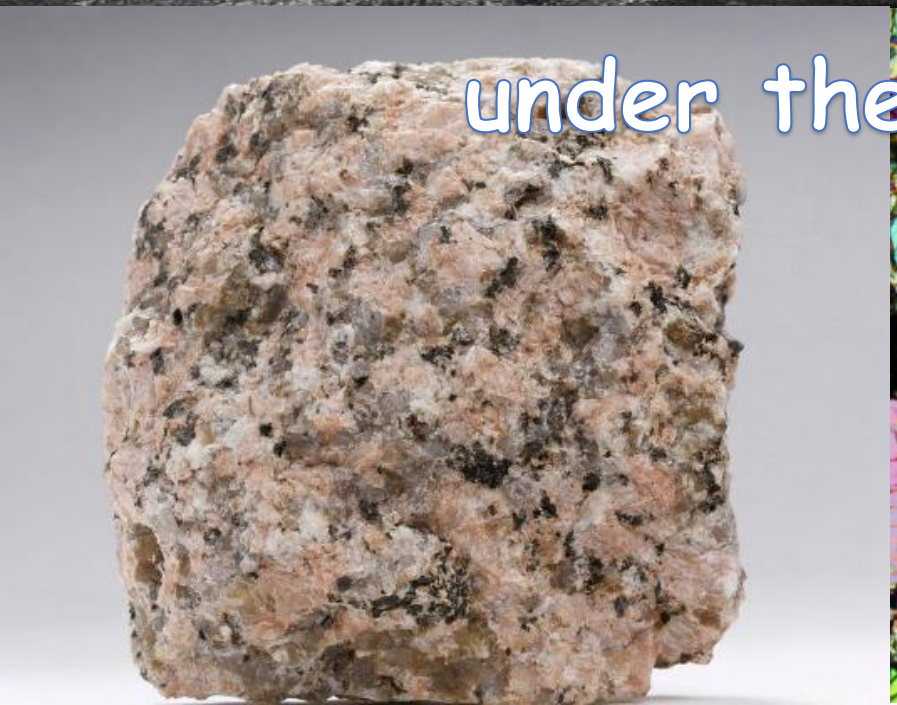
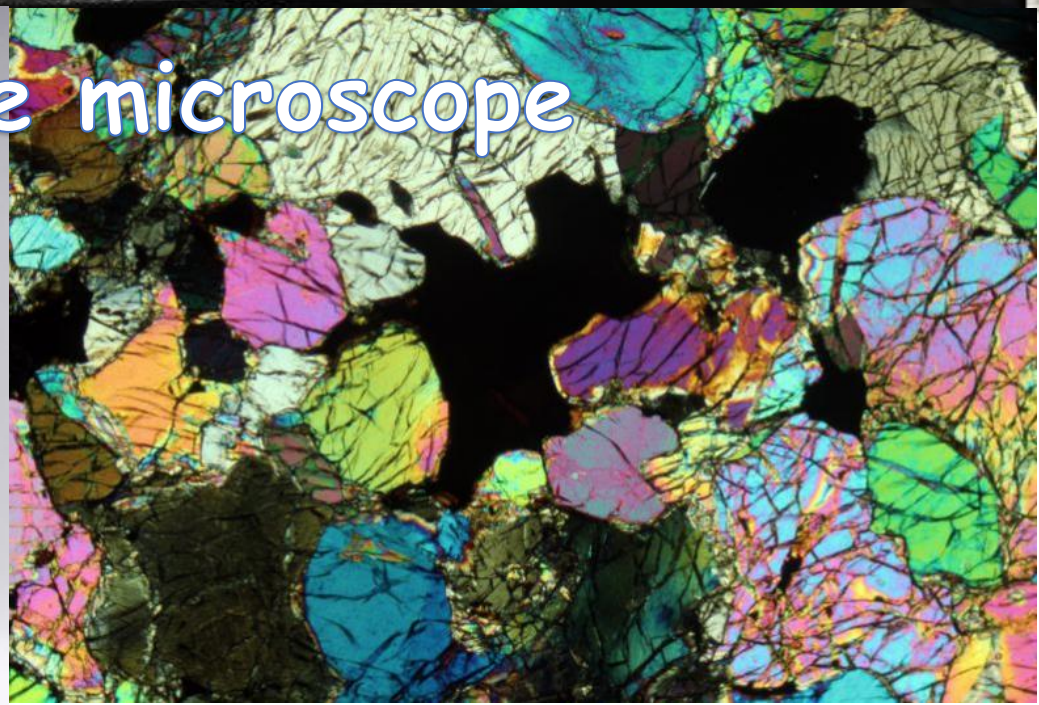
U3A Geology

