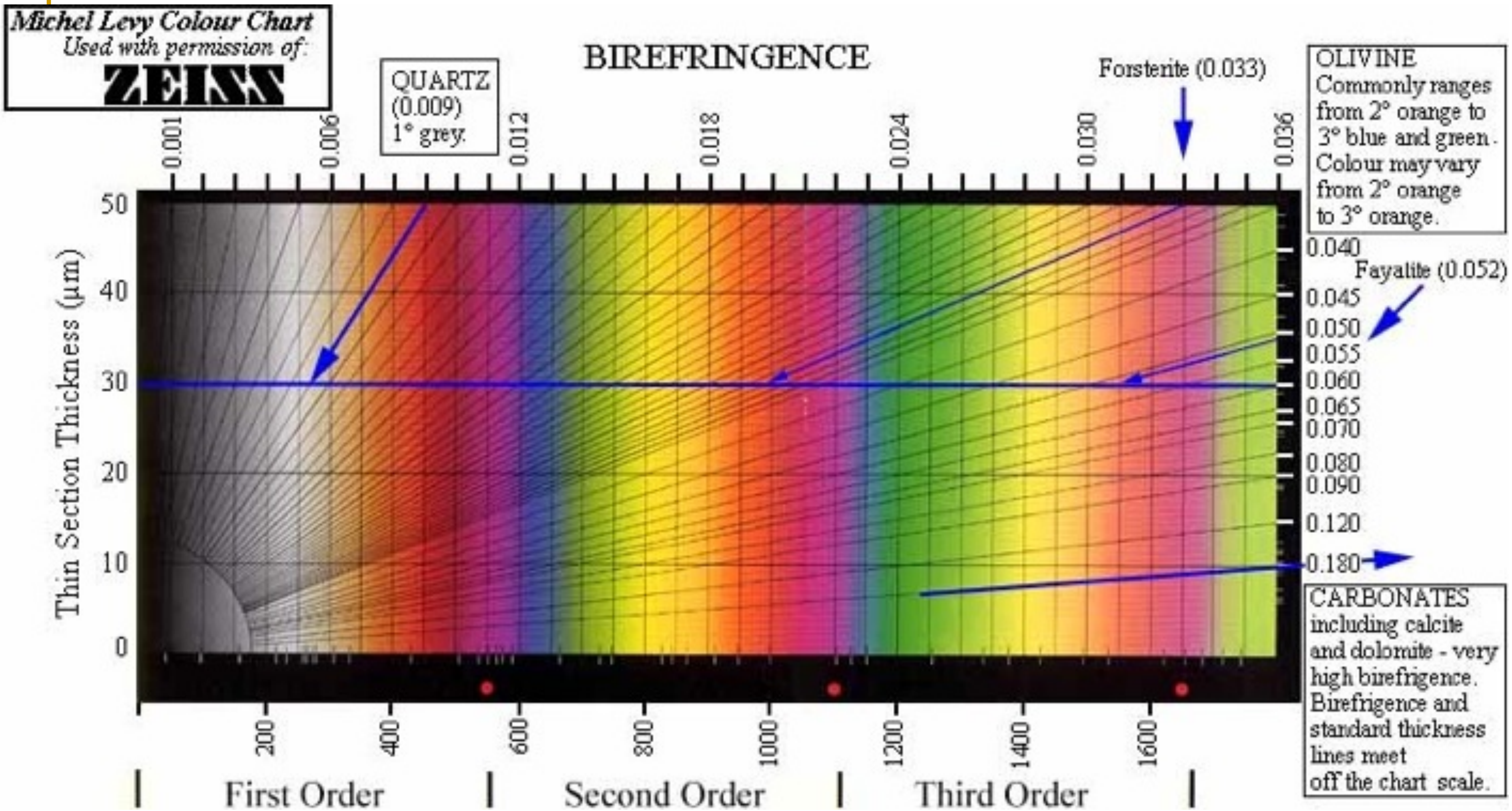
In thin section minerals show either

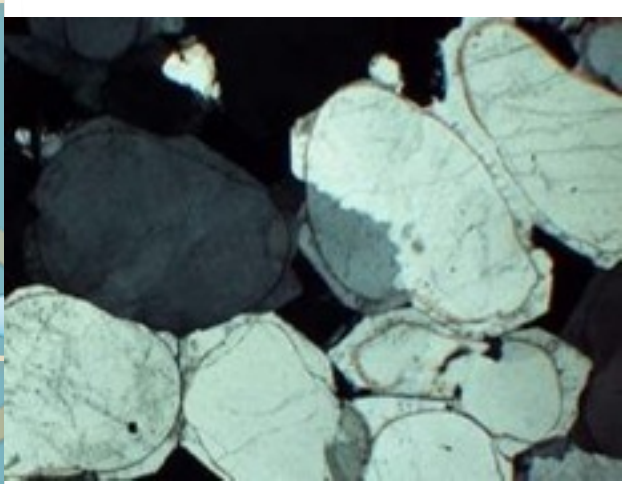
– **low order** interference colors (**grey–white–yellow**)

– **moderate** interference colors (**red–blue–green–yellow–red**)

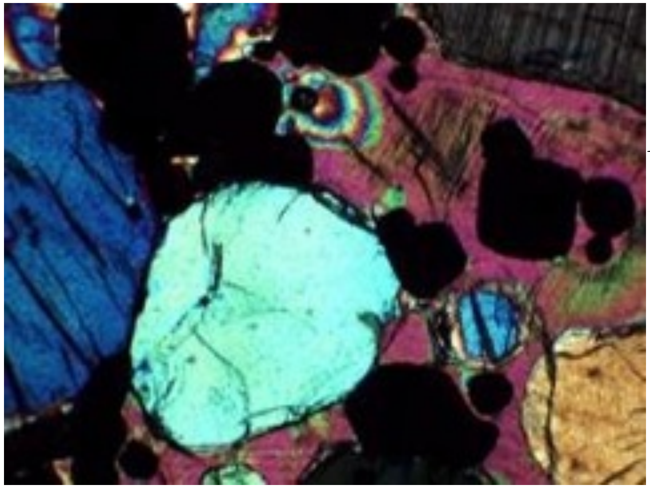
– **high order** interference colors (**pinks and greens**)

– **very high** order colors these tend to merge to produce a **golden color**).

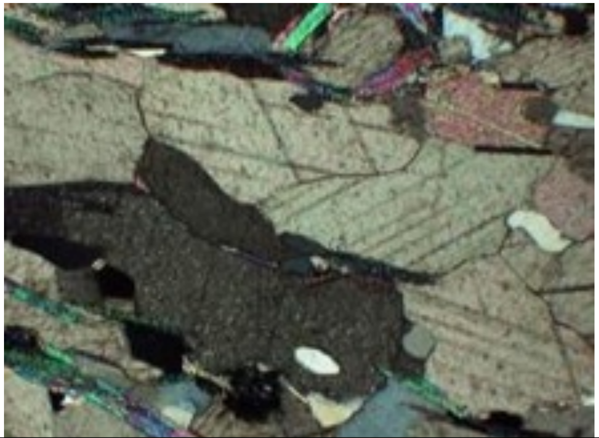

Michel Levy Colour Chart
Used with permission of:
ZEISS
BIREFRINGENCE
QUARTZ (0.009) 1° grey.
Forsterite (0.033)
OLIVINE Commonly ranges from 2° orange to 3° blue and green. Colour may vary from 2° orange to 3° orange.
Fayalite (0.052)
CARBONATES including calcite and dolomite - very high birefrigence. Birefrigence and standard thickness lines meet off the chart scale.
0.001
0.006
0.012
0.018
0.024
0.030
0.036
0.040
0.045
0.050
0.055
0.060
0.065
0.070
0.080
0.090
0.120
0.180
Thin Section Thickness (µm)
50
40
30
20
10
0
200
400
600
800
1000
1200
1400
1600
First Order
Second Order
Third Order



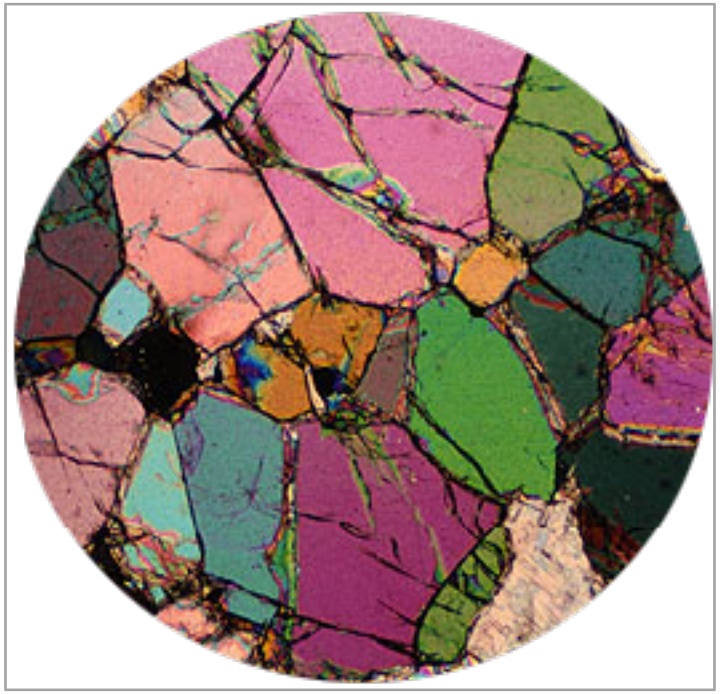
Low order interference colours (quartz)

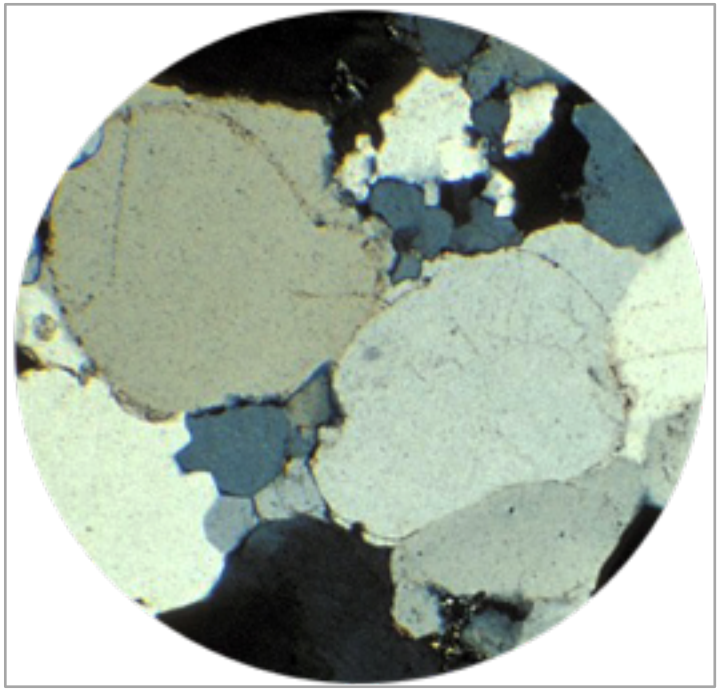


Moderate order interference colours (olivine and clinopyroxene)



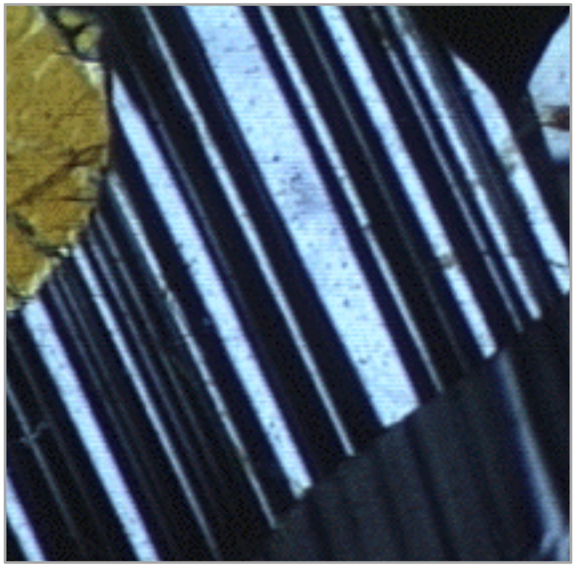
Very high order interference colours (calcite)





A: Olivine\ moderate-high order interference colors. **B: Quartz\ low order interference colors.**

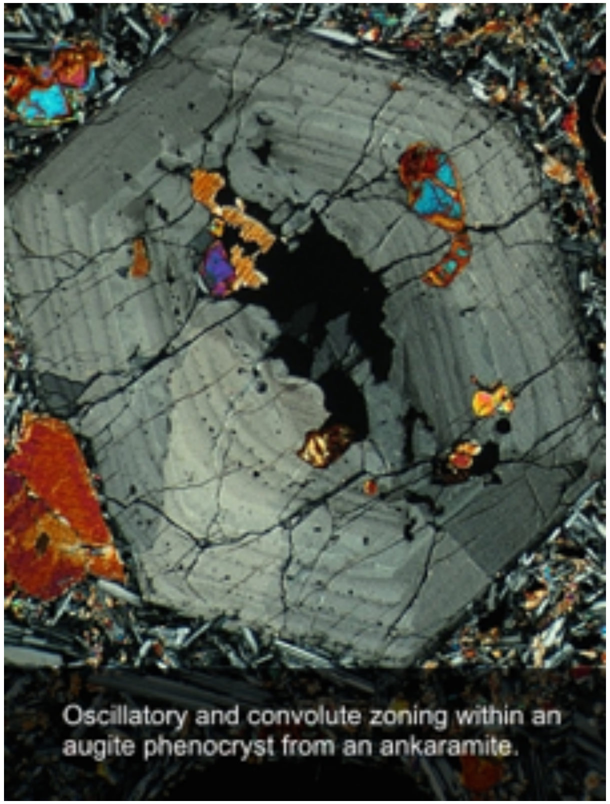
8. **Twinning** – formation of rational symmetry intergrowth of 2 or more grains of crystalline species. a single crystal having different extinction positions

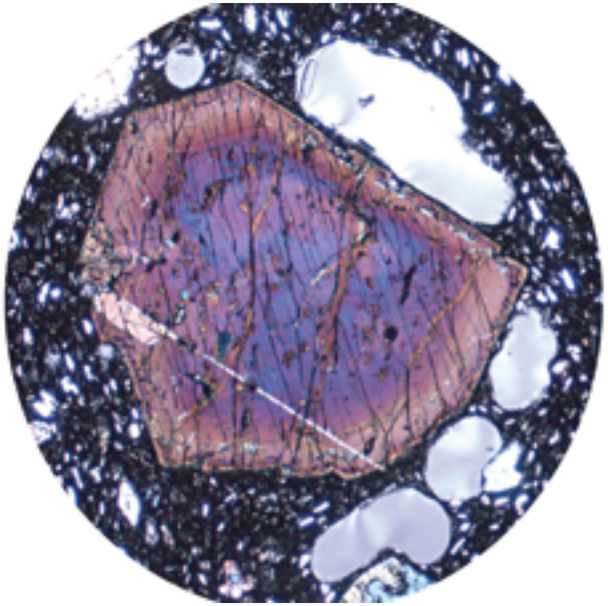


occurs when two separate crystals share some of the same crystal lattice points in a symmetrical manner. The result is an intergrowth of two separate crystals in a variety of specific configurations.

Multiple twins in plagioclase

Zonning


Oscillatory and convolute zoning within an
augite phenocryst from an ankaramite.

