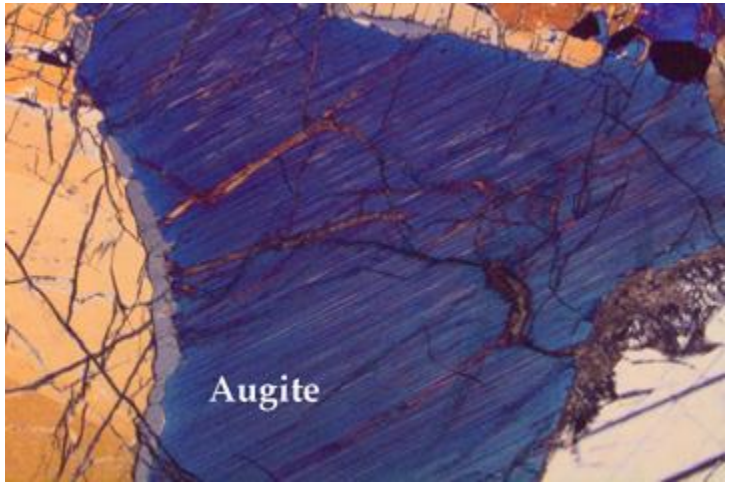
AUGITE

Optical Properties:

- Form : Usually occur in short prismatic crystal with four or eight-sided cross section
- Relief : High
- Color : Colorless, neutral, pale greenish, pale purplish brown
- Pleochroism : Absent to weak
- Birefringence colors : Moderate. The maximum interference color is about middle second order
- Cleavage : {110} in two direction at angles 87^0 and 93^0
- Extinction : Angle varies from 36^0 to 45^0 (longitudinal sections)
- Orientation : Faster ray
- Occurrence : Plutonic rocks (gabbro, pyroxenite, peridotite), volcanic rocks (basalts, essexite), tuff, high-temperature metamorphic rocks.

AUGITE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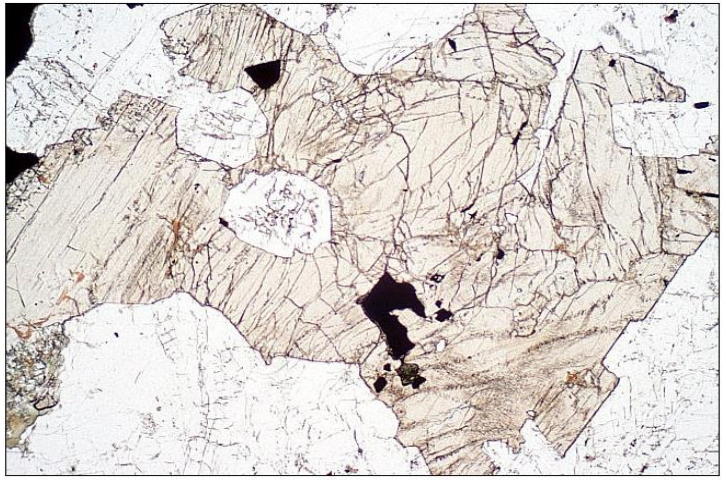
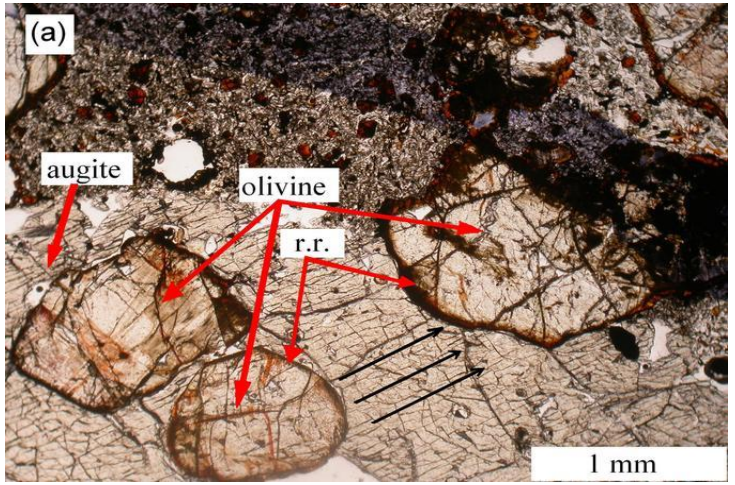
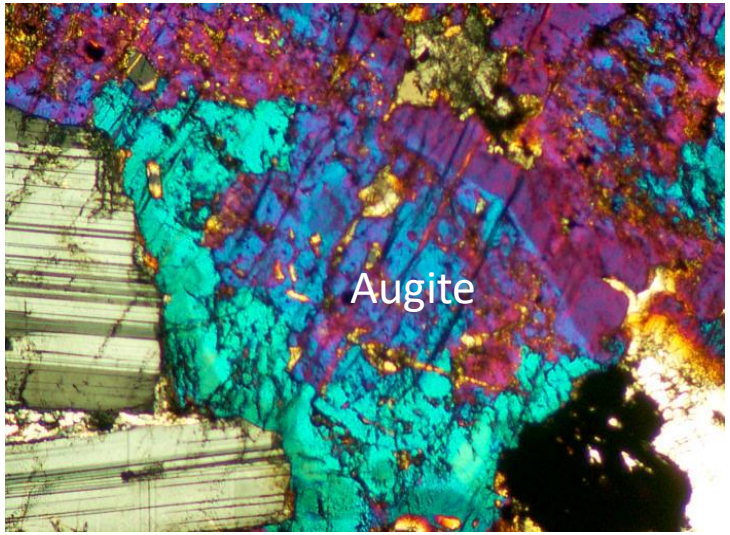



(a)
augite
olivine
r.r.
1 mm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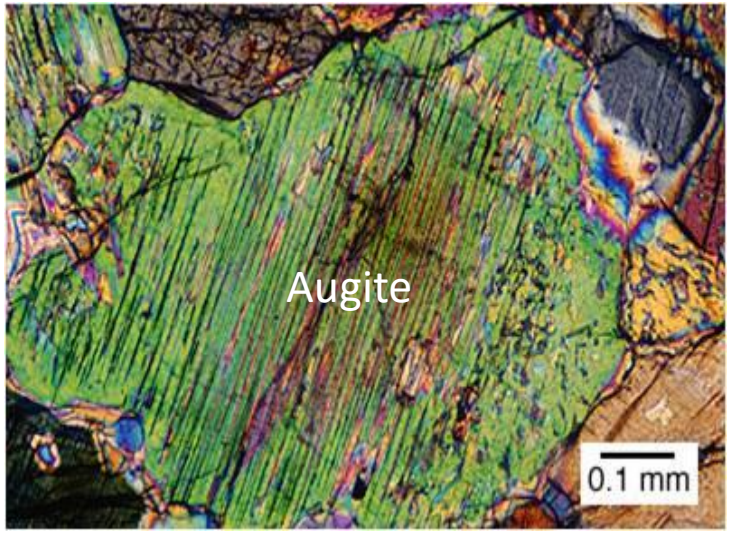
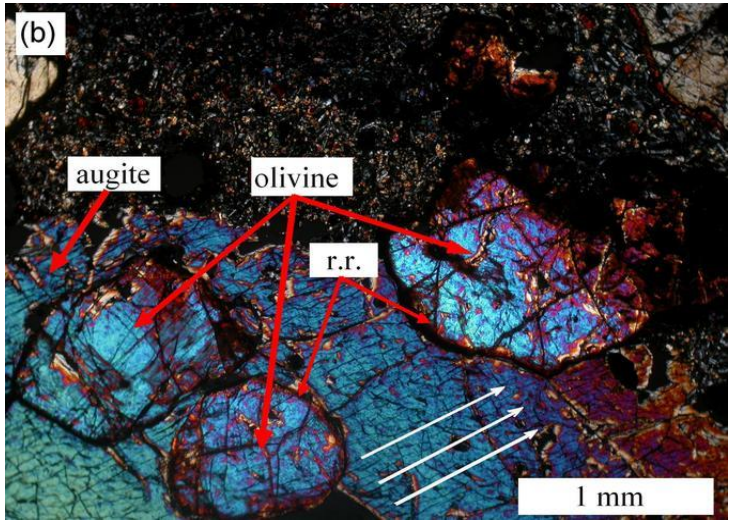

Augite
0.1 mm

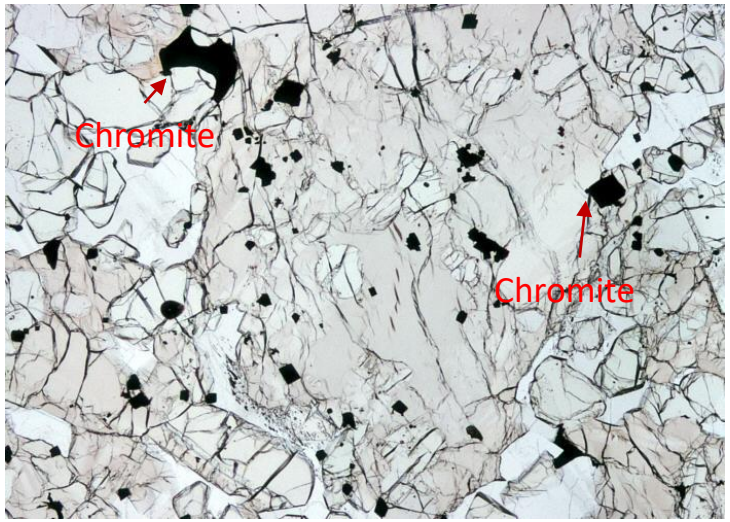

(b)
augite
olivine
r.r.
1 mm

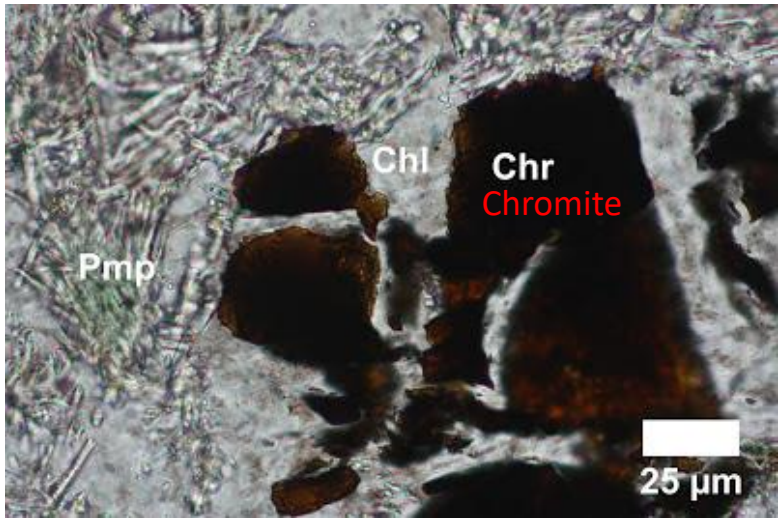
CHROMITE

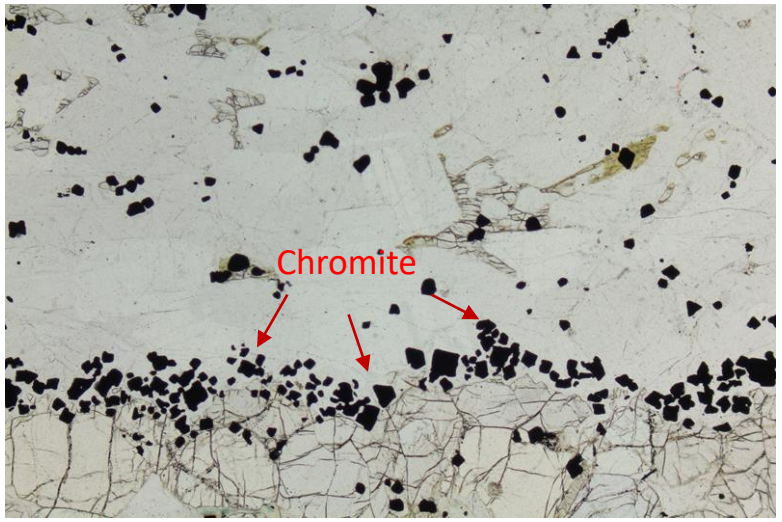
Optical Properties:

- Form : Usually occur in subhedral crystals, grains or aggregates. Sometimes found in octahedral
- Color : Black with submetallic luster in reflected light; often transculent and brown on thin edges
- Occurrence : Mafic and ultramafic rocks; peridotite and serpentinite

CHROMITE


Chromite
Chromite


Chl
Chr
Chromite
Pmp
25 µm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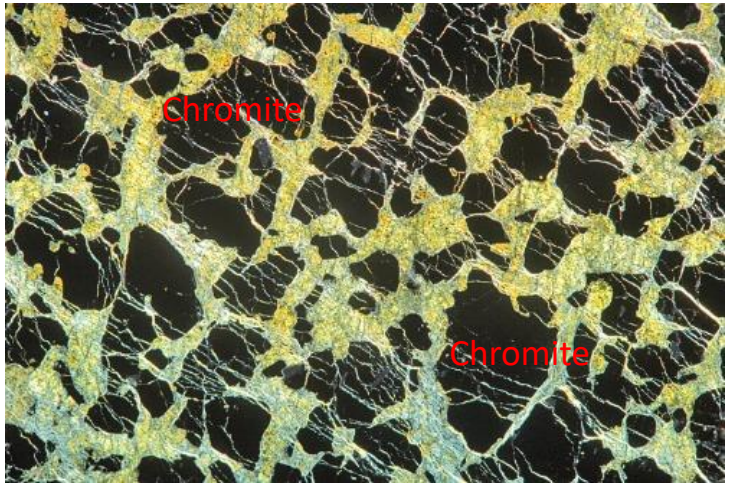
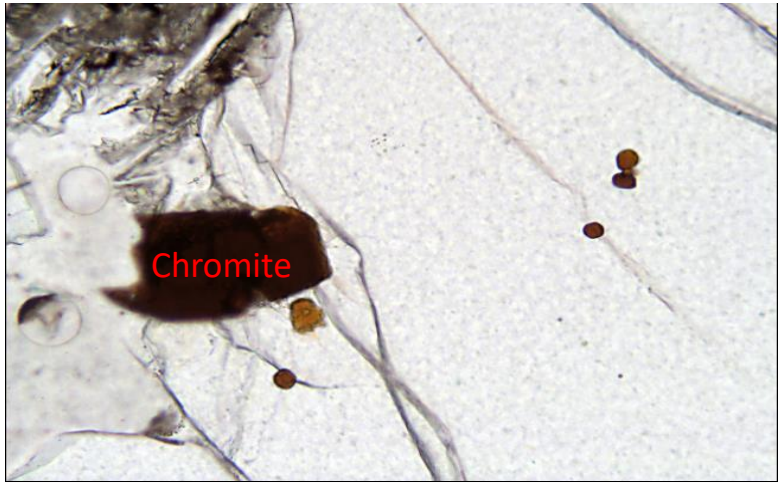

Chromite
Chromite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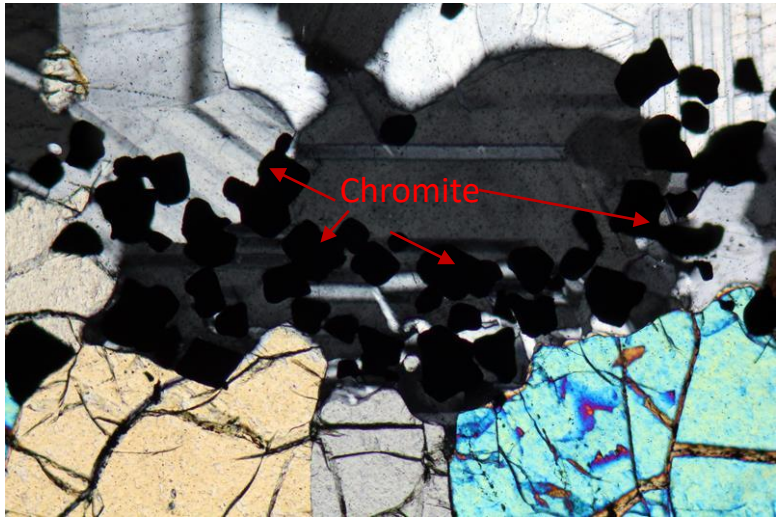
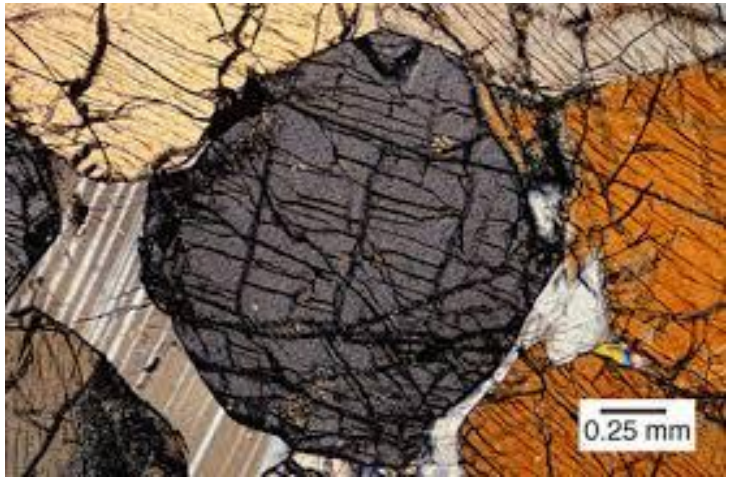

Chromite

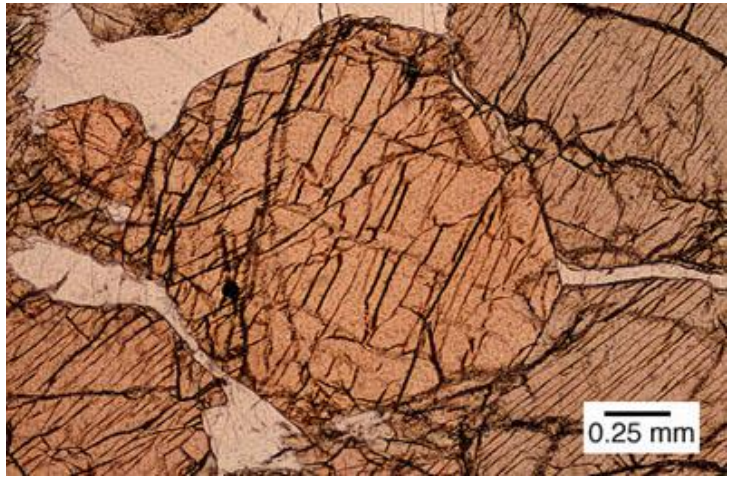
HYPERSTHENE

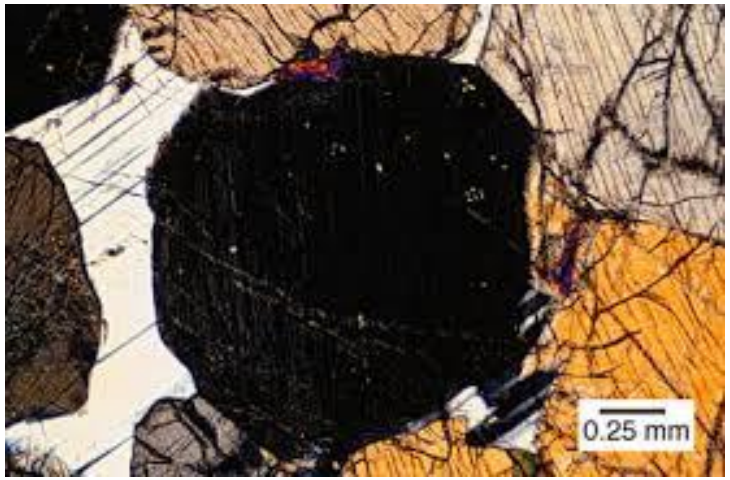
Optical Properties:

- Form : Usually occur in subhedral crystals of prismatic habit
- Relief : High
- Color : Neutral to pale green or pale red in thin section
- Pleochroism : Greenish to pale reddish
- Birefringence colors : Rather weak. The maximum interference color is yellow to red of the first order
- Cleavage : Paralel to {110}; sometimes parallel to {010} and {100}
- Extinction : Parallel in most sections
- Orientation : Length-slow
- Occurrence : Some igneous rocks (norite, hypersthene gabro, andesite, charnockite)

