Identification of Rock Minerals under a Polarizing Microscope

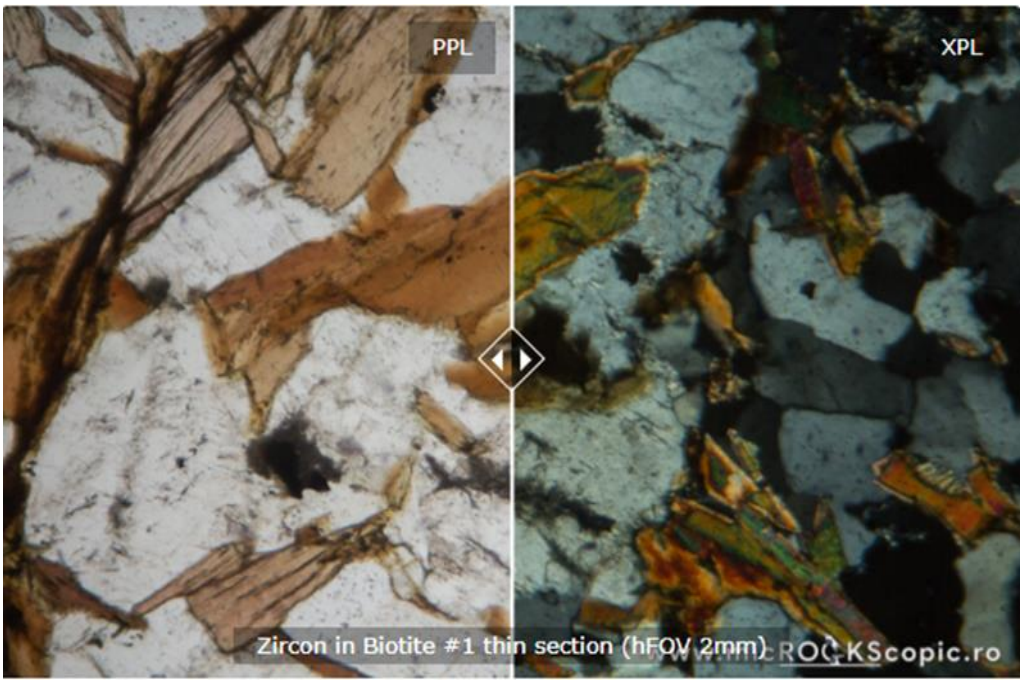
III- Accessory minerals

Accessory minerals include:

- ❑ Iron and titanium oxides:
  - Magnetite Fe_3O_4: cubic system. The most common accessory mineral
  - Hematite Fe_2O_3: hexagonal system. It frequently represents the alteration product of magnetite or forms a solid solution with ilmenite in unaltered igneous rocks.
  - Ilmenite $FeTiO_3$: hexagonal system. The principal ore of titanium. Common in a wide variety of volcanic and plutonic rocks.
- ➢ Spinel $MgAl_2O_4$: cubic system. Common in ultrabasic rocks and sometimes in basalts.
- ➢ Corundum Al_2O_3: hexagonal system. It is common in igneous rocks rich in aluminum (Al).
- ➢ Apatite $Ca_5(PO_4)_3(OH,F)$: hexagonal system. Very common in alkaline igneous rocks (granites, syenites, pegmatites, and equivalent lavas).
- ➢ Zircon $ZrSiO_4$: tetragonal system. It is common in siliceous igneous rocks (granites, granodiorites, syenites). It often contains traces of radioactive elements (Th and U). This mineral is therefore used to date rocks using the U-Pb and Th-Pb methods.
- ➢ Sphene $CaTiSiO_4(OH)$: monoclinic system. It is widespread in many igneous rocks (granites, granodiorites, syenites).
- ➢ Pyrite FeS_2: cubic system. It is widespread in various igneous rocks.
- ➢ La calcite $CaCO_3$: système rhomboédrique. Elle est présente dans les carbonatites.
- ➢ La fluorine (ou fluorite) CaF_2 : système cubique (minerai du fluor). Elle est présente dans les roches magmatiques alcalines (granites, syénites, pegmatites).

