
U3A Geology
Minerals in hand specimen
and under the microscope

Classes: Alternate Thursdays 9.30am – 11am

Location Nunawading Hub

Presenter

Peter Jackson

End of year excursion: Mt Gambier district

House keeping

1. Punctuality
2. Attendance sheets
3. Badges and emergency contact details
4. Contacting class members
5. Mobile phones
6. Parking
7. Emergency evacuation
8. Temperature settings
9. Class cancellation
10. Drinks in studio
11. Noise leaving studio

Term 1 presentations

Week	1	Minerals in hand specimen and under the microscope
	3	Mineral identification (practical)
	5	Rocks in hand specimen and under the microscope
	7	Igneous rocks
	9	Tsunamis

Term 2 presentations

Week	2	Contributions to geology 1
	4	Contributions to geology 2
	6	Contributions to geology 3
	8	Contributions to geology 4
	10	Contributions to geology 5

Introduction

- Minerals can often be identified in rocks in hand specimen providing that the rocks are not too fine-grained
- individual crystals or clusters of crystals are normally able to be identified from their physical properties
- the use of multi-key tables enables the identification from physical properties
- minerals that occur in rocks may be fine-grained but can be identified from their optical properties obtained using a petrographic microscope
- optical properties can be used in a similar way to physical properties

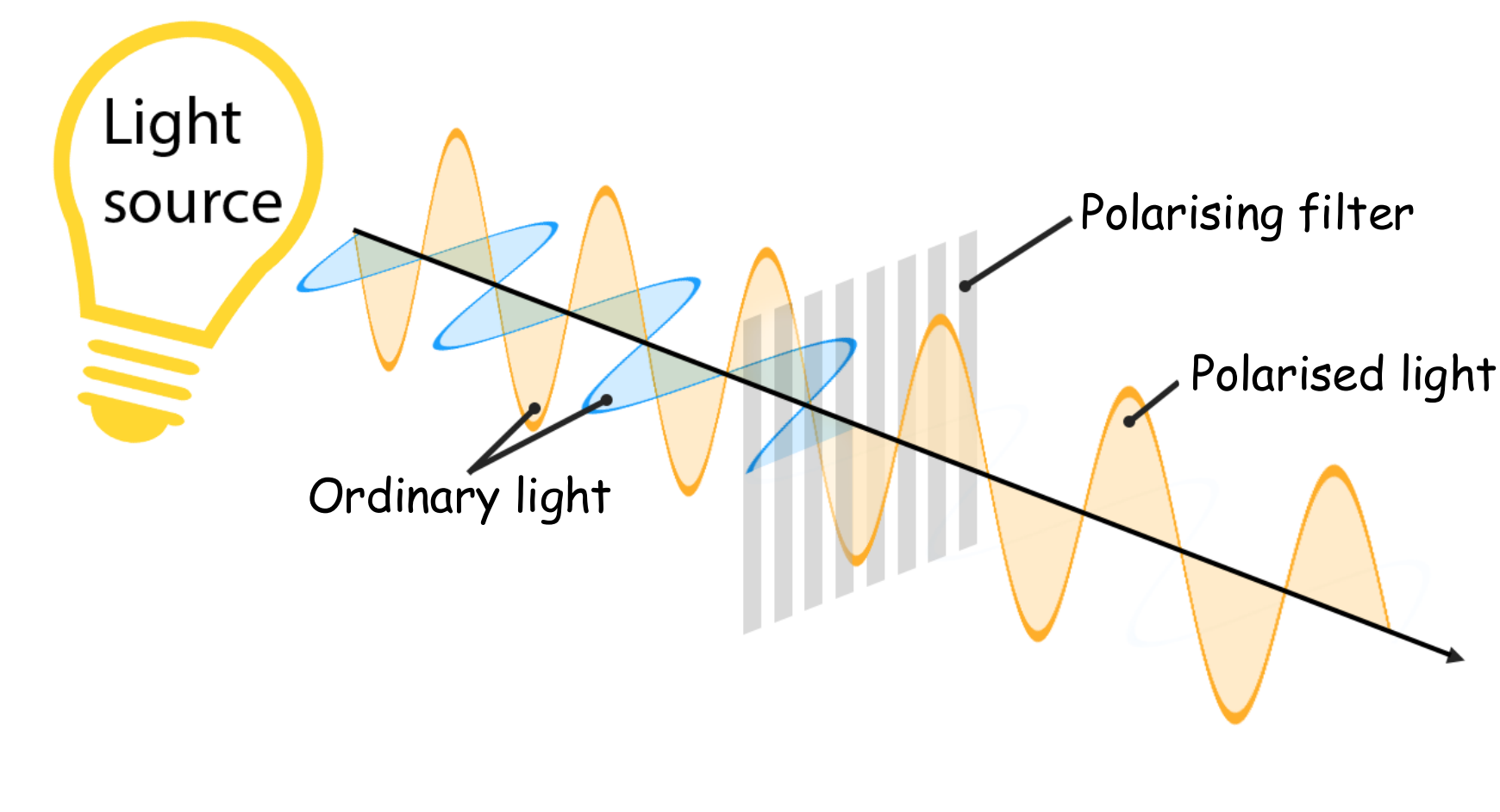
Nikon petrographic microscope

List of physical and optical properties commonly used in mineral identification

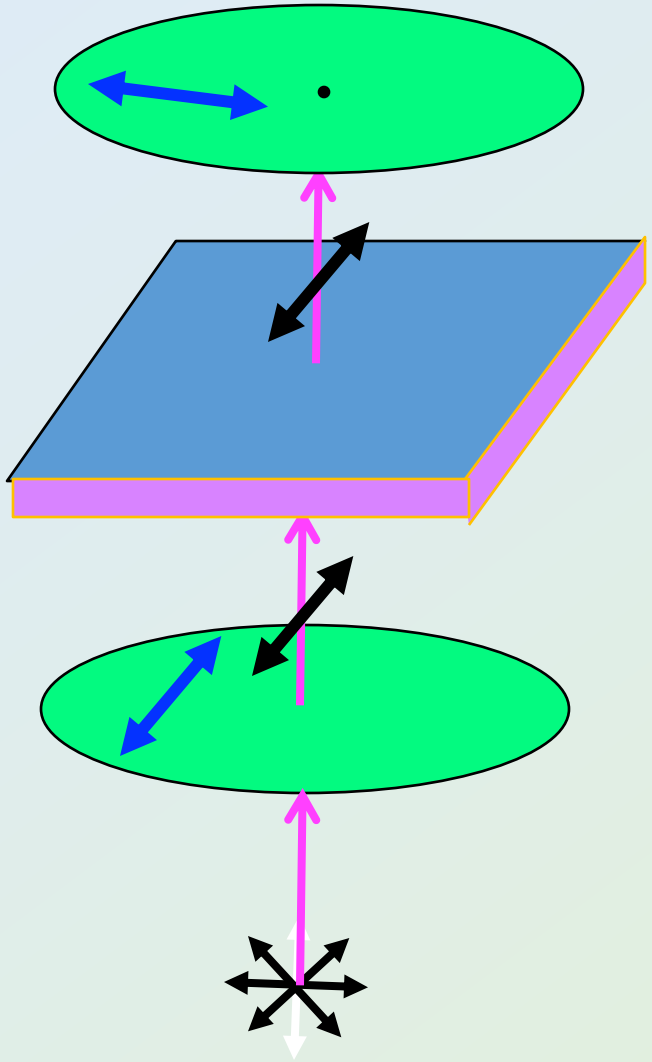
Physical	Optical
lustre	relief
hardness	colour
streak	pleochroism
cleavage	birefringence
colour	crystal system
specific gravity	optic sign
habit	cleavage
	dispersion
	extinction angle
	length fast/slow

Polarised light

- Ordinary light is composed of waves vibrating in all possible planes
- ordinary light entering polarising medium → only allows light vibrations in one direction → privileged vibration direction



A plane polarised ray transmitted by an isotropic medium will have the same direction of polarisation when it leaves the plate as it had when it entered → extinct when analyser in optical pathway