HYPERSTHENE





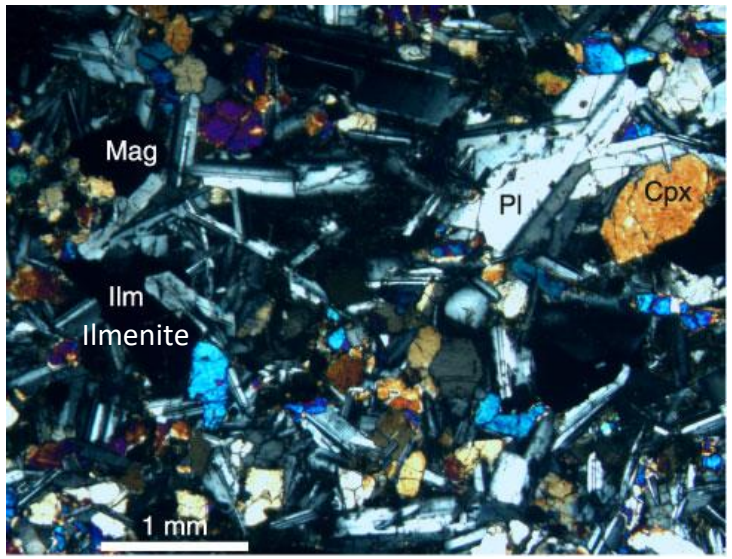


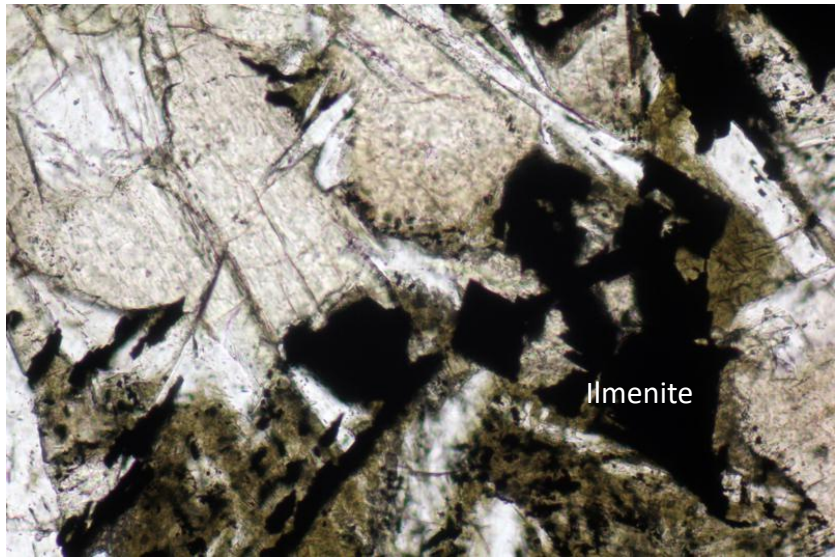
ILMENITE

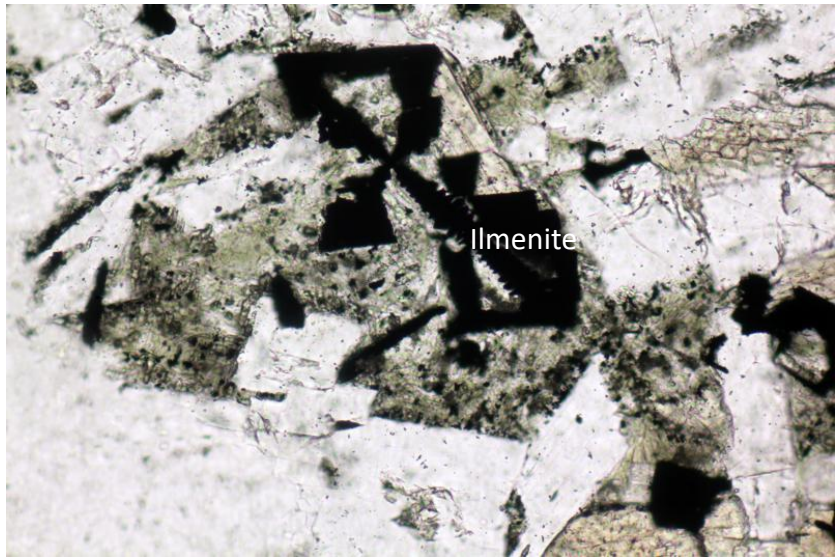
Optical Properties:

- Form : Usually occur in disseminated tabular crystals which may be cut into elongate section; skeleton crystals; irregular grains and masses
- Color : Blue-gray black with metallic luster in reflected light
- Occurrence : Plutonic rocks; pegmatite and nepheline syenite; marine sands; metamorphic rocks (gneiss, chlorite schist, etc).

ILMENITE


Mag
Pl
Cpx
Ilm
Ilmenite
1 mm


Ilmenite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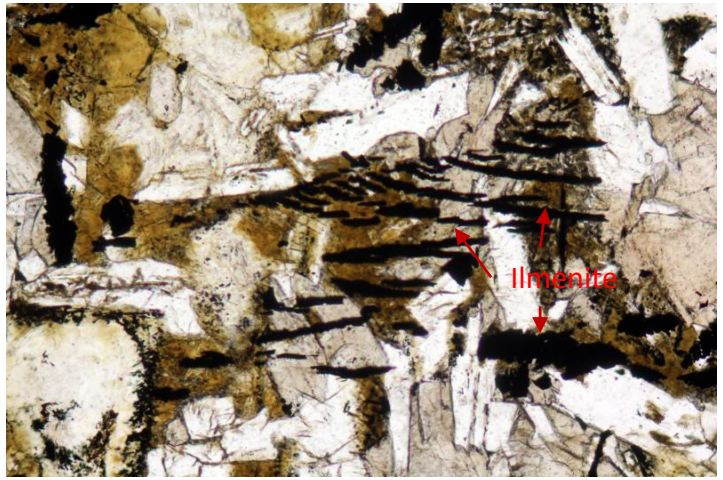
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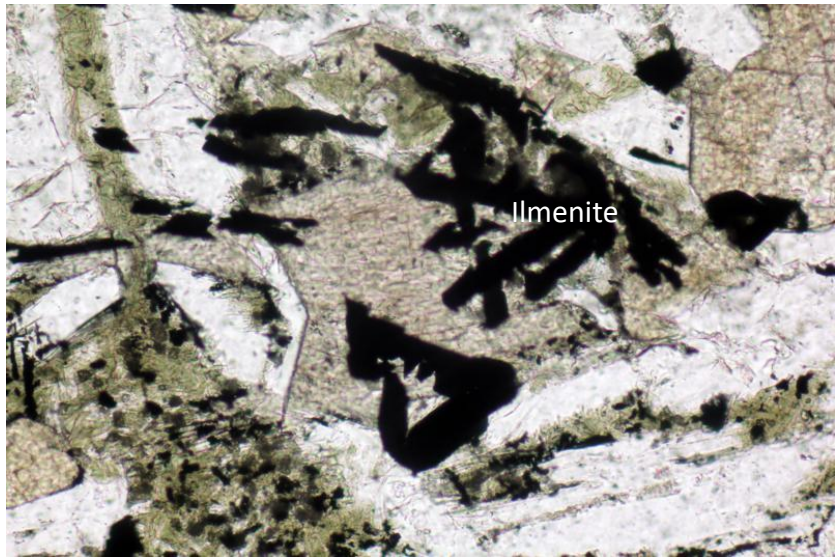
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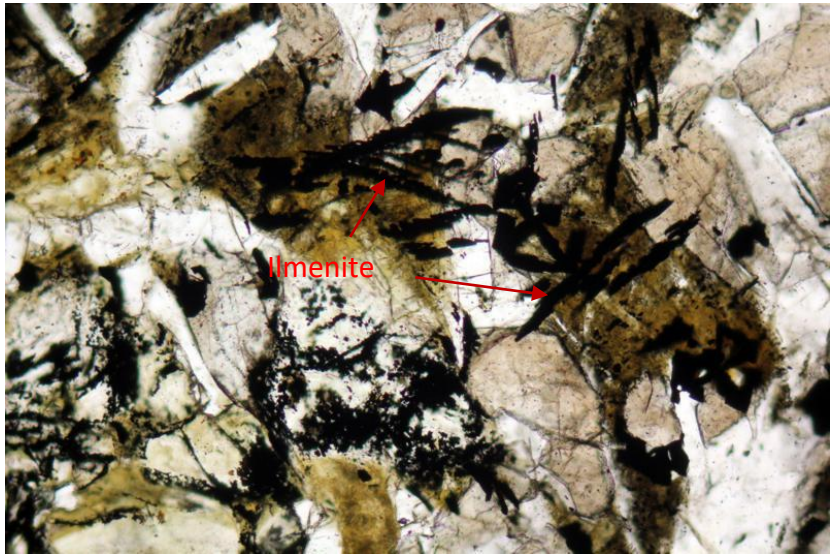

Ilmenite

LEUCOXENE

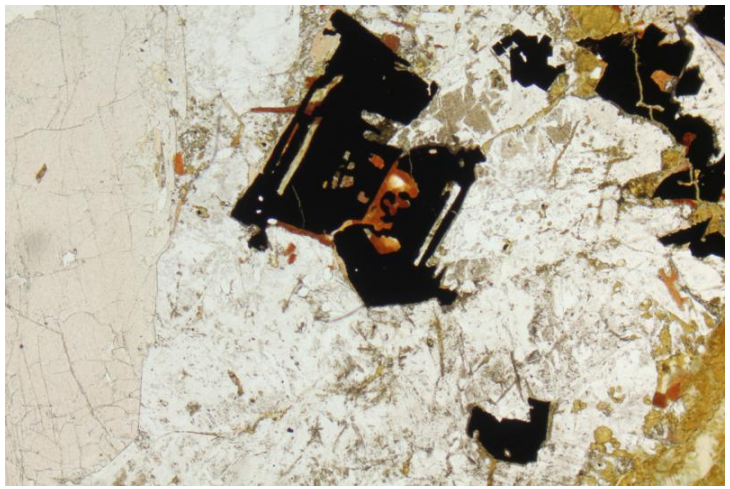
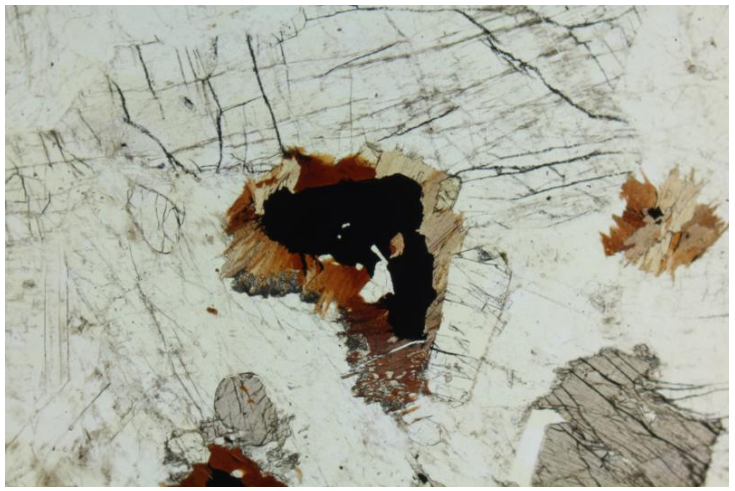
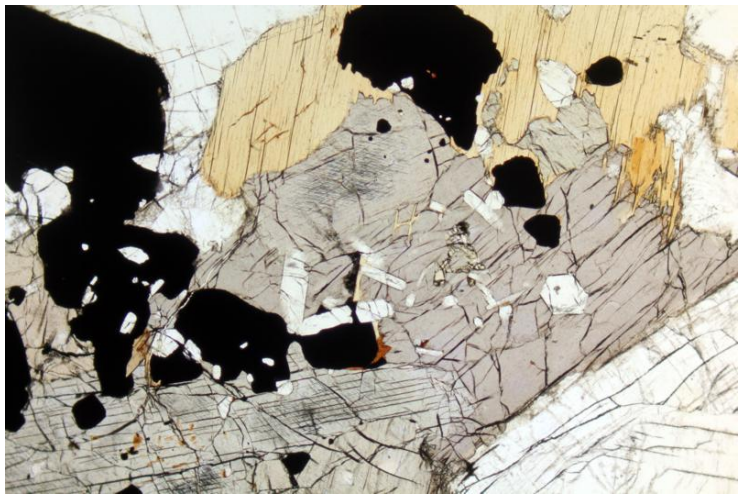
- An opaque white substance
- Alteration product of titanium minerals

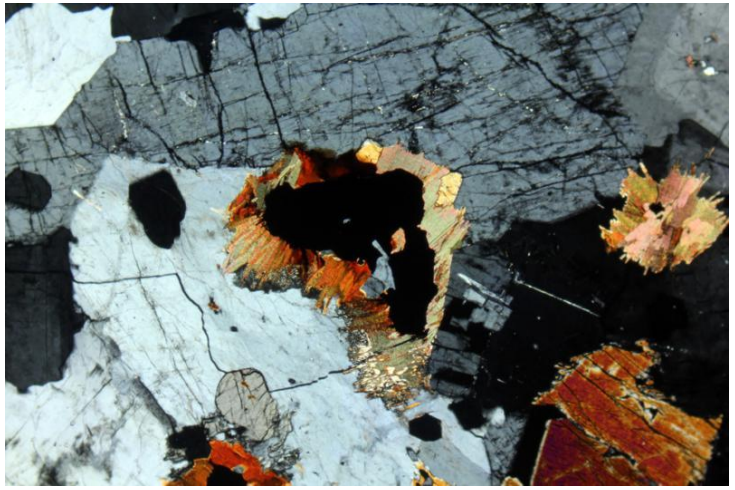
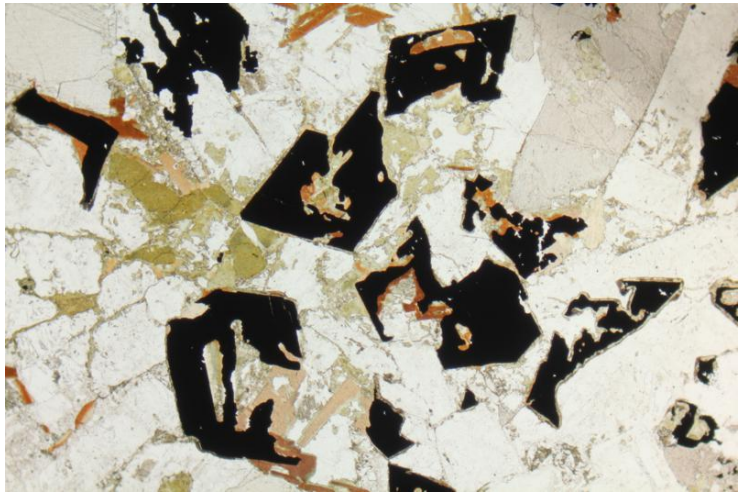
MAGNETITE

Optical Properties:

- Form : Usually occur in octahedral which yield triangular, square or rhombic sections. A triangular pattern due to octa-hedral parting may be present
- Color : Black with metallic luster in reflected light
- Occurrence : Mafic and ultramafic rocks; pegmatite and hydrothermal veins; detrital sedimentary rocks (alluvial and marine sands), dune deposit.

MAGNETITE

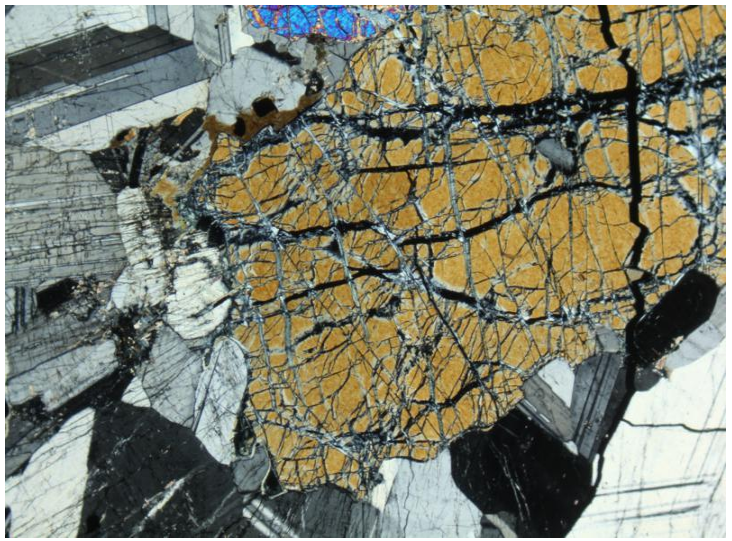



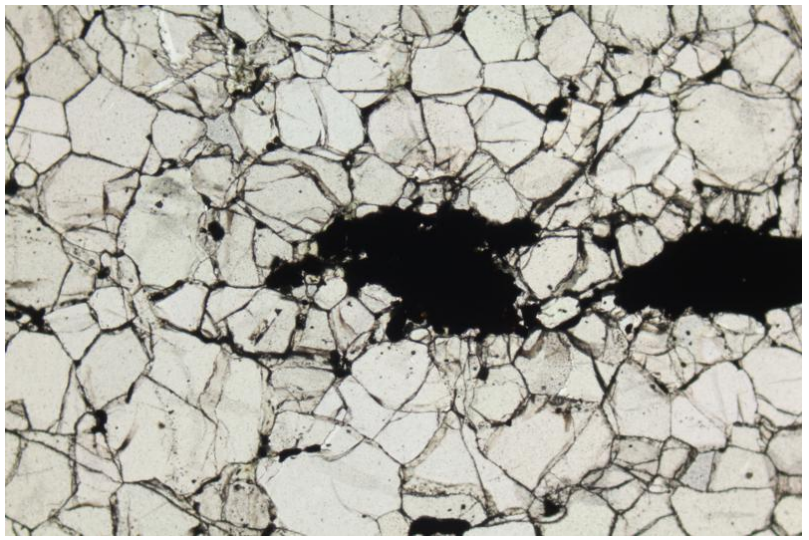
OLIVINE

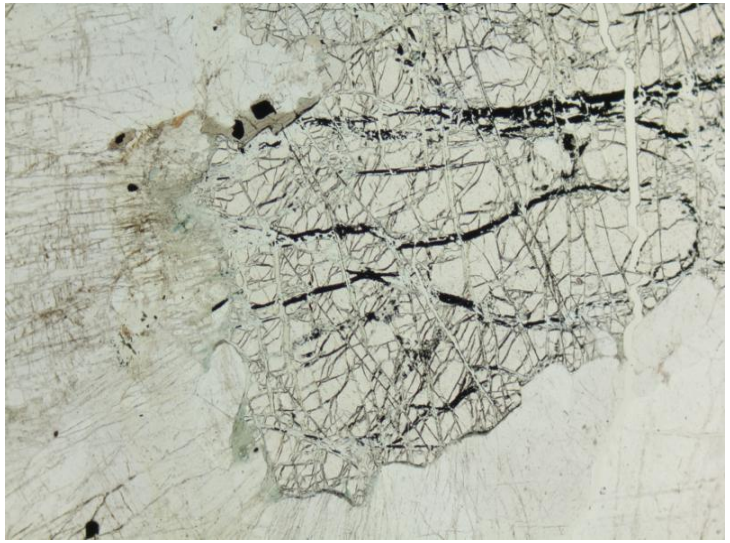
Optical Properties:

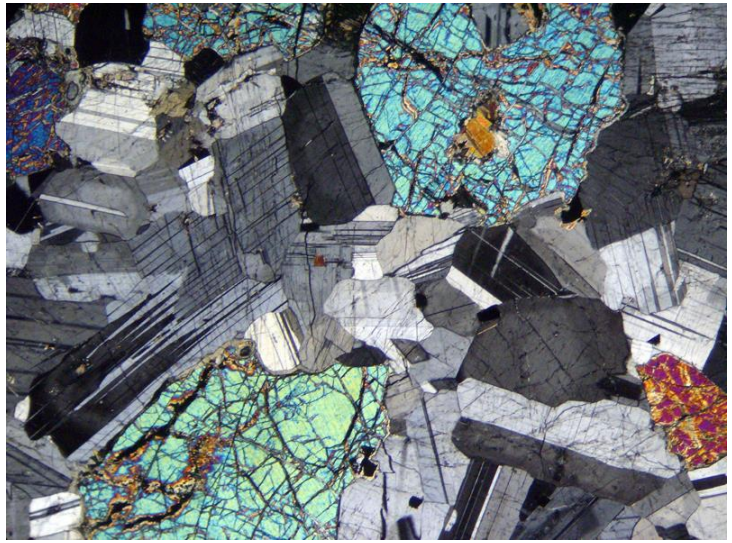
- Form : Anhedral with polygonal outlines; section parallel to (100)
- Relief : Fairly high
- Color : Colorless in thin section
- Birefringence colors : Strong; The maximum interference color is upper second order
- Cleavage : Impefect parallel to {010}; irregular fractures common
- Extinction : Parallel to crystal outline and cleavage traces
- Twinning : Sometimes found
- Orientation : Length-slow
- Occurrence : Ultramafic and mafic intrusive or volcanic igneous rocks