Rocks in handspecimen and under the microscope



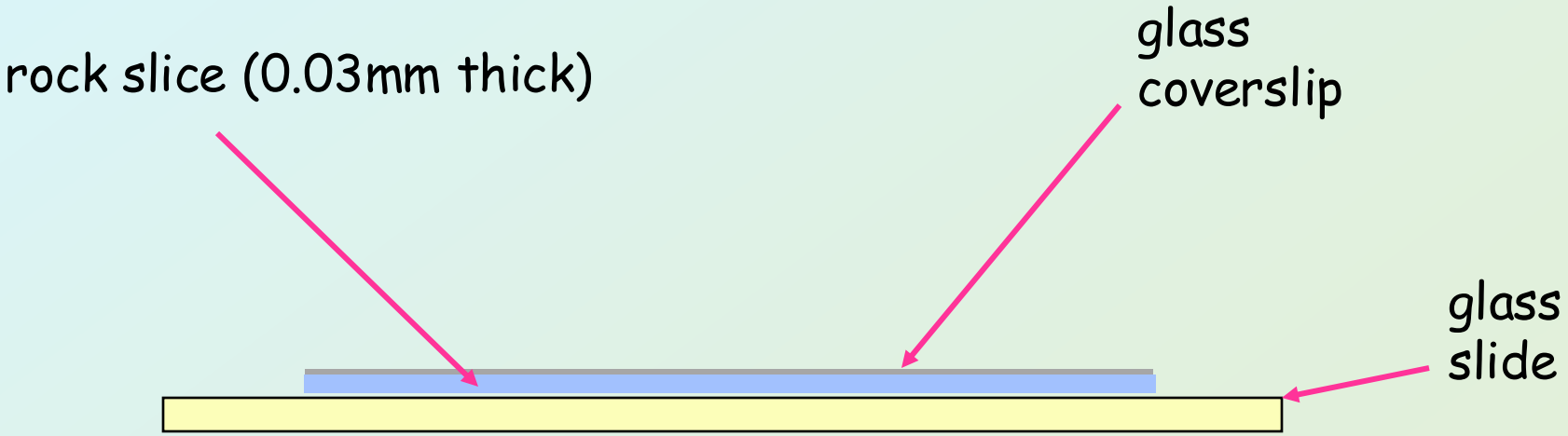


Introduction

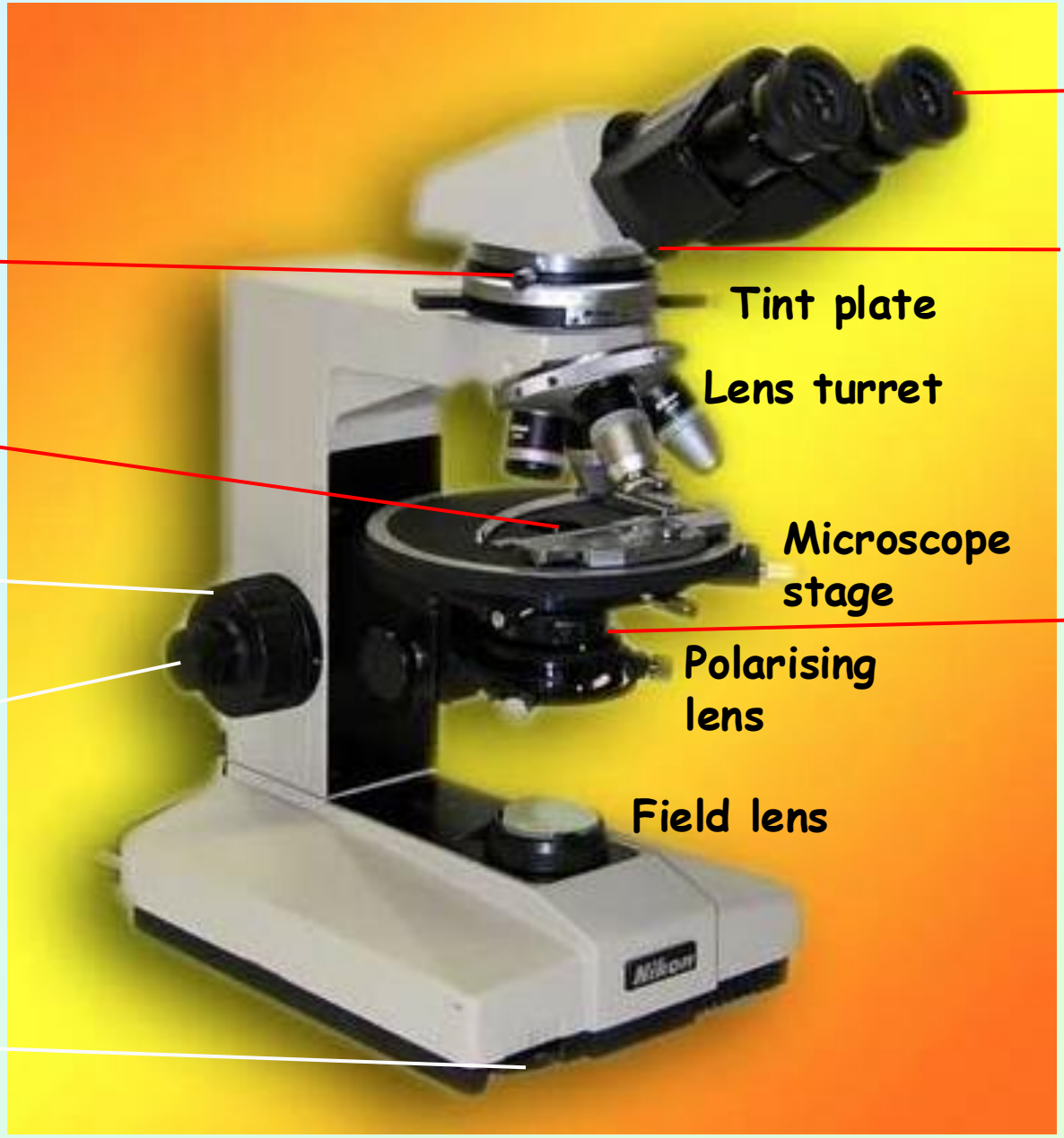
- Rocks can be studied at the levels of outcrop, hand specimen and microscope
- at outcrop level, features such as colour, shape of outcrop, weathering, texture and structure are discernible
- from rocks in hand specimen we can observe colour, texture, structure and in many cases identify the major mineral phases
- the petrographic microscope is used to examine thin sections and identify fine-grained minerals in rocks and determine rock types