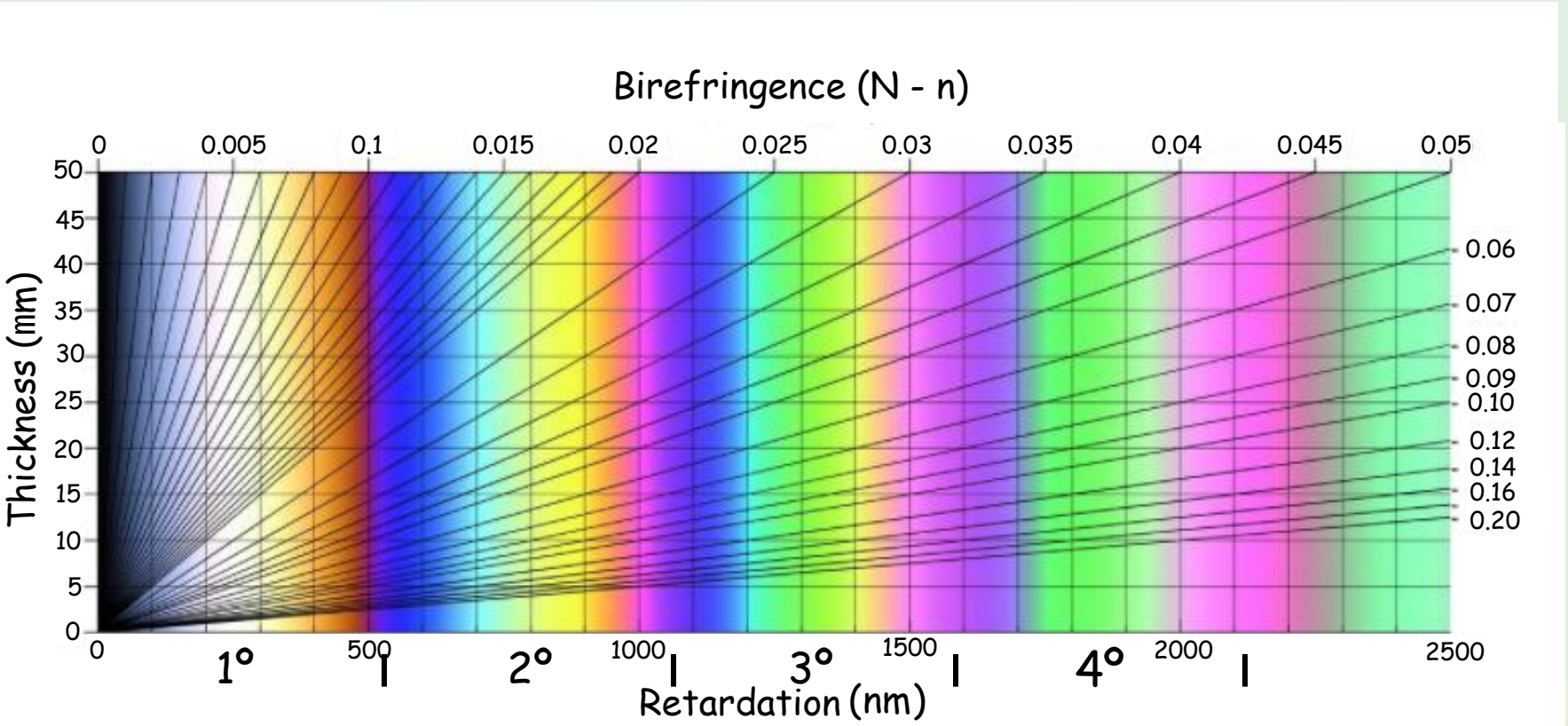
analyser

isotropic medium

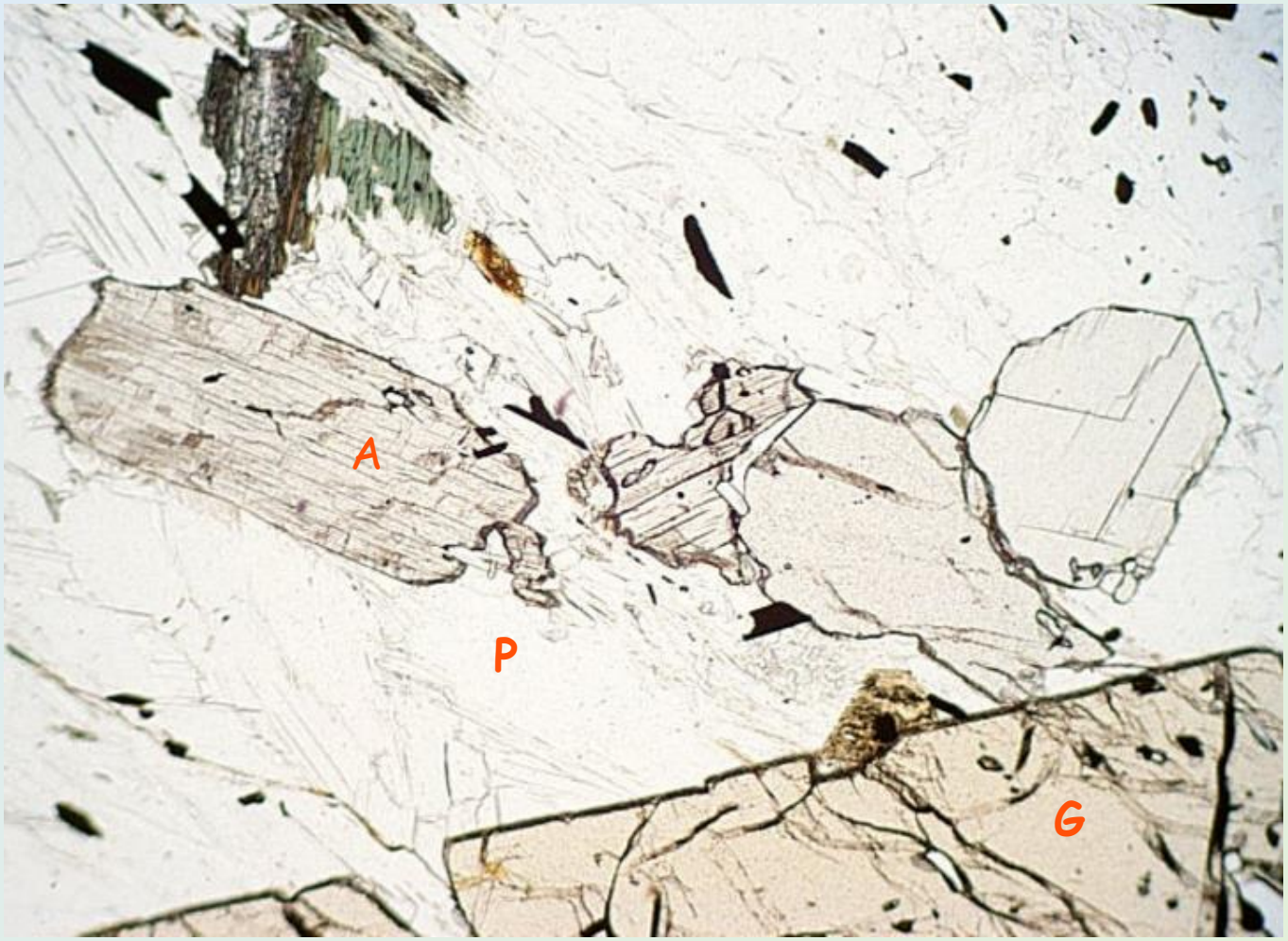
polariser

unpolarised light

Interference colour chart

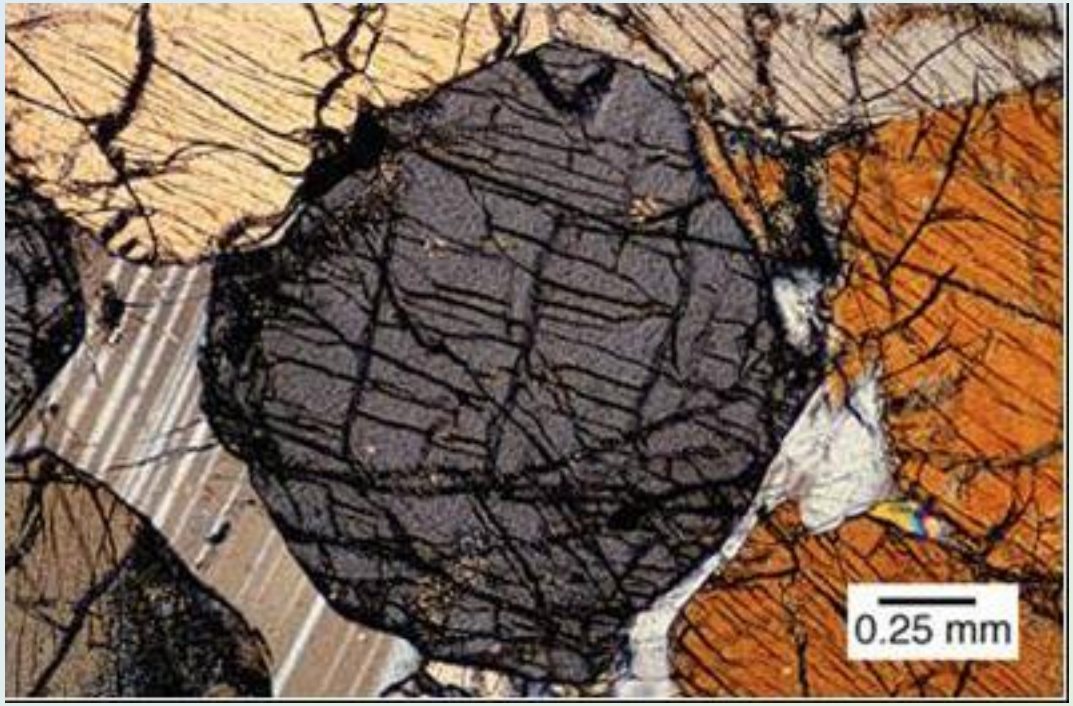


Relief

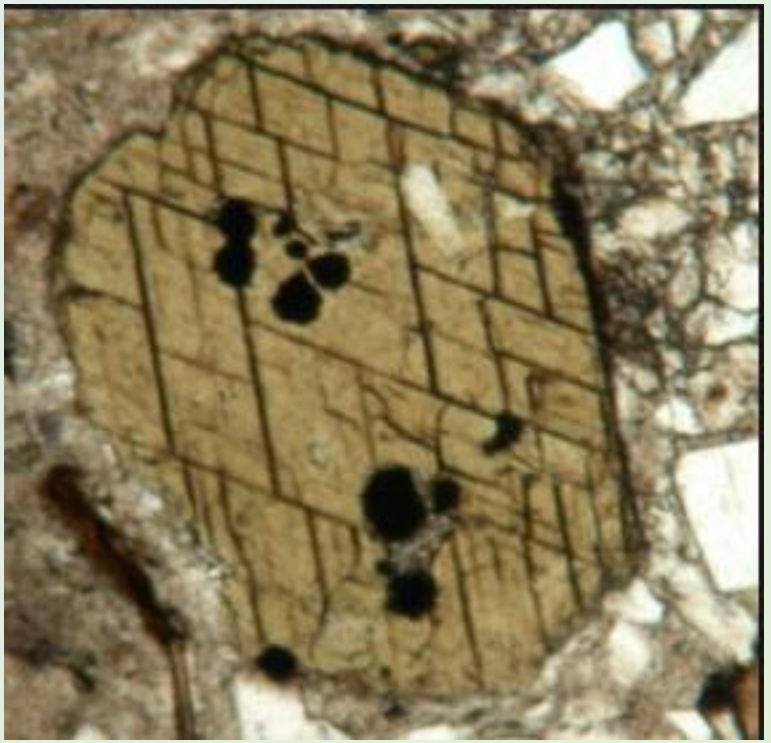


A = amphibole G = garnet P = plagioclase

Mineral cleavage in thin section

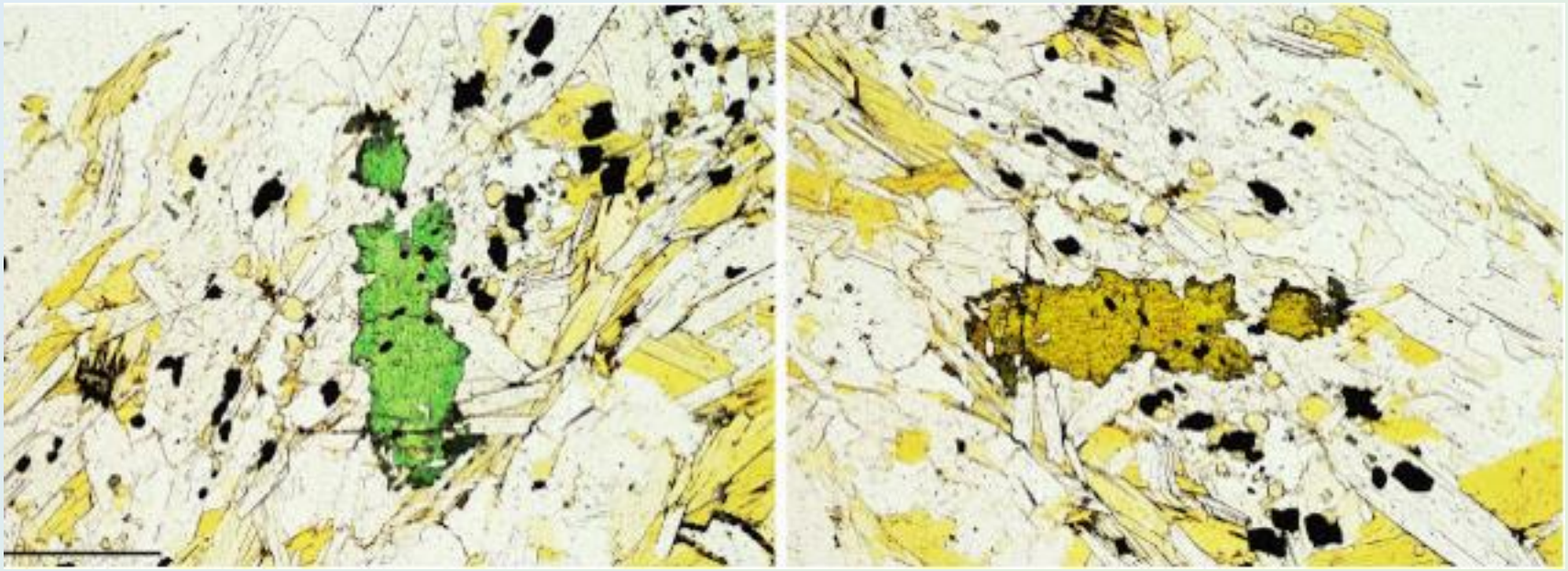


Photomicrograph of clinopyroxene (crossed polars)



Photomicrograph of hornblende (plane polarised light)

Pleochroism



Pleochroism in viridine (plane polarised light)

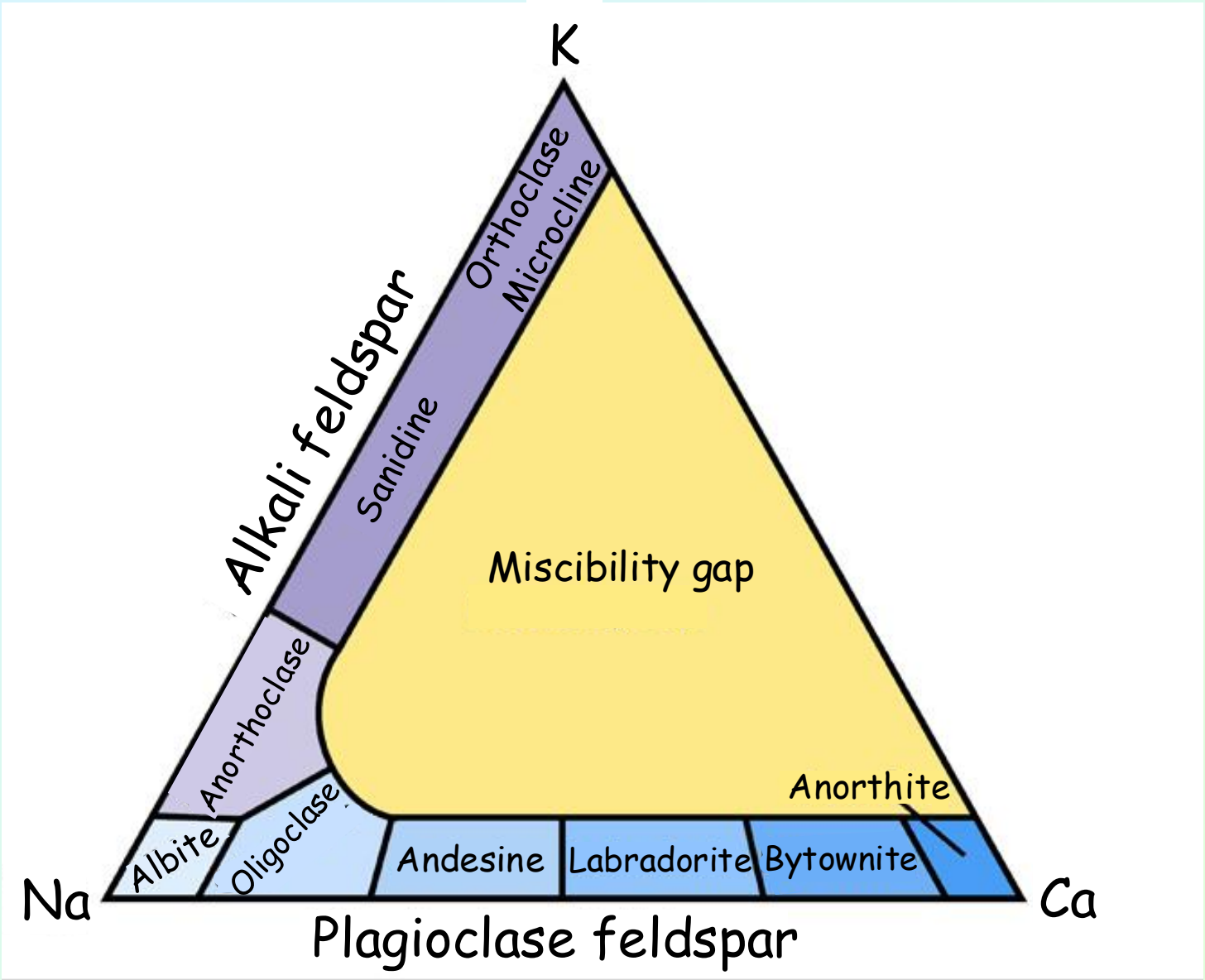
Common minerals in the Earth's crust

- There are more than 3000 mineral species present in the Earth's crust and mantle
- the majority are uncommon or rare
- major rock forming minerals number probably less than 50 and include feldspars, quartz, amphiboles, micas, pyroxenes, olivine, calcite, Fe-oxides and aluminosilicates
- some minerals (e.g. ore minerals) may be locally concentrated but not particularly common on a global scale
- systematic mineral identification of hand specimens enables identification of a large number of minerals