Accessory minerals Minerals under a Microscope

1- Zircon



Formula: $ZrSiO_4$ – may contain minor U, Th, Pb, Hf, Y/REE, P and others elements
System: Tetragonal
Color: Colourless, yellow, etc.
Lustre: Adamantine, Vitreous, Greasy
Hardness: 7½
Density: 4.6–4.7

Zircon PPL properties

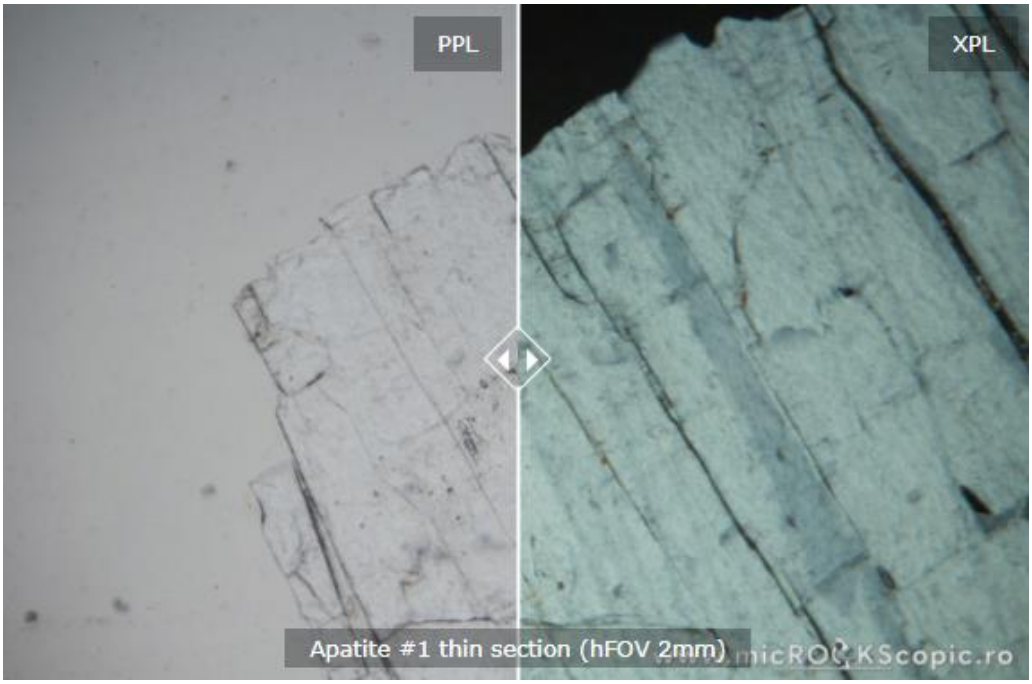
Relief: Very High positive
Habit/Form: Zircon commonly occurs a euhedral to subhedral tetragonal crystals with pyramidal terminations. It is not uncommon for euhedral overgrowths to be developed on rounded or subhedral cores. As detrital particles, zircon ranges from euhedral to rounded, depending on the amount of transport. Complex forms are known by relatively rare.
Color: Colorless (usually), to pale brown, pale yellow, or gray.
Pleochroism: Absent to weak
Cleavage: Absent

Zircon XPL properties

Isotropy/Anisotropy: Anisotropic

Interference color: Order III-IV; bright; detrital grains commonly show high-grade white
Extinction angle: Parallel / 0° / straight to crystal outlines
Twins: Absent
Uniaxial/Biaxial: Uniaxial (+) (anomalous Isotropic)
Optic axial angle (2V): –