Thin section

- Rocks and minerals can be examined and identified in thin section
- thin section → glass slide containing thin (0.03mm) slice of rock or mineral with a glass coverslip



Nikon petrographic microscope



Fundamental Types of Rock

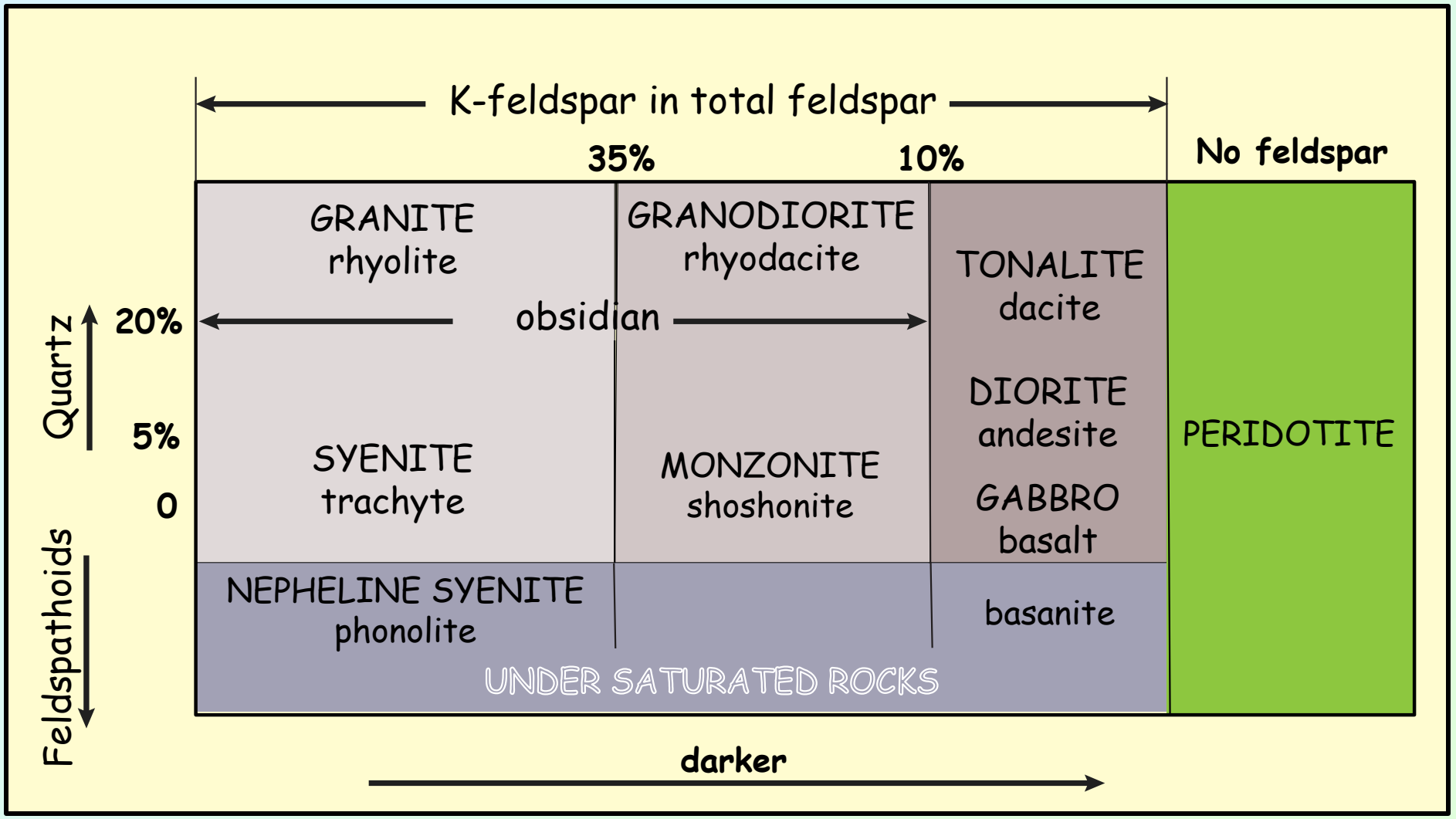
There are three fundamental groups of rocks:

- Igneous rocks
  - make up 75% of the Earth's crust in the continents
  - make up over 90% of the Oceanic crust
- Sedimentary rocks
  - make up 5-10% of the Earth's crust by volume
  - cover about 75% of the continents
- Metamorphic rocks
  - make up <15% of exposed rocks at Earth's surface
  - they occupy a much larger volume within the Earth's crust

Igneous rocks

- Igneous rocks are those rocks that form from the cooling and solidification of molten rock material (magma) generated by partial melting in the upper mantle or lower crust
- Magma can be extruded onto the Earth's surface as a consequence of volcanic activity or, can be emplaced at shallow to deep levels in the Earth's crust
- Lava is magma that has erupted on the Earth's surface
- igneous rocks comprise more than 90% of the total rock content of the crust