Plagioclase feldspar ($NaAlSi_3O_8$ – $CaAl_2Si_2O_8$)

- Plagioclase feldspar is a solid solution series between pure albite $NaAlSi_3O_8$ and anorthite $CaAl_2Si_2O_8$
- the series has six arbitrary species based on albite/anorthosite ratios
- plagioclase feldspar is the most common mineral in the Earth's crust
- occurs in igneous rocks e.g. basalt, diorite; regional metamorphic rocks e.g. amphibolite and some contact metamorphic rocks
- characterised by its cleavage (90°), hardness (6) and multiple twinning
- in thin section → commonly occurs as elongate crystals, low relief, low birefringence

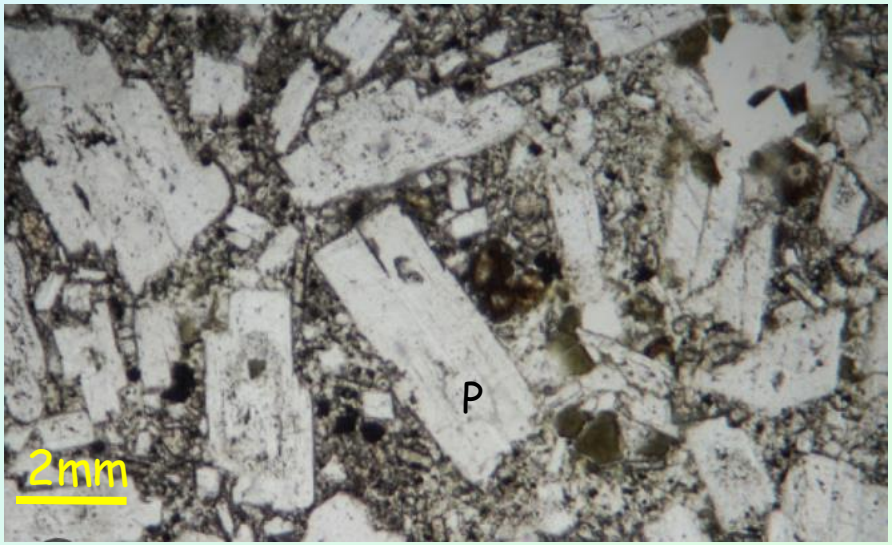
Feldspar ternary diagram (Strekeisen)



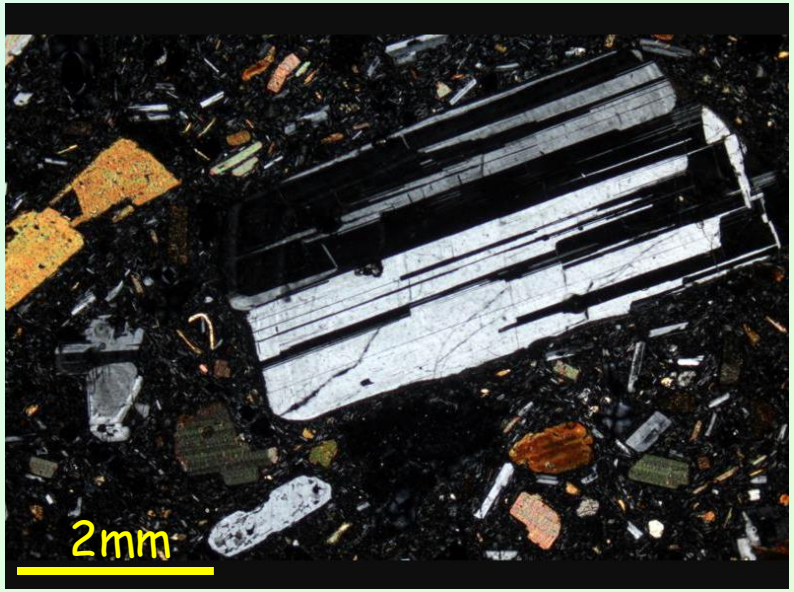
Plagioclase feldspar

Diorite hand specimen

Plagioclase hand specimen



Plagioclase phenocrysts in andesite PPL



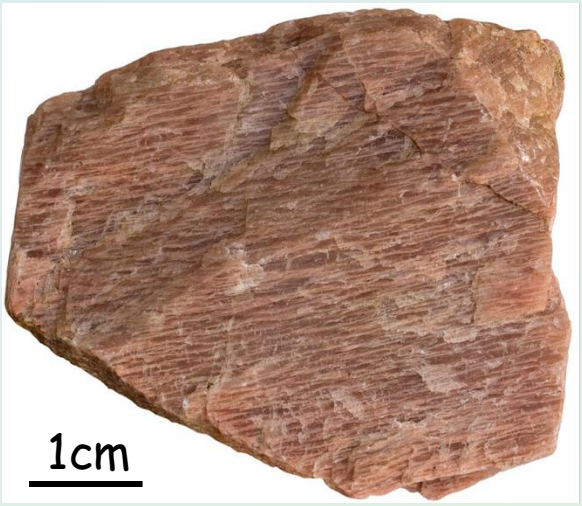
Plagioclase phenocryst in andesite XPL

K-feldspar ($KAlSi_3O_8$)

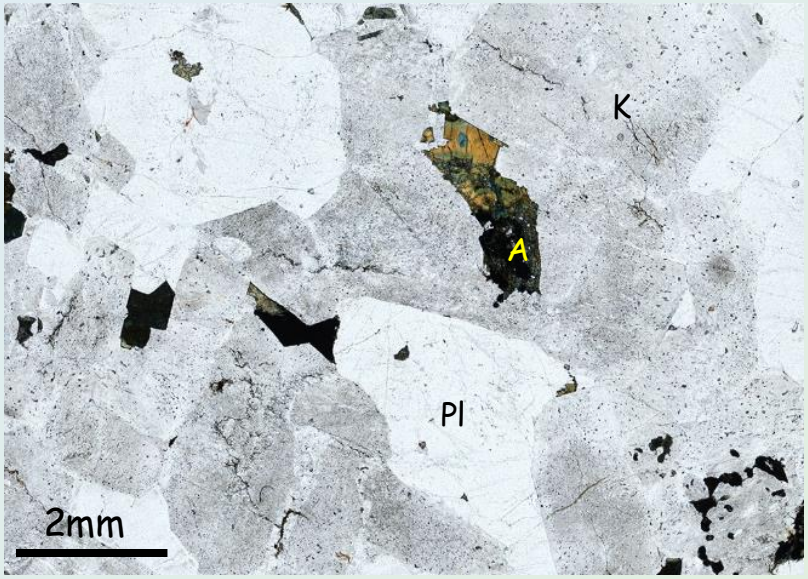
- K-feldspar → very common mineral occurring in both igneous and regional metamorphic rocks
- term commonly used to include orthoclase, microcline and sanadine
- orthoclase major constituent of granite, granodiorite and syenite → cooled at moderate depth, moderate-slow cooling rate
- microcline forms with slow cooling at considerable depth in granite, granodiorite, syenite and gneiss
- alkali feldspar ($NaAlSi_3O_8$ to $KAlSi_3O_8$) shows complete solid solution only at high temperature, at lower temperature, exsolution lamellae occur in orthoclase host → perthitic texture

K-feldspar ($KAlSi_3O_8$)

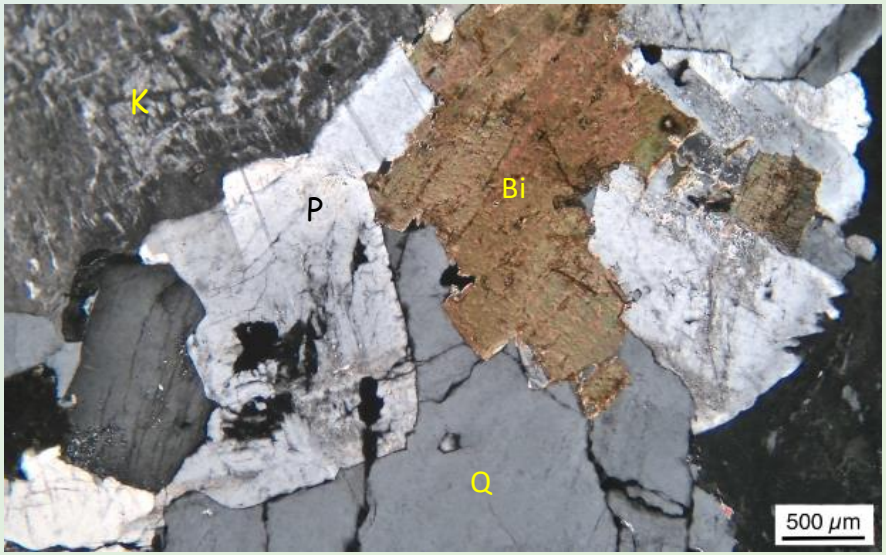
K-feldspar in granite



Orthoclase with perthitic texture



K-feldspar, quartz, aegerine PPL



K-feldspar, plagioclase, biotite XPL

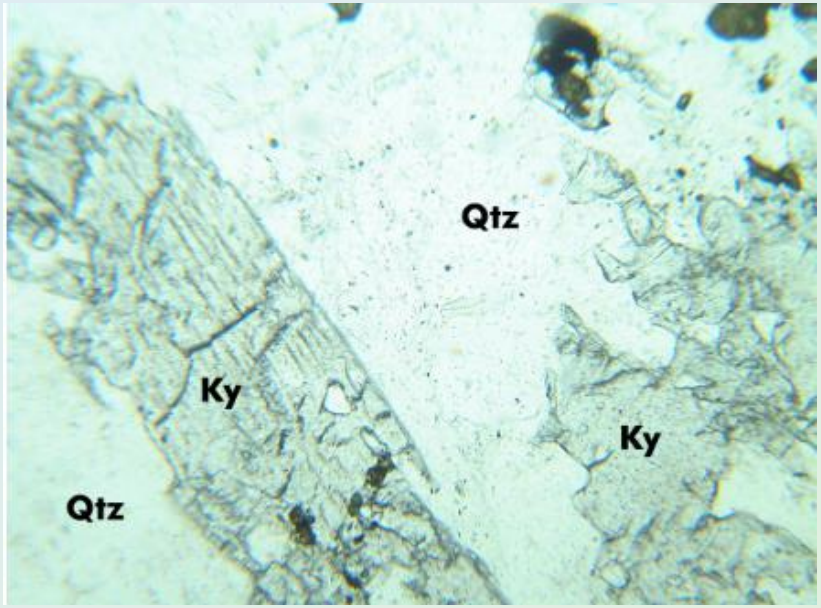
Quartz (SiO_2)

- Quartz is the next most abundant mineral in the Earth's crust after the feldspars
- occurs in most igneous, metamorphic and sedimentary rock types
- also occurs in pegmatites and hydrothermal veins associated with gold and other economic minerals
- highly resistant to both mechanical and chemical weathering → dominant mineral of beach, river, desert sands
- characterised by glassy lustre, conchoidal fracture, hardness = 7
- in thin section → low relief, low birefringence, lack of cleavage

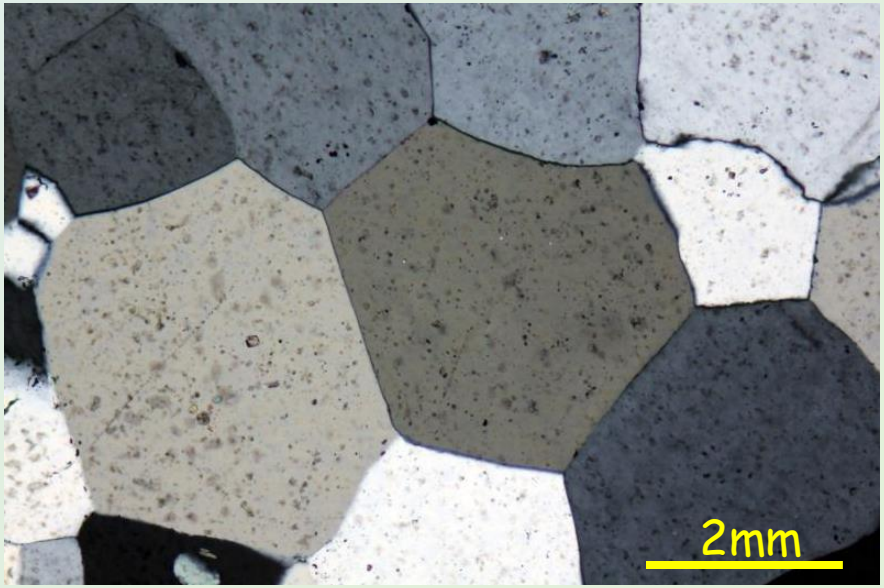
Quartz

Quartzite

Quartz crystals



Quartz biotite and kyanite PPL

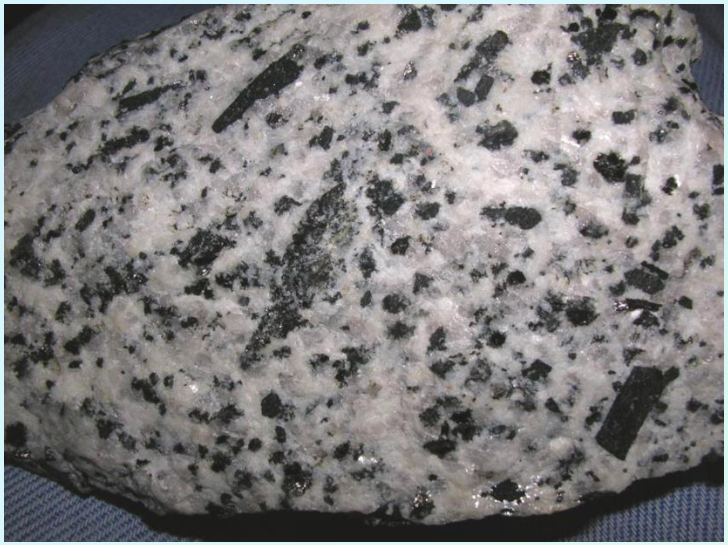


Quartz in metaquartzite XPL

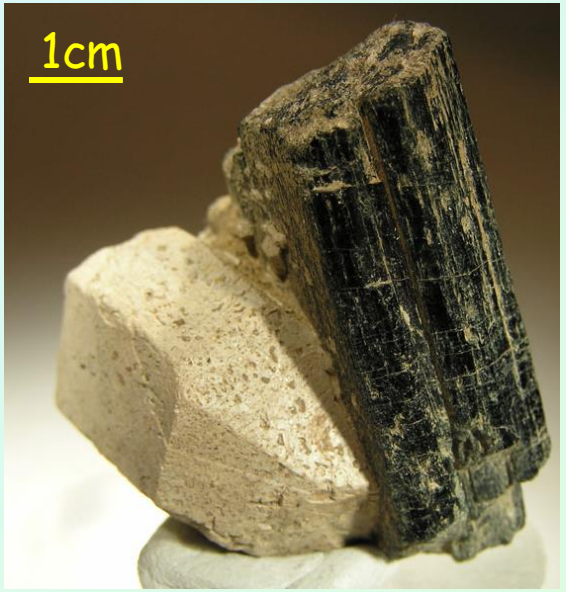
Hornblende [$Ca_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH)_2$]