2- Apatite



- **Apatite hand-specimen**

Formula: $Ca_5(PO_4)_3(OH, F, Cl)$
System: Hexagonal
Color: Colourless, white, etc.
Lustre: Vitreous, Sub-Vitreous, Resinous, Waxy, Greasy
Hardness: 5
Density: 3.10–3.21

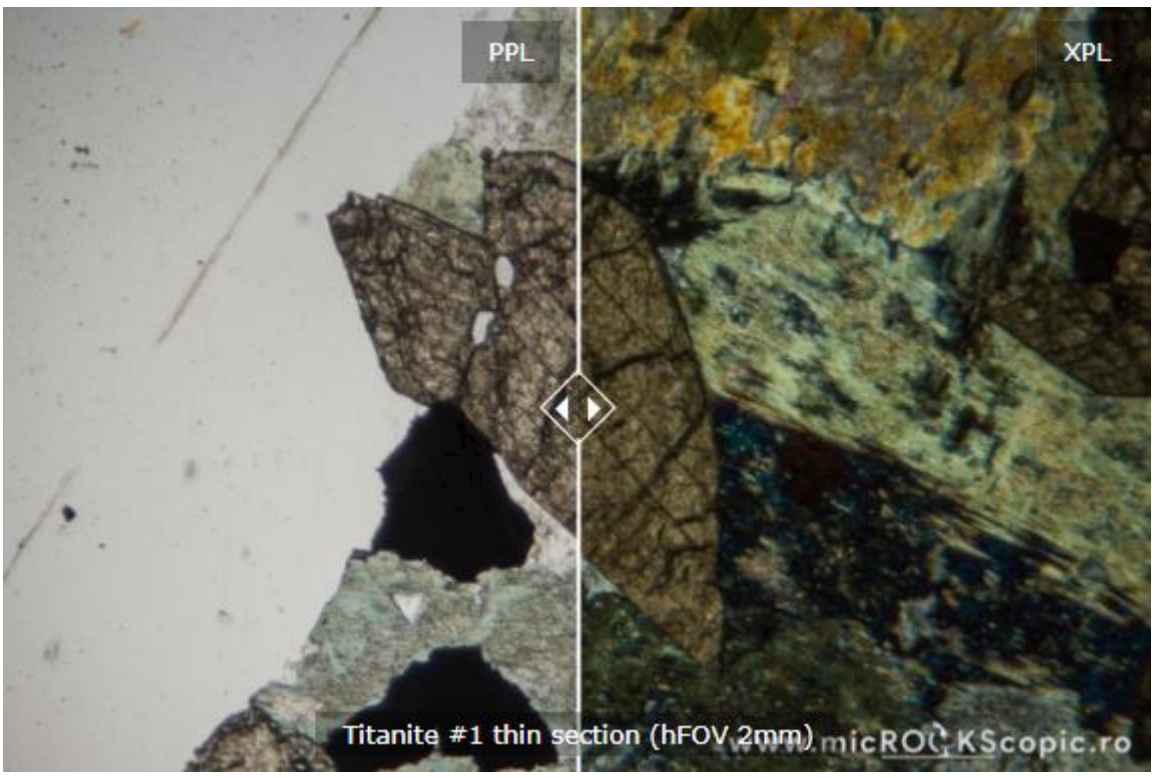
Apatite PPL properties

Relief: Moderate positive
Habit/Form: Apatite forms small euhedral to subhedral elongate prismatic crystals with hexagonal cross sections. Is a major constituent of some fossil bone.
Color: Colorless; detrital crystals may be pale green or exhibit pleochroic purple centers
Pleochroism: Absent to weak – moderate
Cleavage: Imperfect basal {0001} shown as cross fractures. Larger crystals may show imperfect cleavage parallel to the length {1010}.