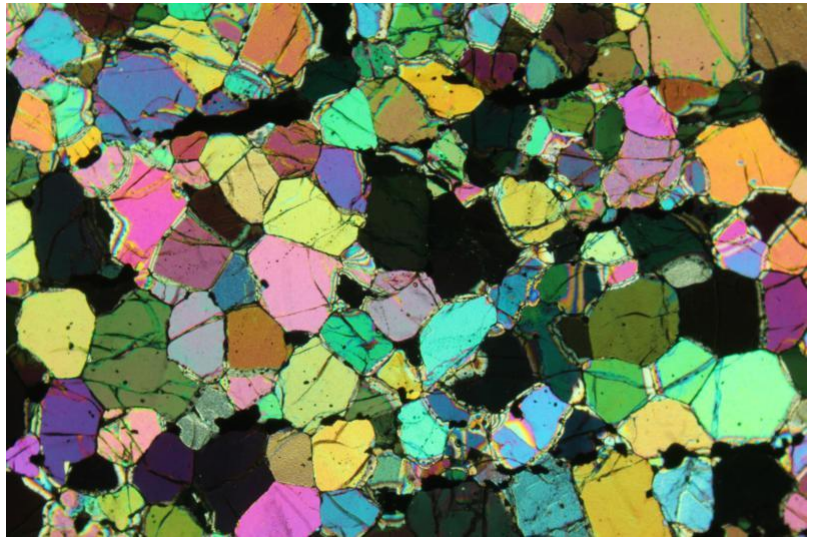
OLIVINE









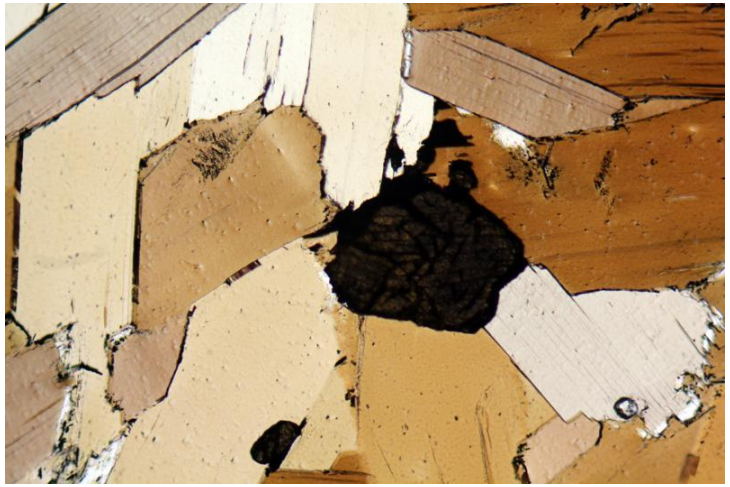


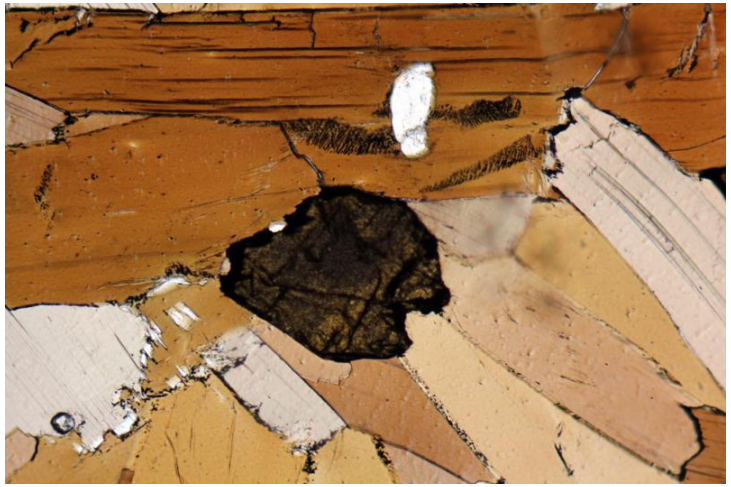
RUTILE

Two polymorphs of rulite are **anatase (tetragonal)** and **brookite (orthorhombic)**

Optical Properties :

- Form : Usually occur in small prismatic crystals to acicular crystals and in grains.
- Relief : Very high.
- Color : Yellowish to reddish brown
- Birefringence colors : Extreme. The interference color is very high
- Cleavage : Parallel to the length of the crystals {110}
- Extinction : Parallel
- Twinning : Common
- Occurrence : Intrusive and metamorphic rocks or in quartz veins

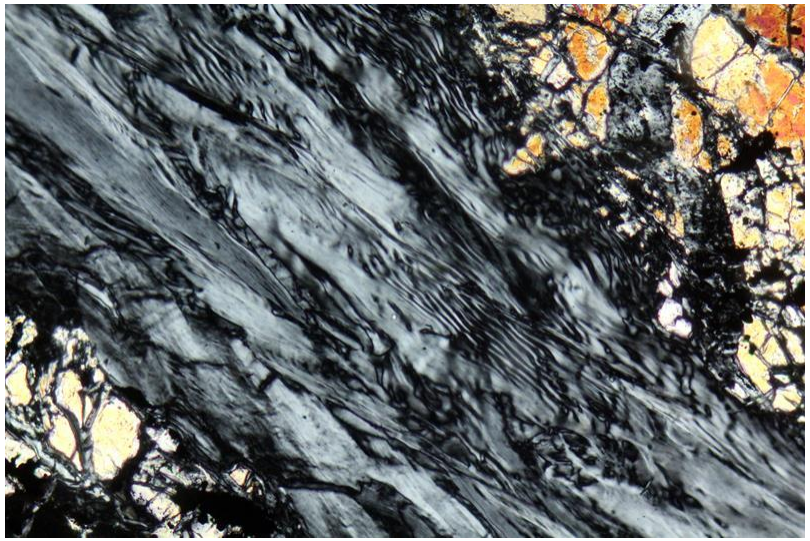




SERPENTINE

Optical properties

- Form : Asbestiform, as parallel fibers or aggregate with cross fibers.
- Color : Colorless to pale green
- Relief : Low
- Interference colors : Low, gray, yellow.
- Occurrence : Low-grade metamorphic environment, mafic and ultramafic rocks; main mineral in serpentinites

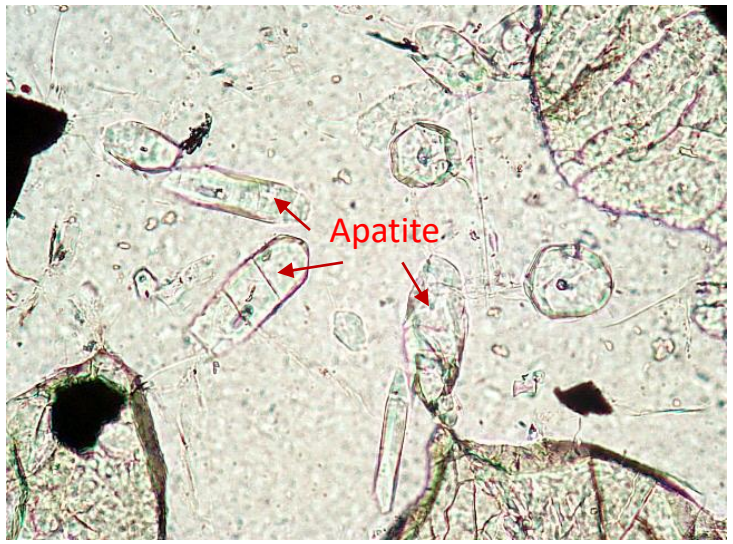


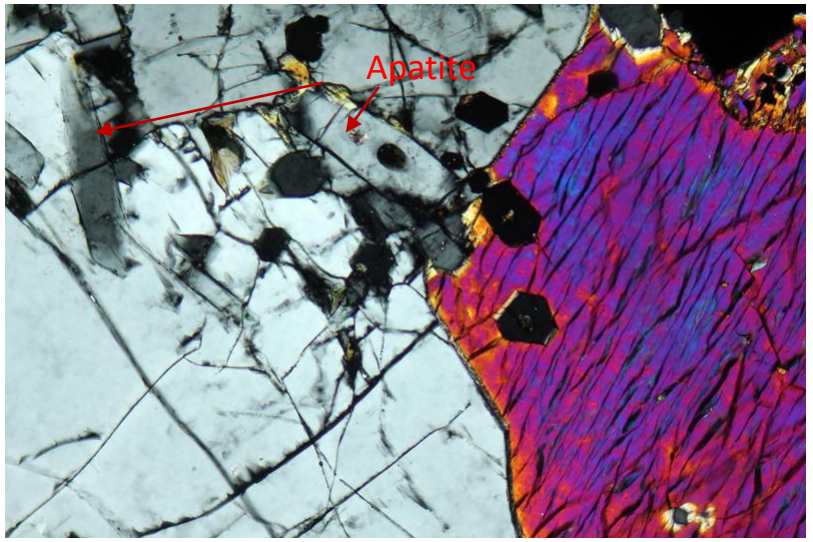
APATITE

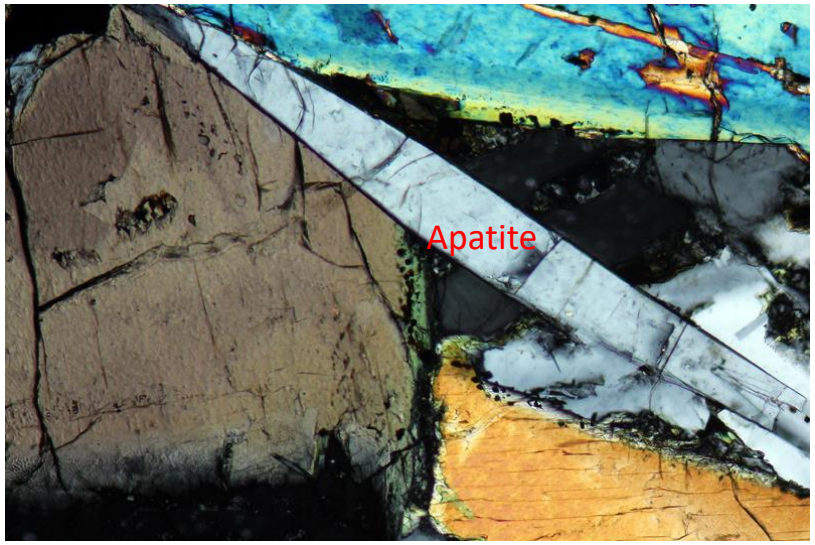
Optical Properties:

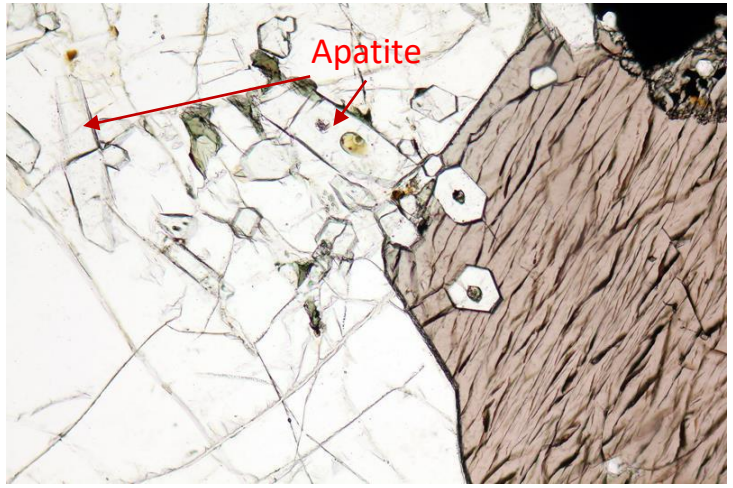
- Form : Usually occur in minute six-sided prismatic crystals.
- Relief : Moderate.
- Color : Colorless in thin section.
- Birefringence colors : Weak. The interference color is first order gray to white. Cross sections are dark between crossed nicols.
- Cleavage : Imperfect basal {0001} shown as cross fractures; larger crystals may show imperfect cleavage parallel to the length {1010}
- Extinction : Parallel
- Orientation : Usually length-fast; crystals of tabular habit are length-slow
- Occurrence : Eruptive rocks, hydrothermal veins, iron-rich igneous deposits and metamorphic rocks of all kinds

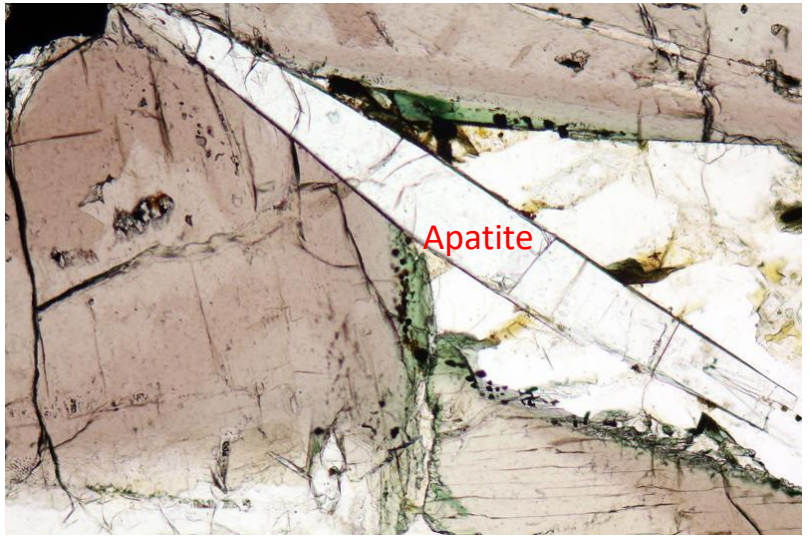
APATITE

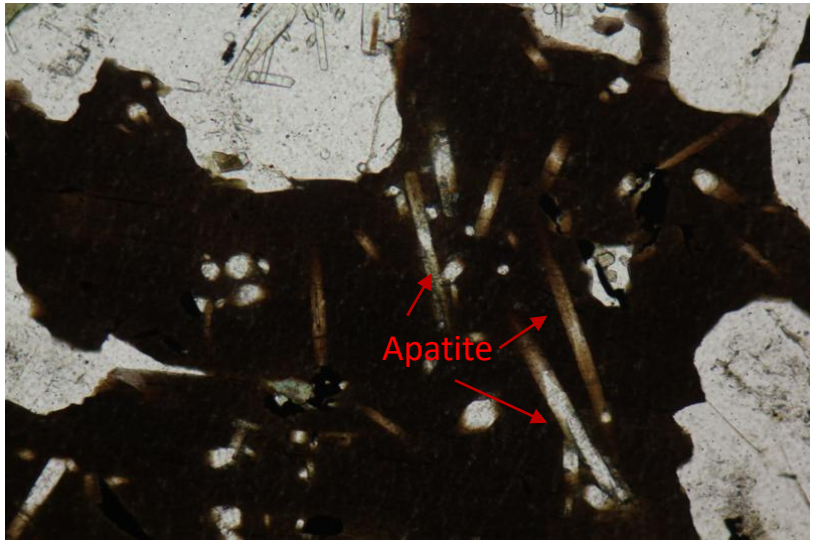










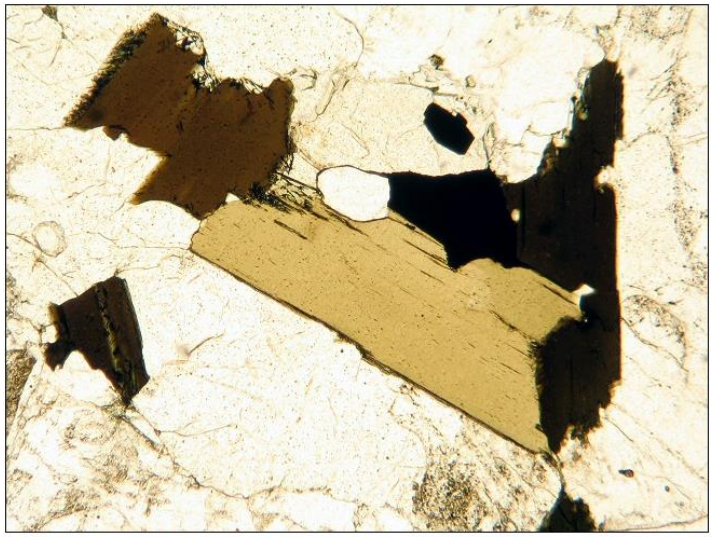
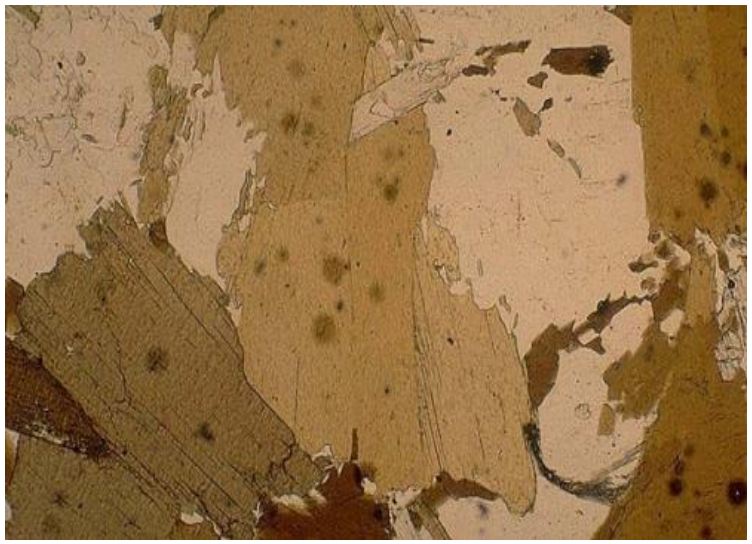
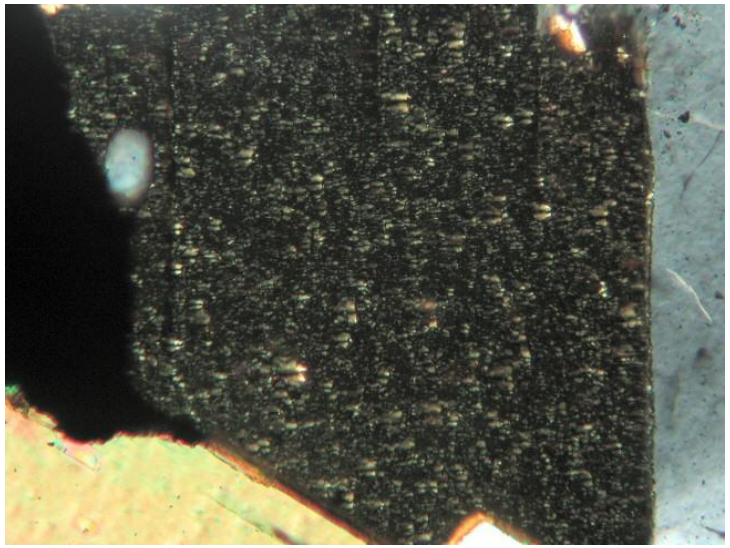
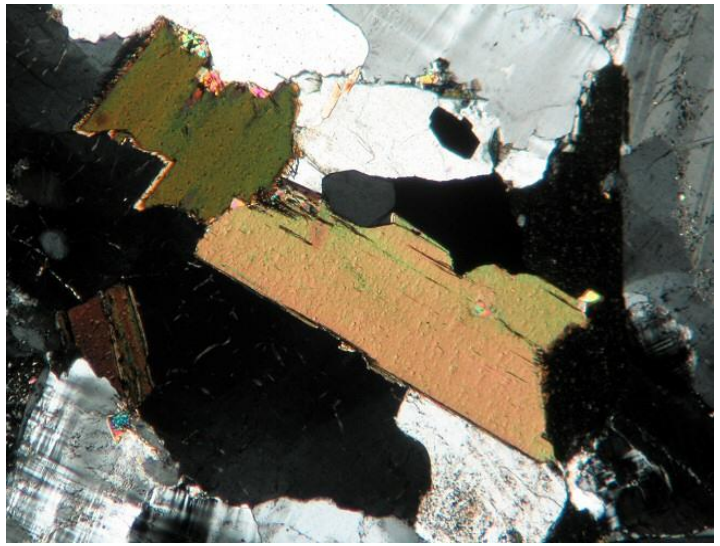
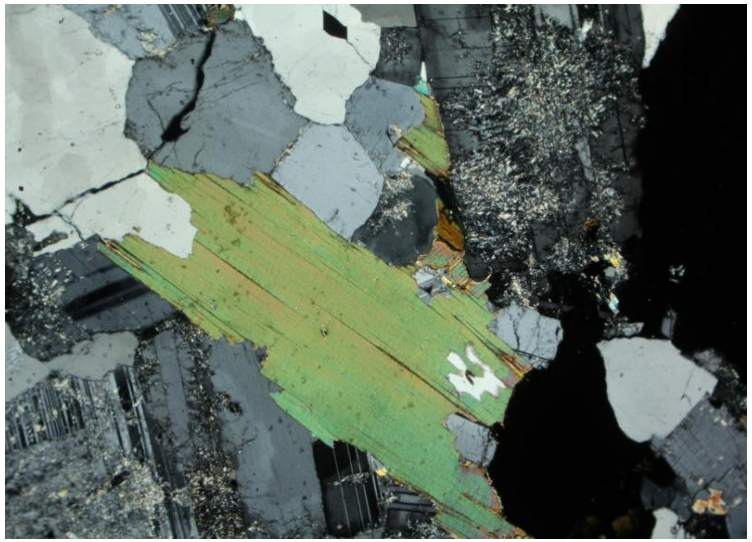