- Hornblende is a member of the amphibole group of minerals green, brown to black in colour
- an important and widely distributed rock-forming mineral occurring in both igneous and metamorphic rocks
- characteristic of medium-grained, regional metamorphic rocks known as amphibolites in association with plagioclase ± garnet
- common constituent of granite, syenite, diorite, gabbro, basalt, andesite, gneiss, schist
- in thin section, hornblende can be identified by its pleochroism, crystal shape and 60/120° cleavage

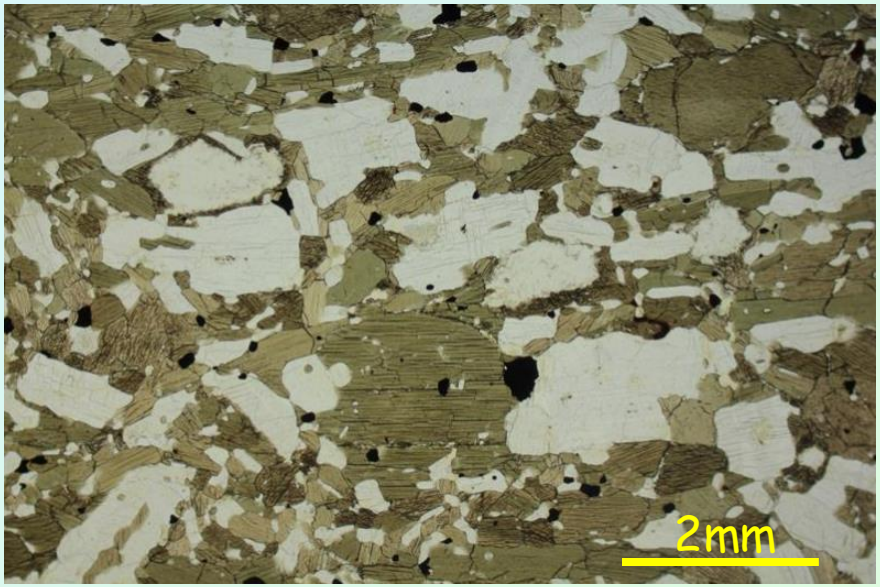
Hornblende



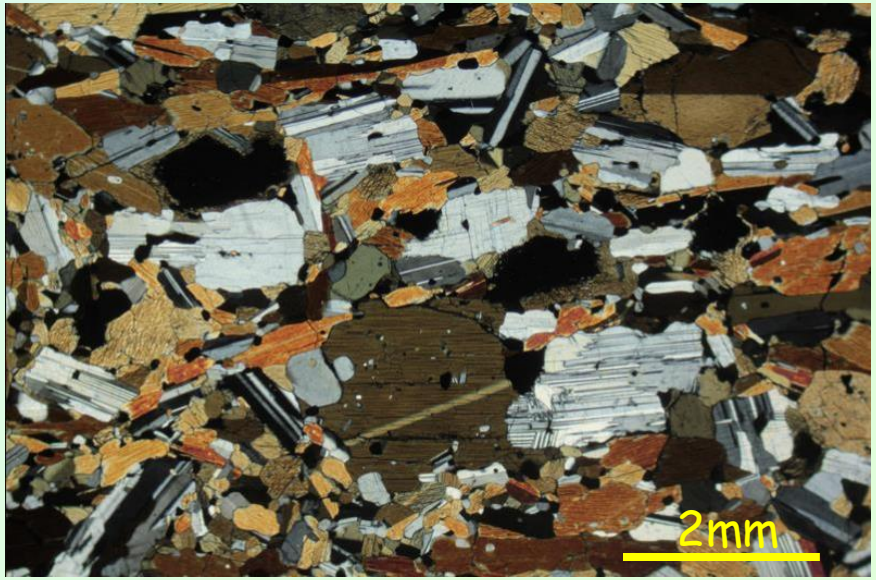
Hornblende tonalite



Hornblende crystal

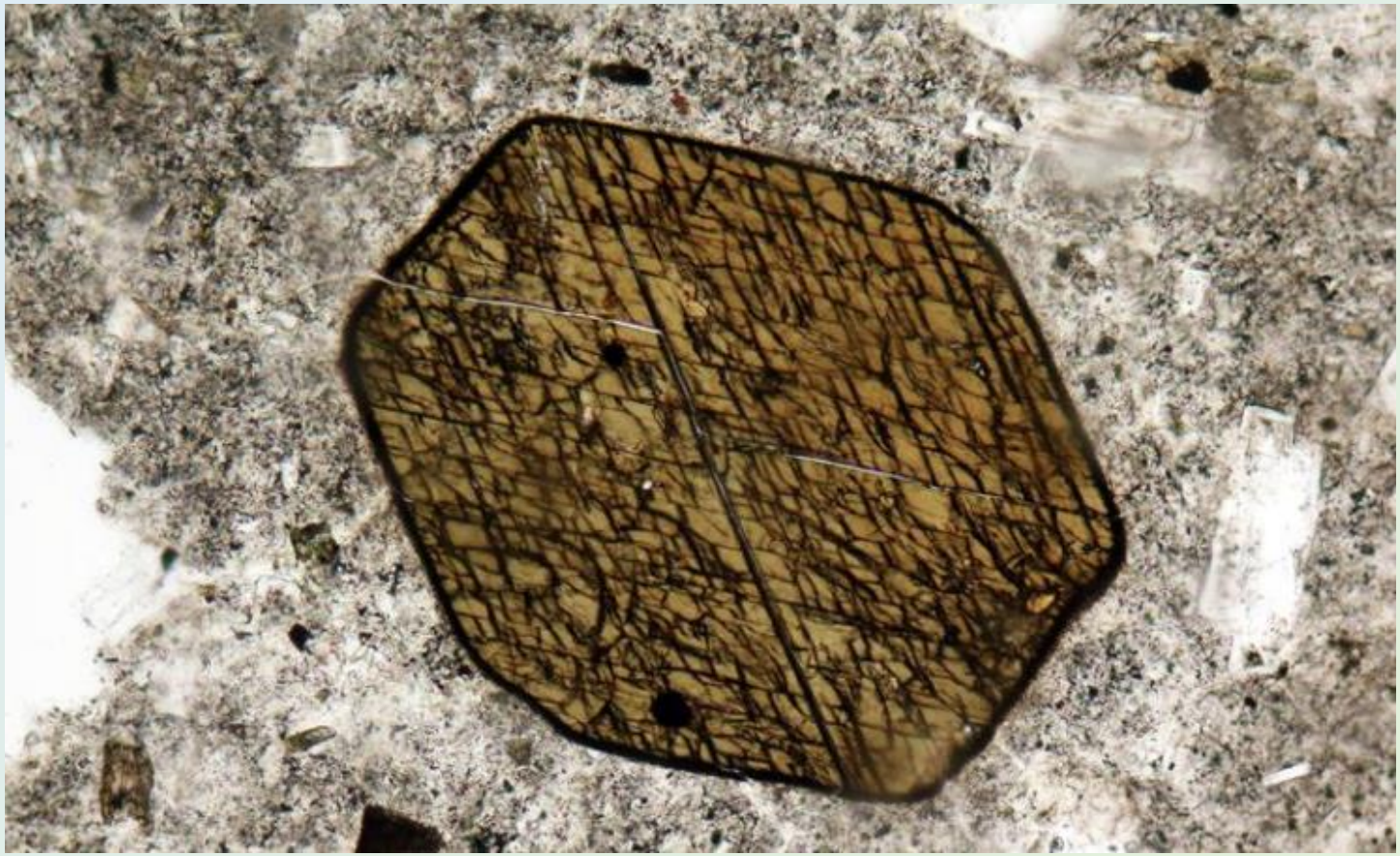


Hornblende and plagioclase PPL



Hornblende and plagioclase XPL

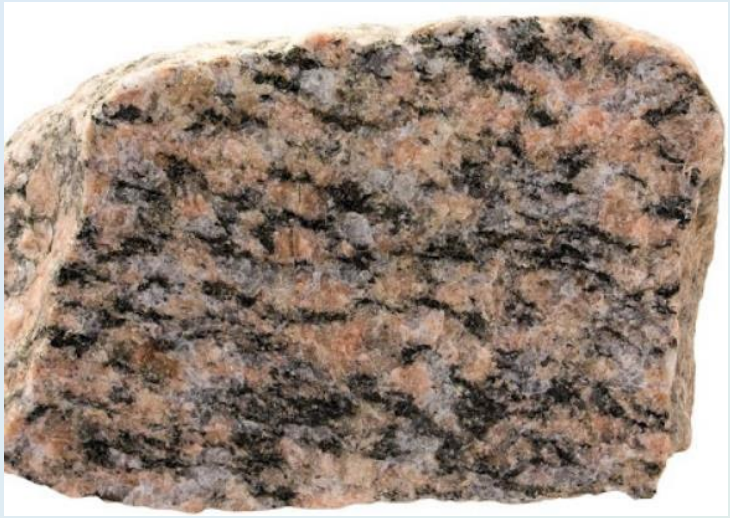
Photomicrograph, hornblende, PPL



Biotite [$K(Mg,Fe)_3(Si_3Al)O_{10}(OH,F_2)$]

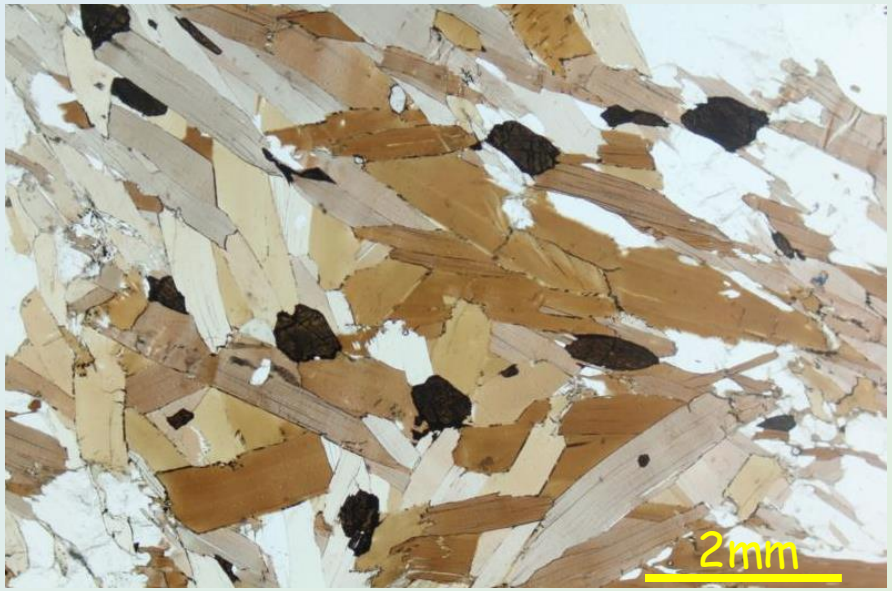
- Biotite → member of mica group of minerals that include phlogopite, muscovite, lepidolite and margarite
- found in igneous rocks varying granite pegmatites to granites; diorites, gabbros and peridotites
- in metamorphic rocks it forms over a wide range of temperatures and pressure conditions in contact and regional metamorphism
- in hand specimen → characterised by dark brown to black coloured platy crystals, basal cleavage, hardness = 2.5-4
- in thin section → strongly pleochroic, moderately high birefringence, platy cleavage