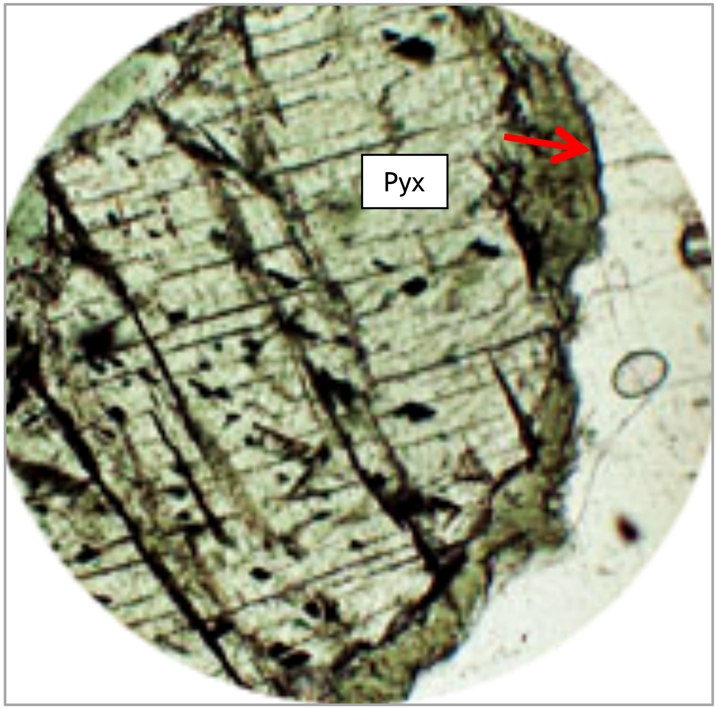


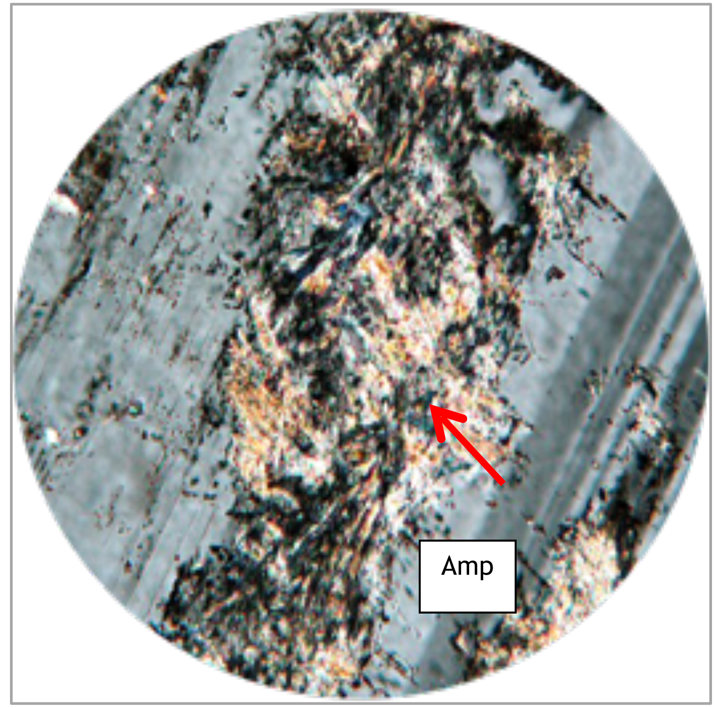
9. Alteration

Minerals formed in high temperatures frequently show alteration to minerals that are more stable at low temperatures during cooling.

Typically the high temperature minerals form large crystals and are surrounded by a rim of an aggregate of fine grained low temperature minerals.

- Common minerals that form at high temperatures: Olivine,Pyroxene, Amphibole and Biotite.
- Common minerals that form as alteration products: Chlorite, Muscovite and Clay minerals.

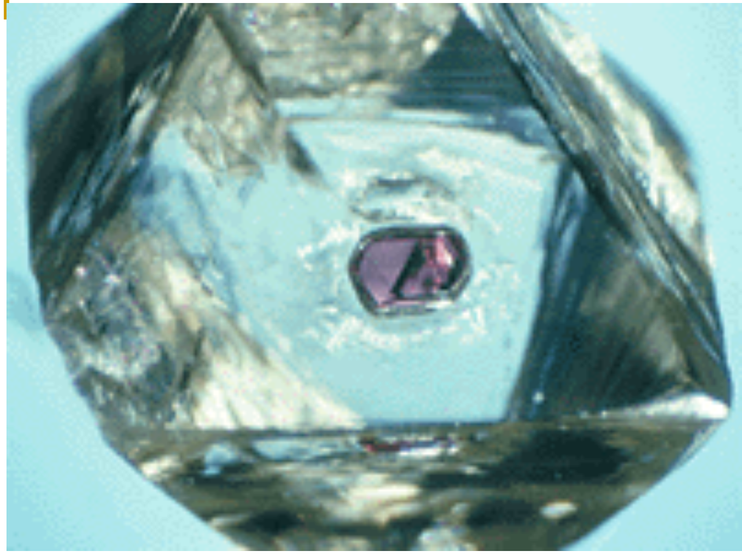


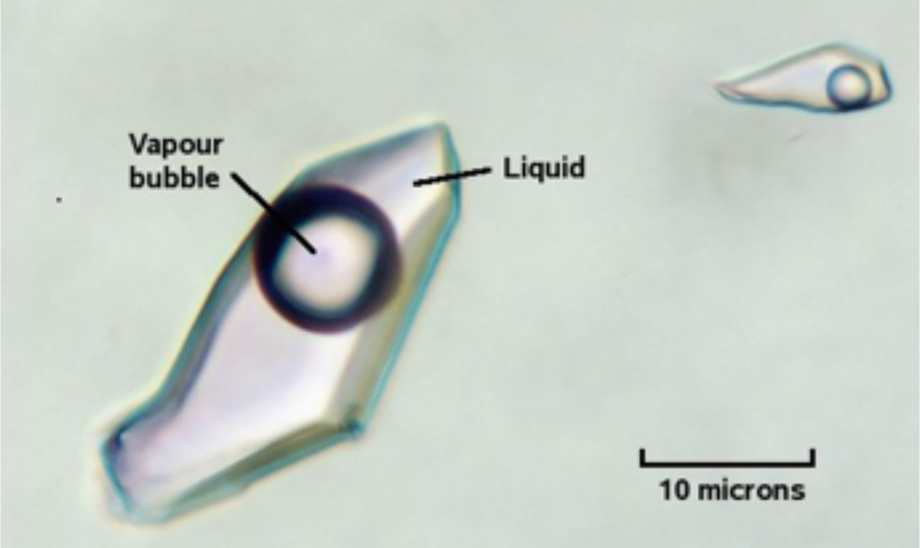


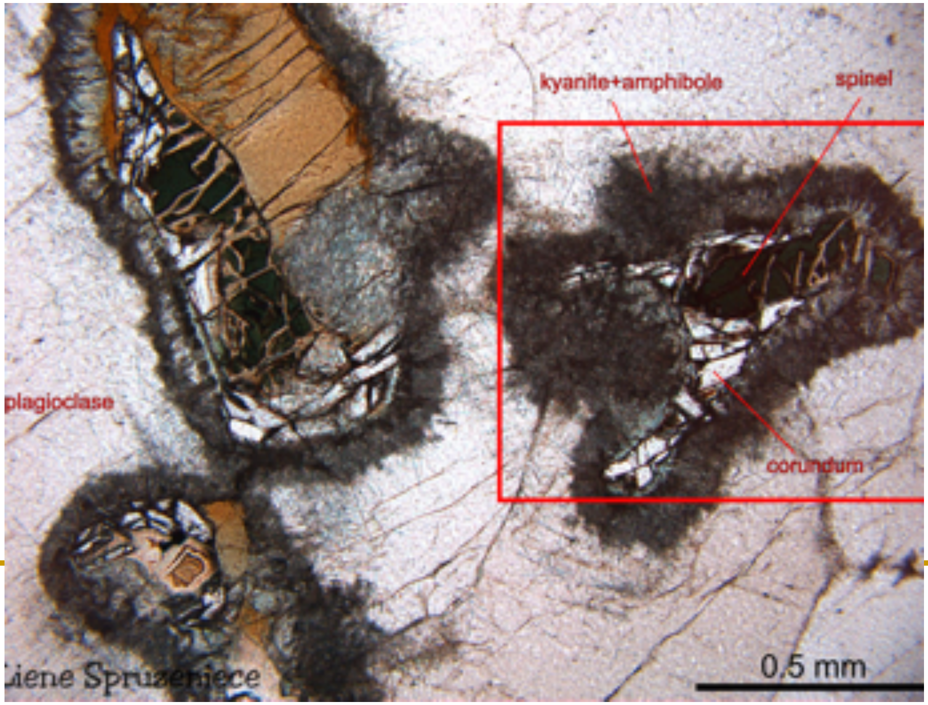
A: Rim of amphibole alteration around original pyroxene.

B: Sericite (fine grained white mica/clays) alteration of plagioclase.

10. Mineral inclusions

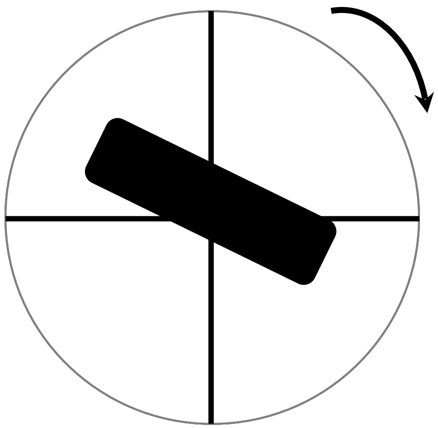






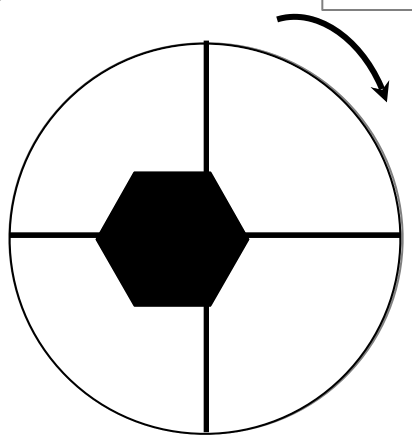
11. Interference Figures

Most mineral grains **change color** as the stage is rotated; these grains go **black** 4 times in 360° rotation- exactly every 90°



These minerals are anisotropic

Glass and a few minerals stay black in all orientations



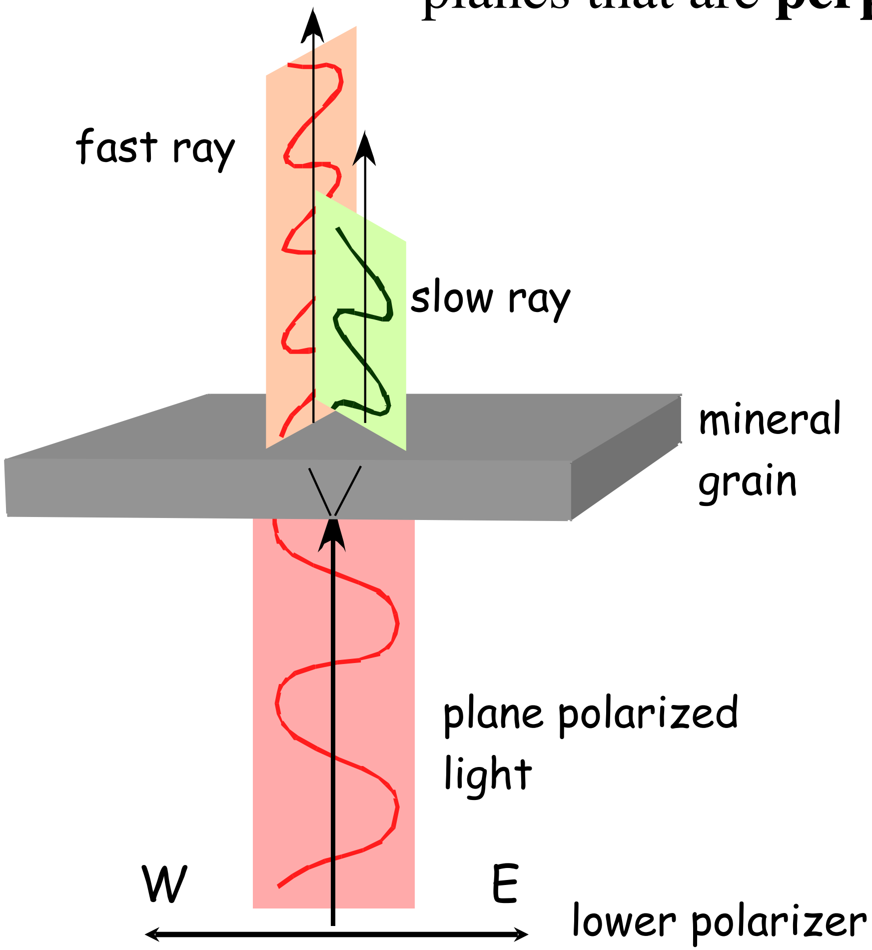
These minerals are isotropic

- All isometric minerals (e.g., garnet) are **isotropic** – they cannot reorient light. Light does not get rotated or split; propagates with same velocity in all directions
  - These minerals are always black in crossed polars.

- All other minerals are **anisotropic** – they are all capable of reorienting light (transmit light under cross polars).

- All anisotropic minerals contain one or two special directions that do **not** reorient light.
  - Minerals with **one** special direction are called **uniaxial**
  - Minerals with **two** special directions are called **biaxial**

All **anisotropic** minerals can resolve light into **two** plane polarized components that travel at **different velocities** and vibrate in planes that are **perpendicular** to one another



Some light is now able to pass through the upper polarizer

When light gets split:

- velocity changes
- rays get bent (refracted)
- 2 new vibration directions
- usually see new colors

How light behaves depends on crystal structure

Isotropic → Isometric

- All crystallographic axes are equal

Uniaxial → Hexagonal, tetragonal

- All axes ⊥ c are equal but c is unique

Biaxial → Orthorhombic, monoclinic, triclinic

- All axes are unequal

The Hashemite University
Faculty of Natural Resources and Environmental Sciences
Department of Earth and environmental Sciences
Dr.Faten Slaty / G.Wafa Al-Argan

Report sheet/ Mineralogy lab

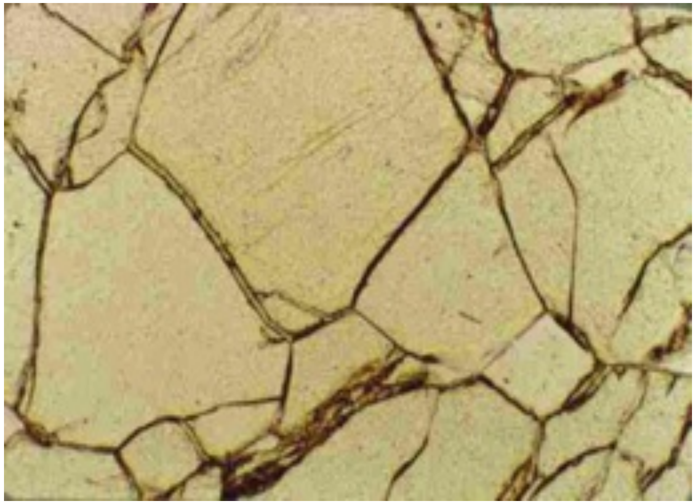
Lab No.:…………………….. **Title:**…………………………………

Student Name:……………………………… **Section:**……………

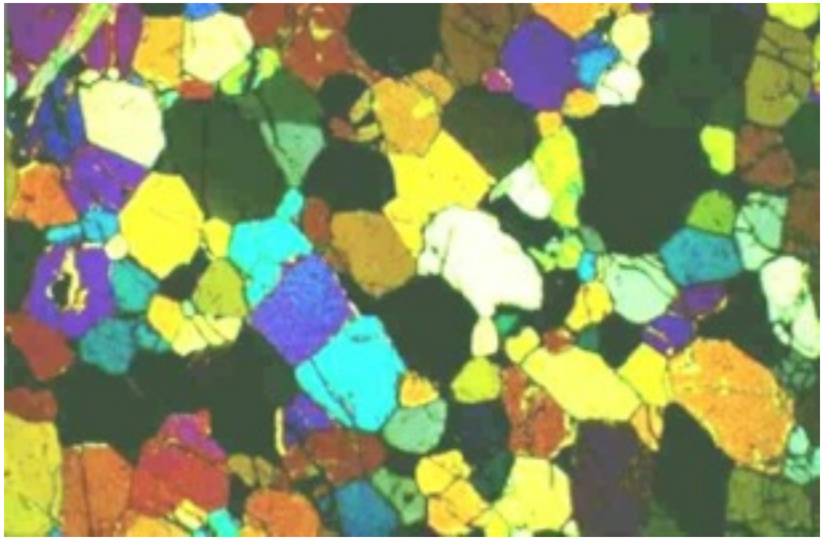
Thin section Name/No. ……………..….	**Mineral Name:** **Mineral Class:** **Subclass:**	**Group:** **Chemical formula:** **Crystal system:**
Thin section view **XPL / PPL**		
Crystal Shape ……………………….	**Color** …………………………	**Pleochroism** ……………………………
Cleavage/angle ………………………	**Relief** …………………………….	**Interference color** …………………………….
Fracture ………………………	**Interference figure** …………………………….	**Extinction/angle** …………………………….
Inclusions ………………………	**Chemical Alteration** …………………………….	**Twining/zoning** …………………………….