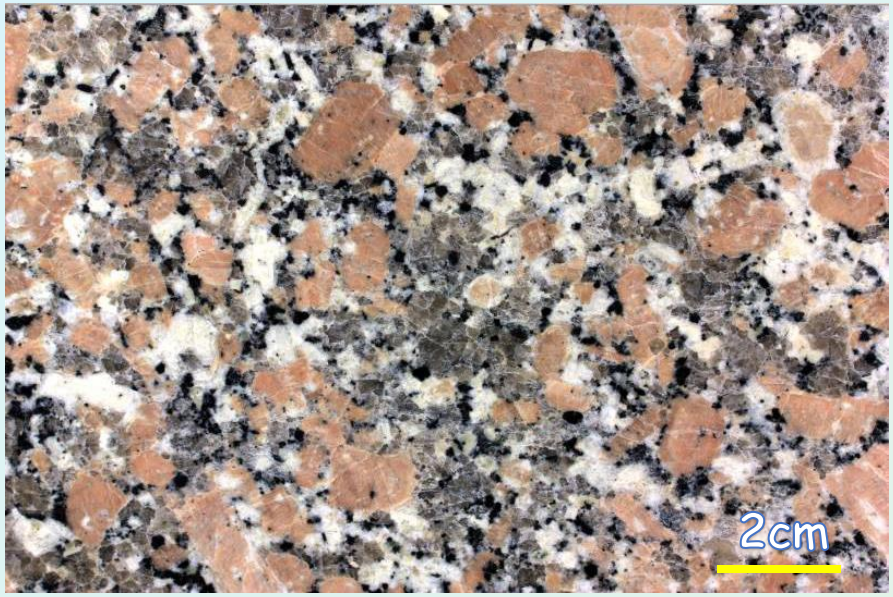
Igneous rock classification chart



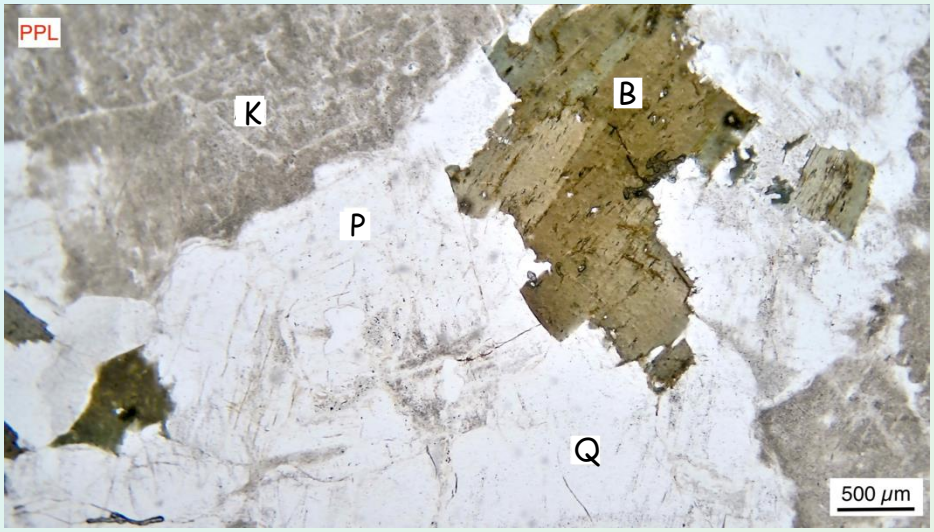
Granite

- Medium to coarse-grained, intrusive, igneous rock with essential quartz (>20%) and alkali feldspar → 35-100% of the total feldspar
- lesser mafic minerals (biotite, hornblende) and muscovite are common
- minor accessory minerals may include sillimanite, andalusite, corundum, cordierite, garnet and topaz. Very minor amounts of magnetite, ilmenite, zircon, rutile or apatite may be present
- the term granite is commonly broadly used to describe rocks of similar appearance with variation in feldspar composition and quartz content e.g. granodiorite, syenite, monzonite, tonalite, the term granitoid is more appropriate
- granite forms from partial melting of rocks in the lower crust