Apatite XPL properties
Isotropy/Anisotropy: Anisotropic

Interference color: Order I (black, gray to white). Cross sections are dark between crossed polars.
Extinction angle: Parallel / 0° / straight
Twins: Apatite twins are rare.
Uniaxial/Biaxial: Uniaxial (-)

3- Sphene (*Titanite*)



Titanite (Sphene) hand-specimen
Formula: $CaTiSiO_5$
System: Monoclinic
Color: Colourless, brown
Lustre: Adamantine, Resinous
Hardness: 5–5½
Density: 3.48–3.6

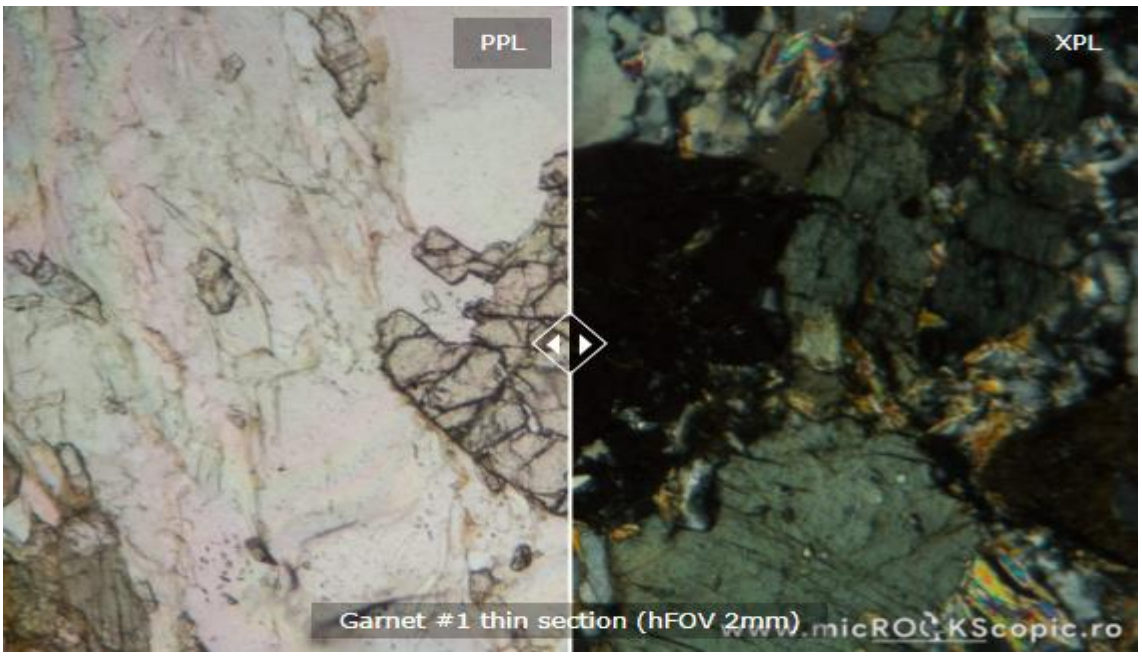
Titanite (Sphene) PPL properties

Relief: Very High positive
Habit/Form: Euhedral to subhedral, radioactive varieties may form pleochroic halos in enclosing biotite, chlorite, or hornblende.
Color: Almost colorless to neutral; tan-brown color or yellow-brown
Pleochroism: Absent to weak
Cleavage: Sphene often has prominent parting (parallel to 221). These parting directions are not parallel to the crystal outlines.

Titanite (Sphene) XPL properties

Isotropy/Anisotropy: Anisotropic
Interference color: High-order cream, pearl-gray; or anomalous blue/brown
Extinction angle: Rhombic/diamond sections have symmetrical extinction. Maximum extinction to cleavage traces is 36° to 45°.
Twins: Simple twinning on {100} is common, dividing diamond sections near the long diagonal. Multiple twinning is rare on {221}.
Uniaxial/Biaxial: Biaxial (+)
Optic axial angle (2V): 2V measured: 17 – 40°, calculated: 68 – 82°