BIOTITE

Optical Properties:

- Form : Common in euhedral six-sided crystals (tabular in habit); lamellar aggregates
- Relief : Fair
- Color : Brown, yellowish brown, reddish brown, olive green or green in thin section
- Birefringence colors : Strong. The interference color range up to second-order red
- Cleavage : Perfect in one direction {001}
- Extinction : Parallel to the cleavage traces
- Twinning : May be present
- Orientation : Slower ray
- Occurrence : Intrusive igneous rocks, pegmatites, lamprophyres, lavas and metamorphic rocks

BIOTITE

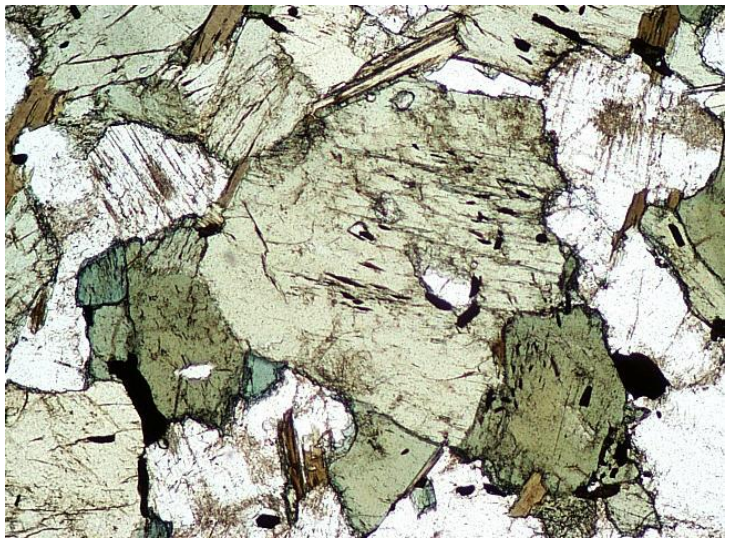







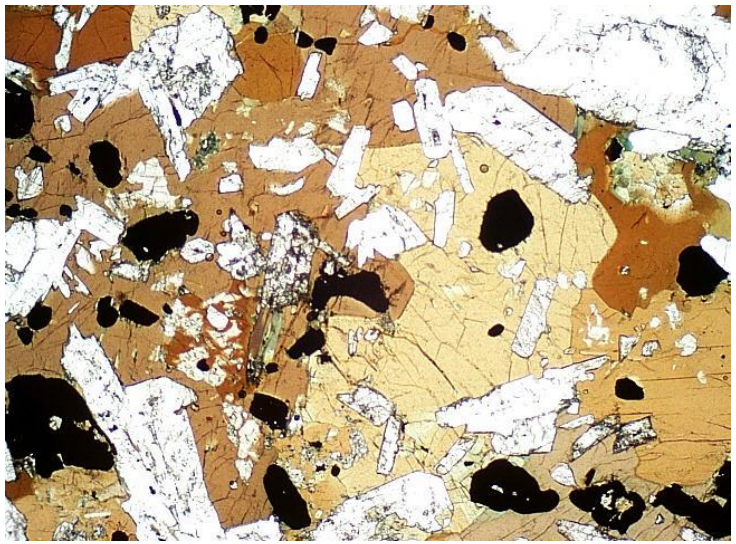
HORNBLENDE

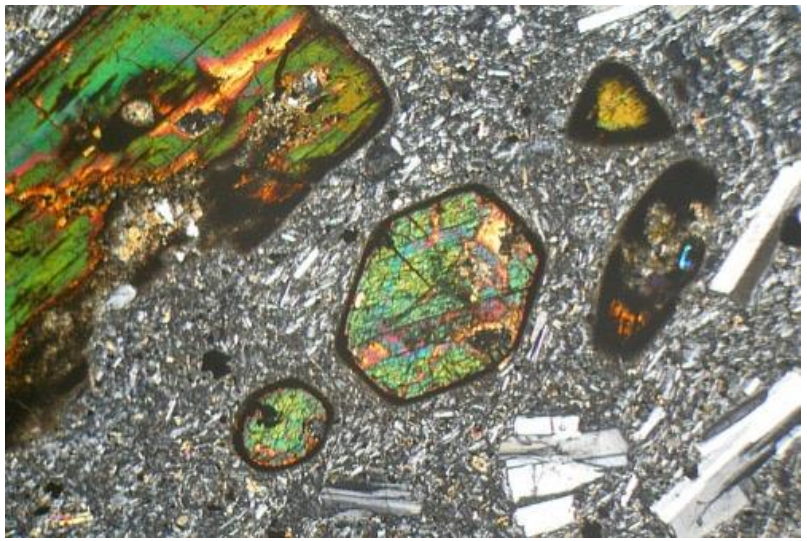
Optical Properties:

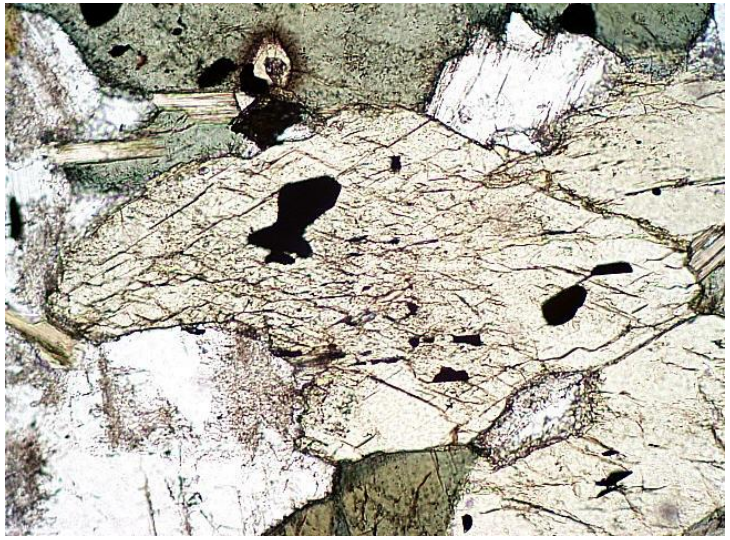
- Form : Prismatic in habit with pseudohexagonal cross section
- Relief : Rather high
- Color : Green or brown
- Pleochroism : Yellow green
- Birefringence colors : Moderate. The maximum interference color is about middle second order
- Cleavage : {110} in two direction at angles 56^0 and 124^0
- Extinction : The maximum extinction angle in longitudinal sections varies from 12^0 to 30^0
- Twinning : Twins with {100} as the twin plane are rather common
- Occurrence : Metamorphic rocks (amphibolites, some granulites and eclogites); mafic and ultramafic igneous rocks both plutonic (diorites, gabbros, hornblendites, etc.) and volcanic (basalts)

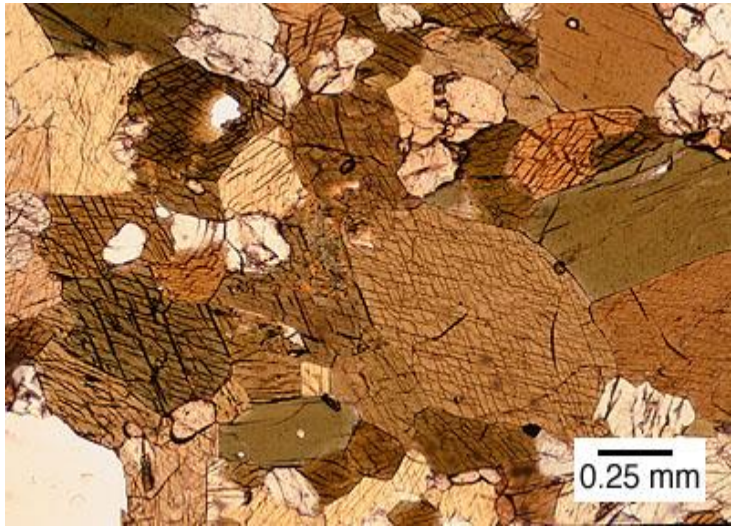
HORNBLENDE

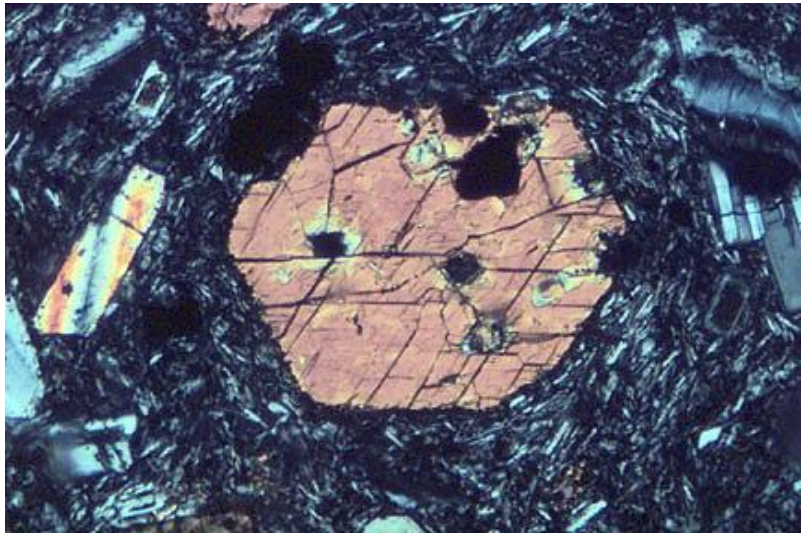










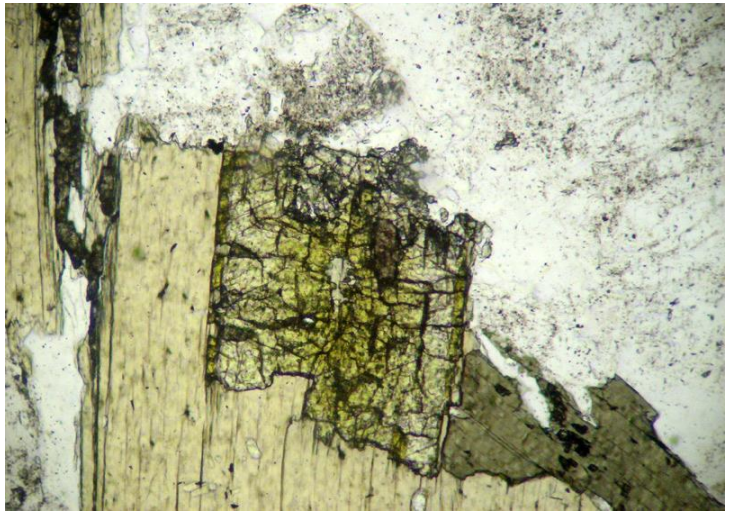
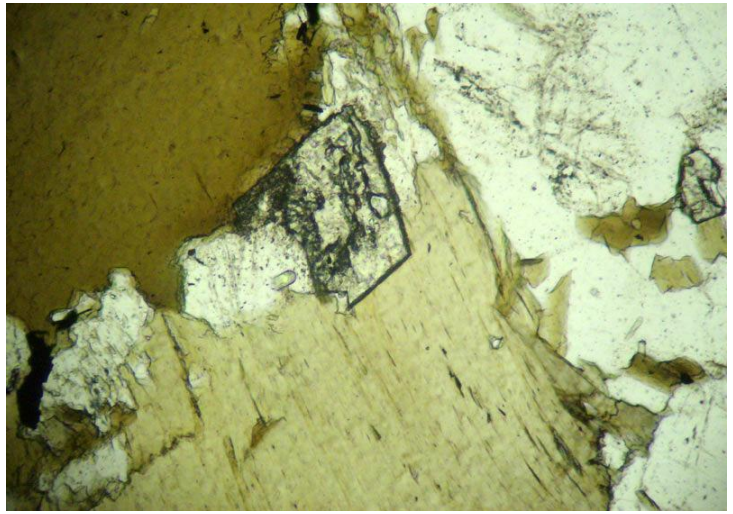
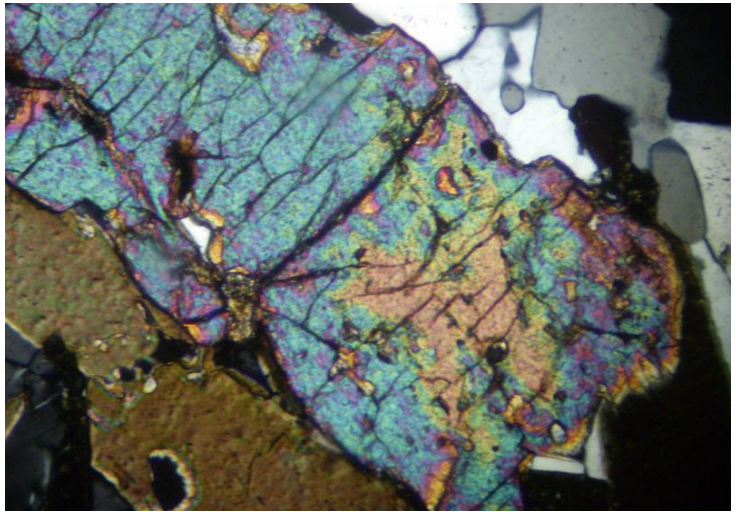
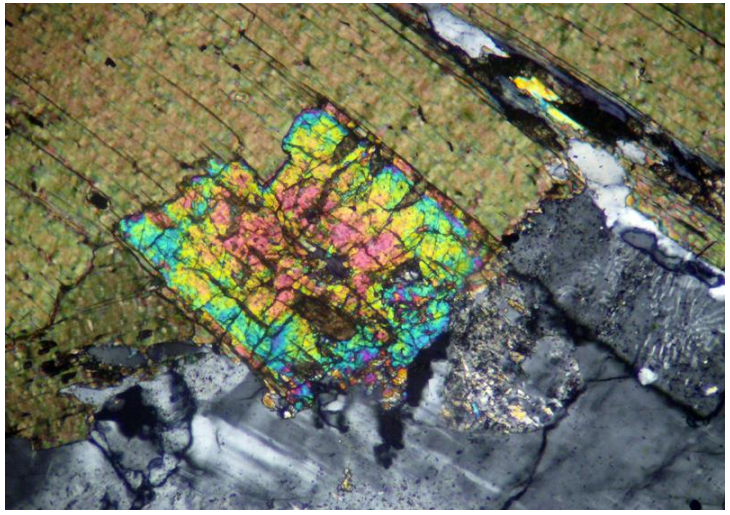
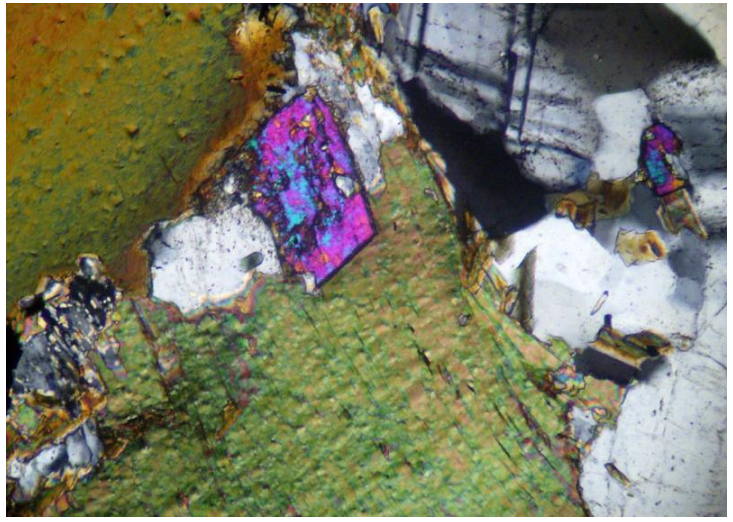
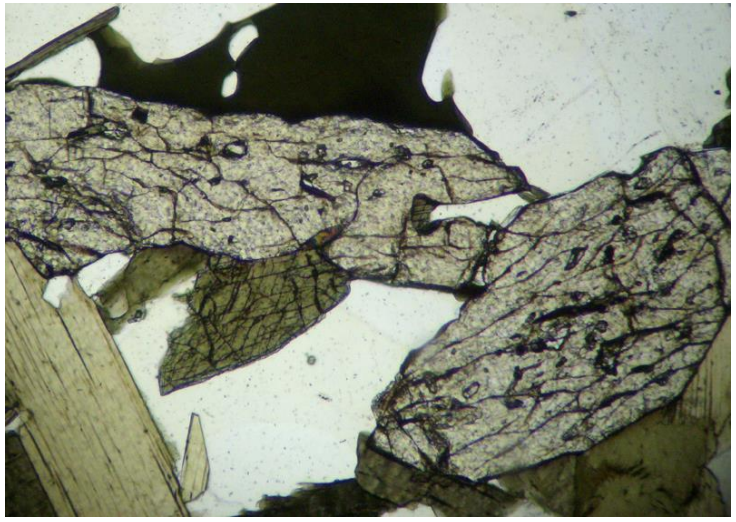


MONAZITE

Optical Properties:

- Form : Usually occur in euhedral crystals
- Relief : Very high
- Color : Nearly colorless to neutral
- Birefringence colors : Strong to very strong. The maximum interference color is upper third or lower fourth order
- Cleavage : Parting parallel to {001} is often prominent
- Extinction : Longitudinal sections have small extinction angle (2 to 10); section parallel to {001} do not show complete extinction
- Orientation : Crystals are length-slow
- Occurrence : Granites, syenites, gneisses and pegmatites

MONAZITE

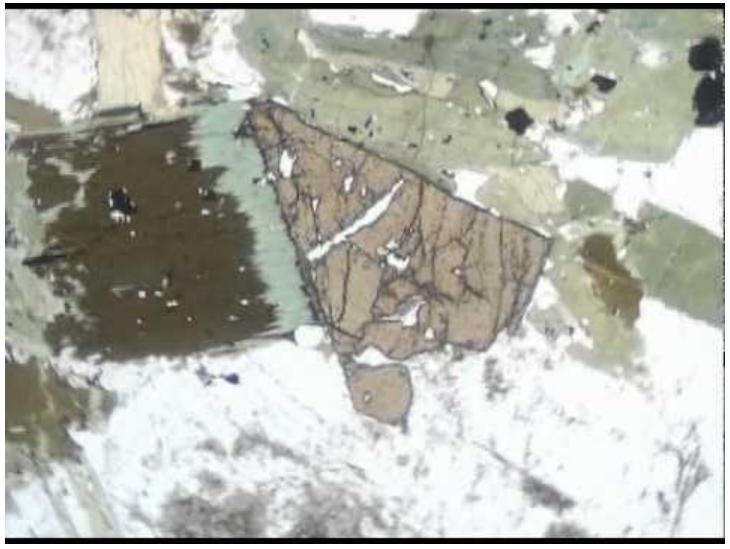







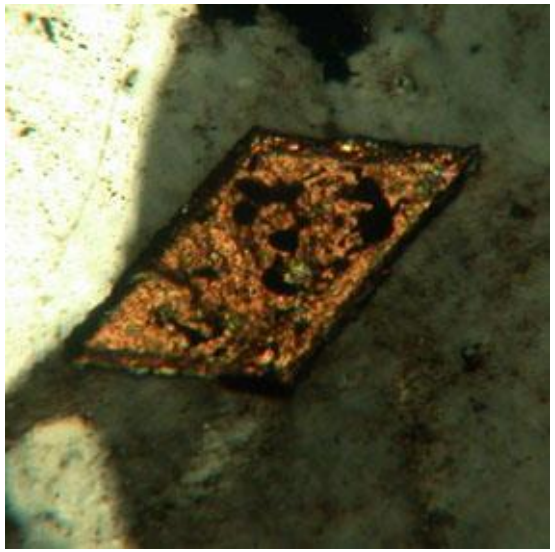
SPHENE

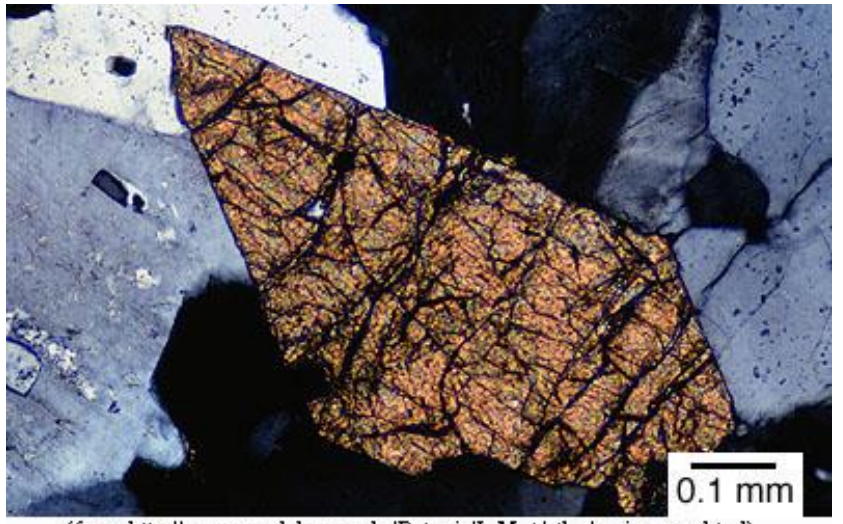
Optical Properties:

- Form : Usually occur in euhedral crystals or in irregular grains
- Relief : Very high
- Color : Almost colorless to neutral
- Pleochroism : Colorless; pale yellow to pale greenish; red to brown
- Birefringence colors : Extreme. The maximum interference color is high order white
- Cleavage : Paralel to 221
- Extinction : Doesn’t show complete extinction; Rhombic sections have symmetrical extinction
- Twinning : Twins with {100} as twin-plane; Polysynthetic twinning parallel to (221)

SPHENE







(from http://www.geolab.unc.edu/Petunia/IgMetAtlas/mainmenu.html)

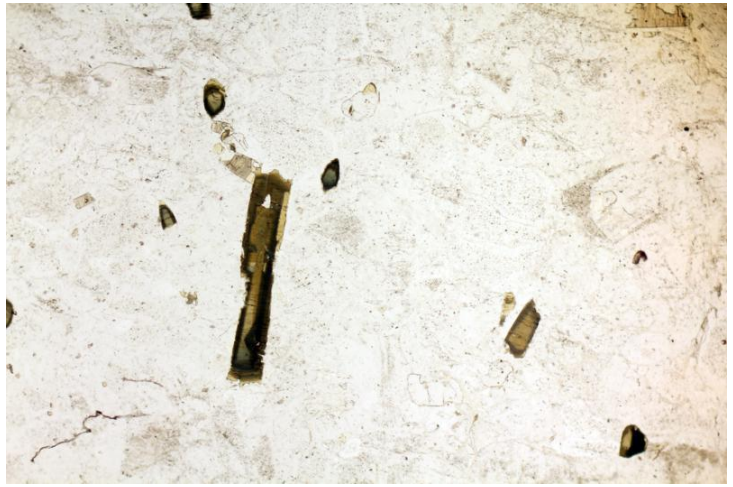
TOURMALINE

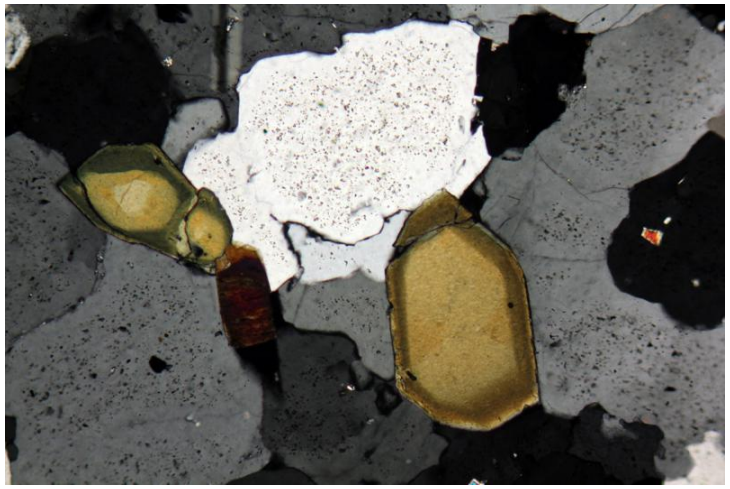
Optical Properties:

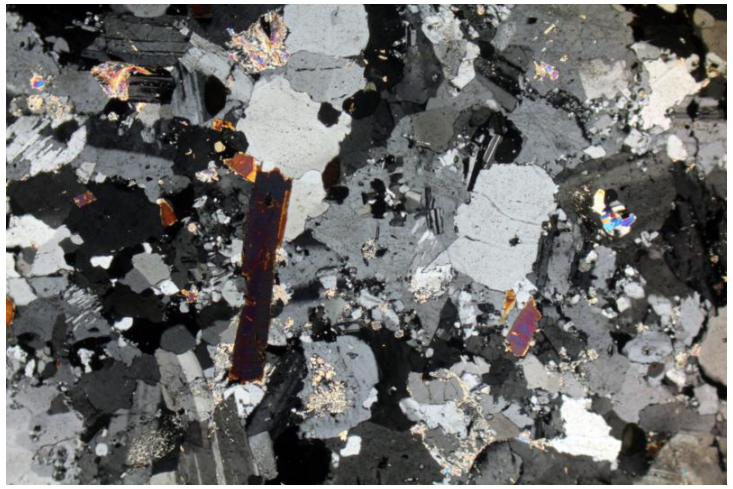
- Form : Tourmaline may be euhedral ranging from stubby columnar crystals to acicular crystals
- Color : Highly variable and often irregular, brown, yellow, red, blue, green.
- Relief : Medium
- Interference colors : III order
- Occurrence : Igneous rocks, metamorphic rocks and sedimentary rocks. Common in pegmatites, greisen and marble

Tourmaline is distinguished from biotite and hornblende by the absence of cleavage, the presence of striated prisms, and (for hornblende) parallel extinction. Lighter colored tourmalines can be confused with topaz, apatite or corundum, but can be distinguished by certain optical properties. Topaz is biaxial, apatite has lower birefringence, and corundum has higher indices of refraction.

TOURMALINE





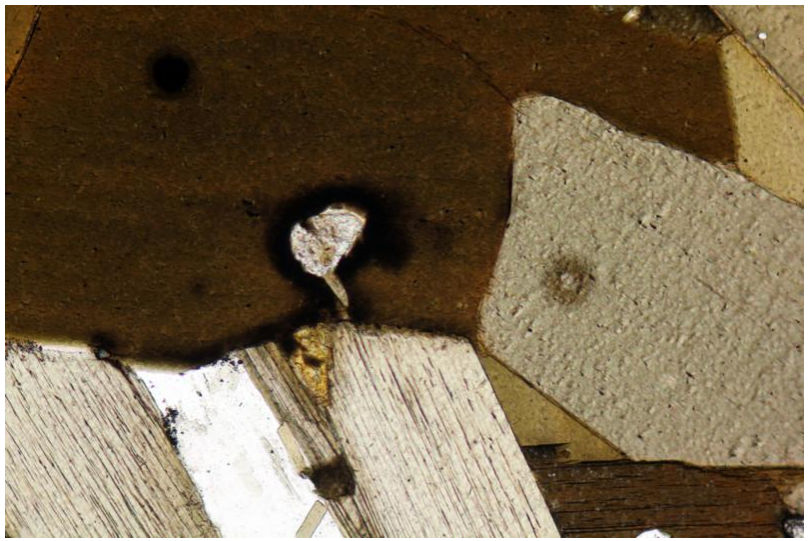


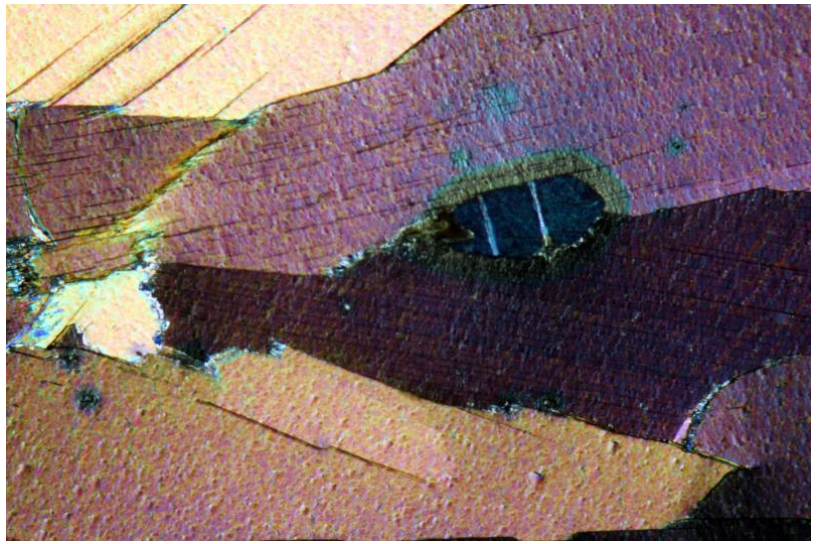
ZIRCON

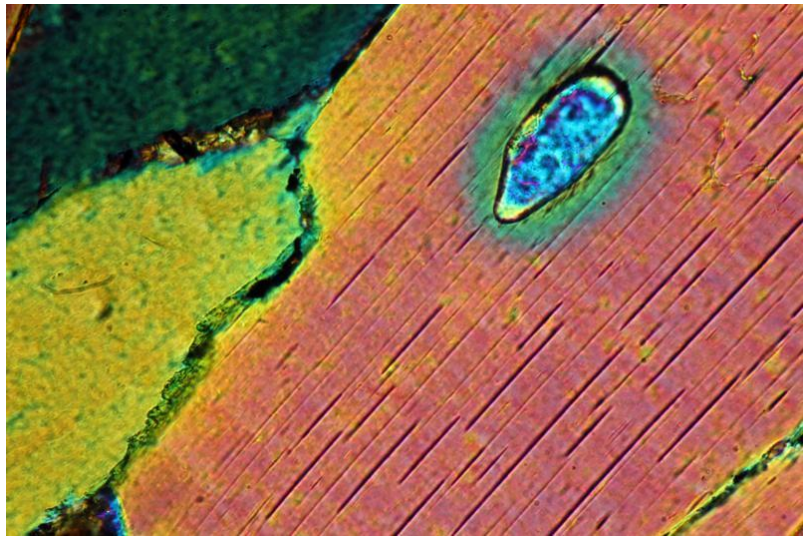
Optical Properties:

- Form : Minute crystals of short prismatic habit
- Relief : Very high.
- Color : Colorless to pale colors
- Birefringence colors : Very strong. The maximum interference colors are pale tints of fourth order
- Cleavage : Absent
- Extinction : Parallel
- Orientation : Length-slow
- Occurrence : Acidic igneous rocks and alluvial deposits

ZIRCON





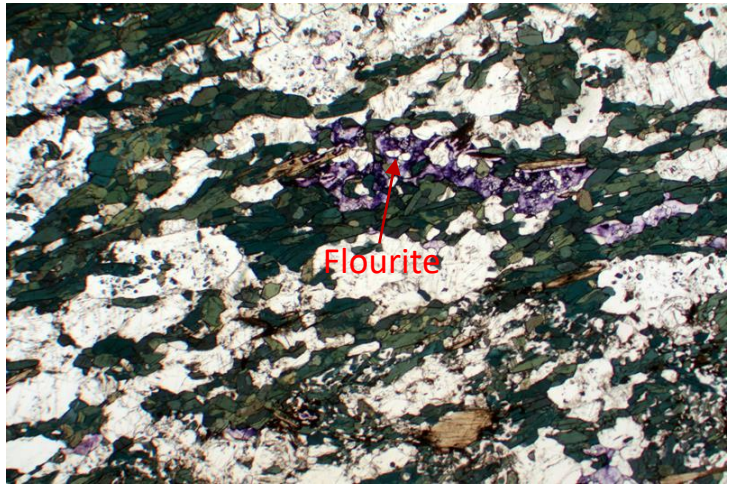


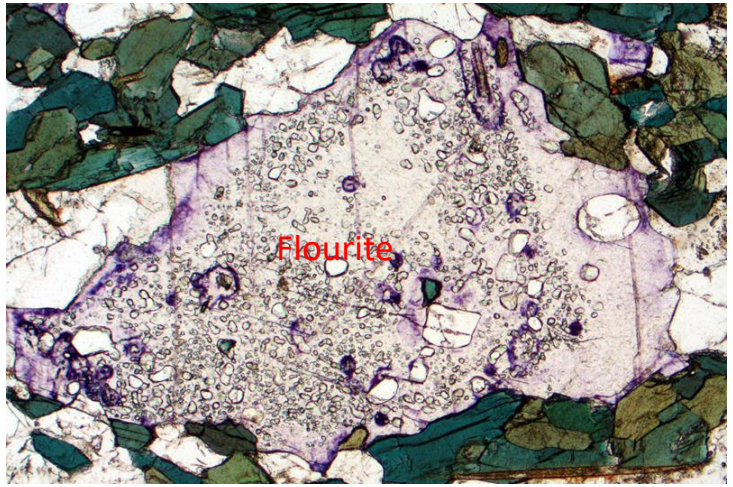
FLOURITE

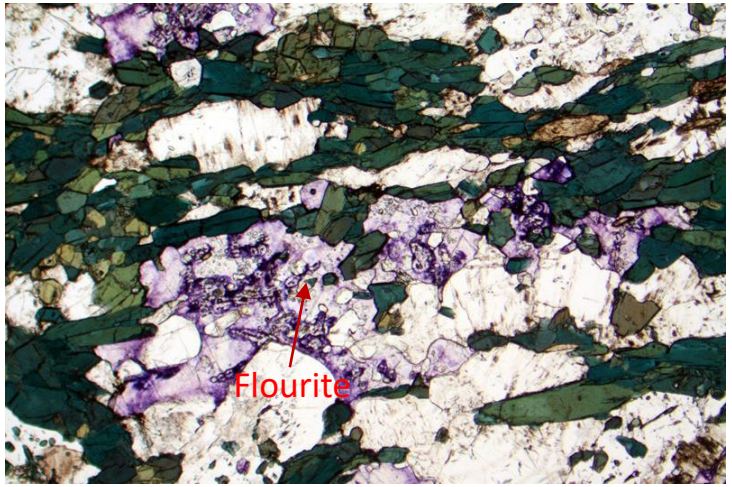
Optical properties:

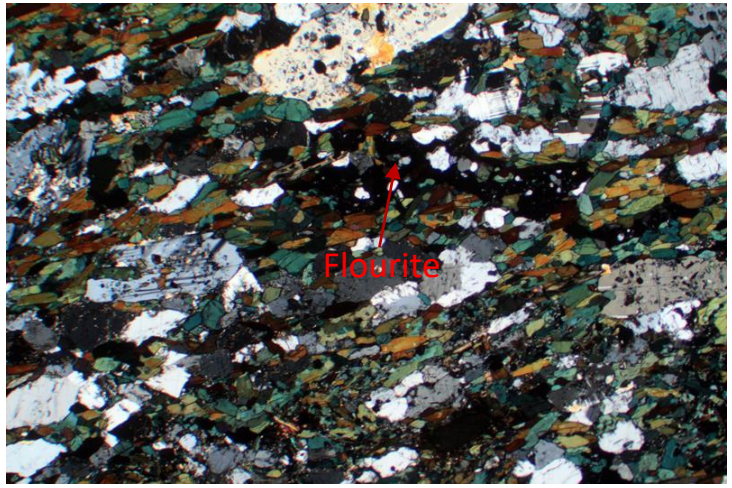
- Form : Euhedral crystals with square outline, anhedral, fills the spaces between other minerals
- Relief : Fairly high
- Color : Colorless or purple in bands or spots
- Birefringence colors : Nil. Dark between crossed nicols
- Cleavage : Perfect octahedral {111}
- Occurrence : Hydrothermal veins, rare in pegmatites, felsic and intermediate intrusives, volcanic rocks

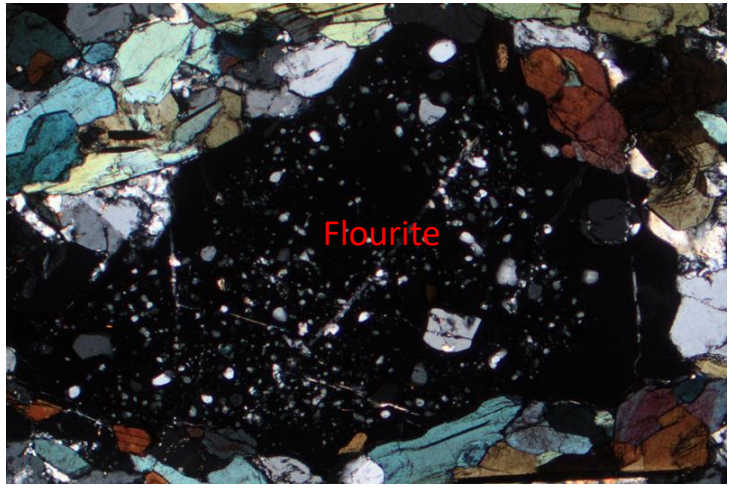
FLOURITE

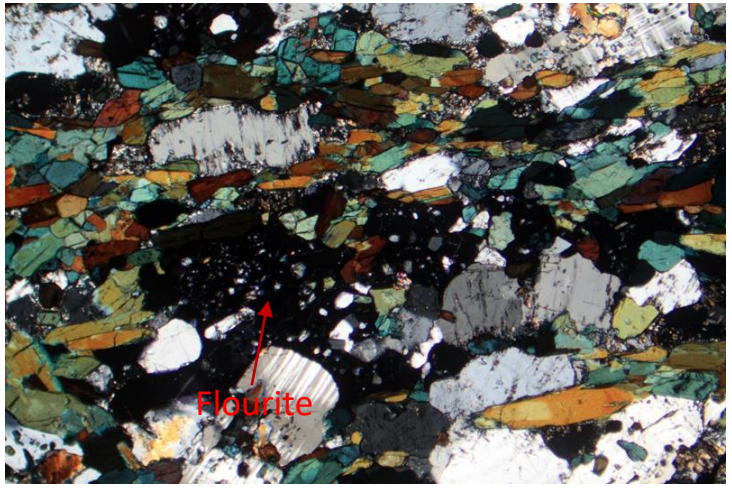










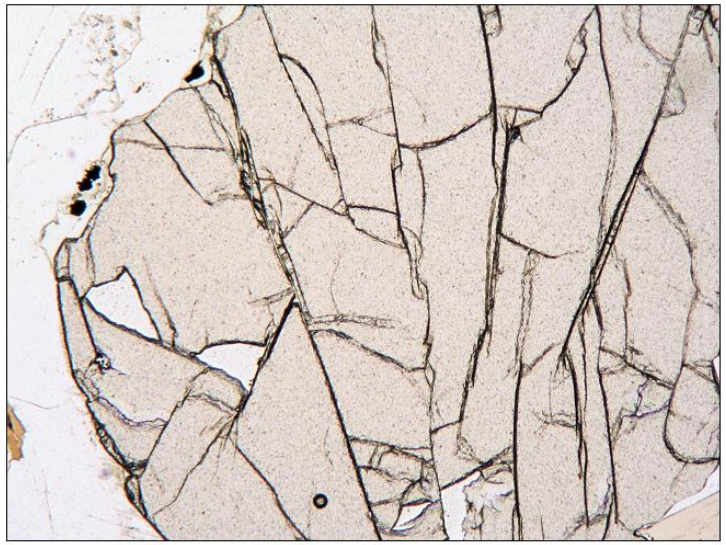


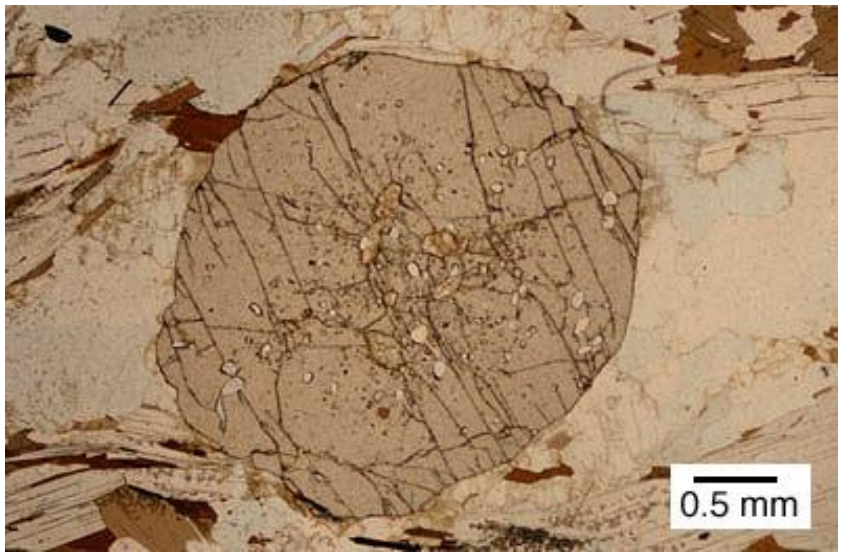
GARNET

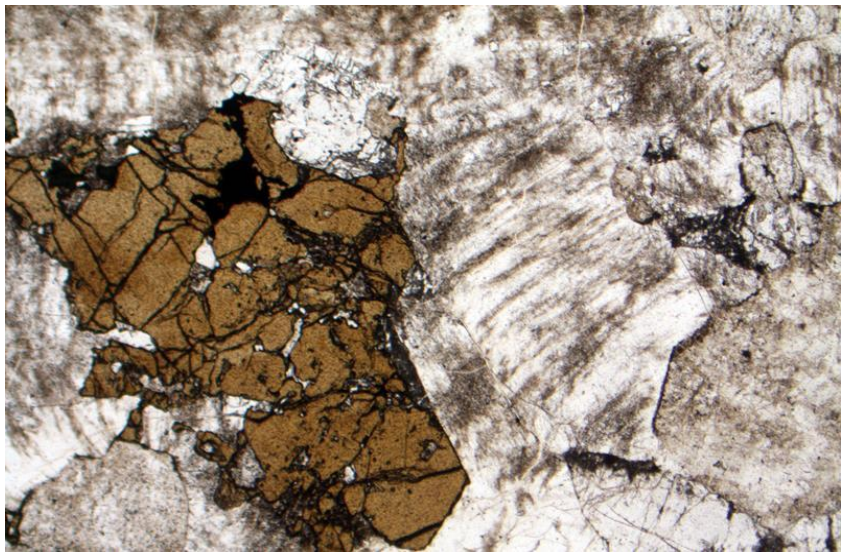
Optical Properties:

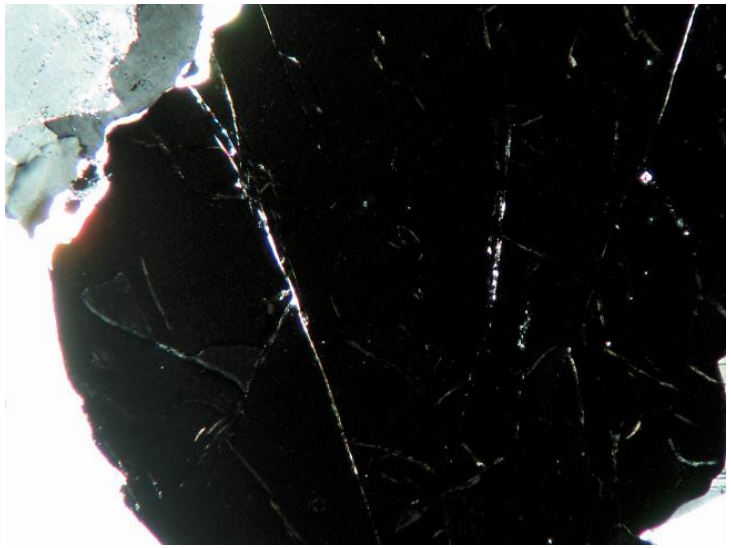
- Form : Euhedral dodecahedral crystals in six-sided sections and trapezohedral crystals in eight-sided sections; polygonal grains, aggregates and masses.
- Relief : Very high.
- Color : Colorless, pale reddish, pale to dark brown, greenish gray.
- Birefringence colors : Dark between crossed nicols but some have weak or very weak.
- Cleavage : Absent; but it may have parting parallel to (110); irregular fractures.
- Occurrence : Metamorphic rocks (schists and gneisses)

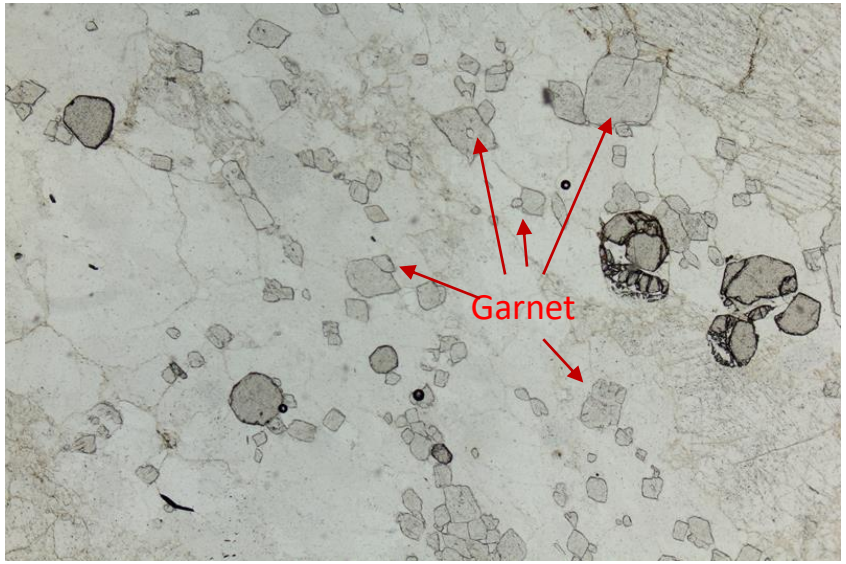
GARNET









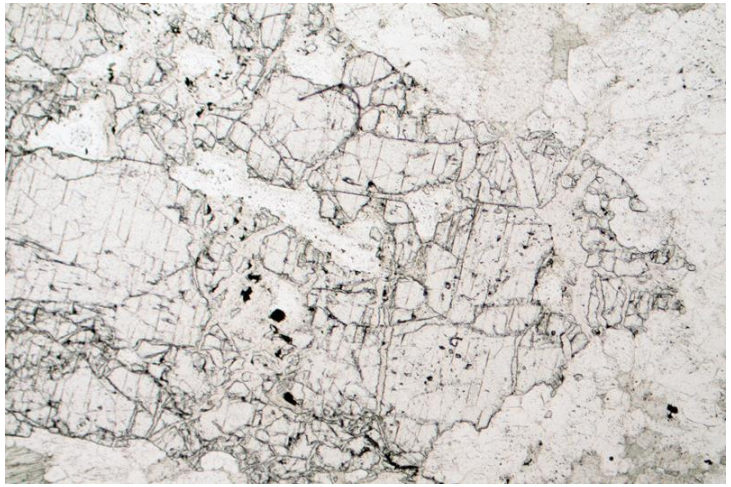
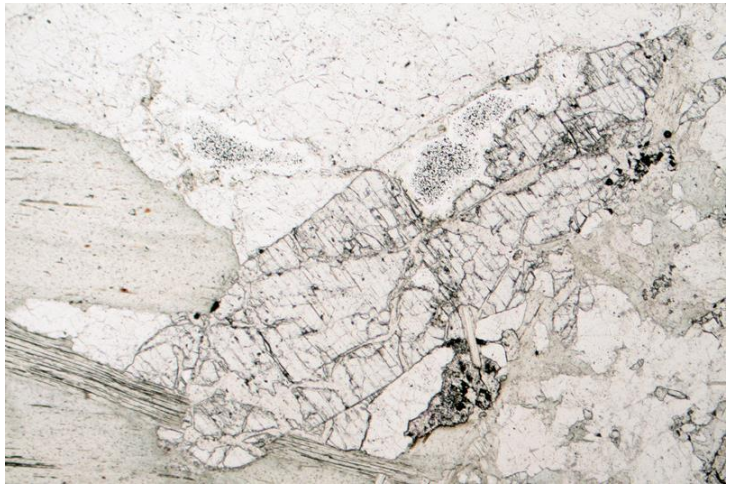
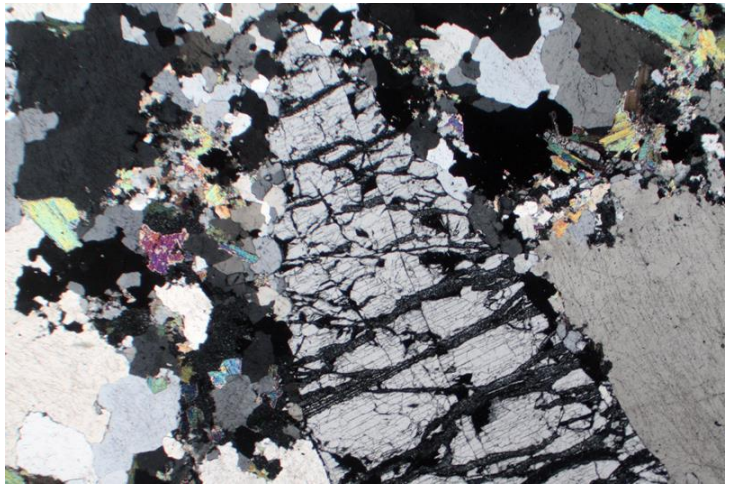
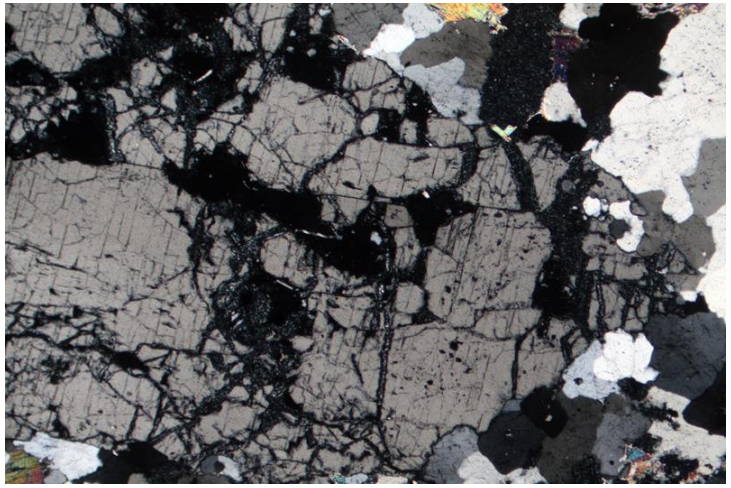
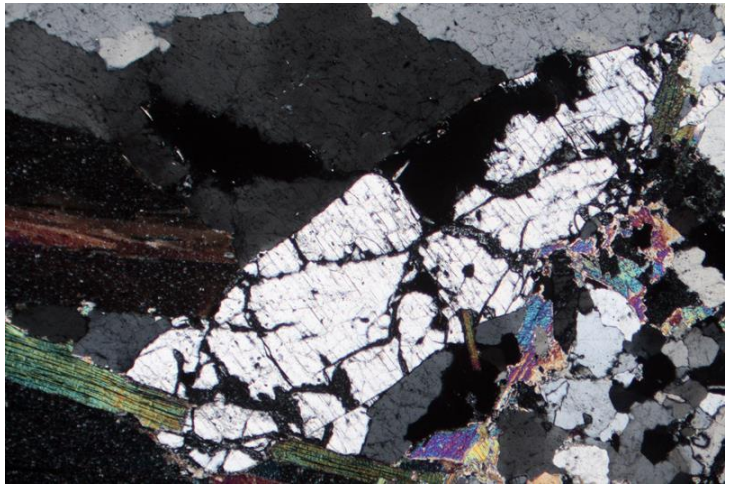


TOPAZ

Optical Properties:

- Form : Euhedral crystals of short prismatic habit, anhedral grains and columnar aggregates
- Relief : Fairly high
- Color : Colorless
- Birefringence colors : Rather weak. The maximum interference colors are gray, white, or straw yellow of the first order
- Cleavage : Perfect in one direction parallel to {001}
- Extinction : Parallel in longitudinal sections and symmetric al in basal section
- Orientation : Parallel to the faster ray
- Occurrence : Greisen, granites and miarolitic cavities in rhyolites, high-temperature hydrothermal veins

TOPAZ

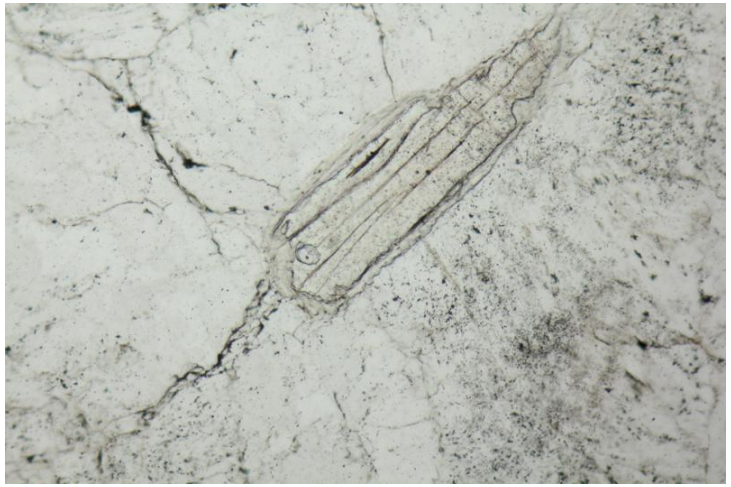
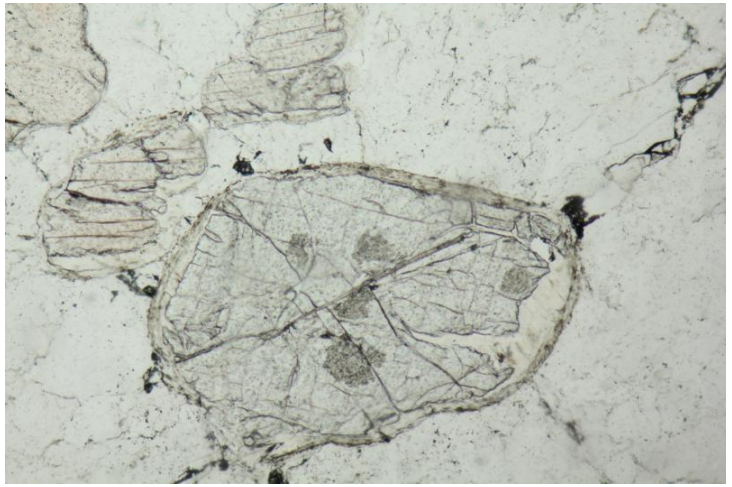
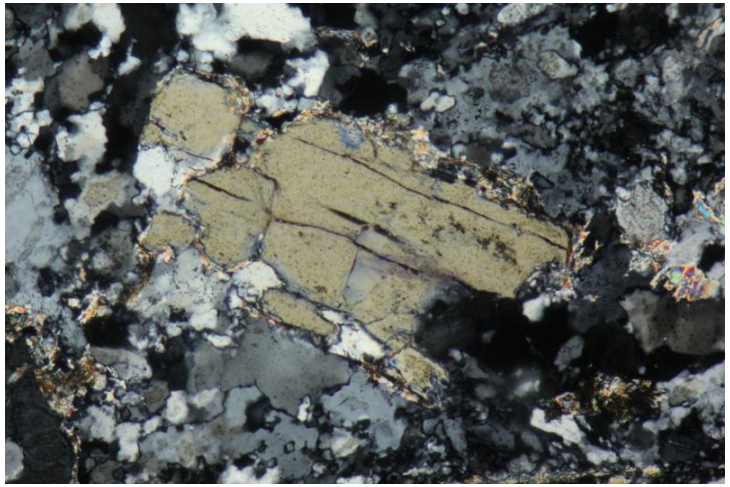
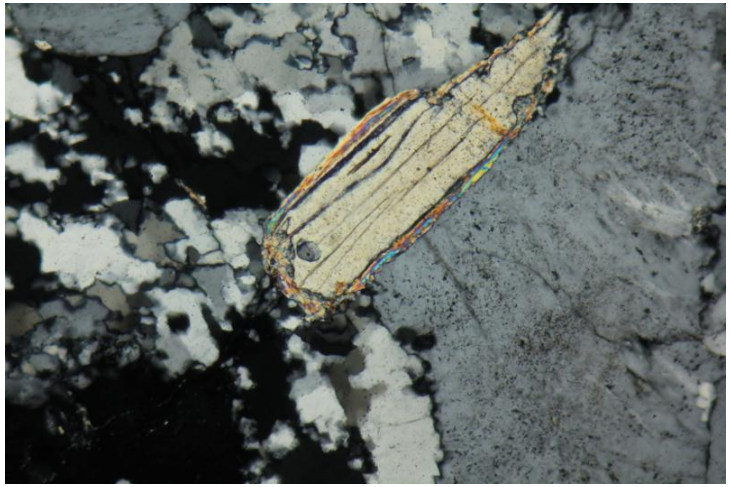
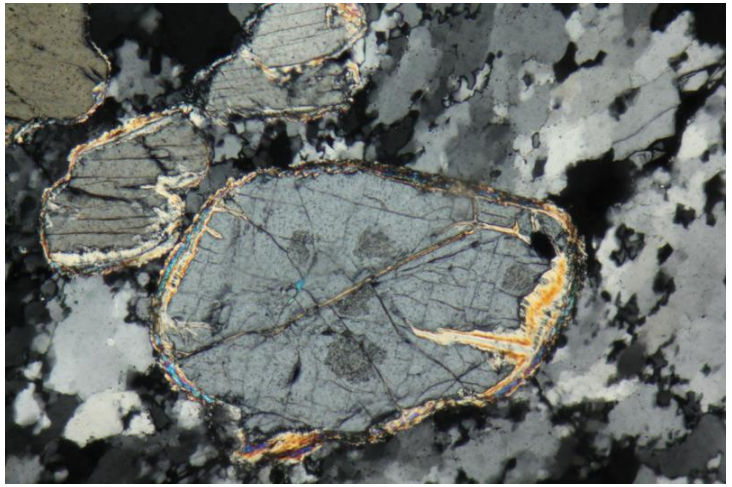







ANDALUSITE

Optical properties :

- Form : Euhedral crystals or columnar aggregates.
- Relief : Fairly high.
- Color : Colorless, rarely reddish.
- Birefringence colors : Rather weak. The maximum interference colors range up to first-order yellow.
- Cleavage : Parallel to {110}
- Extinction : Parallel in most sections
- Orientation : Length-fast
- Occurrence : Low-pressure metamorphic rocks, rare in pegmatites and hydrothermal veins

ANDALUSITE

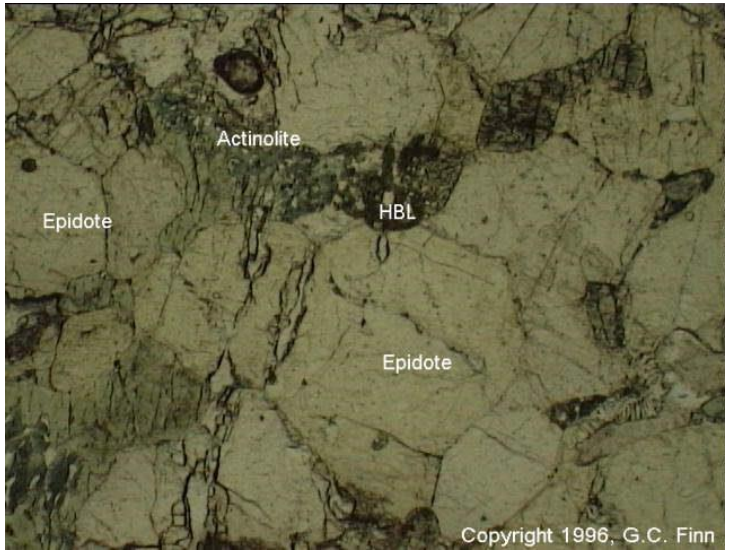







EPIDOTE

Optical properties:

- Form : Granular to columnar aggregates
- Relief : High.
- Color : Colorless to yellowish green
- Birefringence colors : Moderate to strong. The maximum interference color is range from low second-order to upper third-order colors.
- Cleavage : Perfect in one direction {001}
- Extinction : Parallel in elongate sections
- Twinning : Twins with {100} as twin-plane
- Orientation : Length-slow and length-fast
- Occurrence : Regional and contact metamorphic rocks (green schist facies); in cracks in amphibolites and gabbros