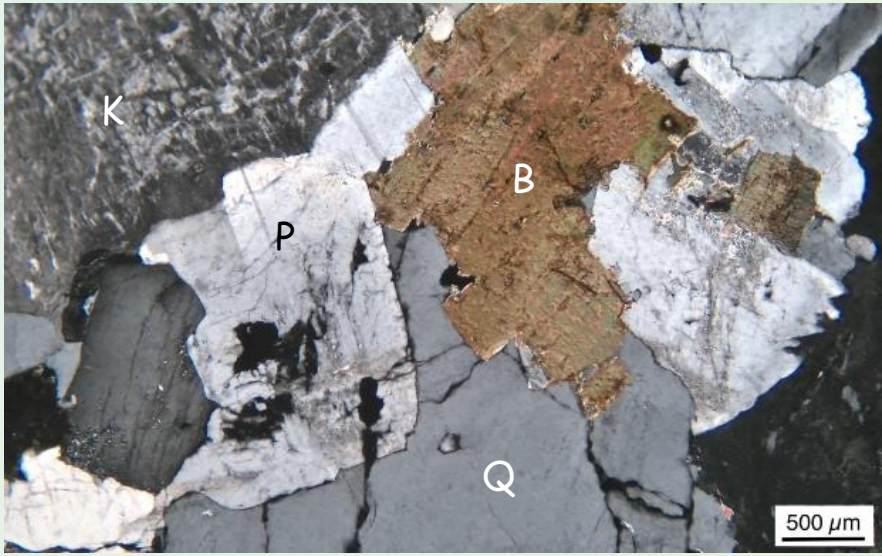
Granite



Granite hand specimen



Granite thin section PPL



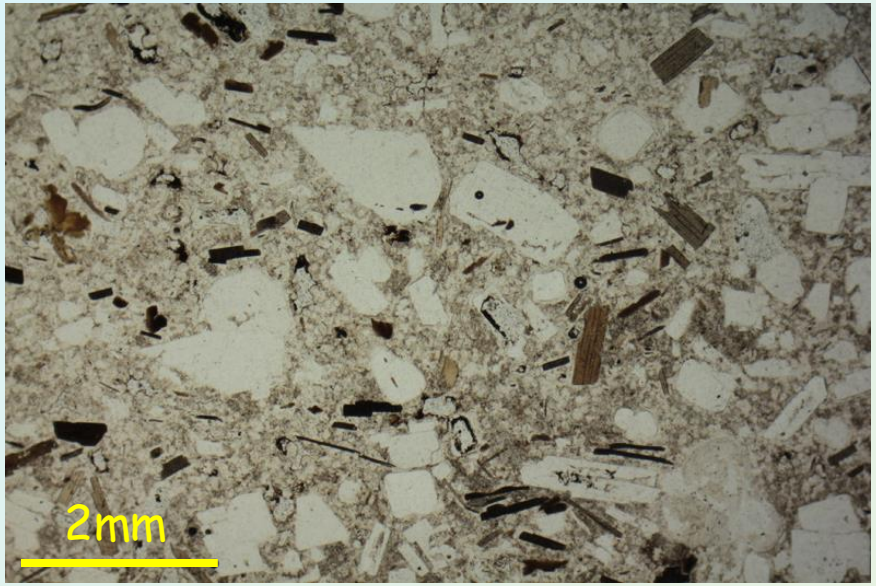
Granite thin section XPL

Rhyolite

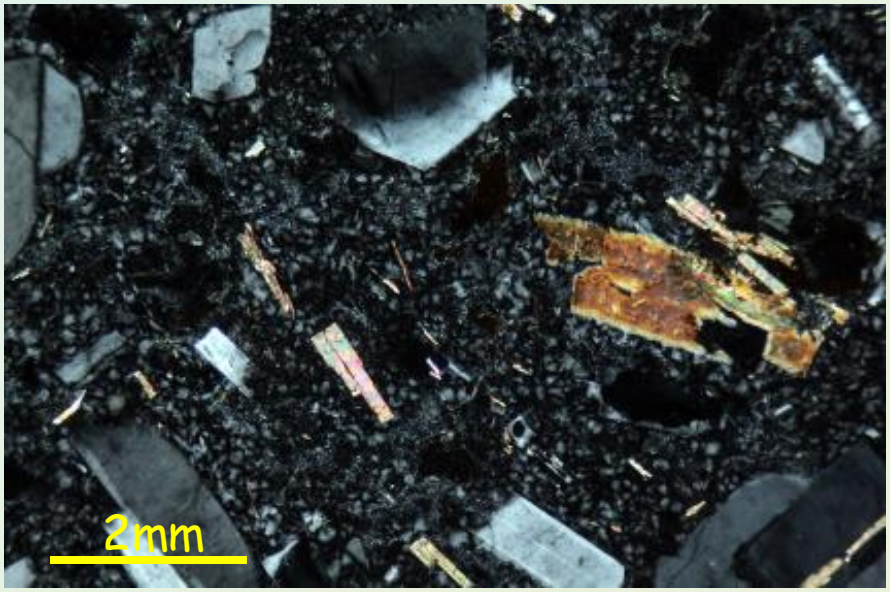
- Same chemical composition as granite but is of volcanic or subvolcanic origin
- comprises phenocrysts of quartz and alkali feldspar often with minor plagioclase and biotite in microcrystalline or glassy groundmass
- rapid cooling produces glassy rhyolites that include pumice, obsidian, perlite and pitchstone
- explosive eruptions may produce tuff, tephra or ignimbrite
- high SiO_2 levels together with low eruptive temperatures increases viscosity of melts → lavas erupt as thick domes over volcanic vents