- **Associated minerals:**
- **Common rock:**

Rock- Forming Minerals in Thin Section

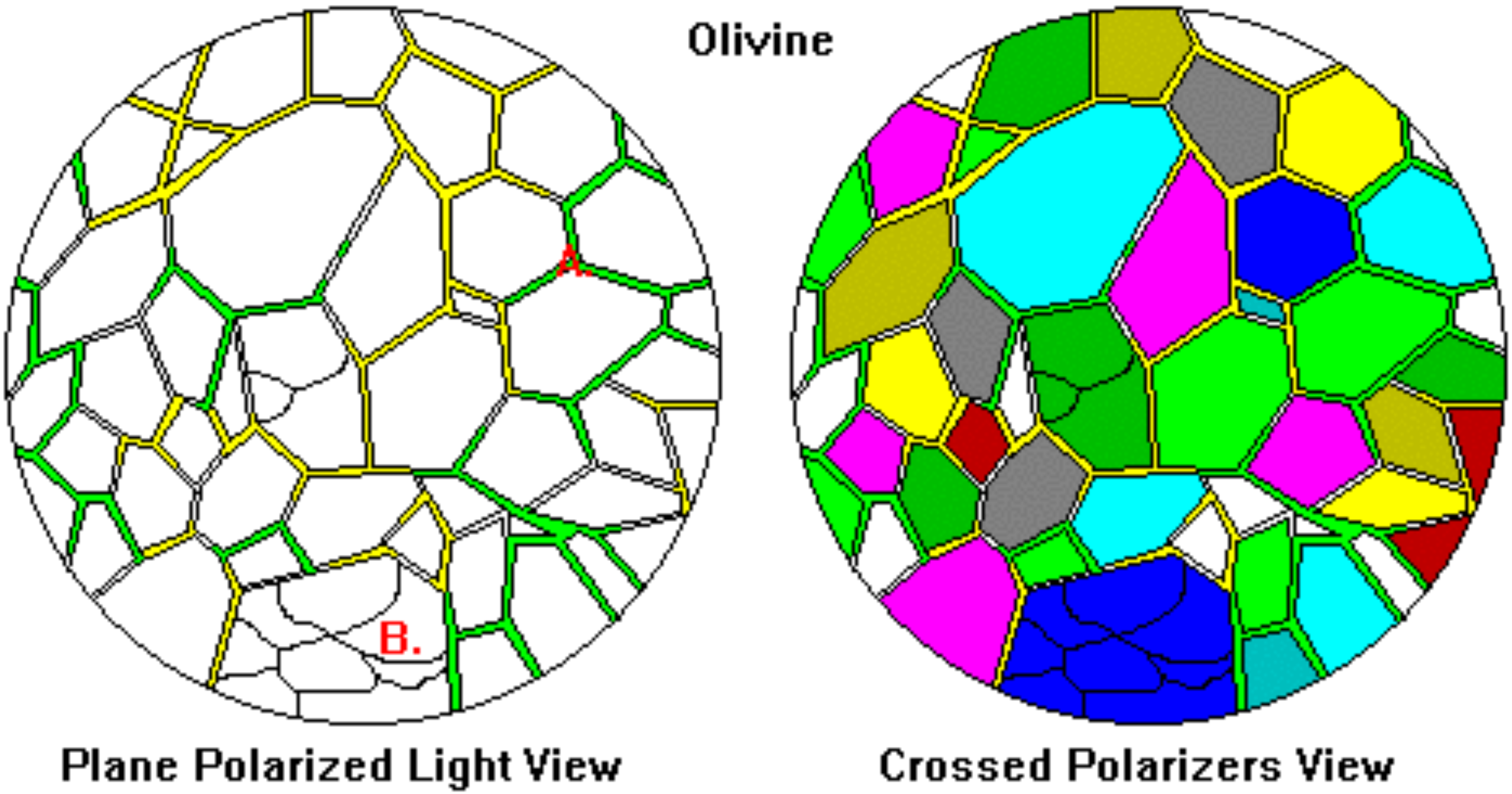


Olivine (Uncrossed polars)



Olivine (Crossed polars)

OLIVINE


Olivine
A.
B.
Plane Polarized Light View
Crossed Polarizers View

Olivine Description

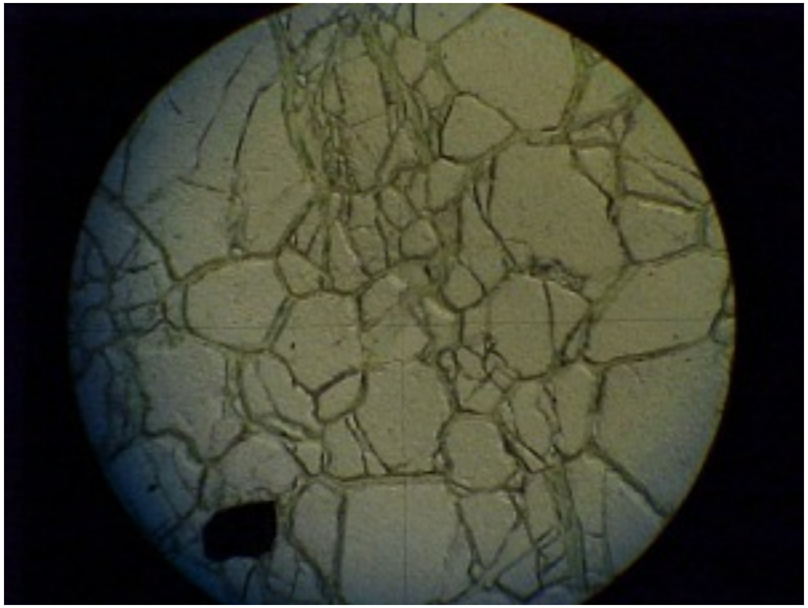
Plane-Polarized Light

- Moderately high relief
- Clear, occasionally very light yellowish or greenish
- No cleavage
- Commonly rimmed with greenish alteration products (A)
- Internal fracturing of grains common (B)
- Never occurs with quartz

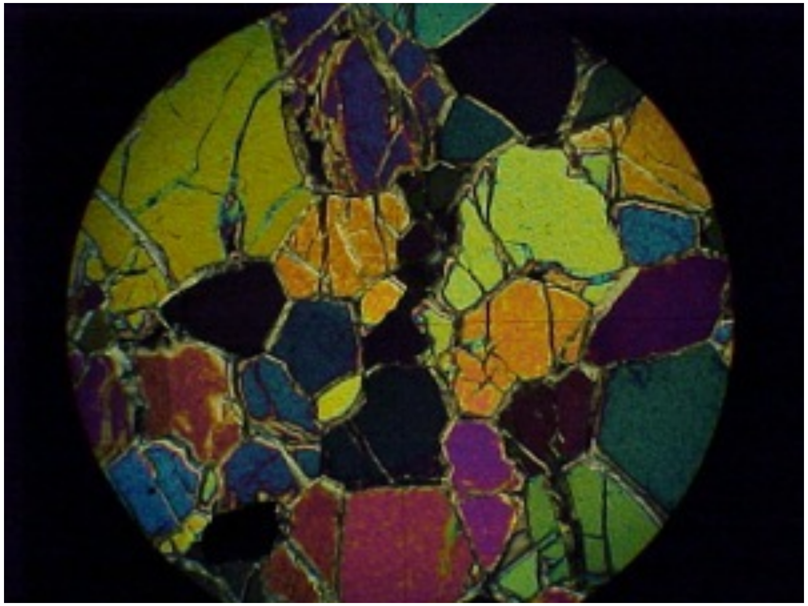
Crossed Polarizers

- Bright second-and third-order interference colors.
- Alteration products tend to have low interference colors.

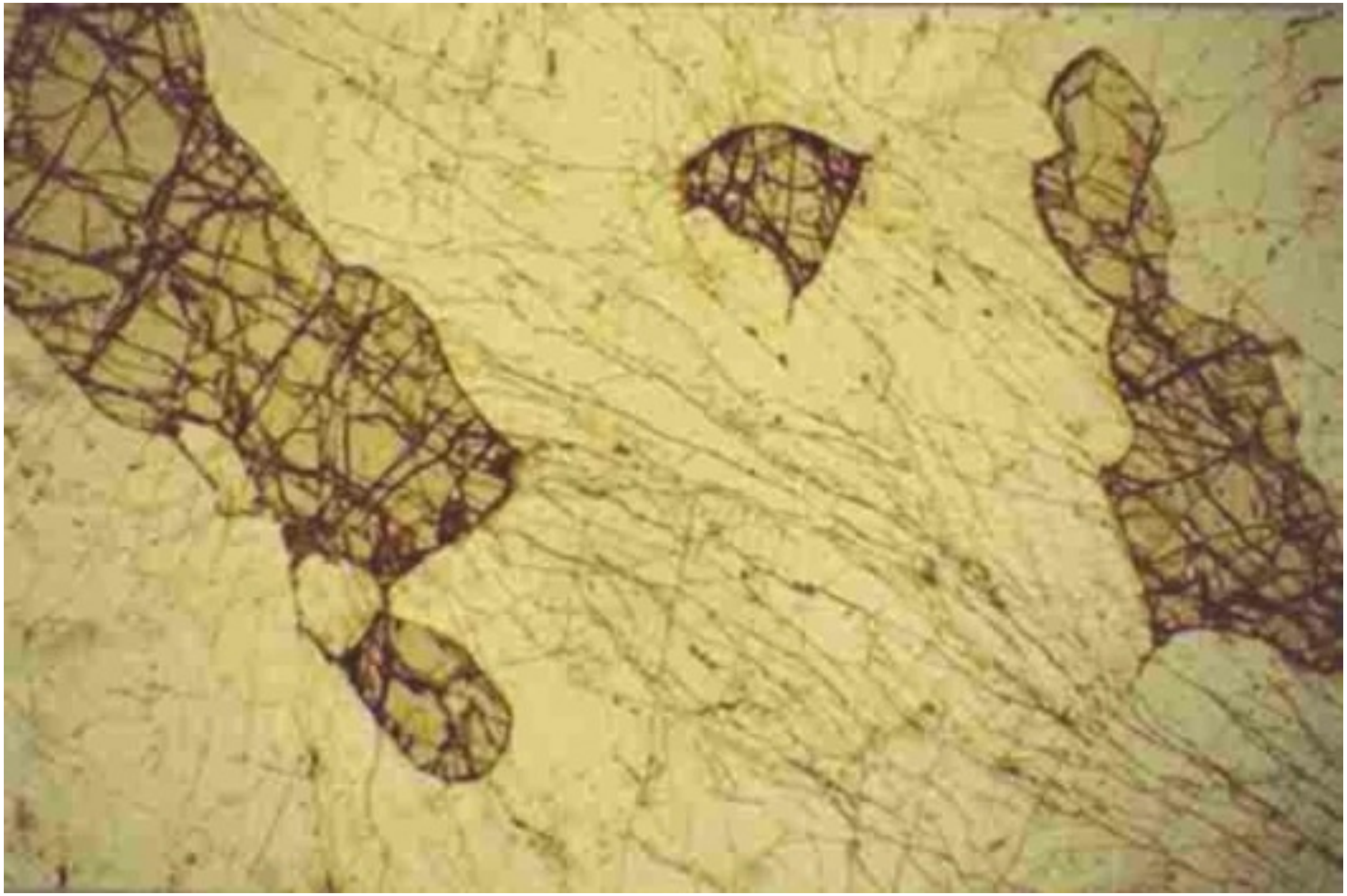
Below is a typical view of olivine in plane polarized light. Note the high relief and the low-relief alteration products between grains.