EPIDOTE


Actinolite
Epidote
HBL
Epidote
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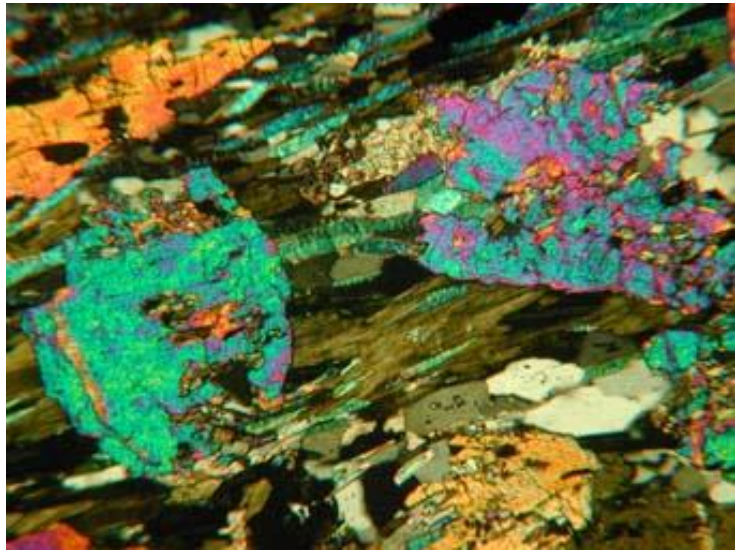

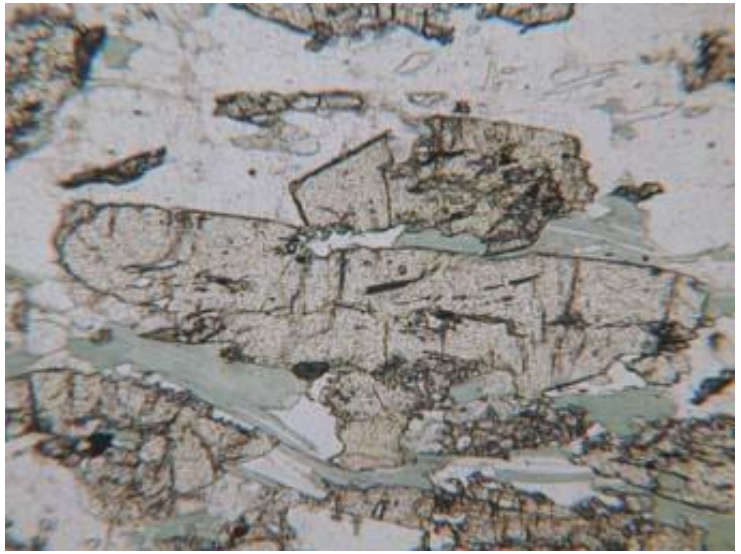

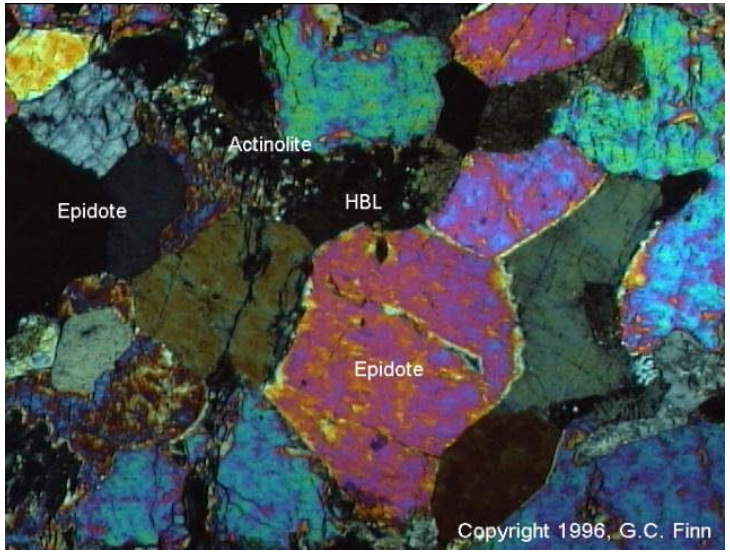
Actinolite
Epidote
HBL
Epidote
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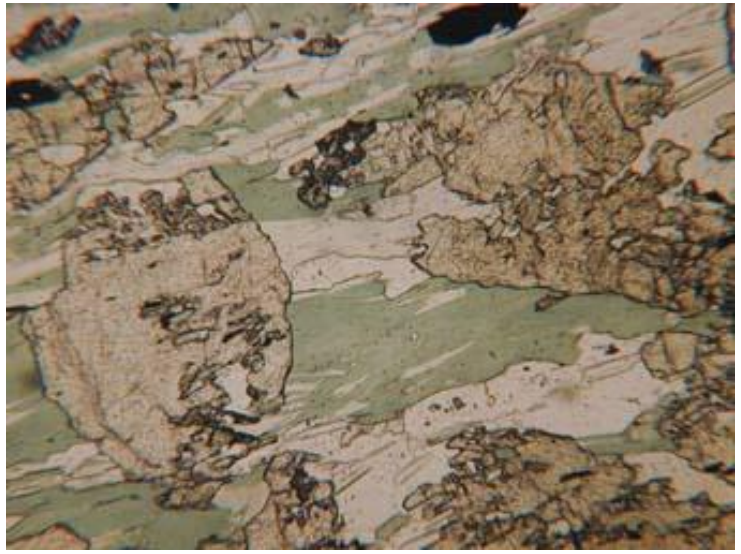
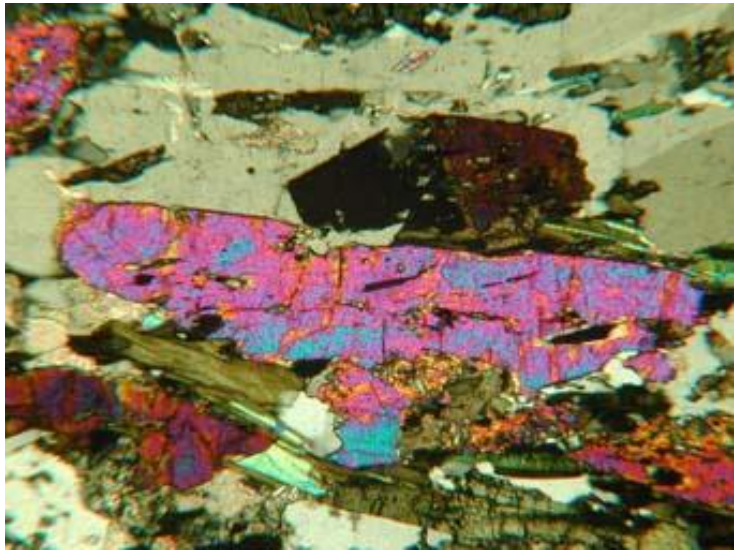


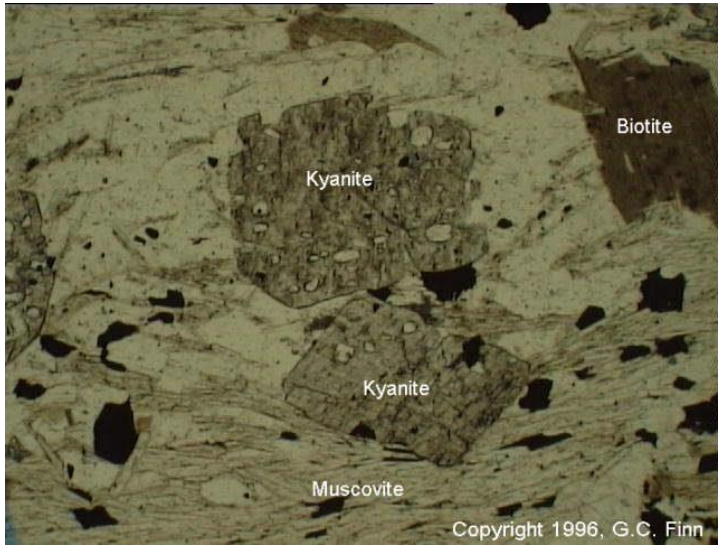


KYANITE

- **Optical properties:**

- Form : Broad elongate tabular parallel to (100) and narrow sections parallel to (010).
- Relief : High.
- Color : Colorless or pale blue
- Birefringence colors : Moderate. The maximum interference colors range up to first-order red.
- Cleavage : Inconspicuous parallel to (010)
- Extinction : Perfect parallel to {100}, less parallel to {010}, cross parting {001} at angels 85^0
- Twinning : Frequent
- Orientation : Slow ray
- Occurrence : Pelitic rocks, metamorphosed under high pressure (gneiss, mica schists, amphibolites and eclogites), pegmatite veins and emery deposits

KYANITE


Biotite
Kyanite
Kyanite
Muscovite
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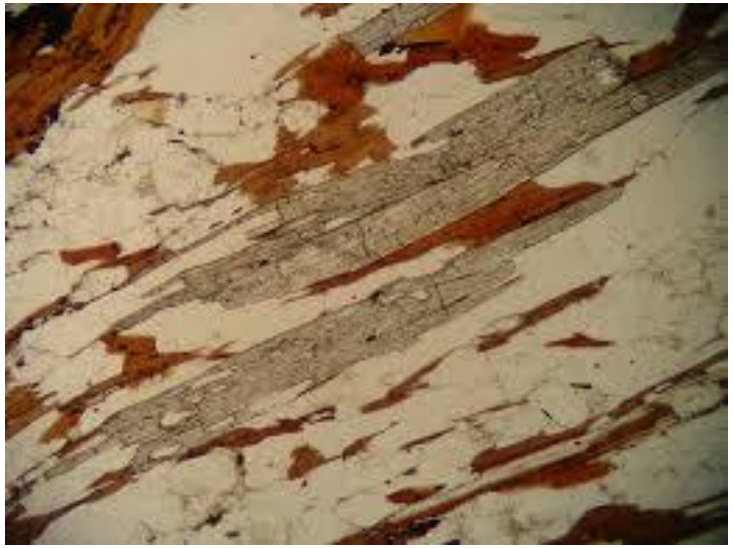

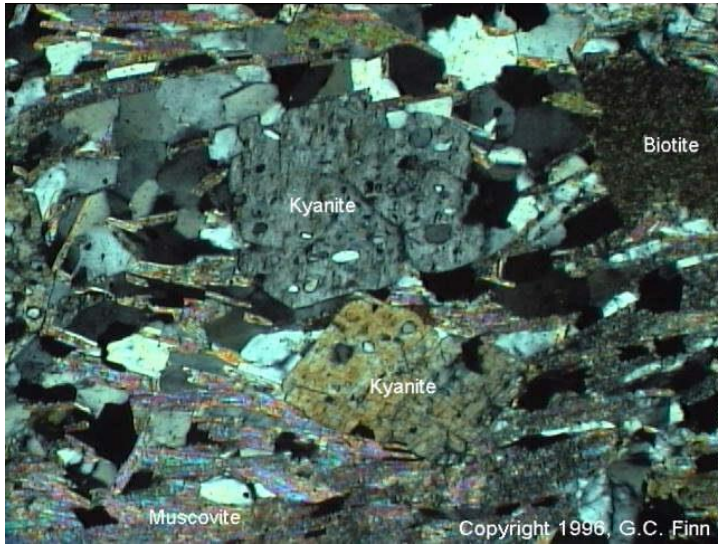
Biotite
Kyanite
Kyanite
Muscovite
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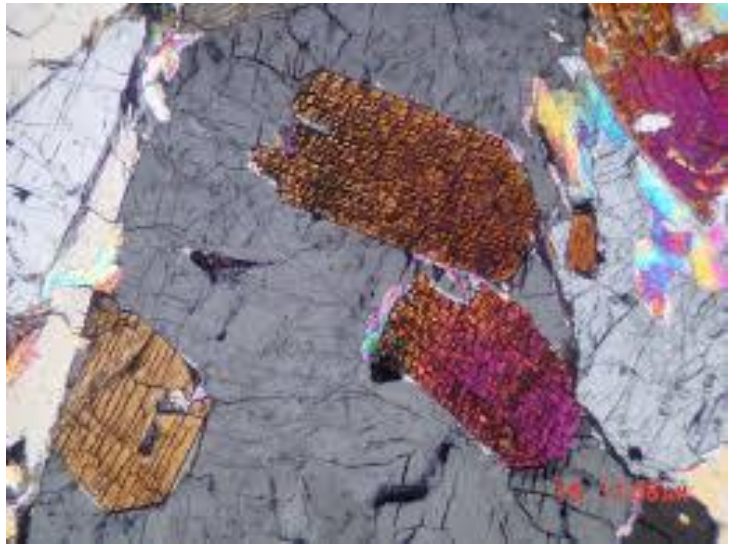
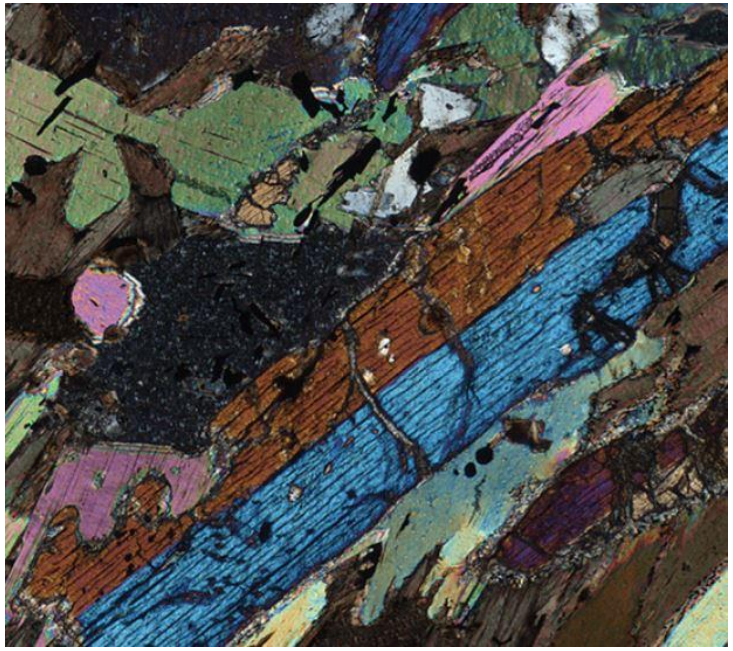


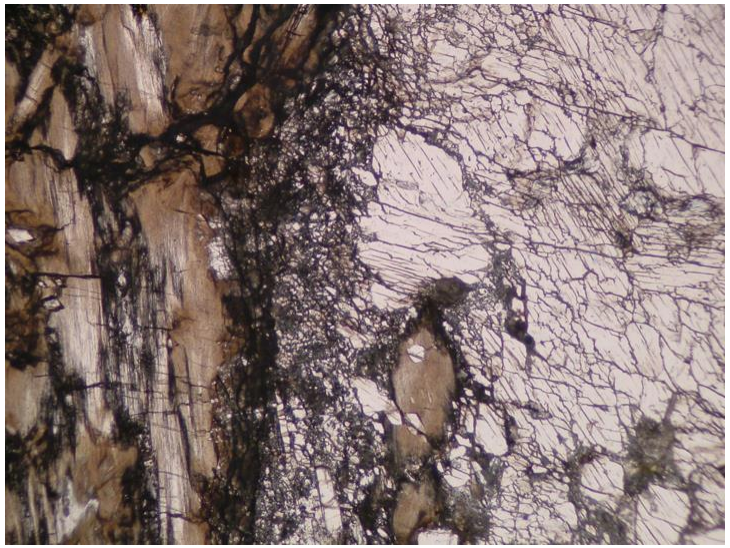
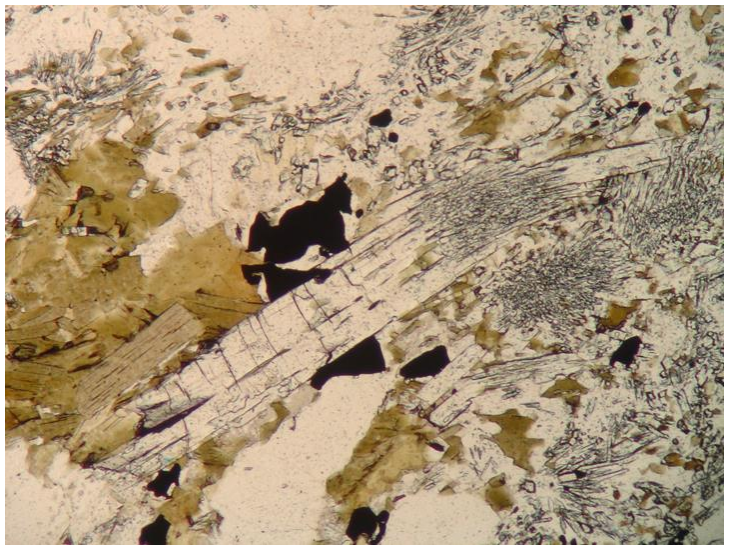
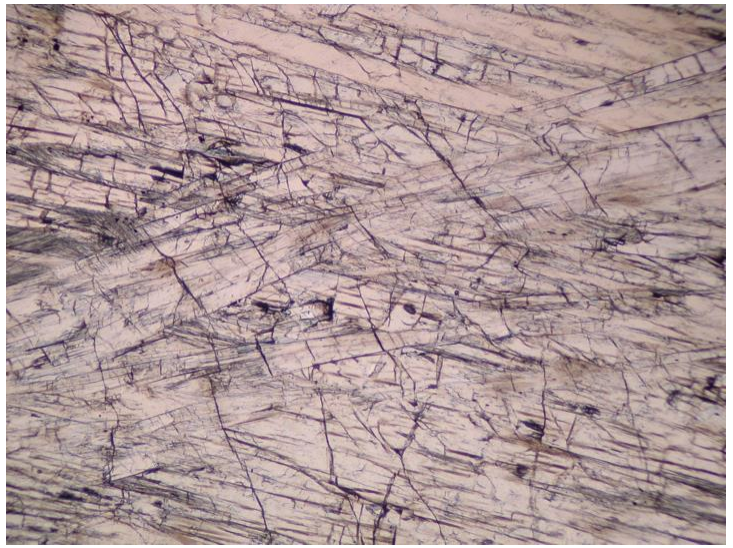
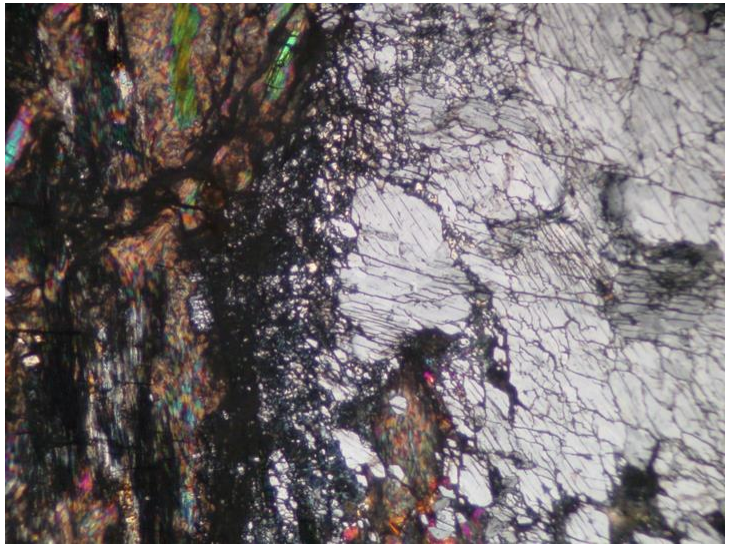
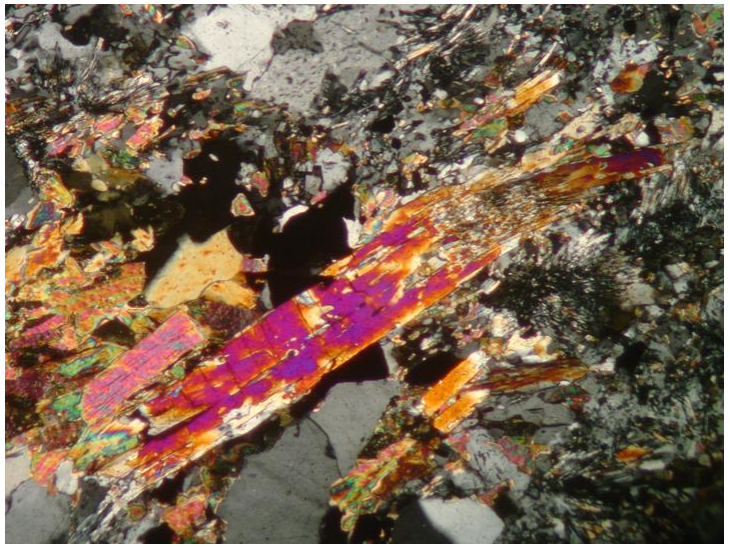
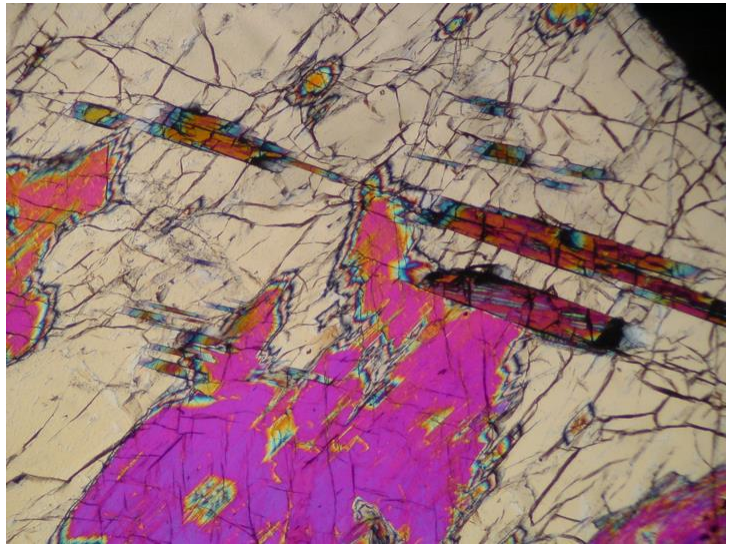