4- Garnet



Garnet PPL properties

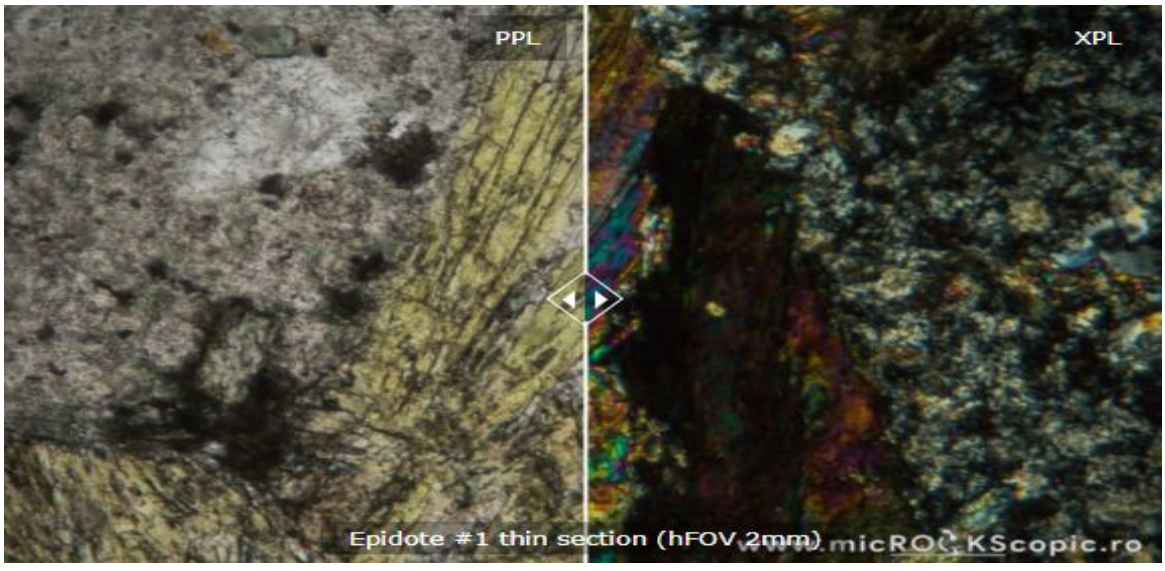
Relief: High positive
Habit/Form: Garnets commonly occur as euhedral to subhedral,
Color: Garnet group: nearly colorless to a pale-brown/pink/green.
Almandine: nearly colorless, pink, light reddish-brown.
Pyrope: colorless, pink.
Spessartine: pale orange, pale pink, pale brown.
Andradite: light green, light brown.
Grossular: colorless, very pale green.
Crystals are often zoned.
Pleochroism: –
Cleavage: Absent; irregular fractures are characteristic.

Garnet XPL properties

Isotropy/Anisotropy: Isotropic, some varieties may show weak birefringence. Spessartine may be distinctly anisotropic; grossular not uncommonly is birefringent in low-order grays and is commonly twinned in 'pie-cut' sectors.
Interference color: The garnets are isometric, and pyrope and almandine are truly isotropic. Spessartine, grossular and andradite may show weak anisotropism.
Extinction angle: –
Twins: Absent
Uniaxial/Biaxial: Isotropic (anomalous Biaxial)

5- Epidote

Clinozoisite-Epidote hand-specimen
Formula: $[Ca_2][Al_3]O(Si_2O_7)(SiO_4)(OH) – [Ca_2][Al_2Fe^{3+}]O(Si_2O_7)(SiO_4)(OH)$
System: Monoclinic
Color: Yellowish-green, green, brownish-green, black
Lustre: Vitreous, Pearly
Hardness: 6
Density: 3.38–3.49