Rhyolite

Rhyolite hand specimen



Rhyolite in thin section PPL



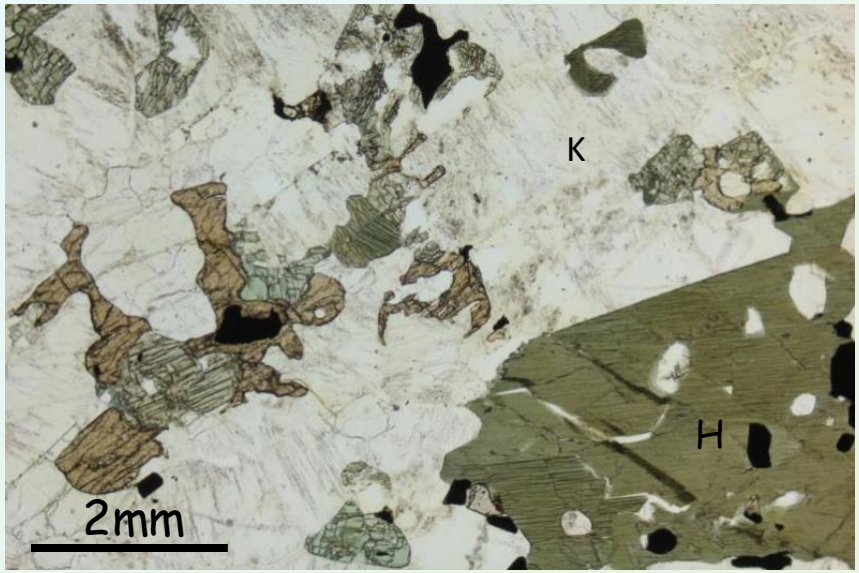
Rhyolite in thin section XPL

Syenite

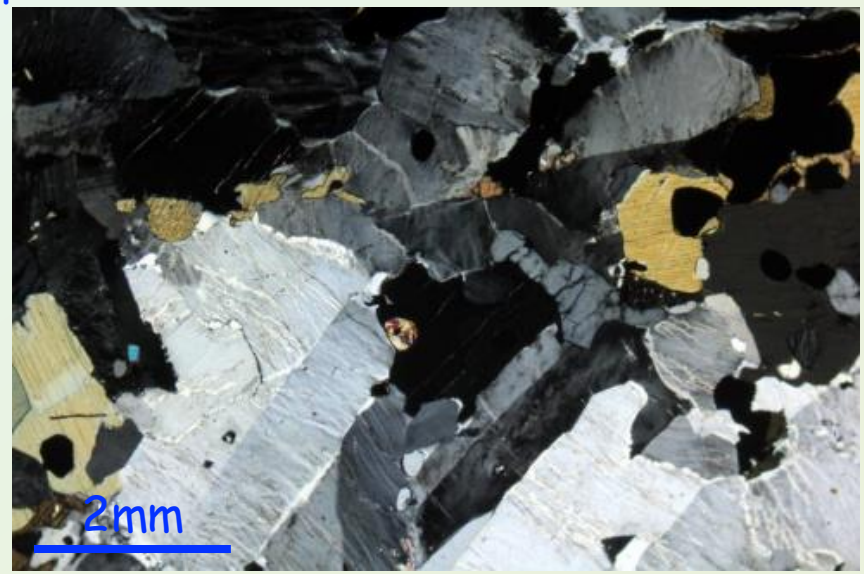
- Syenite → coarse-grained, silica-saturated rock in which K-feldspar (orthoclase) is the main mineral phase
- slight silica oversaturation may be evident → presence of small amount of quartz; slight undersaturation may be evident → presence of nepheline ($NaAlSi_2O_6$)
- generally form in thick continental crust areas and some subduction zones
- form as a result of low degrees of partial melting of granite protolith
- mineralogy: orthoclase, hornblende, clinopyroxene, minor plagioclase, magnetite

Syenite

Syenite hand specimen



Thin section of syenite PPL

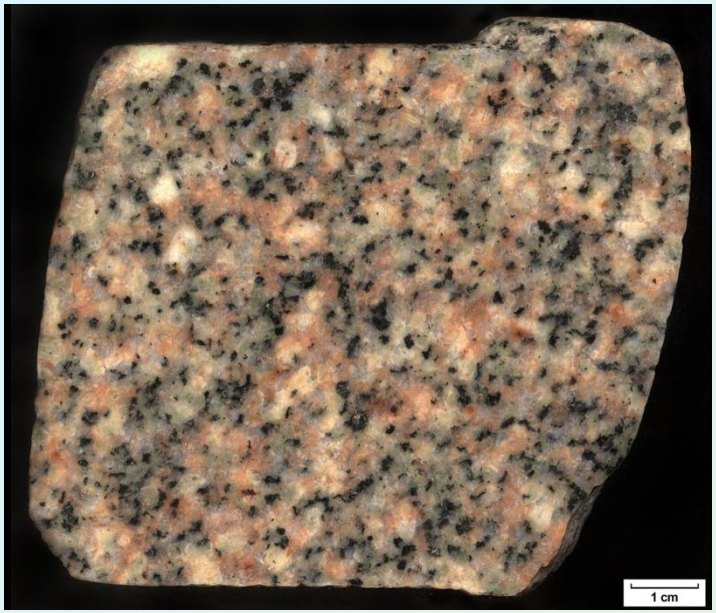


Thin section of syenite XPL

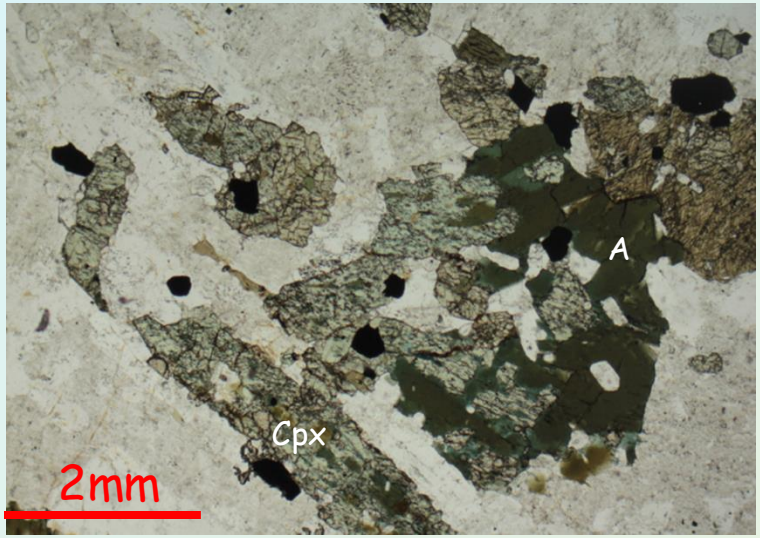
Monzonite

- Monzonite → relatively uncommon plutonic igneous rock, intermediate in composition between syenite and diorite
- composed of approximately equal amounts of alkali feldspar and plagioclase with <5% quartz
- may contain minor amounts of hornblende, biotite and other minerals (e.g. pyroxene, magnetite)
- rarely forms its own plutons → forms part of generally more granitic plutons