SILIMANITE

Optical properties:

- Form : Small, often minute, slender prismatic crystals
- Relief : Fairly high.
- Color : Colorless
- Birefringence colors : Moderate. The maximum interference colors range up to second-order blue.
- Cleavage : Parallel to {010}
- Extinction : Parallel (longitudinal) and symmetrical (cross section)
- Orientation : length-slow
- Occurrence : High-temperature regional metamorphic rocks and occasionally in pegmatites

SILIMANITE

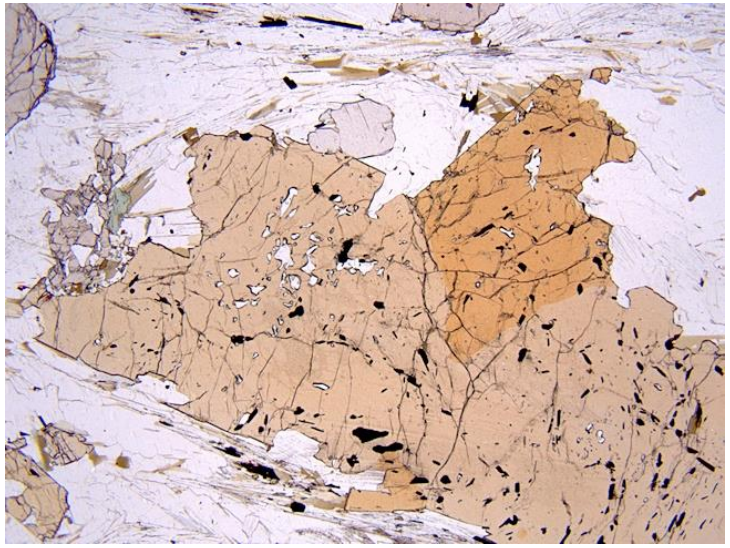







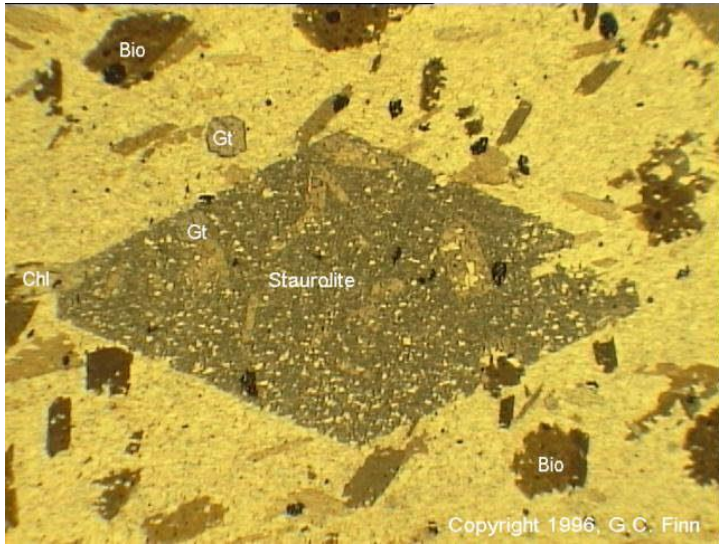
STAUROLITE

- **Optical properties:**

- Form : Euhedral crystals of short prismatic and six-sided cross section
- Relief : High.
- Color : Pale yellow
- Pleochroism : Yellow to brown
- Birefringence colors : Rather weak. The maximum interference color is first-order yellow to red
- Cleavage : Inconspicuous parallel to (010)
- Extinction : Parallel in most sections
- Twinning : Penetration twins with {023} or {232} as twin plane. Staurolite is famous for its twinned crystals that form into the shape of a cross; Staurolite forms two twin types; one that is nearly 90^0 and one that is nearly 60^0. The 60^0 type is more common but the 90^0 type is the most sought after.
- Occurrence : Pegmatites, contact metamorphic rocks and alluvial sands

STAUROLITE




Bio
Gt
Gt
Chl
Staurolite
Bio
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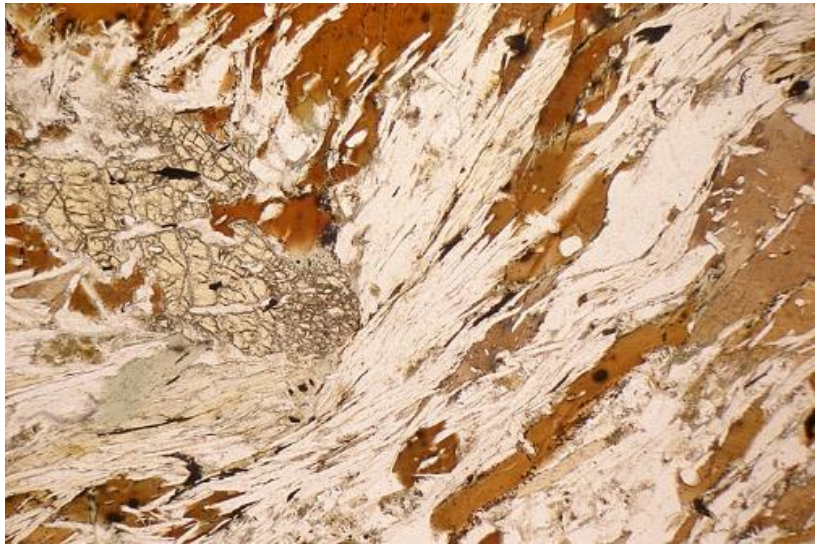

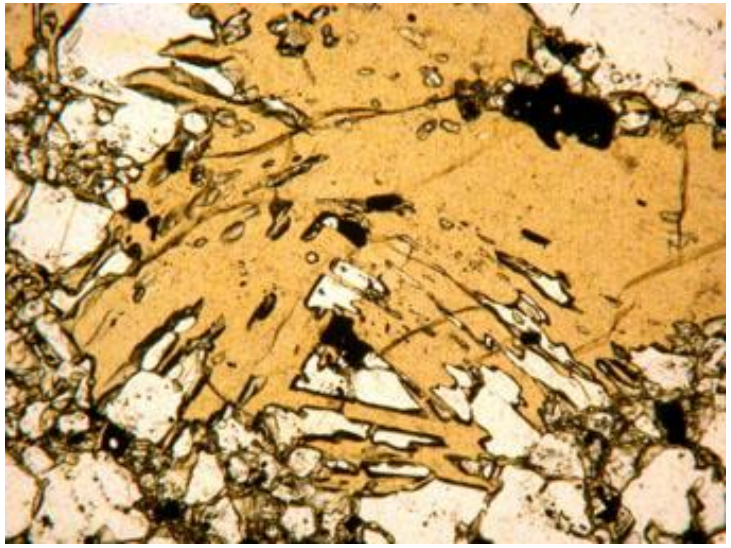

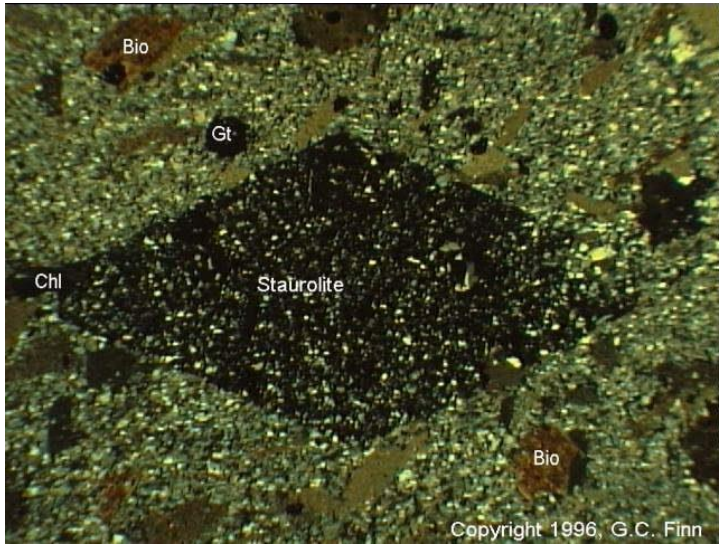
Bio
Gt
Chl
Staurolite
Bio
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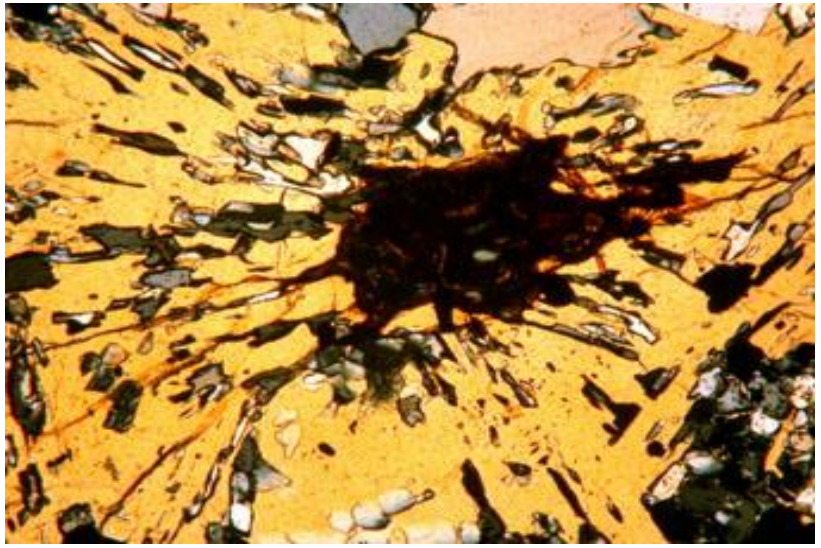
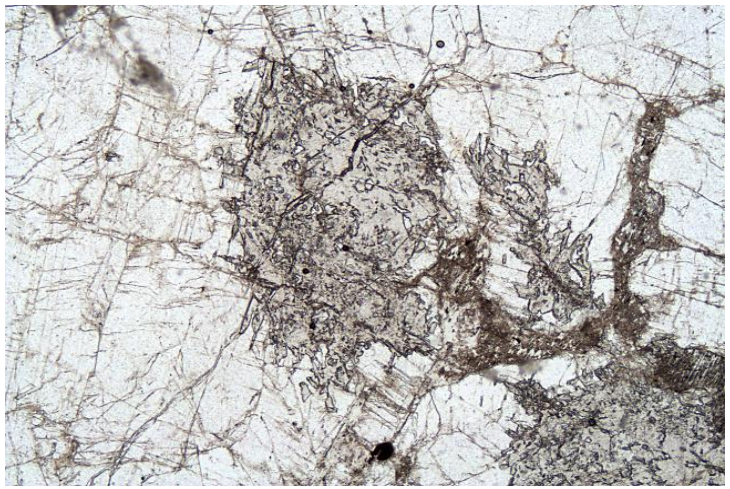
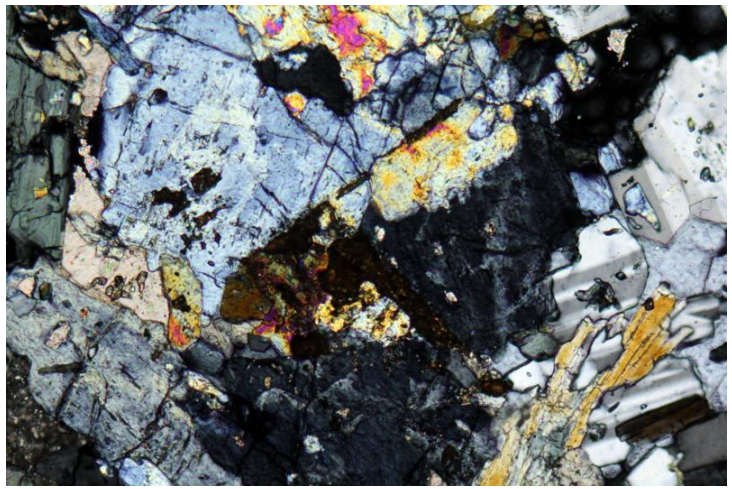
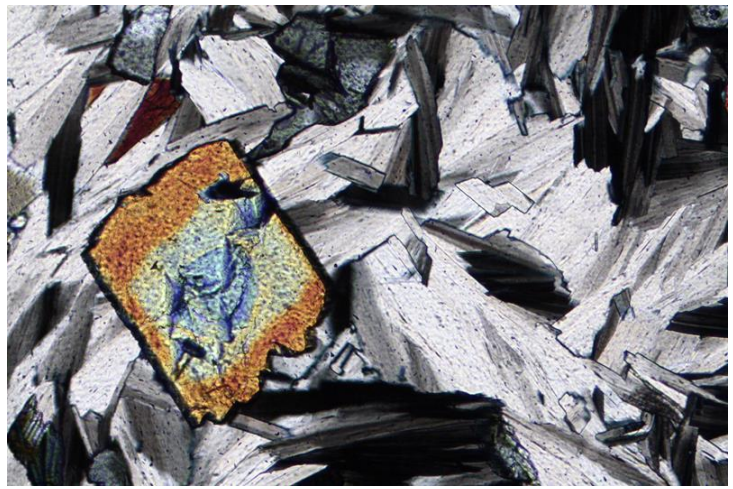
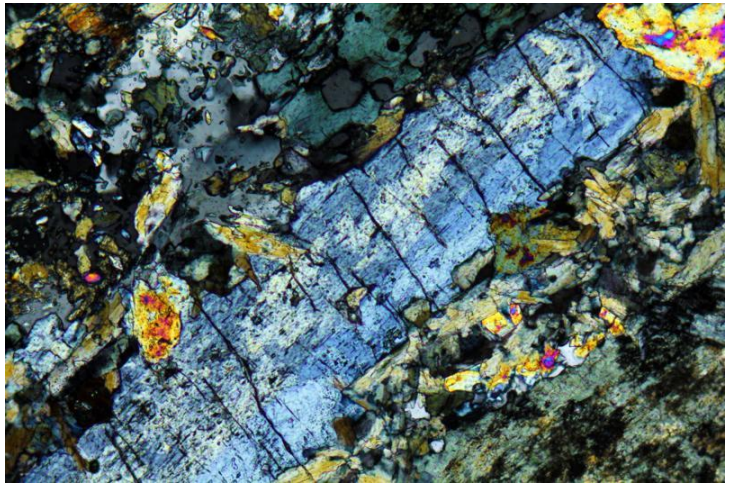
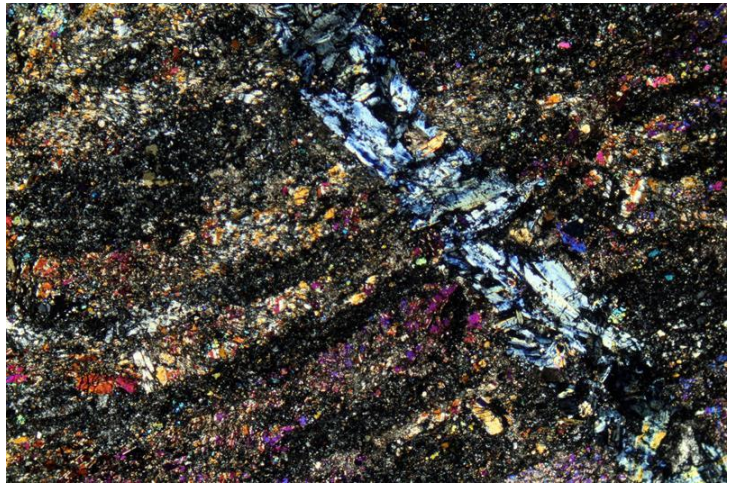
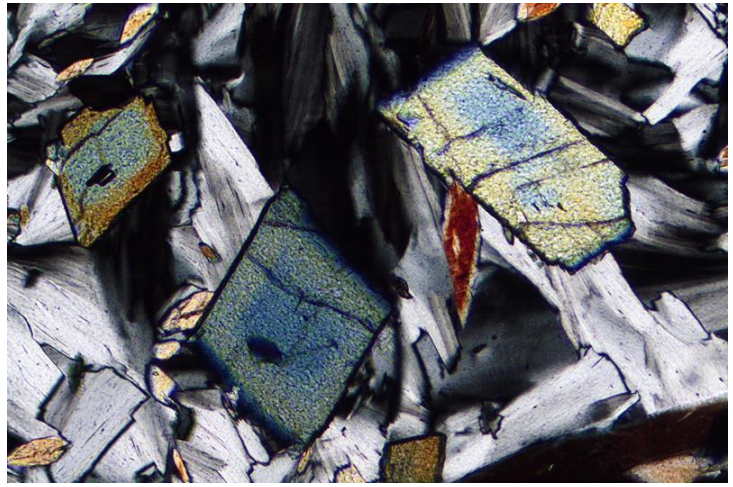


ZOISITE

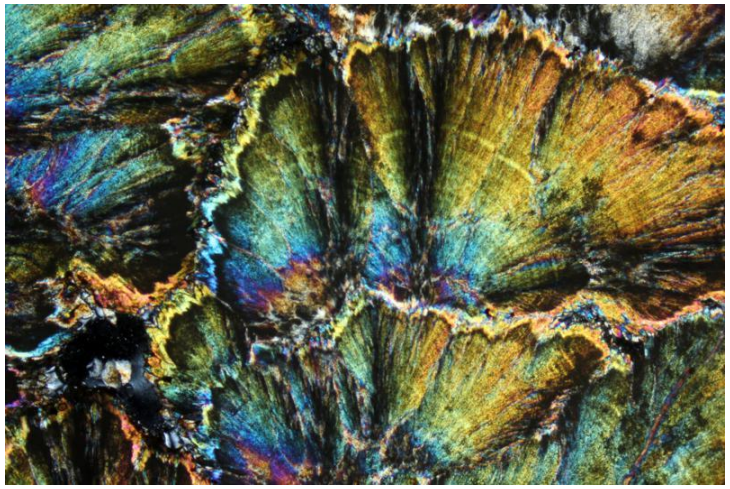
- **Optical properties:**

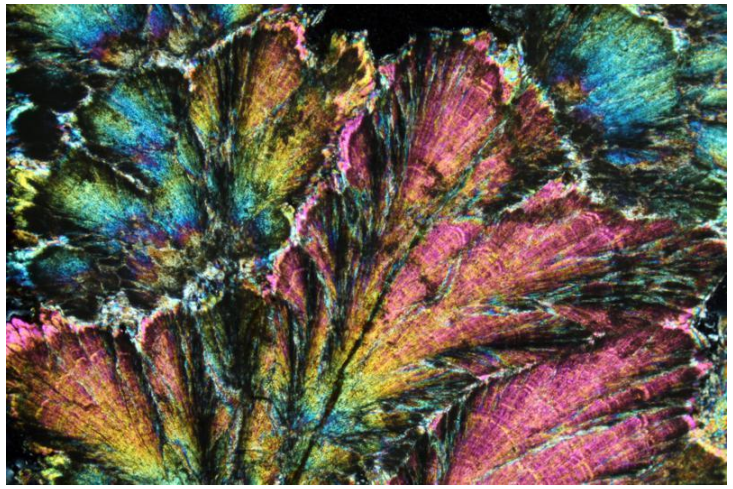
- Form : Columnar aggregates
- Relief : High.
- Color : Colorless; pink (manganian zoisite)
- Birefringence colors : Weak to moderate. The maximum interference colors are normal and anomalous (deep blue)
- Cleavage : Perfect {010}
- Extinction : Parallel in most sections
- Twinning : Polysynthetic twinning
- Occurrence : high-temperature and high-pressure metamorphic rocks (eclogites, granulites and some gneiss), hydrothermal veins and extrusive rocks

ZOISITE

BARITE





- **Optical properties :**

- Form : Granular aggregates, elongate, needlelike, plumose
- Relief : Fairly high.
- Color : Grey or colorless
- Birefringence colors : Rather weak. The maximum interference color is rarely above first-order yellow or orange
- Cleavage : Paralel to {001} and {110}; at angles of 90^0 and 78^0.
- Extinction : Paralel to {001}
- Twinning : Polysynthetic twinning with {110}
- Occurrence : Low-medium hydrothermal veins and basaltic rocks