Clinozoisite-Epidote PPL properties

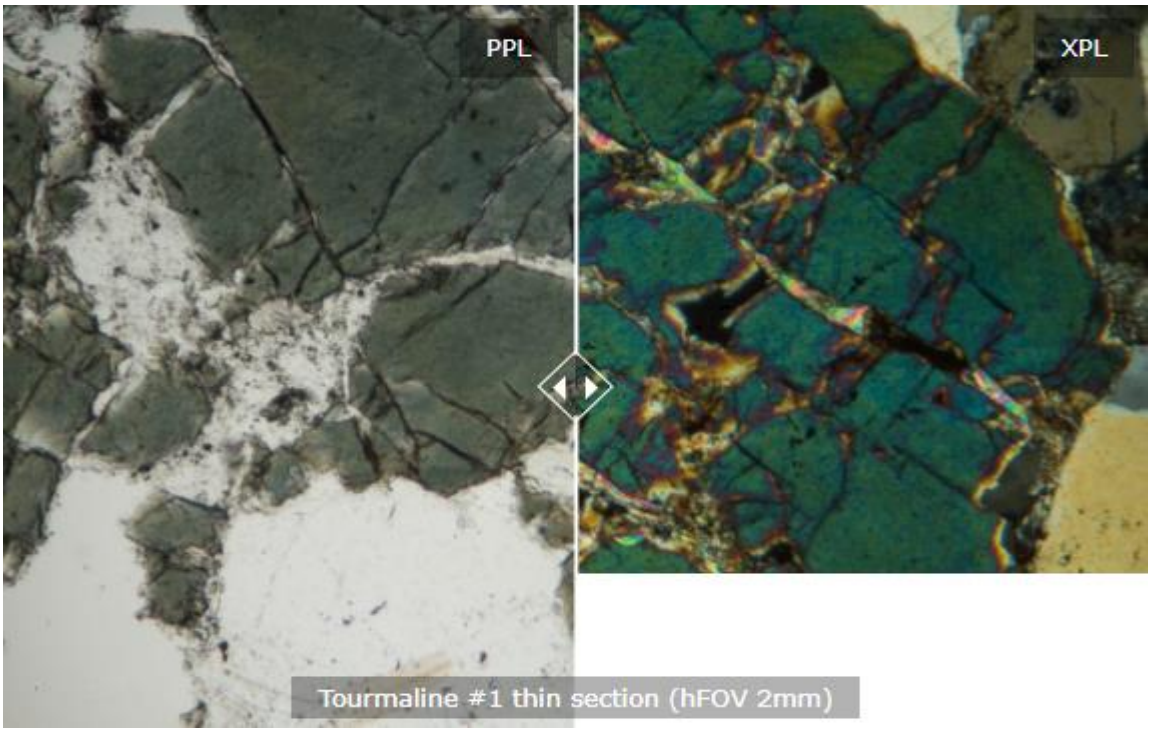
Relief: High positive
Habit/Form: Often found as anhedral grains or granular aggregates. Crystals are columnar, prismatic, bladed, or acicular with the long dimension parallel to the *b* axis.
Color: Clinozoisite is colorless; epidote is colorless, pale yellow, pale green, greenish yellow, yellowish green
Pleochroism: Colourless to yellow and green.
Cleavage: Perfect basal cleavage

Clinozoisite-Epidote XPL properties

Isotropy/Anisotropy: Anisotropic
Interference color: Clinozoisite – order I gray, white and yellow; often anomalous blue or yellow-brown.
Epidote – order II – III (very bright or 'fluorescent'); increasing with increase in iron content. The maximum interference colors range from low second-order to upper third-order colors.
Extinction angle: Parallel / 0° / straight to length of elongate crystals.
Twins: Multiple normal twinning.
Uniaxial/Biaxial: Biaxial, Clinozoisite (+) and Epidote (-)

6- Tourmaline

Tourmaline hand-specimen
Formula: $(Na,Ca)(Mg,Li,Al,Fe^{2+})_3Al_6\ (BO_3)_3Si_6O_{18}(OH)_4$
System: Trigonal
Color: Pale brown to dark-brown to brownish-black, also dark-yellow, blue
Lustre: Vitreous, Resinous
Hardness: 7
Density: 2.9–3.1