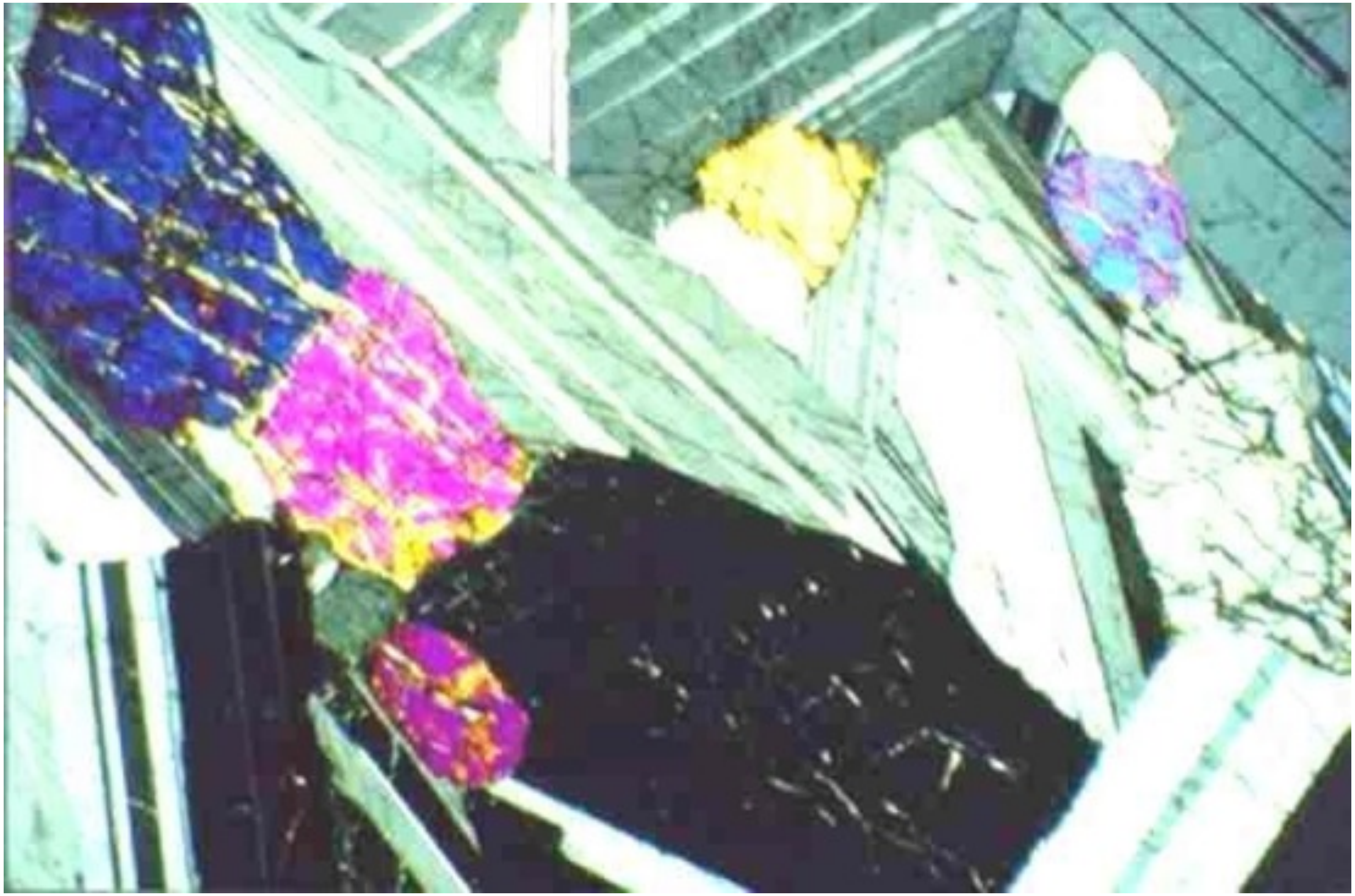
Olivine in uncrossed polars



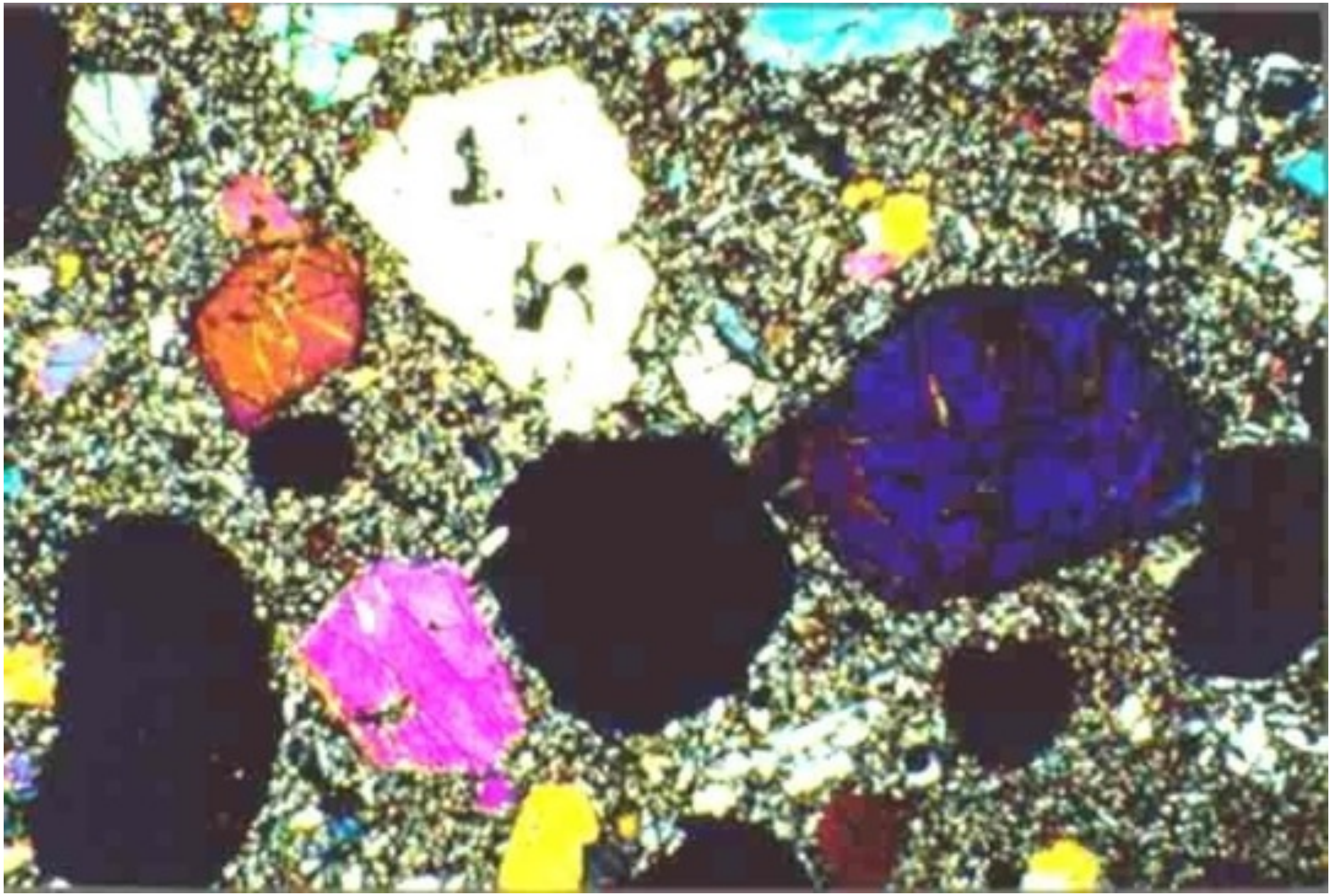
Olivine in crossed polars



cracks from olivine in gabbro

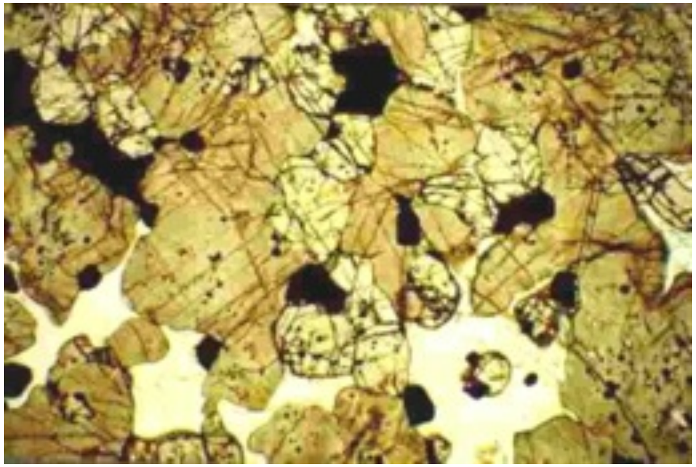


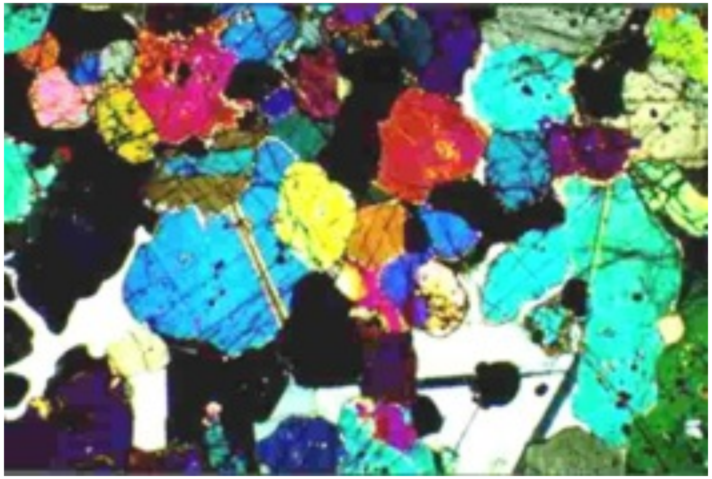
olivine in gabbro (crossed polars)



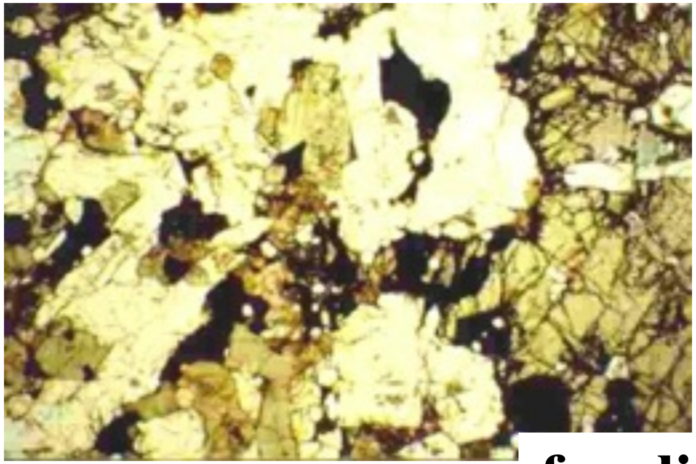
olivine in basalt (crossed polars)

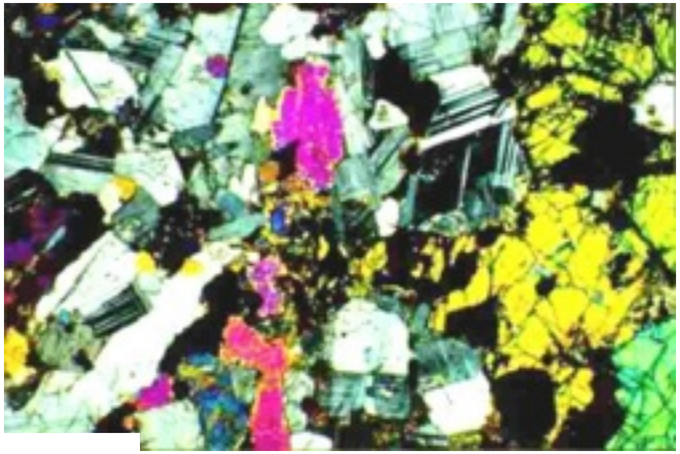
Sample photos of Olivine:





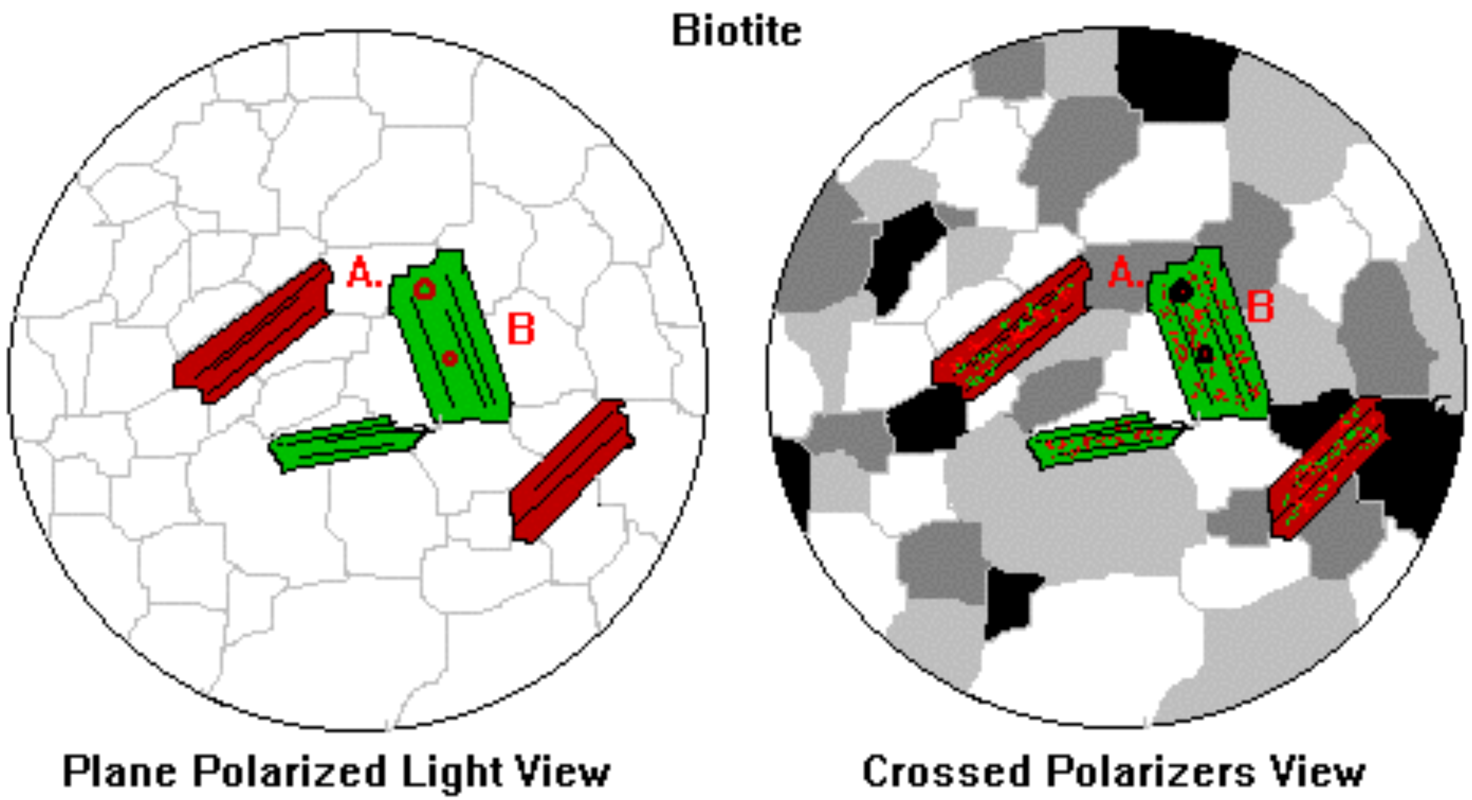
olivine gabbro





fayalite gabbro

BIOTITE


Biotite
A.
B
A.
B
Plane Polarized Light View
Crossed Polarizers View

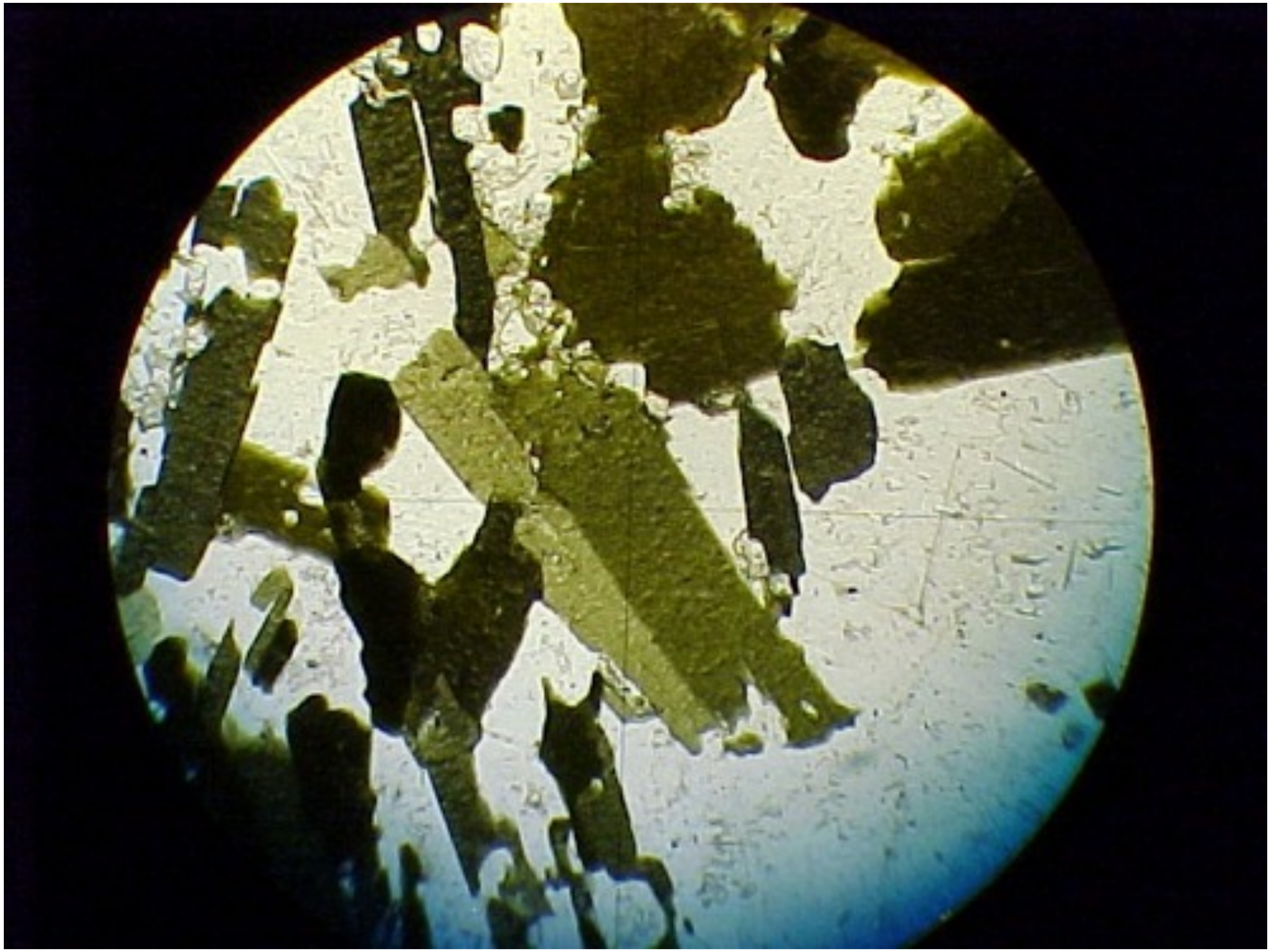
Biotite Description

Plane-Polarized Light

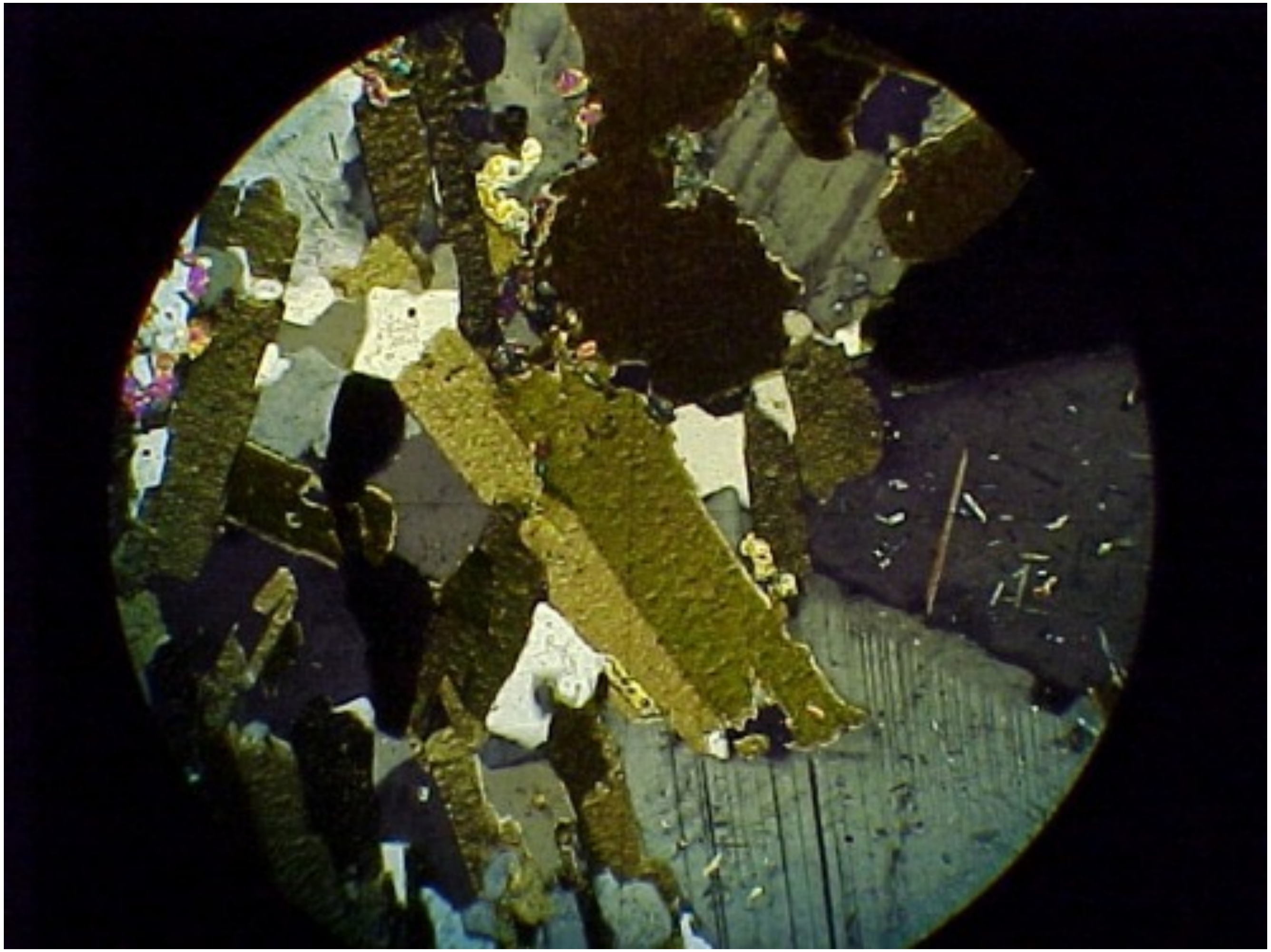
• Moderate relief
• Orange, brown or dark green (A)
• Perfect micaceous cleavage
• May be dark pleochroic halos around inclusions of zircon or other mildly radioactive minerals (B)

Crossed Polarizers

• Second-and third-order interference colors usually not strikingly evident because of the strong natural coloration.
• Mottling common, giving the mineral a gnarly or "birds-eye maple" texture (A)
• May be dark pleochroic halos around inclusions of zircon or other mildly radioactive minerals (B)

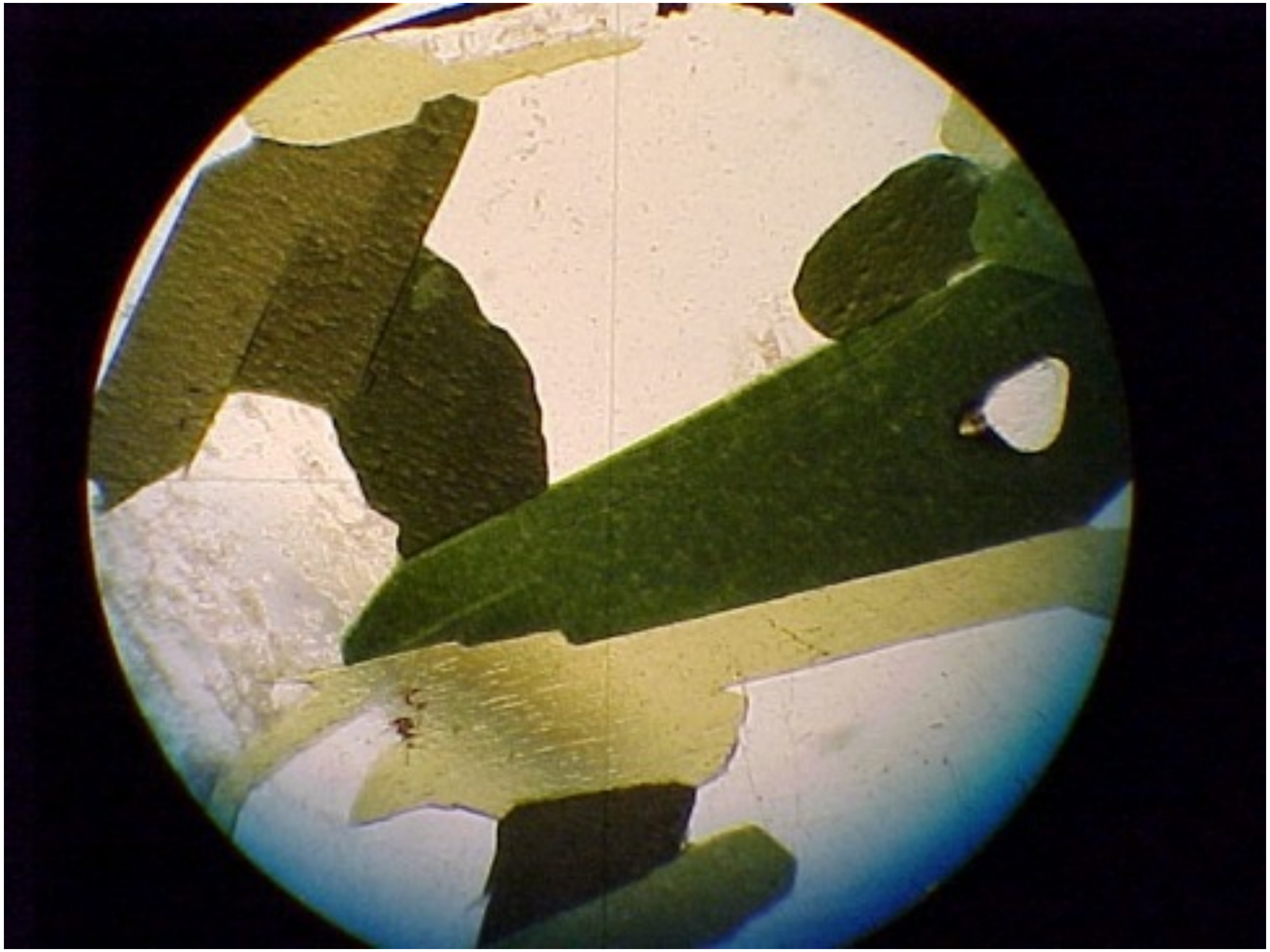


Biotite in plane polarized light. This biotite is dark green to brown. Note the mottled texture.

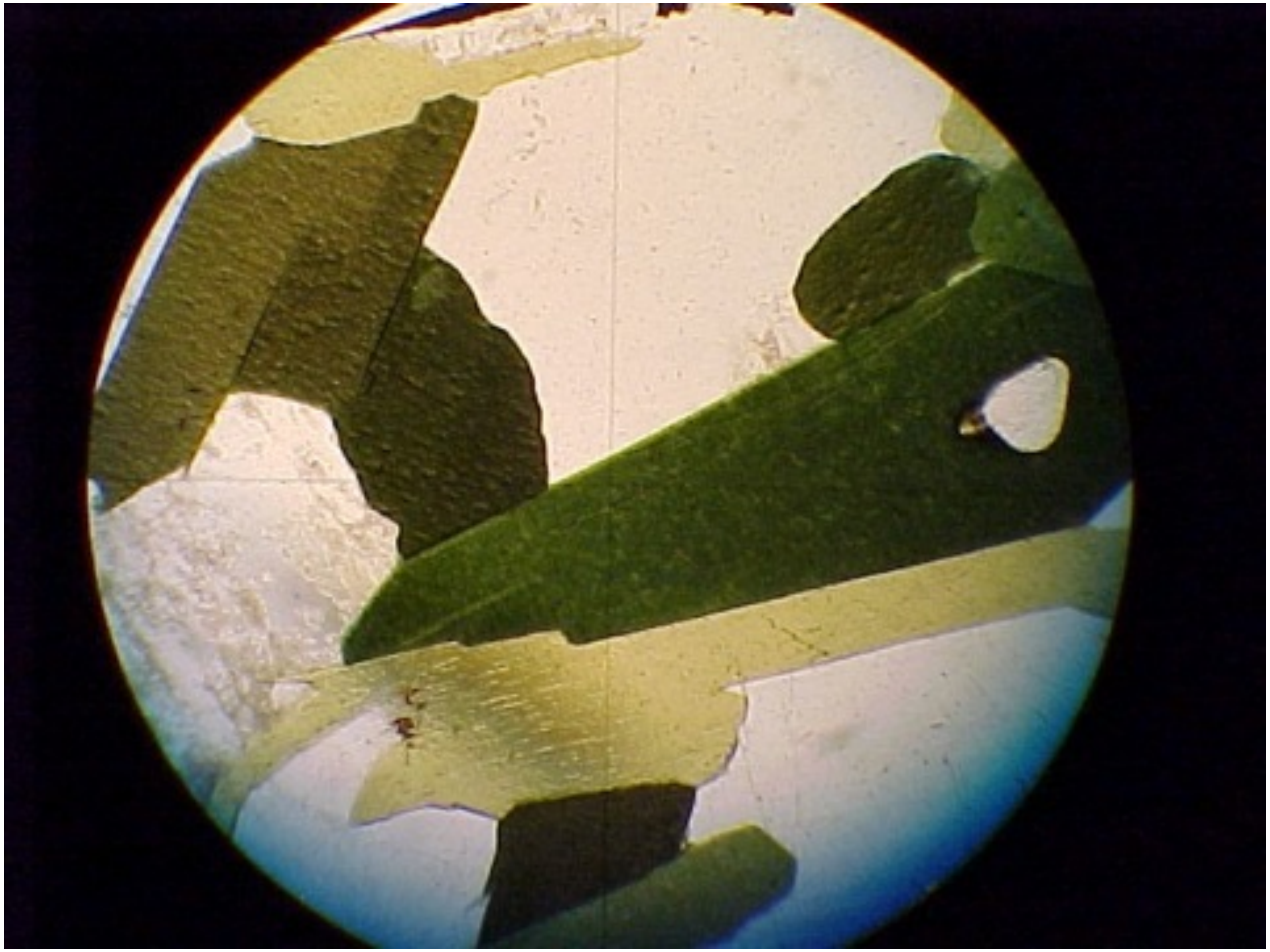


Same field in crossed polarizers. The appearance is dominated by deep color.

Plane polarized light. This biotite is very pleochroic and changes color from light greenish brown to nearly opaque.