Biotite

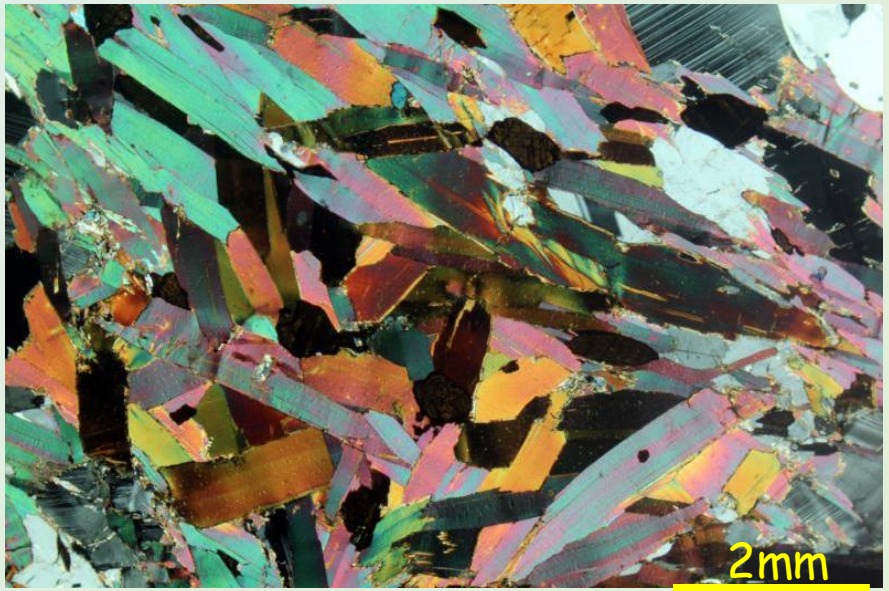


Foliated biotite granite

Biotite



Biotite, quartz, magnetite,plagioclase PPL



Biotite, quartz, plagioclase XPL

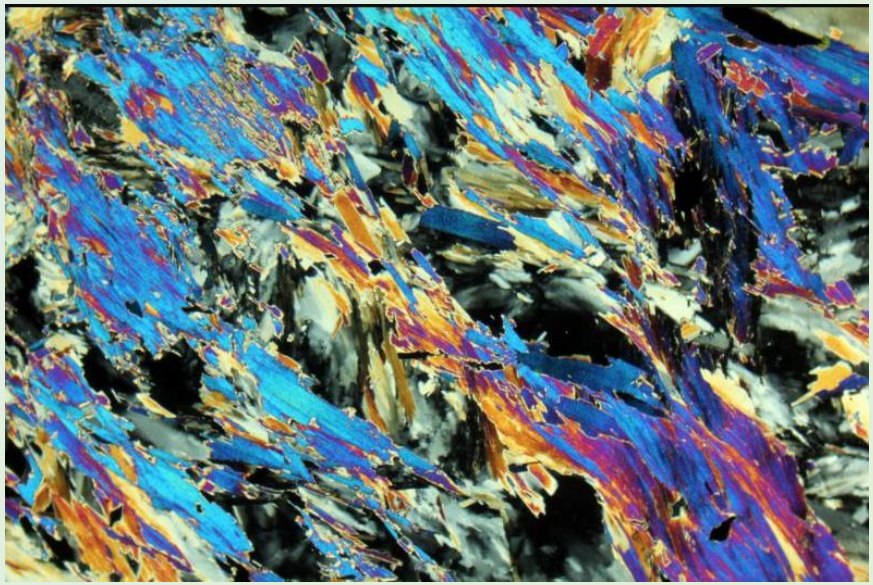
Muscovite [$KAl_2(Si_3Al)O_{10}(OH,F)_2$]

- Muscovite → widespread common rock-forming white mica mineral characteristic of some granites and granite pegmatites
- in pegmatites, muscovite in association with quartz and feldspar may occur in large foliated aggregates called books
- it is very common in regional metamorphic rocks forming the chief constituent of mica schist
- because of high dielectric and high resistivity properties → used as insulating material in manufacture of electrical apparatus
- hand specimen → colourless platy crystals, perfect basal cleavage, hardness = 2.5-3

Muscovite

Muscovite schist

Muscovite books in pegmatite



Muscovite in schist XPL

Olivine [$(Mg,Fe)_2SiO_4$]

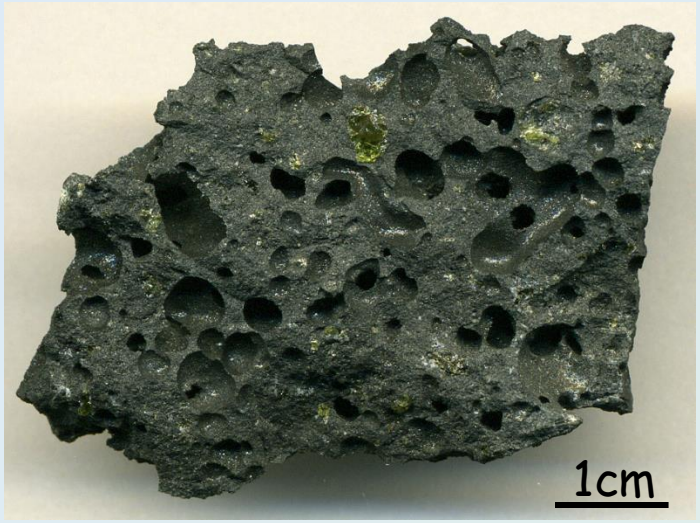
- Most common series in olivine group is a solid solution between forsterite ($MgSiO_4$) and fayalite ($FeSiO_4$)
- it is a common rock-forming mineral found principally in mafic and ultramafic rocks such as basalt, gabbro and peridotite
- in these rocks it coexists with plagioclase and pyroxene
- olivine is unstable in presence of excess SiO_2

$$MgSiO_4 + SiO_2 \rightarrow MgSi_2O_6$$

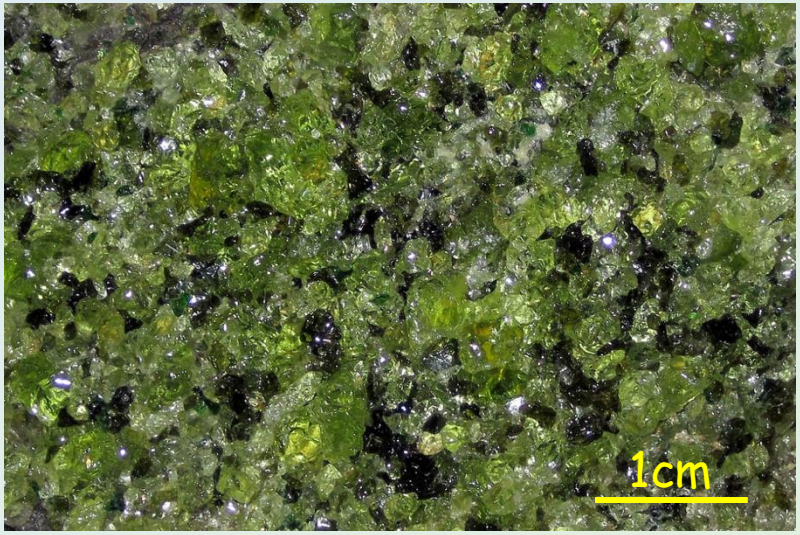
forsterite pyroxene

- diagnosed in hand specimen by glassy lustre, green colour, conchoidal fracture
- in thin section by high birefringence and high 2V

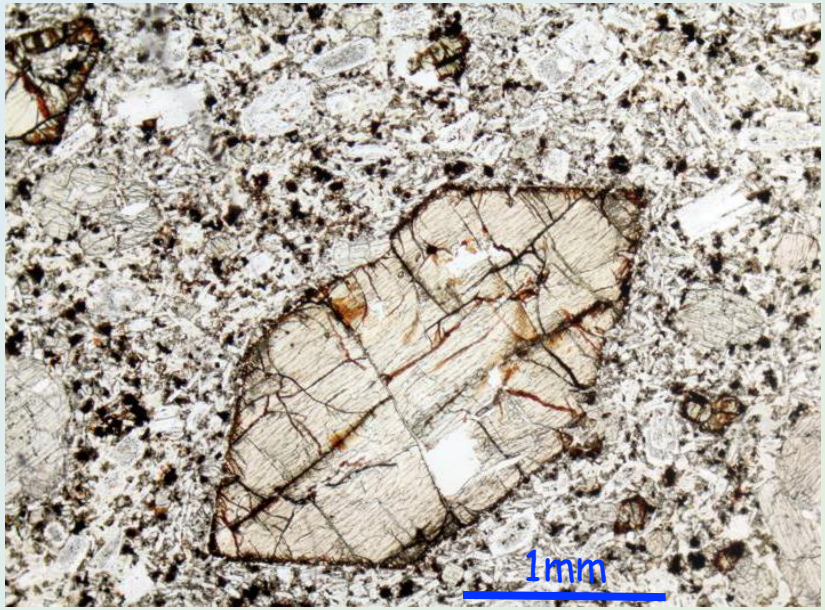
Olivine



Vesicular olivine basalt



Olivine crystals in peridotite



Olivine phenocryst in basalt PPL

Olivine phenocryst in basalt XPL

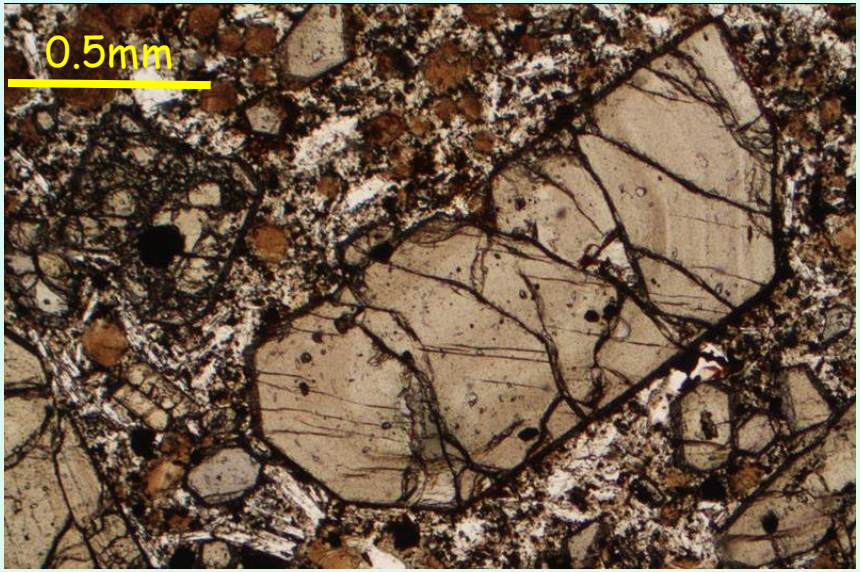
Augite [$(Ca,Mg,Fe)_2Si_2O_6$]

- Augite → a clinopyroxene (cpx) → part of pyroxene group
- most common pyroxene and an important rock-forming mineral
- found chiefly in mafic igneous rocks → basalt, andesite, gabbro, peridotite, less frequently in ultrabasic and intermediate rocks
- range widely in composition → show continuous variation
- typical pyroxene of basic alkaline rocks e.g. Ti-basalts
- chemically zoned augites common in quickly cooled rocks such as lunar basalts
- augite is characterised in hand specimen and thin section by its crystal shape and 87/93° cleavage.

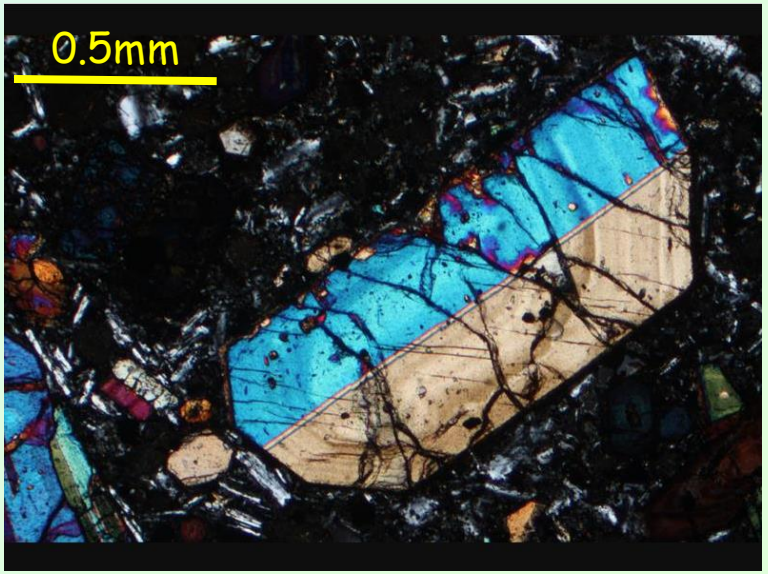
Augite

Gabbro

Augite



Growth-zoned augite PPL

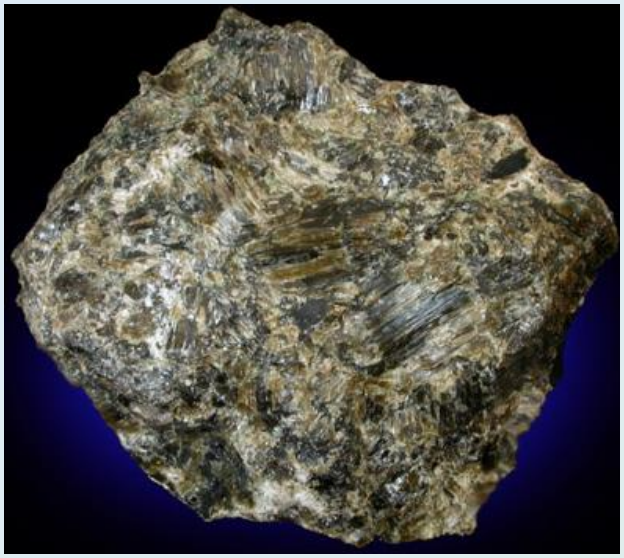


Growth-zoned twinned augite XPL

Enstatite ($MgSiO_3$)