Tourmaline PPL properties

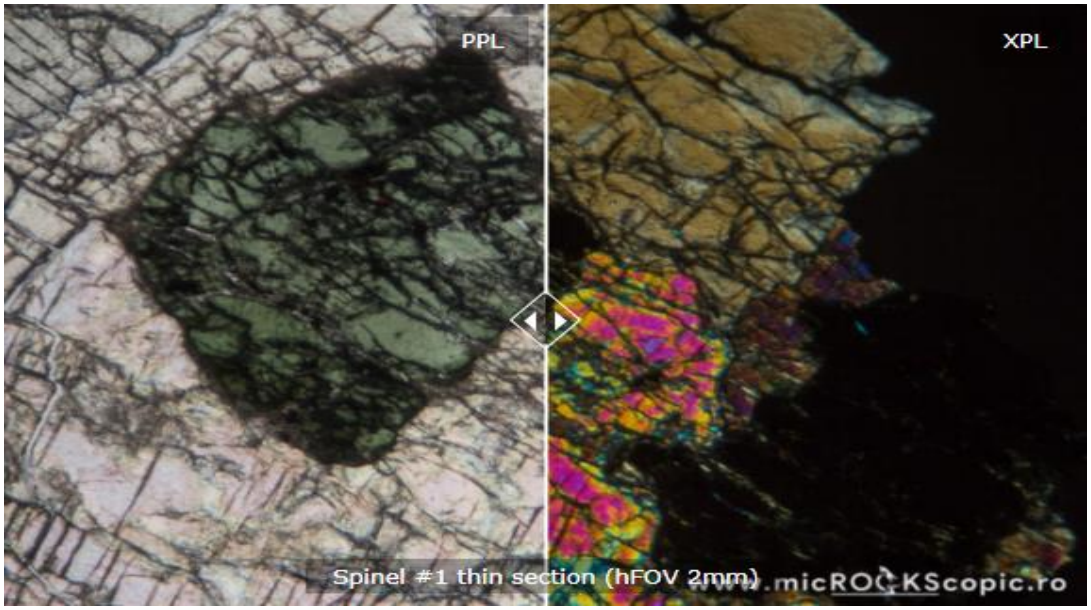
Relief: Moderate positive
Habit/Form: Tourmaline commonly forms euhedral, stubby columnar to acicular crystals that show a rounded triangular or crudely hexagonal cross section. Longitudinal sections are usually roughly rectangular. Acicular crystals may form radiating masses. Also found as anhedral grains or irregular masses.
Color: Schorl: pale yellow, pale brown, yellow-brown.
Dravite: colorless, yellowish, greenish, brownish, pale yellow.
Elbaite*:* colorless, yellow, olive green, purple, colorless, pink, pale green, pale blue, deep blue. Tourmaline is often color-zoned.
Pleochroism: Intense
Cleavage: Absent but irregular fractures are common.

Tourmaline XPL properties

Isotropy/Anisotropy: Anisotropic
Interference color: Order II yellow/green to low order III
Extinction angle: Parallel / 0° / straight in longitudial sections. Cross sections remain dark on rotation.
Twins: Absent
Uniaxial/Biaxial: Uniaxial (-)

7- Spenel

Spinel hand-specimen
Formula: $MgAl_2O_4$
System: Cubic (Isometric)
Color: Black, blue, red, violet
Lustre: Vitreous
ardness: 7.5–8
Density: 3.6–4.1