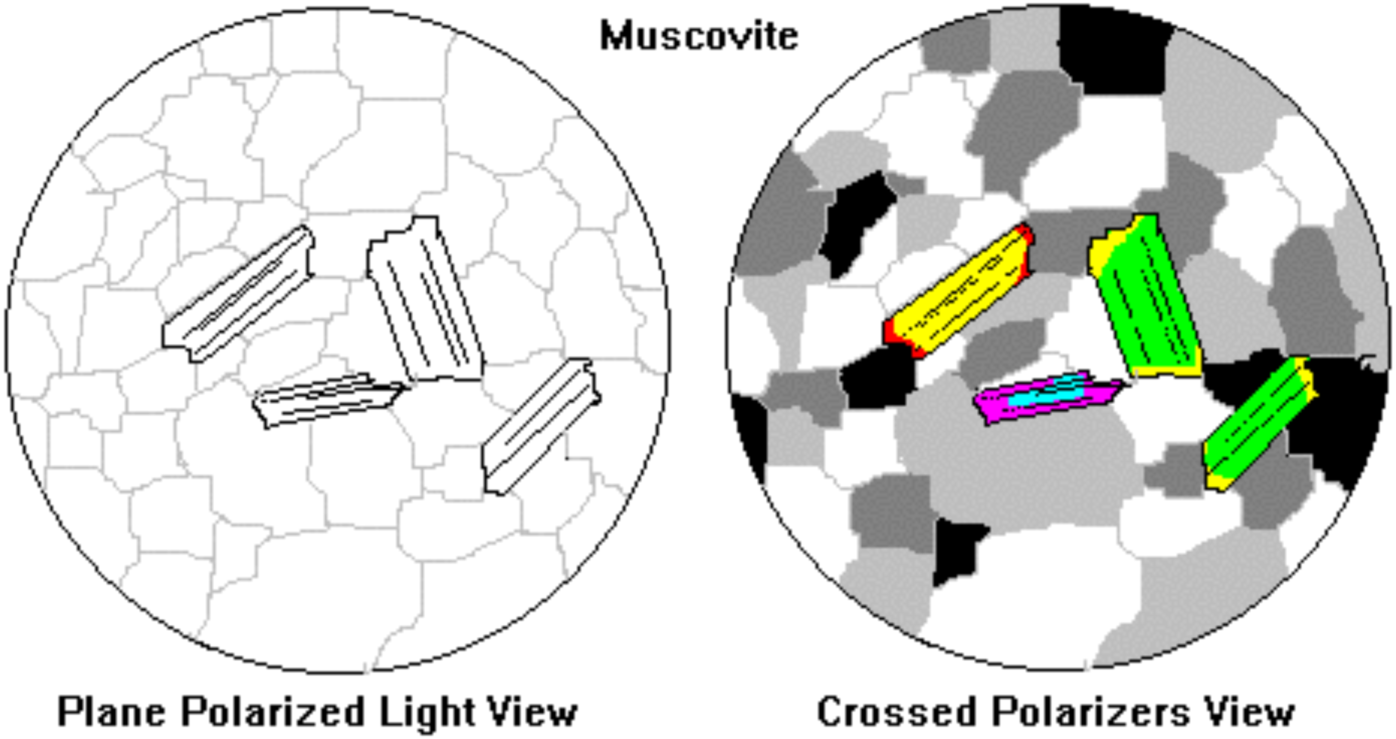


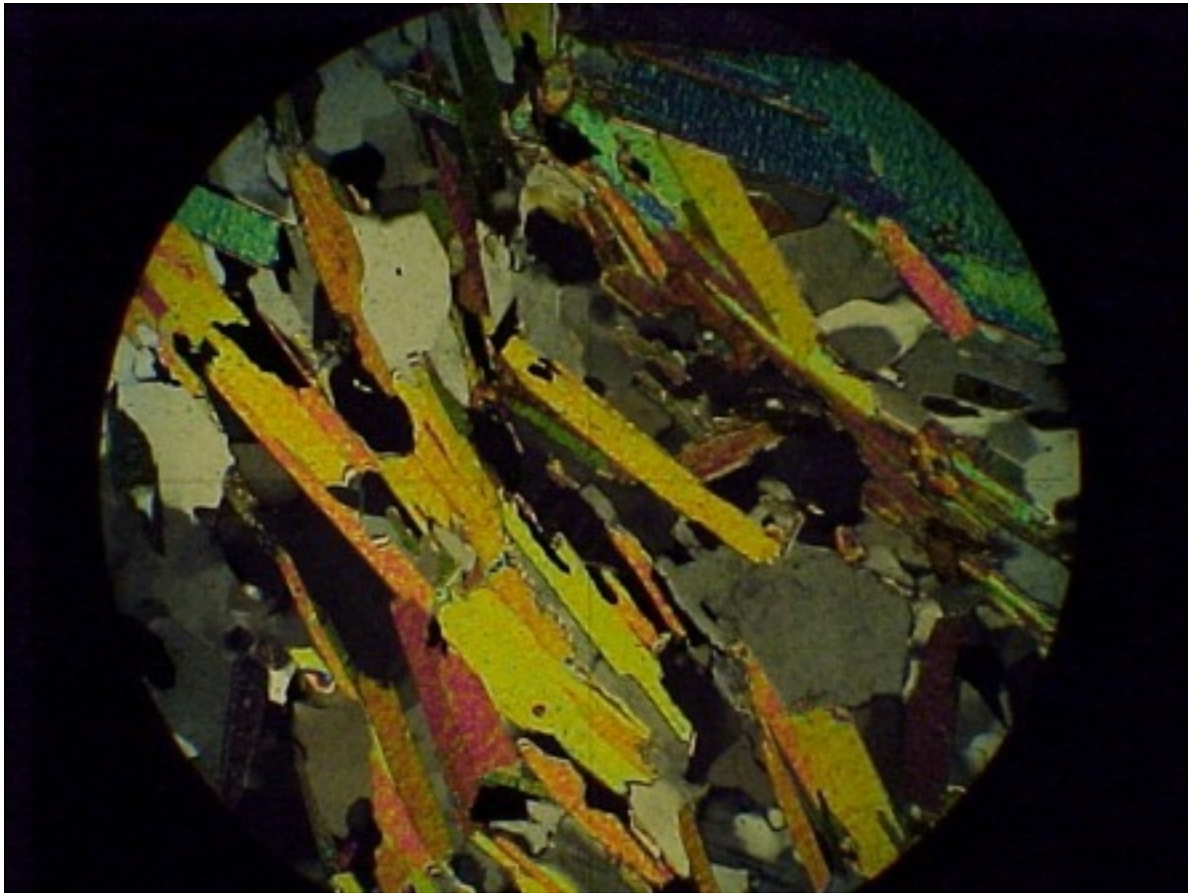
A plane polarized light view of biotite ranging from light yellow-green to dark green in color. Note the good cleavage



Same field in crossed polarizers. Light biotite grains can show appreciable interference color.

MUSCOVITE


Muscovite
Plane Polarized Light View
Crossed Polarizers View



Muscovite with biotite in crossed polars

Muscovite Description

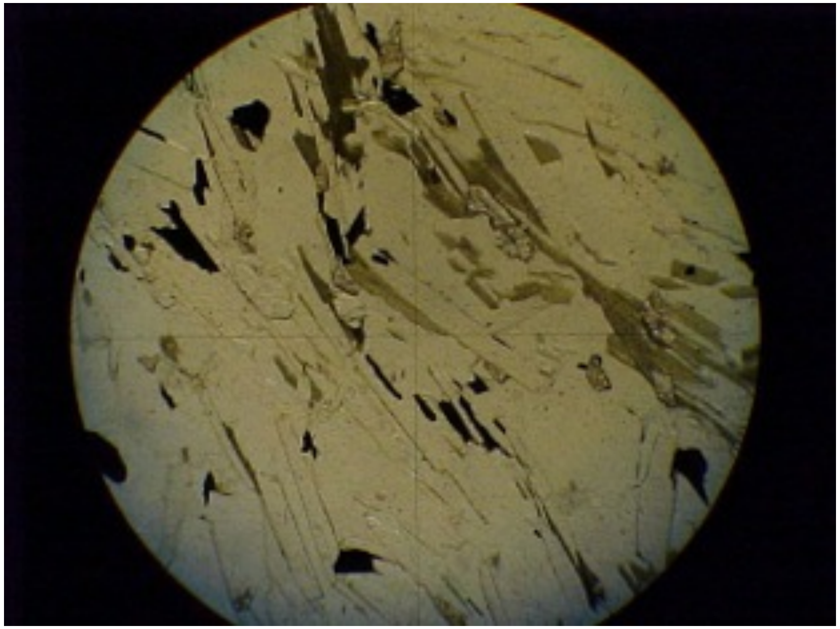
Plane-Polarized Light

- Low relief
- Clear
- Perfect micaceous cleavage

Crossed Polarizers

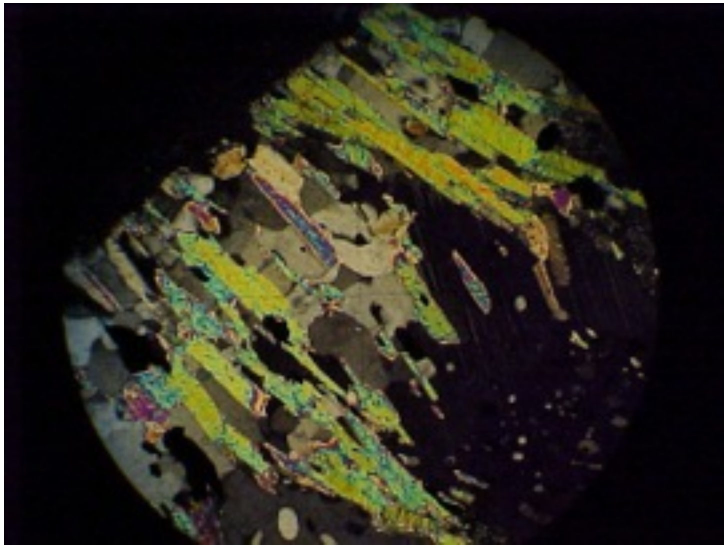
- Bright second-and third-order interference colors
- Generally not as much mottling as biotite

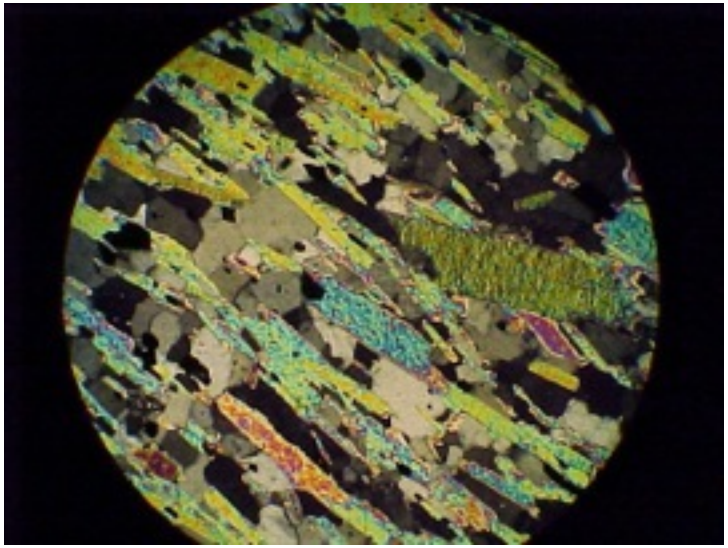
Both muscovite and biotite are present in the plane-polarized view below. The muscovite is barely visible



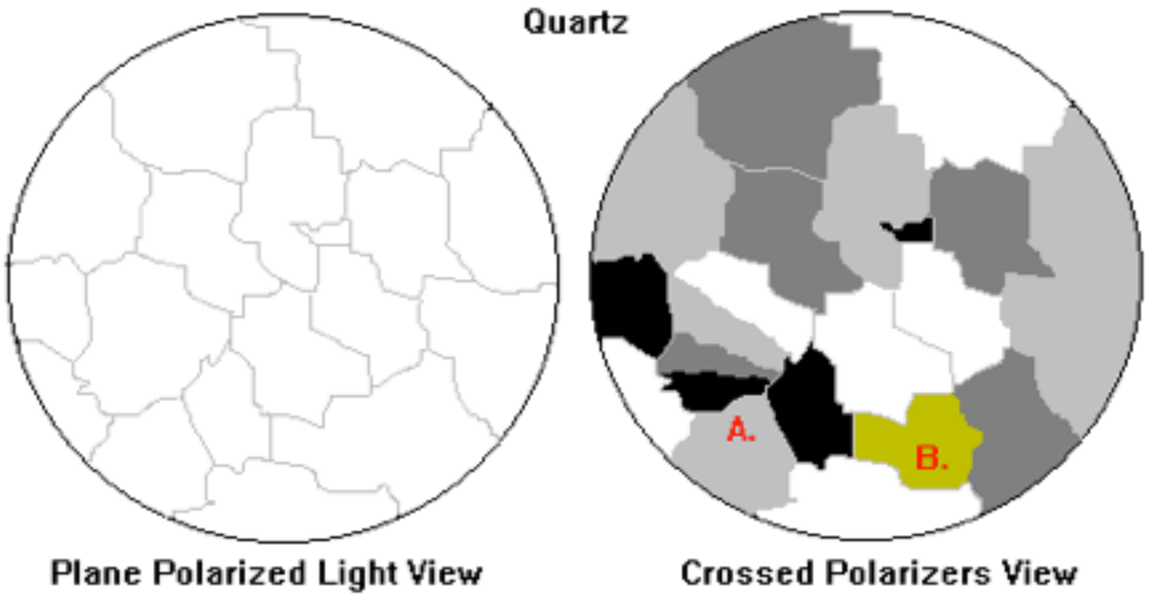
In crossed polarizers, muscovite generally has vivid second- and third-order colors. The interference colors of biotite are a bit lower order and more subdues because of biotite's coloration. Note the relative lack of mottling in the muscovite compared to the biotite.

Below are two more fairly typical crossed-polarizer views of muscovite





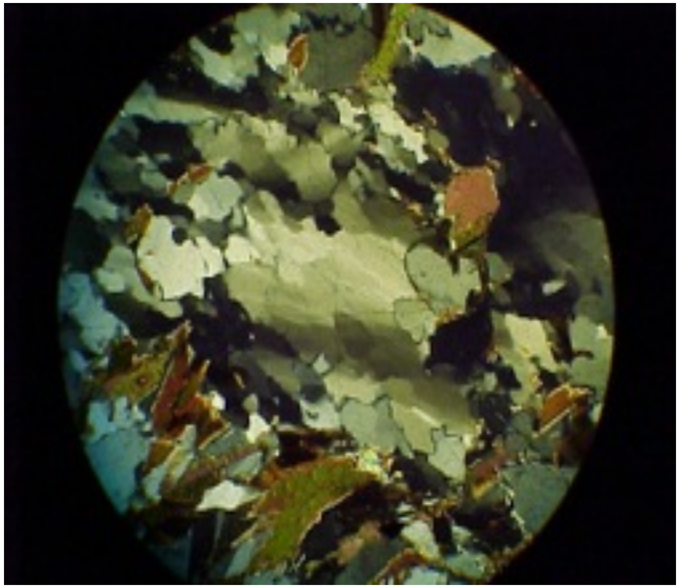
QUARTZ



Quartz in thin section is generally very clean looking without many inclusions. It frequently shows undulose extinction (A, right) or slightly yellowish interference colors (B).