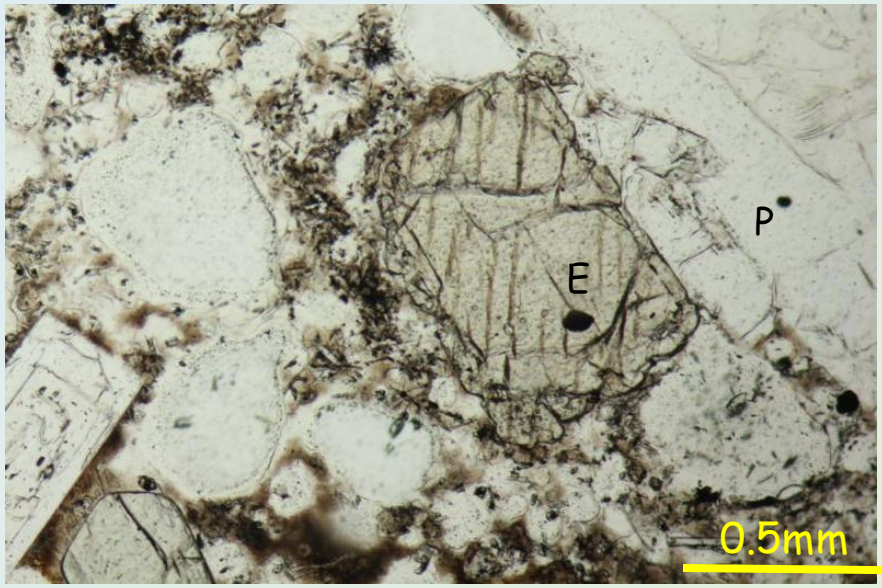
- Enstatite → Mg-rich orthopyroxene (opx) mineral a common constituent of peridotites, gabbros, norites and basalts
- commonly associated with cpx, olivine and plagioclase
- may be found in regional metamorphic rocks of high T and P
- orthopyroxenes frequently show exsolved lamellae of Ca-rich cpx
- opx commonly coexists with cpx because of large immiscibility gap between the two
- in thin section enstatite can be recognised through straight extinction, weak pink to green pleochroism, moderately low birefringence

Enstatite

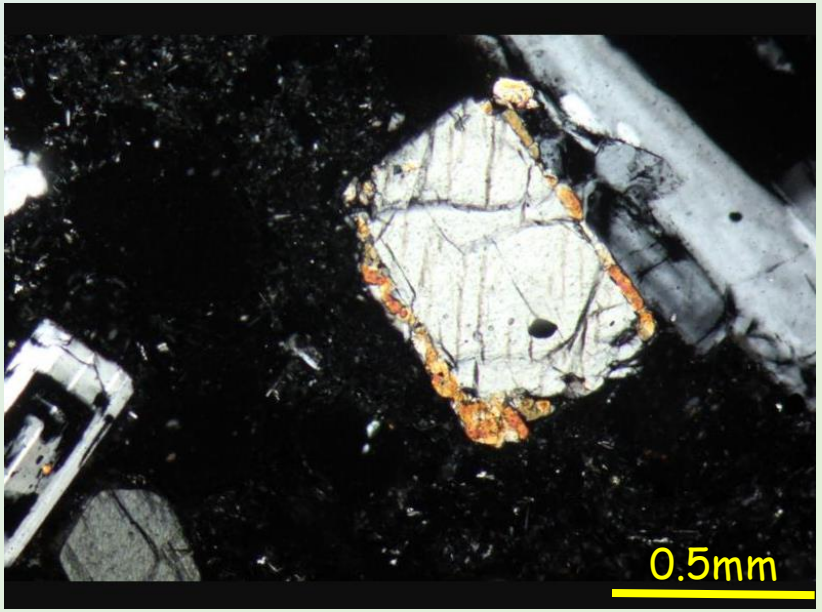


Enstatite in pyroxenite

Enstatite crystal



Enstatite, plagioclase fine groundmass PPL



Enstatite, plagioclase fine groundmass XPL

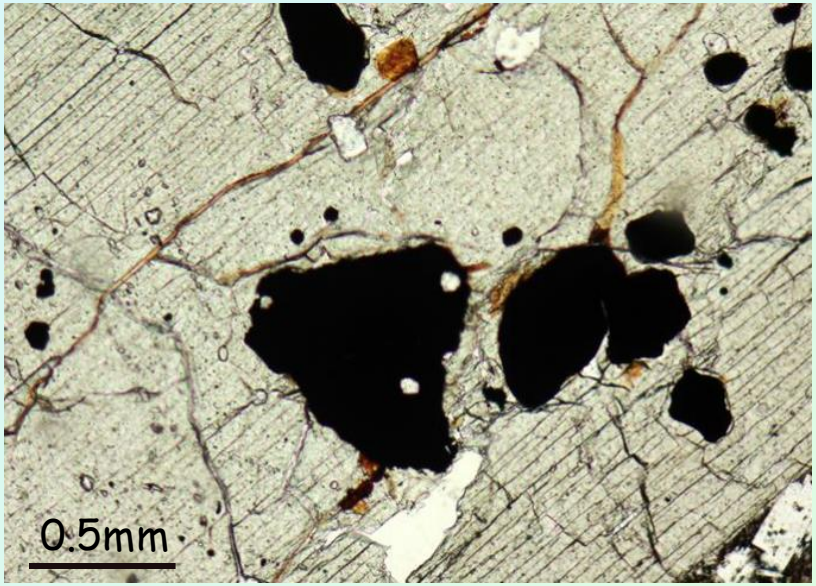
Magnetite (Fe_3O_4)

- Magnetite → iron oxide mineral found as a disseminated accessory through most igneous rocks
- in certain rock types through segregation, magnetite may become one of the main components of rock-forming ore bodies
- magnetite is a common constituent of sedimentary and metamorphic banded Precambrian formations
- occurs in beach sands → eroded from rocks and transported by rivers → concentrated by wave action and currents
- present in certain skarn deposits with wolframite
- characterised in hand specimen chiefly by its strong magnetism, black colour and hardness = 6

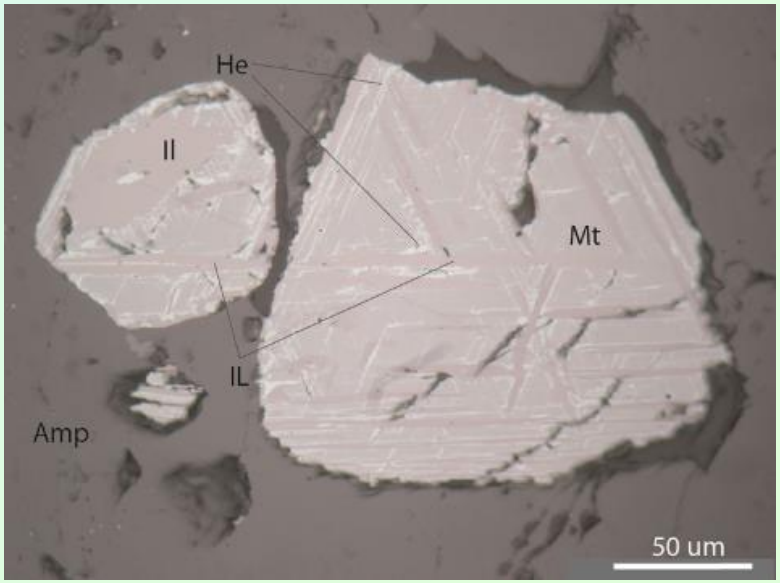
Magnetite

Magnetite

Magnetite crystal aggregate



Magnetite inclusions in enstatite PPL



Magnetite with ilmenite lamellae XPL

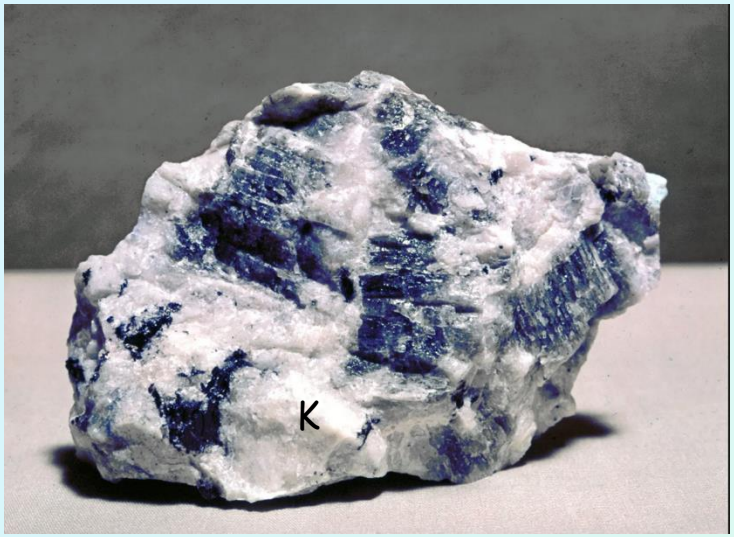
Nepheline ($NaAlSi_2O_6$)

- Nepheline is a feldspathoid mineral found in silica deficient intrusive and extrusive rocks
- rocks containing nepheline include nepheline syenite, foidite and phonolite
- often occurs with leucite, sodalite, K-feldspar, Na-rich plagioclase, hornblende or pyroxene
- never associated with quartz:

$$\underset{\text{nepheline}}{NaAlSi_2O_6} + SiO_2 \rightarrow \underset{\text{albite}}{NaAlSi_3O_8}$$

- characterised in hand specimen by its greasy lustre
- well-formed crystals are found on Mt Vesuvius

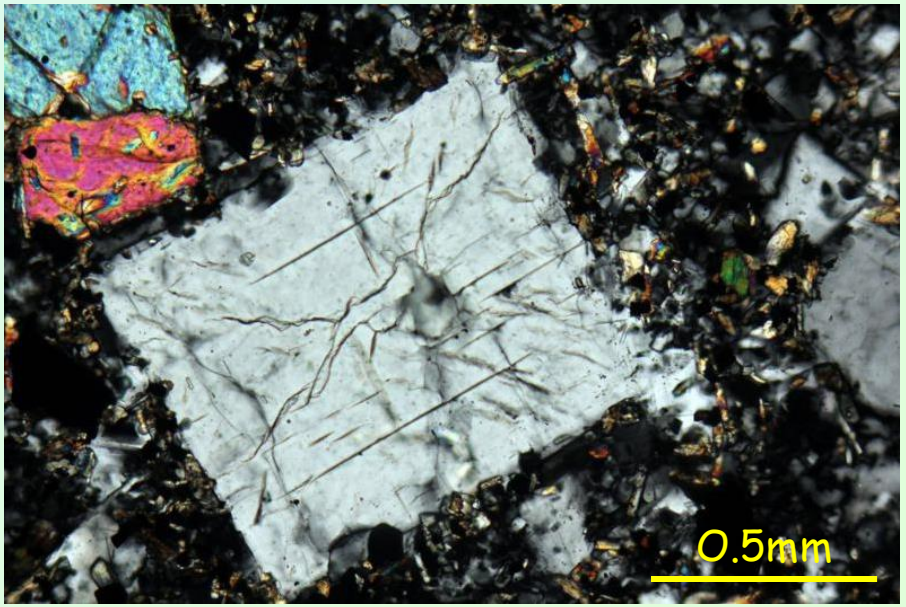
Nepheline



Nepheline syenite

Nepheline crystals in phonolite cavity

Nepheline phenocryst PPL



Nepheline phenocryst XPL

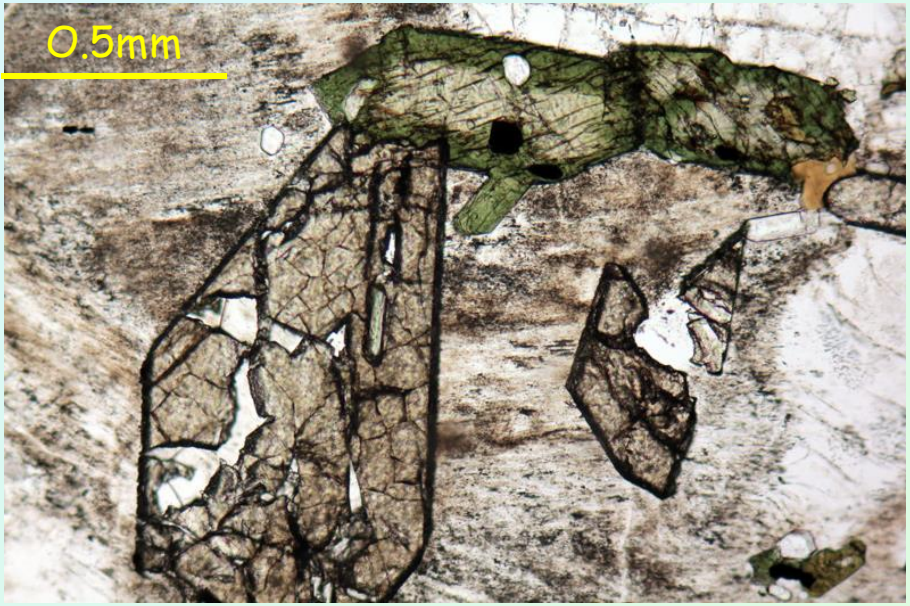
Titanite ($CaTiSiO_5$)

- Titanite (sphene) is a common accessory mineral in granites, granodiorites, diorites, syenites and nepheline syenites
- crystals of significant size occur in gneisses, chlorite schists, and crystalline limestone
- also formed with Fe ores, pyroxene, amphibole, scapolite, zircon, apatite, feldspar and quartz
- some titanite metamict due to radioactive decomposition of often significant thorium content
- commonly associated with chlorite, may alter to fine-grained aggregate of Ti-oxides e.g. rutile, anatase