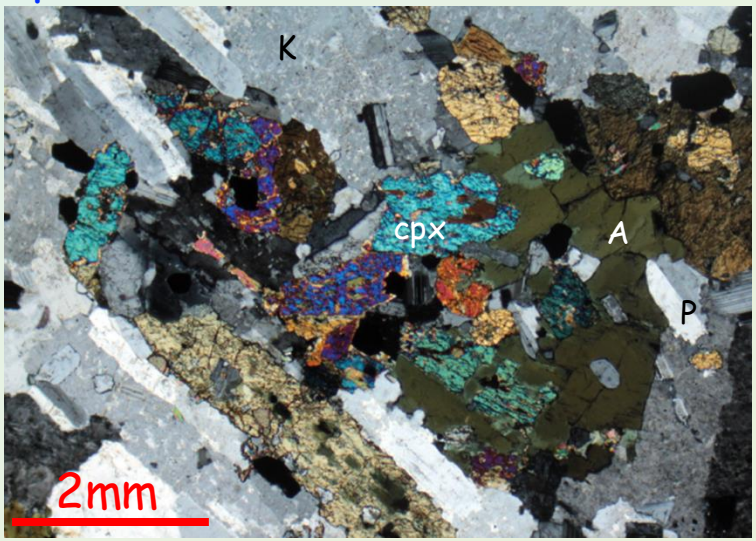
Mozonite



Monzonite hand specimen



Thin section of monzonite PPL

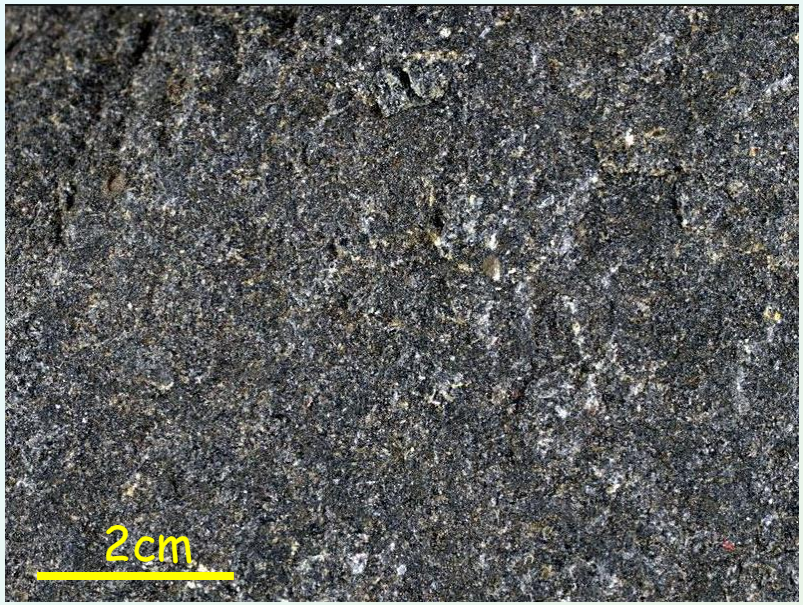


Thin section of monzonite XPL

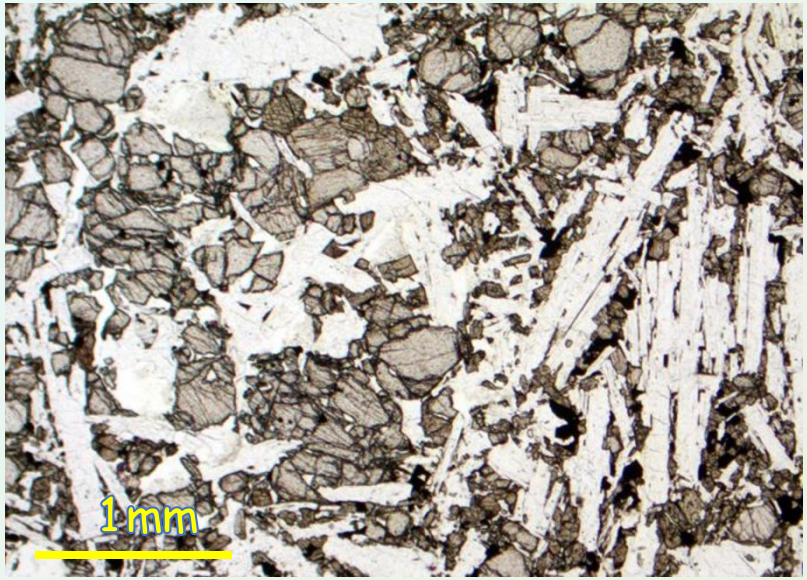
Basalt

- Fine-grained, basic volcanic rock containing plagioclase and clinopyroxene (augite) with or without olivine
- often porphyritic and may contain mantle xenoliths
- basic igneous rocks contain 45-52% SiO_2, abundant Fe, Mg, Ca and minor Na and K
- two main types → tholeiitic (silica saturated), alkali (silica under-saturated)
- product of melting in Earth's mantle → erupt in a variety of tectonic environments (e.g. mid-ocean ridges, island arcs, back arc basins, ocean islands, large igneous provinces, intra-continental rifts)