Quartz Description

Plane-Polarized Light

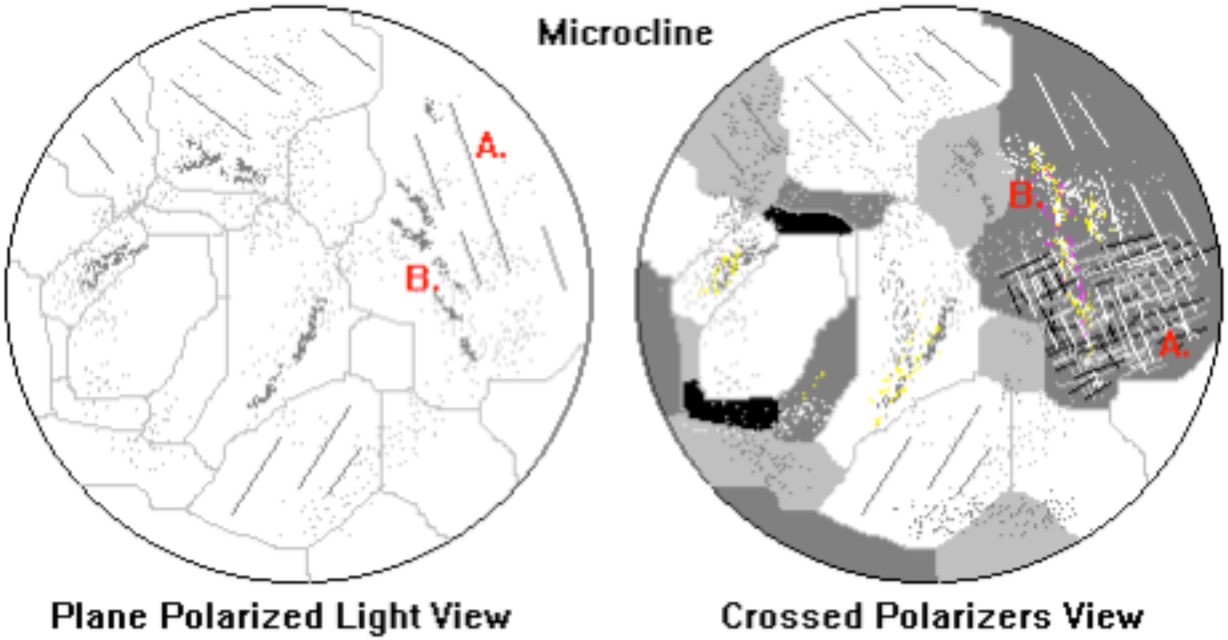


- Low relief
- Clear
- No cleavage
- Usually free of inclusions

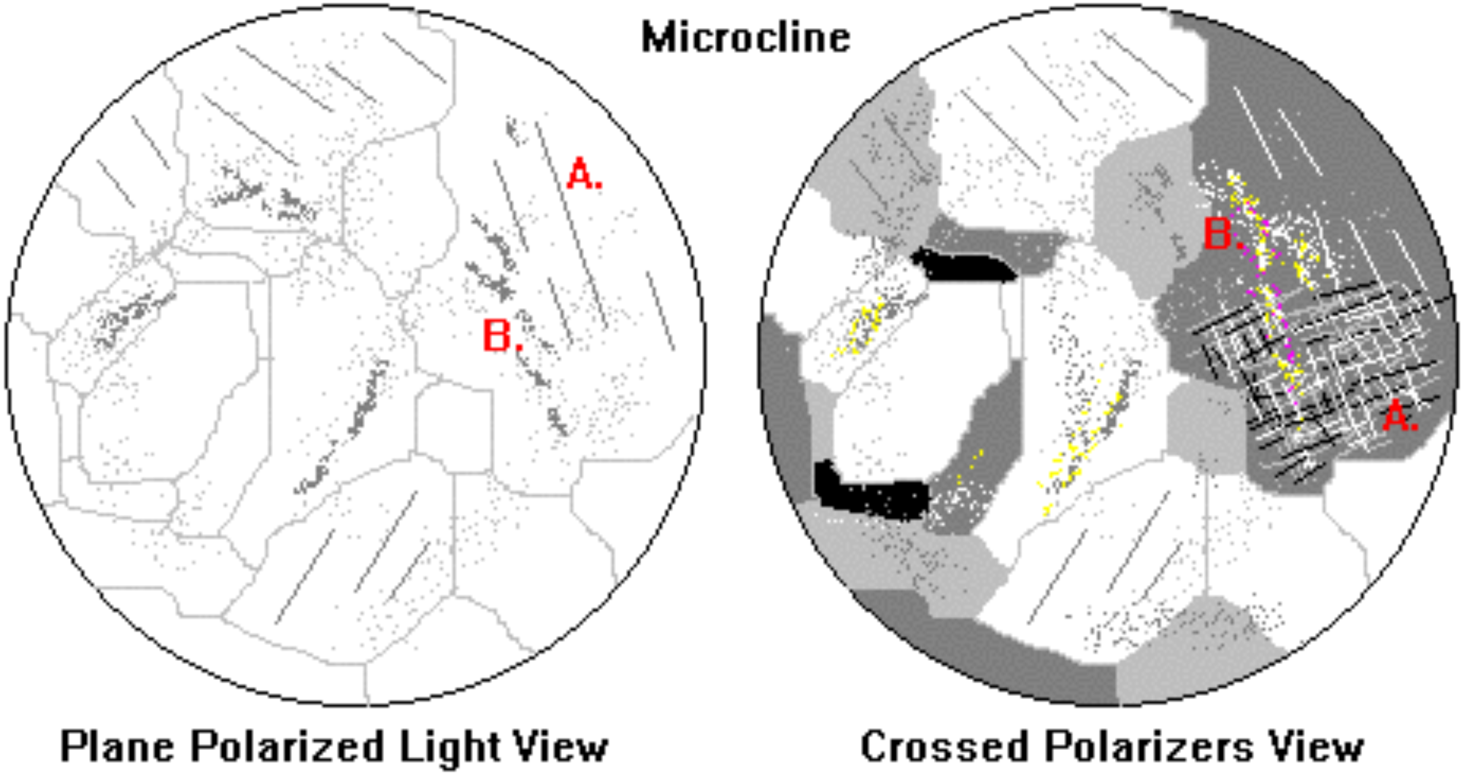
Crossed Polarizers

- Gray to white interference colors, sometimes to light yellowish white
- Undulose extinction common, often with a fan-like pattern (A)
- Grains with highest interference color sometimes look yellowish-brown near extinction (B)

POTASSIUM FELDSPAR



Potassium feldspar often shows good cleavage (A, left) and has a "dusty" appearance from tiny alteration inclusions (B). If "tartan" twinning is visible (A, right) the identification is certain. The inclusions often consist of sericite, or fine-grained muscovite, and show high interference colors (B)



microcline (B), perthite (C) and quartz (not labeled).

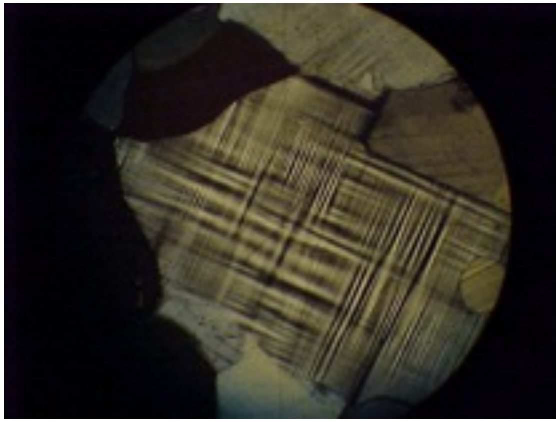
Potassium Feldspar Description

Plane-Polarized Light

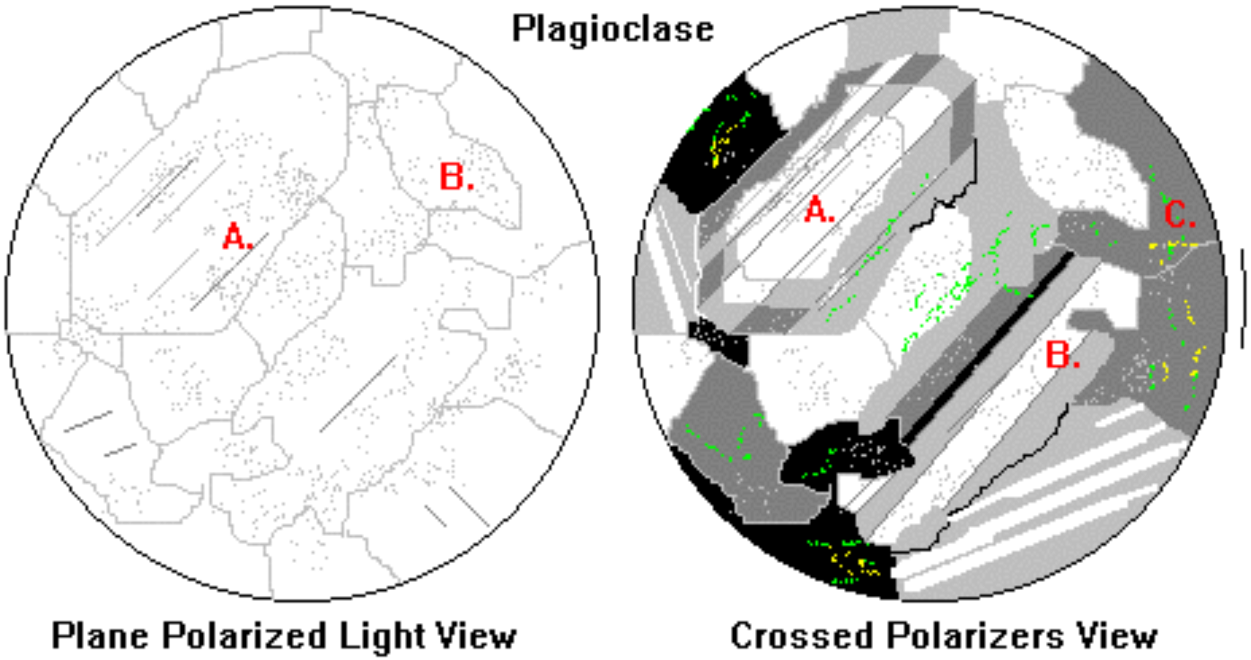
- Low relief
- Clear
- Cleavage often visible (A)
- Usually numerous inclusions, giving it a much dustier look than quartz. The inclusions are due to microscopic alteration (B)

Crossed Polarizers

- Gray to white interference colors, slightly lower than quartz
- Alteration products often have high interference colors (A)
- Often has a distinctive crosshatch or "tartan" twinning pattern.(B)
- Perthitic texture, due to exsolution of plagioclase, is very common (C). It is easily visible in hand specimen as irregular milky streaks.

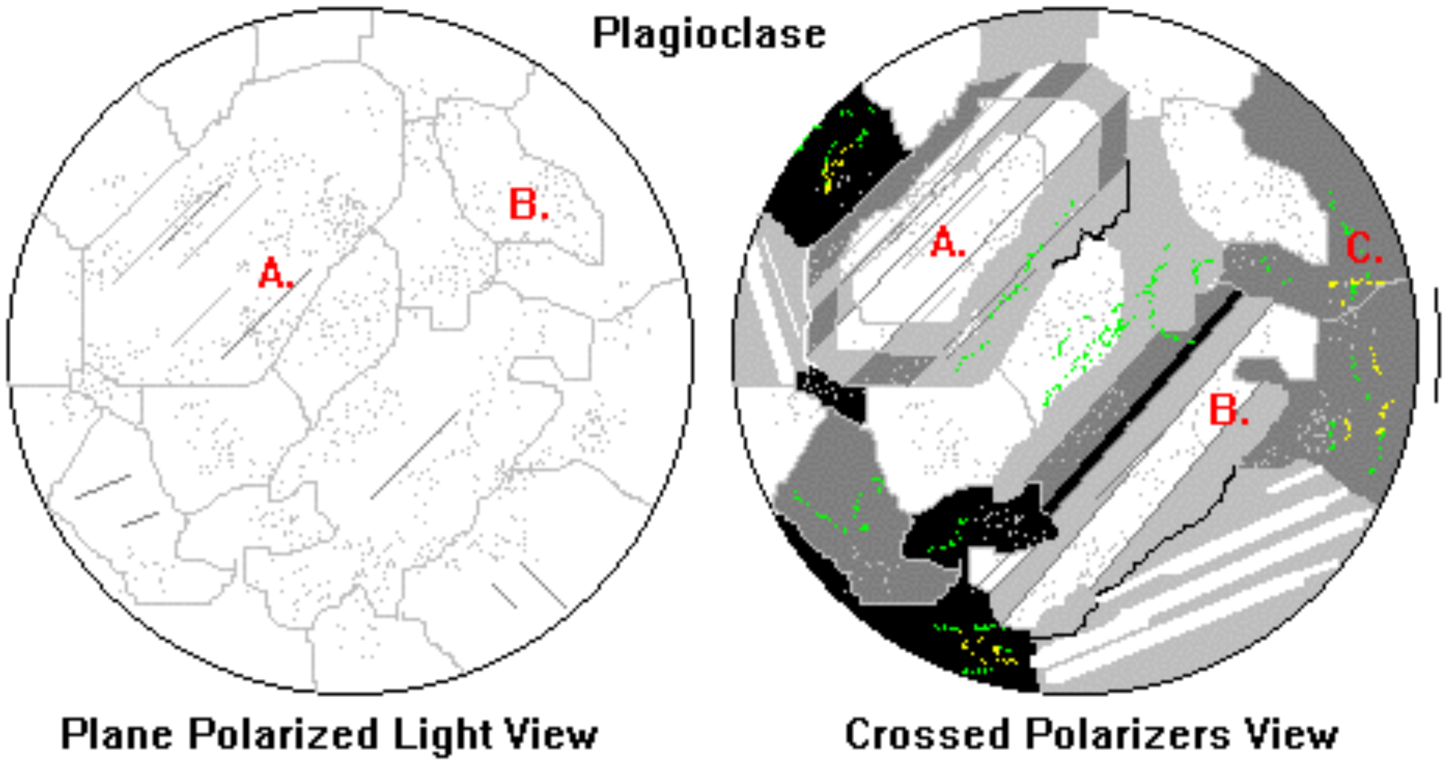


PLAGIOCLASE



Plagioclase feldspars also have good cleavage (A, left) and a dusty appearance from inclusions. They often show compositional zoning (A, right), but their most diagnostic feature is prominent lamellar twinning (B). The inclusions commonly turn out to be tiny crystals of epidote (C).