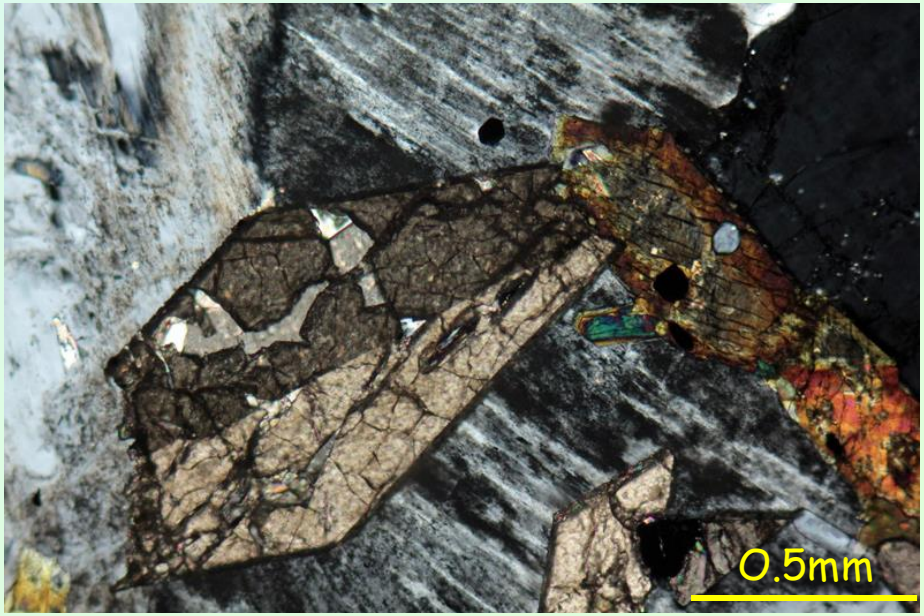
Titanite

Pink titanite and biotite

Titanite crystal



Titanite amphibole and K-feldspar PPL



Titanite, amphibole and K-feldspar XPL

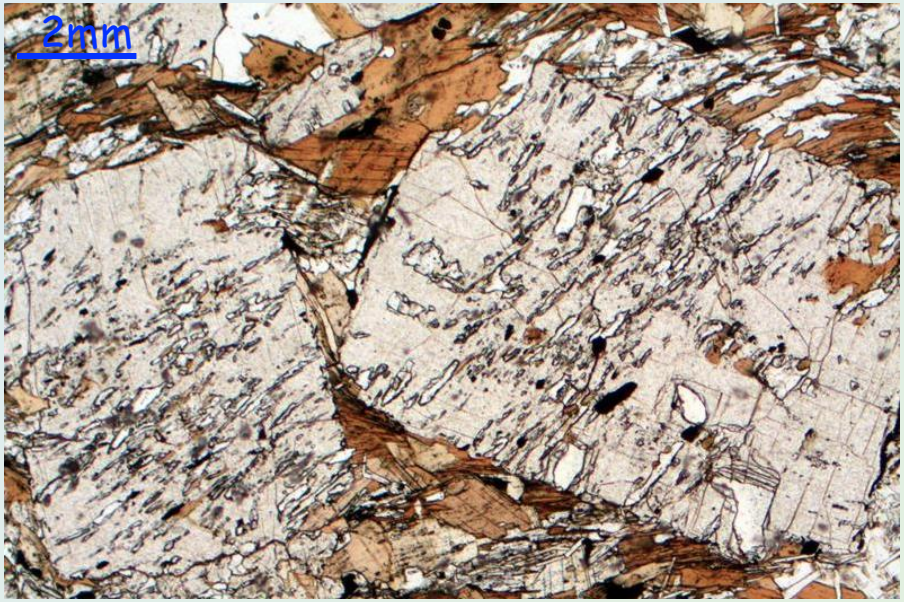
Andalusite (Al_2SiO_5)

- Typically formed in contact aureoles of igneous intrusion into argillaceous (muddy) rocks along with cordierite
- found in association with polymorphs kyanite, sillimanite in regionally metamorphosed terrains
- a variety of andalusite called chiastolite contains dark inclusions of graphite or clay forming cruciform pattern in cross-section
- viridine is a green coloured variety of andalusite in which manganese substitutes for aluminium
- characterised in handspecimen by nearly square prisms

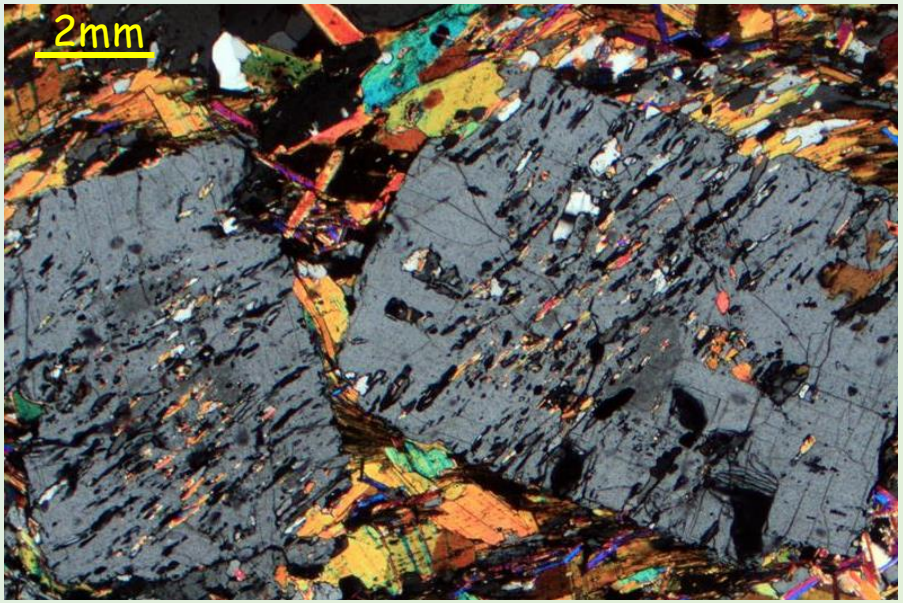
Andalusite

Andalusite schist

Andalusite (chiastolite)



Andalusite poikiloblasts and biotite PPL



Andalusite poikiloblasts and biotite XPL

Tourmaline

$[(Na,K,Ca)(Mg,Fe,Mn,Li,Al)_3(Al,Fe,Cr,V)_6Si_6O_{18}(BO_3)_3(O,OH,F)]$

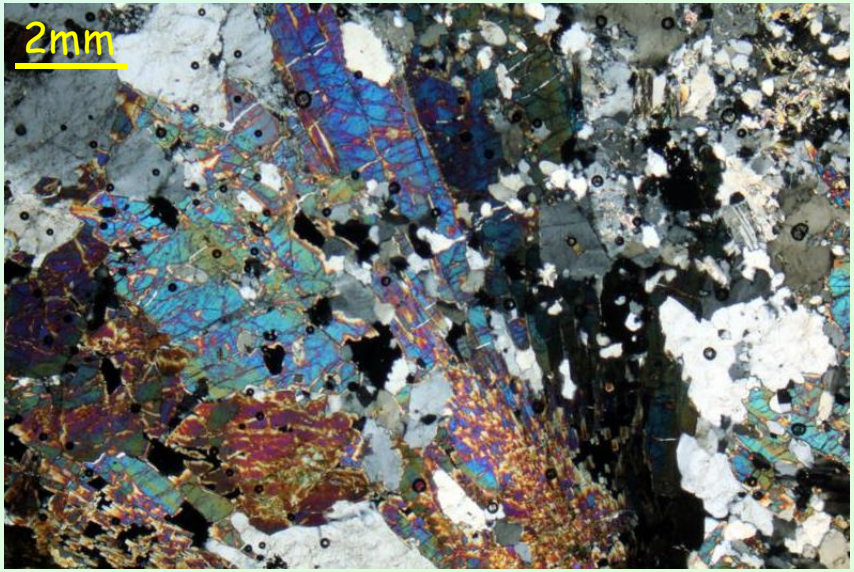
- Most common occurrence of tourmaline is inpegmatites and surrounding rocks
- also found as an accessory mineral in igneous and metamorphic rocks and a major mineral phase in greisens
- most pegmatitic tourmaline is black and associated with common pegmatitic minerals → microcline, albite, quartz and muscovite
- pegmatites also host light-coloured, lithium-bearing tourmaline associated with lepidolite, beryl, apatite, fluorite and rarer minerals
- usually recognised in hand specimen by characteristic, rounded, triangular cross-section of crystals

Tourmaline

Tourmaline crystals in pegmatite

Joined tourmaline (dravite) crystals

Tourmaline crystals in quartz PPL



Tourmaline crystals in quartz XPL

Watermelon tourmaline

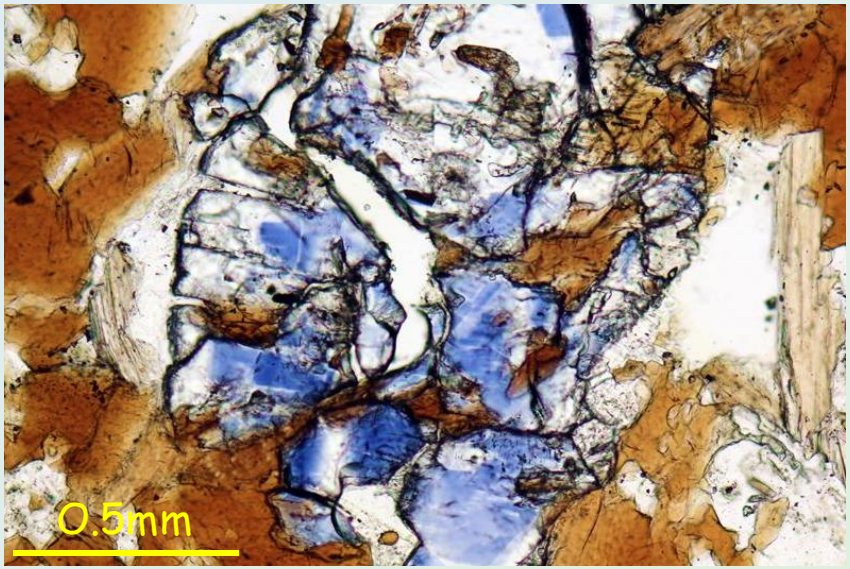
Corundum (Al_2O_3)

- Corundum → Al-oxide that commonly forms hexagonal, barrel shaped crystals
- common accessory mineral in some metamorphic rocks e.g. marble, mica schists, gneiss
- also found in Si undersaturated rocks such as syenites and nepheline syenites
- red corundum is called ruby → trace amounts of Cr
  blue corundum is called sapphire → trace amounts of Fe,Ti
- found concentrated in alluvial deposits because of durability
- characterised by its hardness = 9 and hexagonal crystals

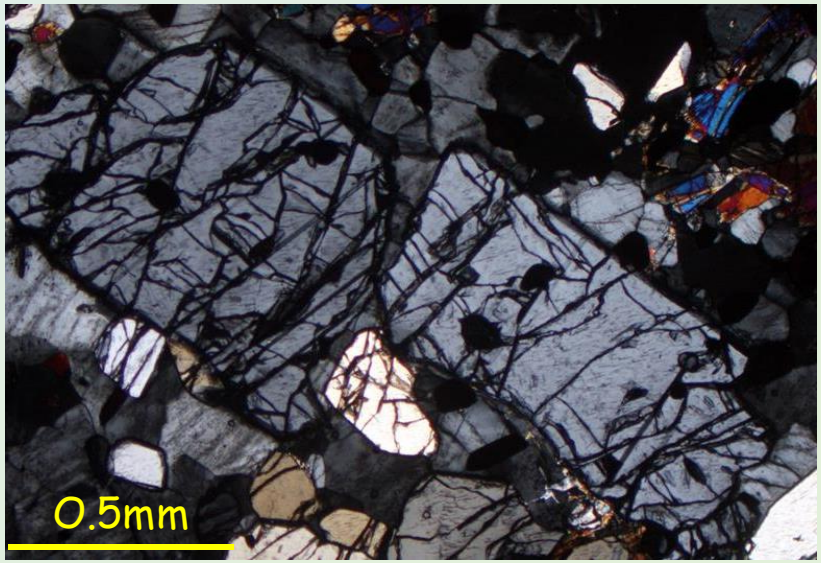
Corundum

Corundum crystal in granite

Ruby corundum crystals



Corundum with biotite PPL



Corundum crystal XPL

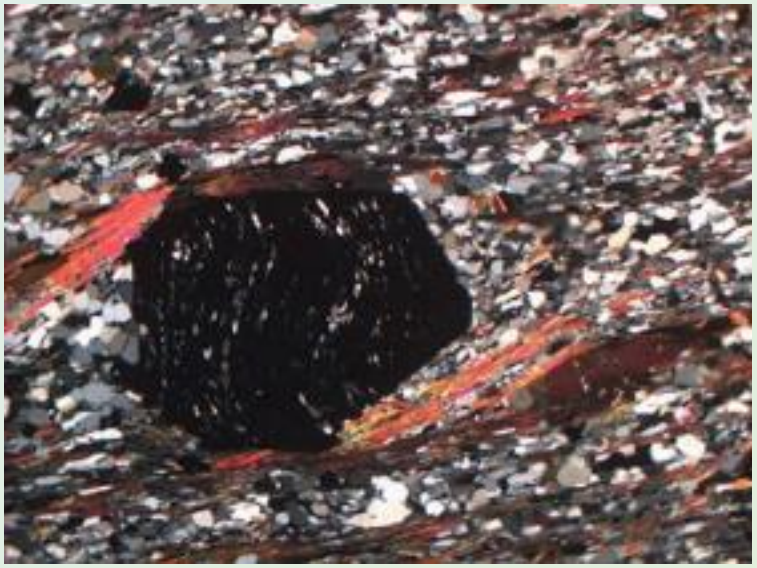
Garnet $(Ca,Fe,Mg,Mn)_3(Al,Fe,Mn,Cr,Ti,V)_2(SiO_4)_3$