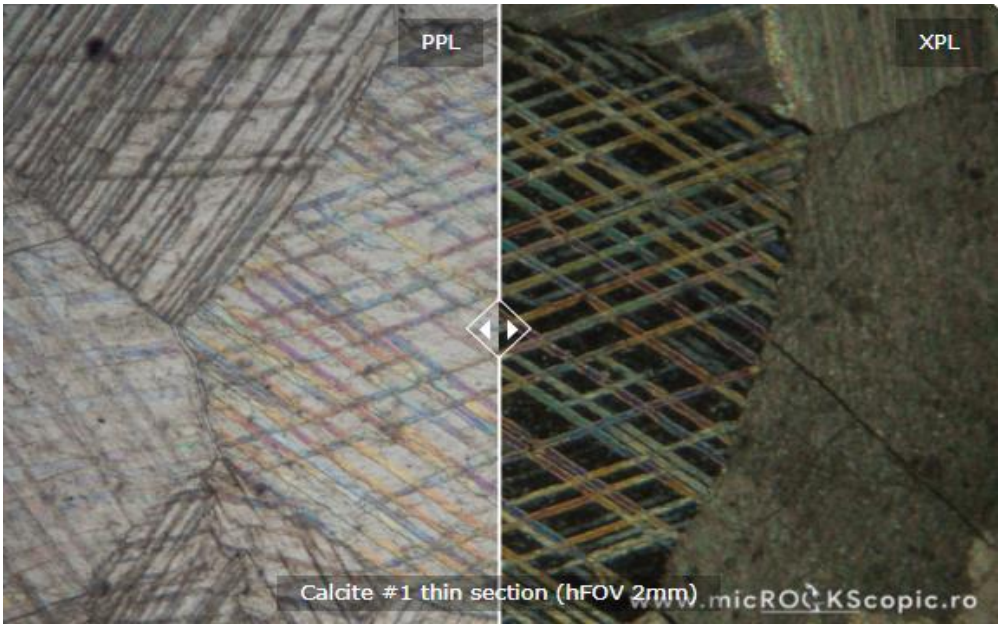
Spinel PPL properties

Relief: High positive
Habit/Form: Crystals are usually octahedrons yielding triangular, square, or diamond-shaped cross sections in thin section. Subequant anhedral grains also are common.
Color: Colorless, pale gray, pale gray-green, pale green, pale blue, pale pink
Pleochroism: Anomalous pleochroism is sometimes observed.
Cleavage: Absent
Spinel XPL properties
Isotropy/Anisotropy: Isotropic
Interference color: It is one of the few isometric minerals that is invariably isotropic.
Extinction angle: –
Twins: Twinning according to the spinel law with {111} as twin-plane is rather common, but it does not usually show in the slide.
Uniaxial/Biaxial: Isotropic

8- Calcite

Calcite hand-specimen

Formula: $CaCO_3$
System: Trigonal
Color: White, Yellow, Red, etc.
Lustre: Vitreous, Sub-Vitreous, Resinous, Waxy, Pearly
Hardness: 3
Density: 2.71



Calcite PPL properties

Relief: Low to high; twinkling; variable relief.
Habit/Form: Crystals of calcite have many habits but usually consist of combination of scalenohedrons and rhombohedrons. However, in most rocks, calcite forms anhedral grains or

aggregates of grains. Fossil shells and thin veins may be fibrous or columnar.
Color: Colorless (often cloudy); can be white, grey, pink
Pleochroism: –
Cleavage: Rhombohedral cleavage

Calcite XPL properties

Isotropy/Anisotropy: Anisotropic
Interference color: High-order; the maximum interference color is pearl gray or white of the higher orders. Thin edges of the slide usually show bright colors of the fourth and fifth orders and tints of higher orders. Thin films and twin lamellae of calcite usually show bright interference colors.
Extinction angle: Symmetrical or inclined to the rhombohedral cleavages. When a section is in one of the extinction position, fine birefringent calcite dust formed by griding is prominent.
Twins: Polysynthetic twinning. The twin lamellae are usually so thin that they show first-order interference colors.
Uniaxial/Biaxial: Uniaxial (-)
Optic axial angle: –