Plagioclase



Plagioclase Description

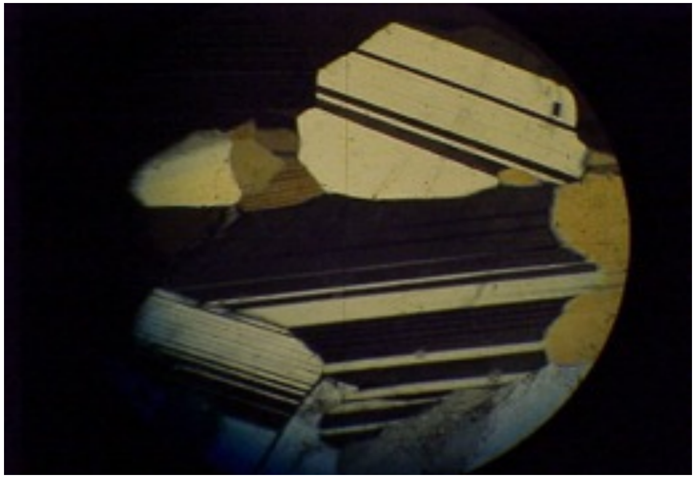
Plane-Polarized Light

- Low relief
- Clear
- Cleavage often visible (A)
- Usually numerous inclusions, giving it a much dustier look than quartz. The inclusions are due to microscopic alteration (B)

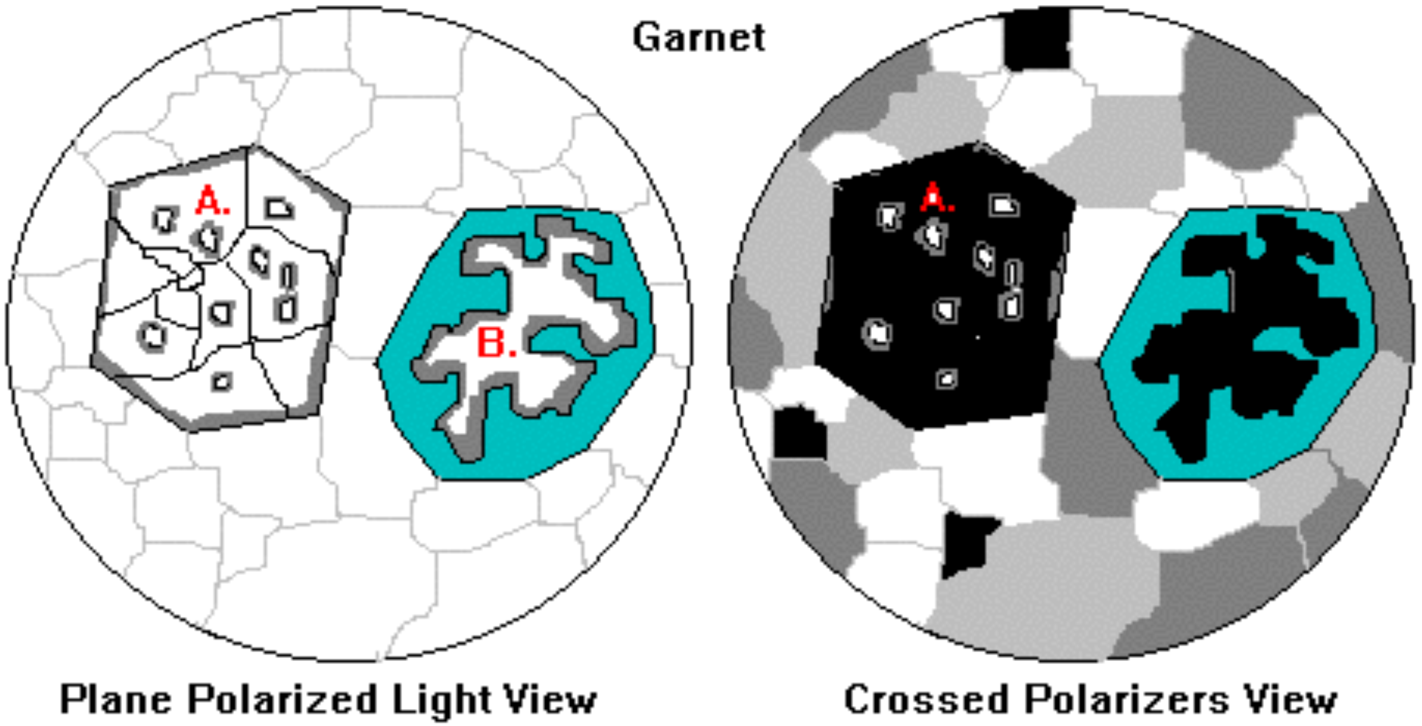
Crossed Polarizers

- Gray to white interference colors, slightly lower than quartz
- The tiger-stripe twinning is far and away the most distinctive feature, but beware! Not all plagioclase shows twinning.
- Euhedral crystals are common and frequently zoned (A). Zoning is a valuable tracer of magmatic history.
- Corroded crystals (B) are also common due to alteration or reaction with magma or other minerals
- Alteration products often have high interference colors (C). Tiny euhedral epidote crystals are common as alteration products.

Typical appearance of plagioclase in thin section (Note: Twinning features)



GARNET


Garnet
A.
B.
A.
Plane Polarized Light View
Crossed Polarizers View

Garnet Description

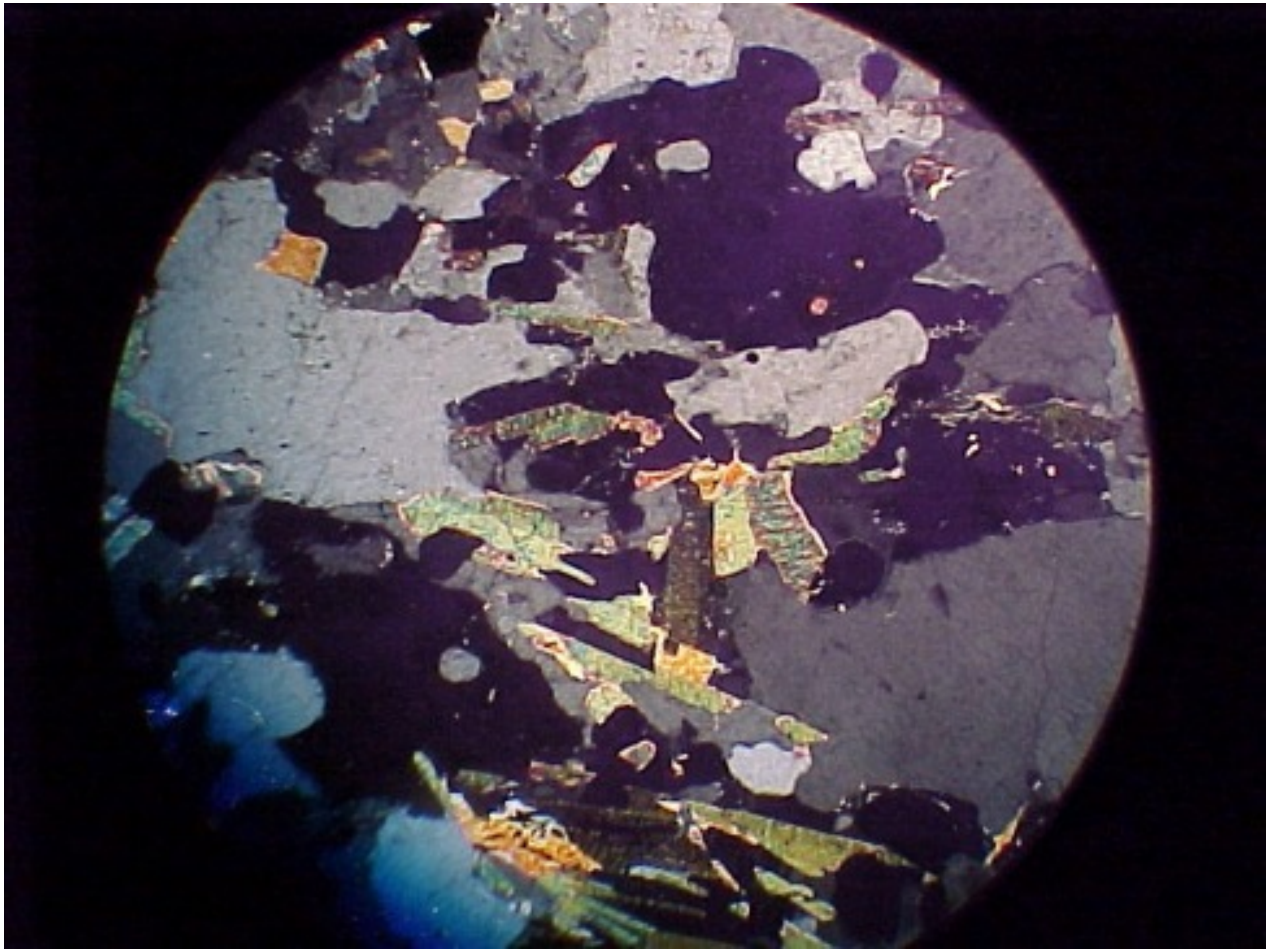
Plane-Polarized Light

- High relief
- Clear, occasionally very light pinkish
- No cleavage
- Euhedral crystals common (A)
- Retrograde metamorphism common (B). Garnet will revert to greenish amphiboles or chlorite, still retaining the original outline of the crystal. Remnants of garnet are often preserved in the interior
- Internal fracturing of grains common
- Crystals commonly contain inclusions, incorporated as the garnet grew.

Crossed Polarizers

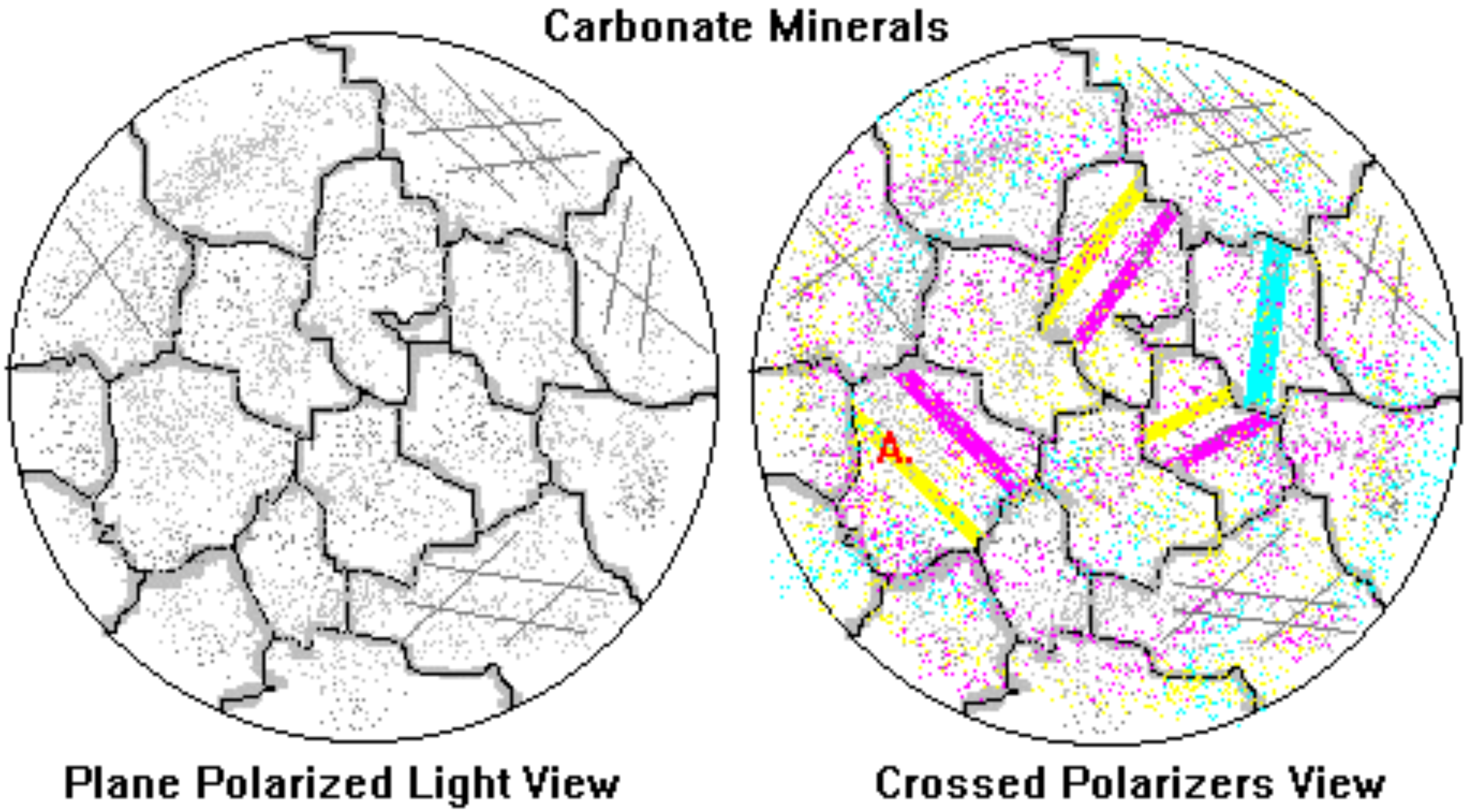
- The most common isotropic mineral

In plane-polarized light, garnet is clear and has very high relief. The light brown material is biotite. Most of the clear material is quartz



In crossed polars, garnet is isotropic. The black areas are larger than the visible garnet above because of plucking - part of the garnet broke off the slide during the grinding process.

CARBONATE MINERALS



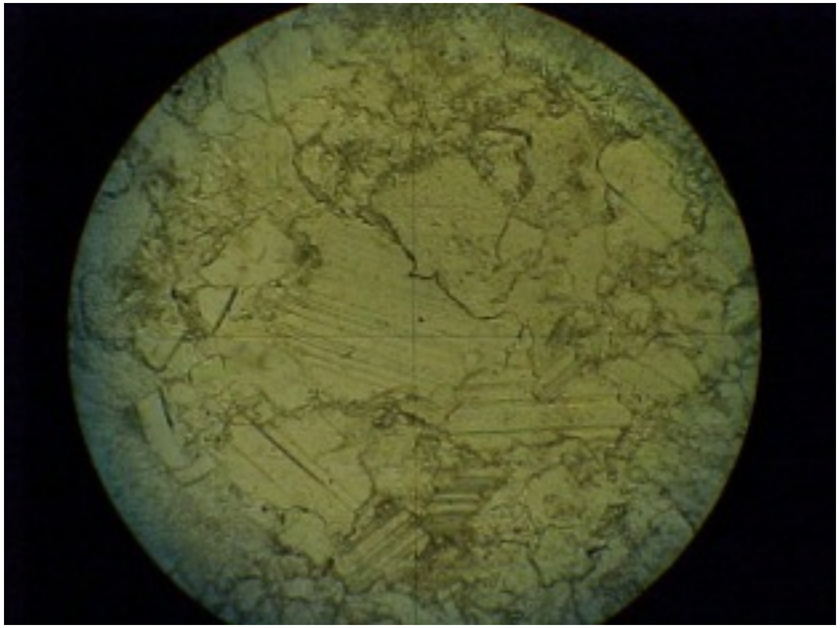
Carbonate Minerals Description

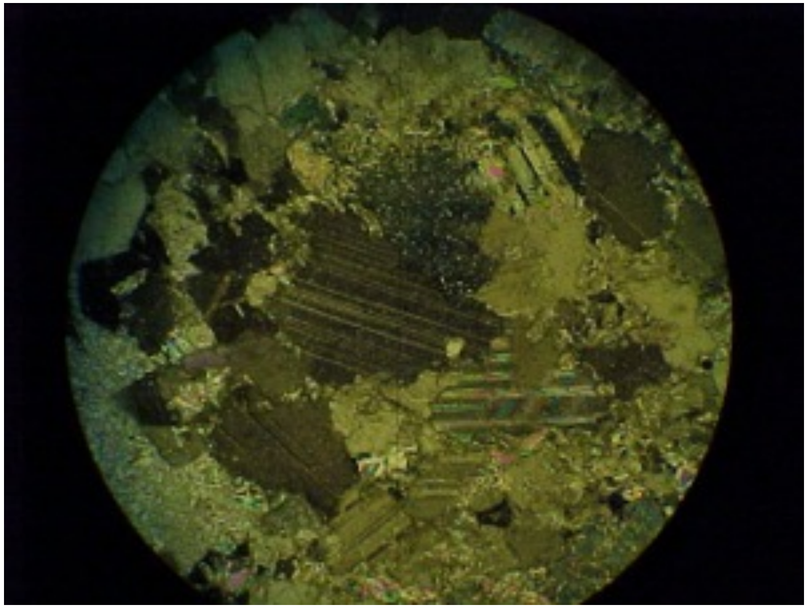
Plane-Polarized Light

• Calcite, Dolomite, Siderite and other common carbonates are almost indistinguishable in thin section.
• Extremely high relief
• Colorless, but tends to be grainy in appearance. The extremely high relief means even the tiniest irregularities stand out.
• Perfect rhombohedral cleavage

Crossed Polarizers

• Extremely high order interference colors. Has a pearly appearance because of tiny patches of color. Even the slightest variation in thickness due to grinding results in noticeable color variation.
• Twin bands are common (A). These often have moderate but highly mottled color because the crystallographic orientation in the twin band partially cancels out the interference color of the rest of the crystal. Calcite is extremely ductile and these are often due to deformation.





Calcite in crossed polarizers, the interference colors are extremely high order and twin lamellae are common.