- Garnet → large group of rock-forming minerals commonly widely distributed, abundant in some metamorphic rocks accessory in some igneous rocks
- all species of garnet possess similar physical properties but different chemical composition
- most garnets are compositionally zoned, found in every colour with reddish colours most common
- most garnets form at convergent plate boundaries where they are metamorphosed
- garnets start as tiny grains → enlarge over time as metamorphism progresses

Garnet

- As garnets grow, they displace, replace and include surrounding rock material
- garnets are usually identified by isometric crystal shape, hardness
- garnet species:

pyrope	$Mg_3Al_2Si_3O_{12}$
almandine	$Fe_3Al_2Si_3O_{12}$
spessartine	$Mn_3Al_2Si_3O_{12}$
grossular	$Ca_3Al_2Si_3O_{12}$
andradite	$Ca_3Fe_2Si_3O_{12}$
uvarovite	$Ca_3Cr_2Si_3O_{12}$

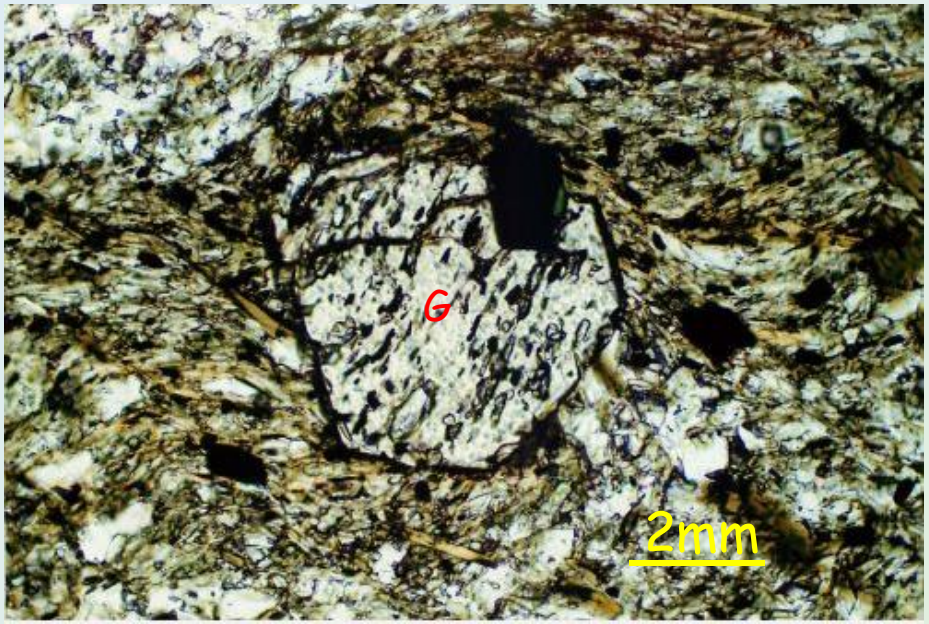


Poikiloblastic garnet

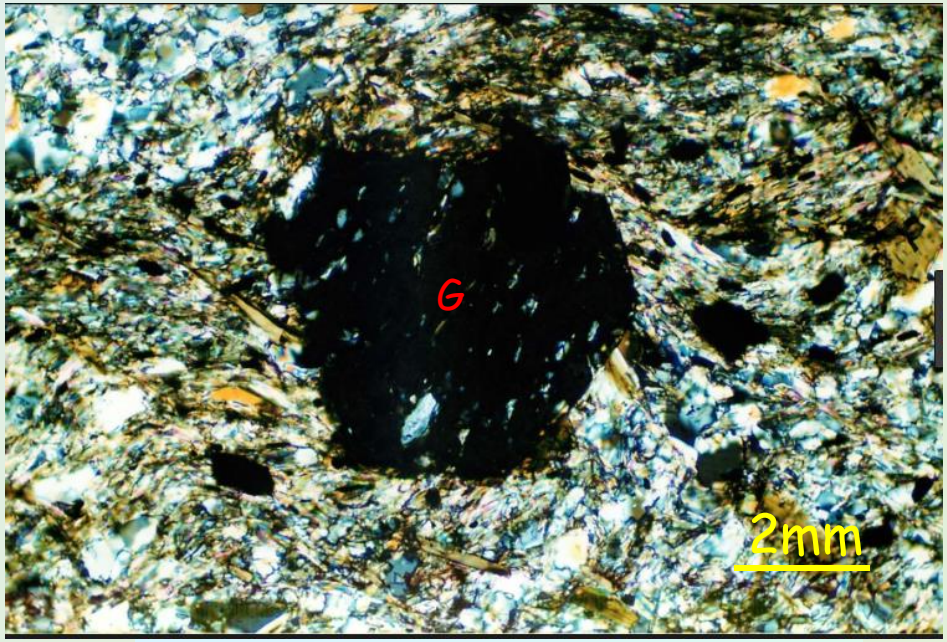
Garnet

Garnet gneiss

Garnet crystals



Garnet (G) in thin section PPL



Garnet (G) in thin section XPL

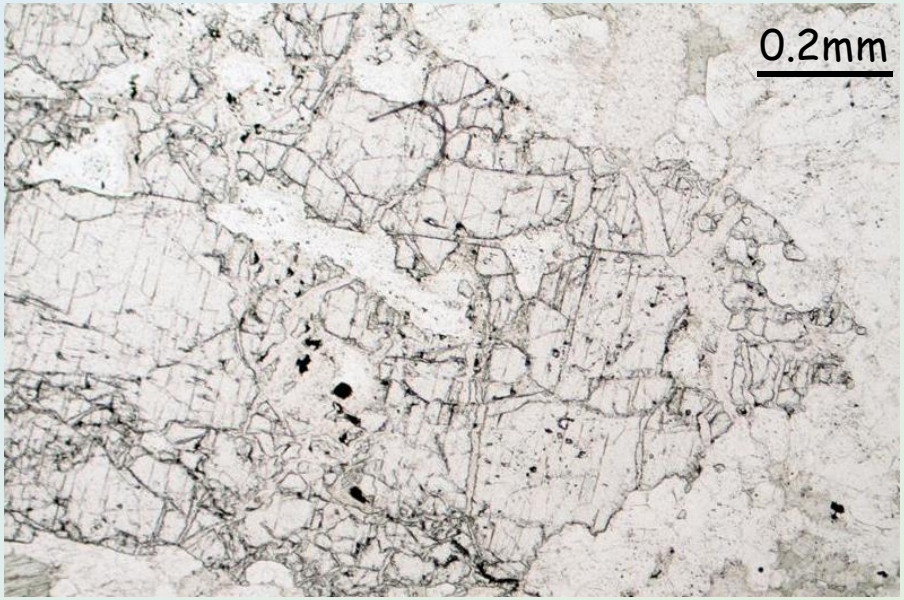
Topaz $Al_2SiO_4(OH,F)_2$

- Topaz → silicate mineral containing Al and F
- formed by fluorine-bearing vapours given off in late stages of solidification of siliceous igneous rocks
- found in cavities of rhyolitic lavas and granite
- characteristic of Sn-bearing pegmatites and greisens associated with tourmaline, cassiterite, fluorite, quartz and muscovite
- perfect basal cleavage, vitreous lustre and hardness = 8

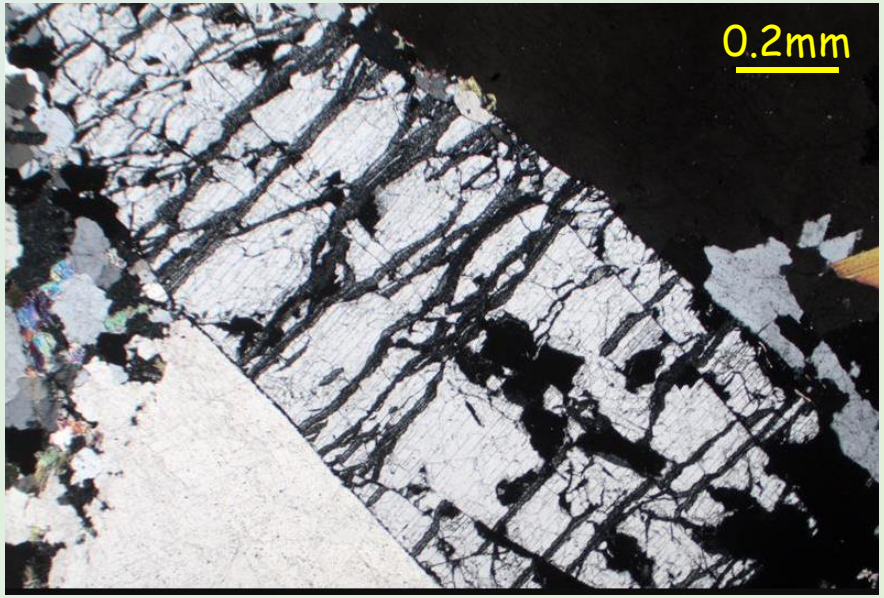
Topaz

Topaz greisen

Topaz crystal



Topaz and quartz in topaz greisen PPL



Topaz and quartz in topaz greisen PPL

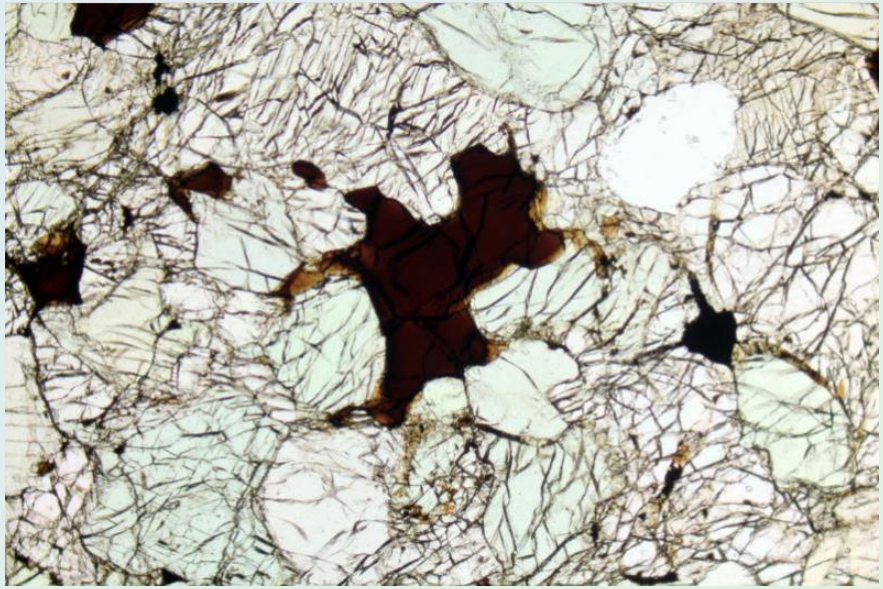
Spinel ($MgAl_2O_4$)

- Spinel → common high temperature accessory mineral occurring in contact metamorphosed limestones and mudstones poor in SiO_2
- associated with phlogopite, chondrodite $[(Mg,Fe)_5(SiO_4)_2(F,OH)_2]$, and graphite in contact metamorphosed mudstones
- also occurs as a primary mineral in rare mafic igneous rocks where magmas are deficient in alkalis relative to Al
- spinel is common in peridotites in the uppermost part of the mantle
- characterised by its hardness = 8 and octahedral crystal shape

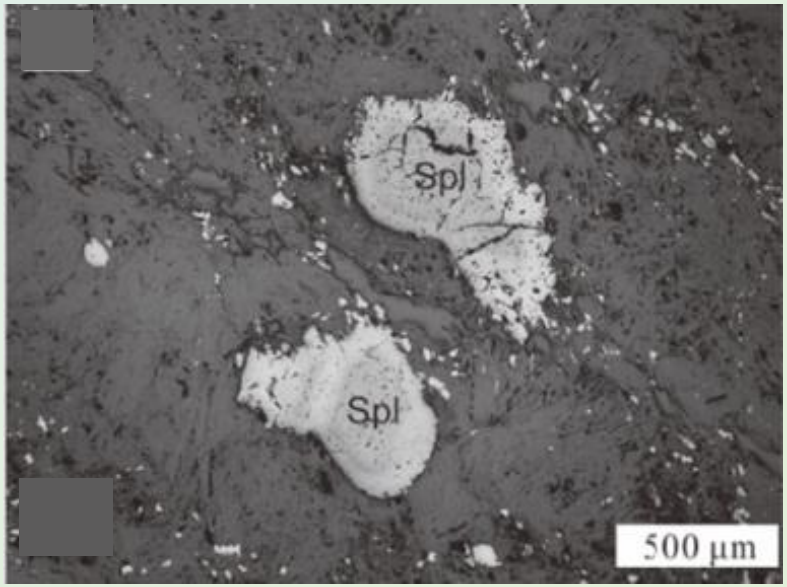
Spinel

Peridotite inclusion

Black spinel octahedral crystals



Spinel in lhertzolite PPL



Spinel in reflected light