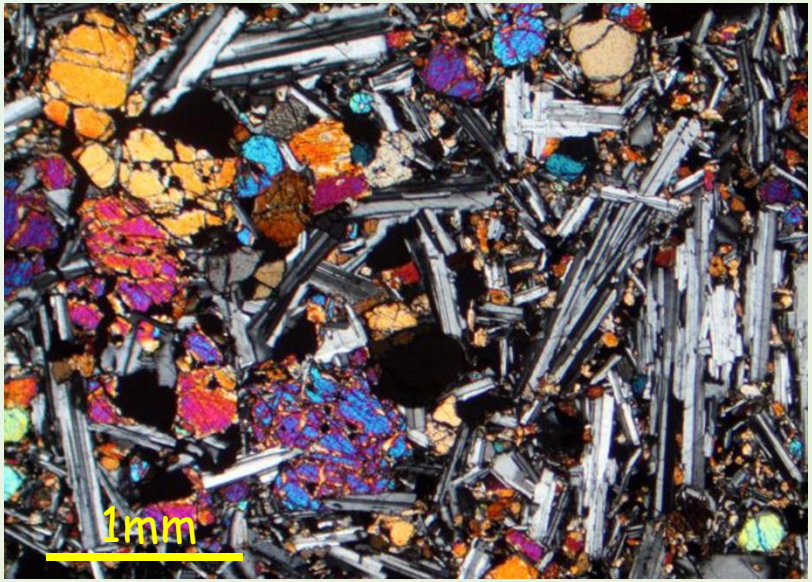
Basalt



Basalt hand specimen



Thin section of basalt PPL

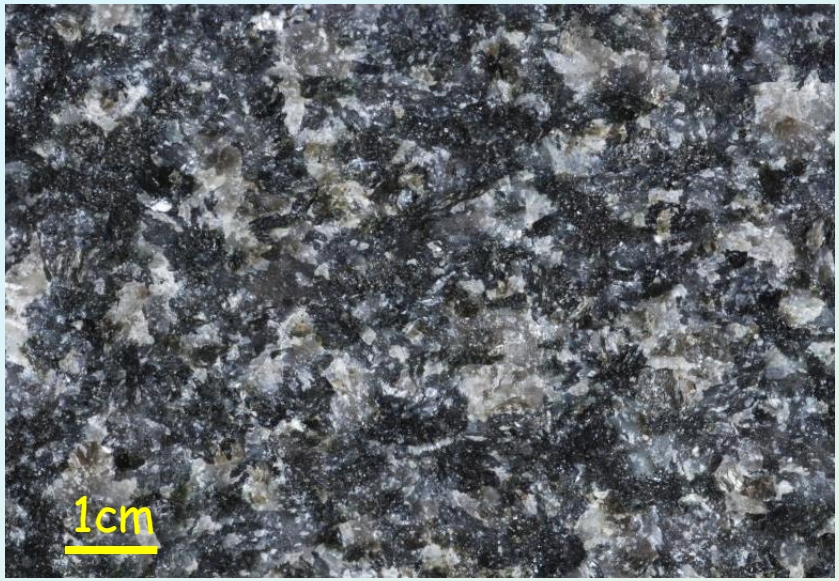


Thin section of basalt XPL

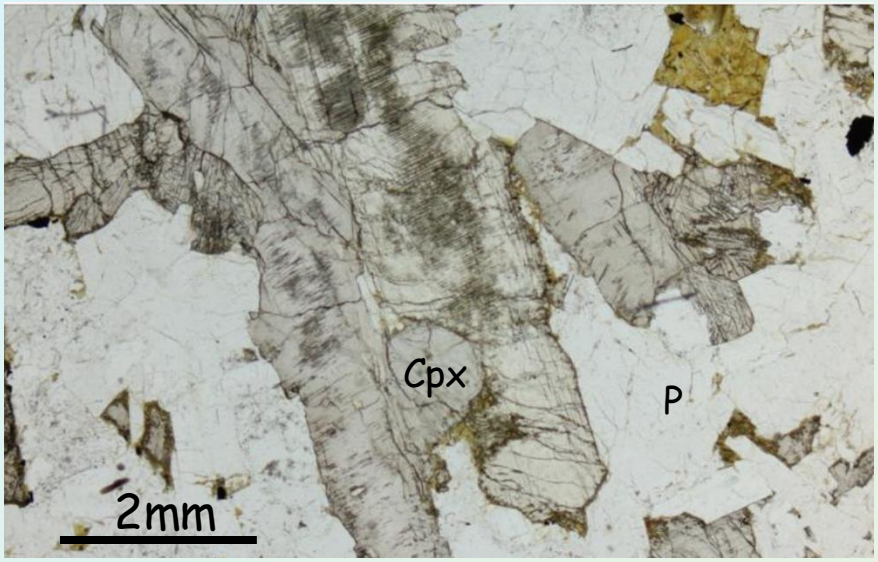
Gabbro

- Coarse-grained basic intrusive rocks → intrusive analogue of basalt
- composed of calcic plagioclase, pyroxene (mainly clinopyroxene but small amounts of orthopyroxene may be present)
- if opx is >95% of total pyroxene the rock is called norite
- if >90% plagioclase is present rock is called anorthosite, if more than 90% pyroxene → pyroxenite
- gabbros may contain small amounts of olivine, hornblende and biotite
- gabbros can contain small amounts of quartz (<5% oversaturation) or nepheline (undersaturated)

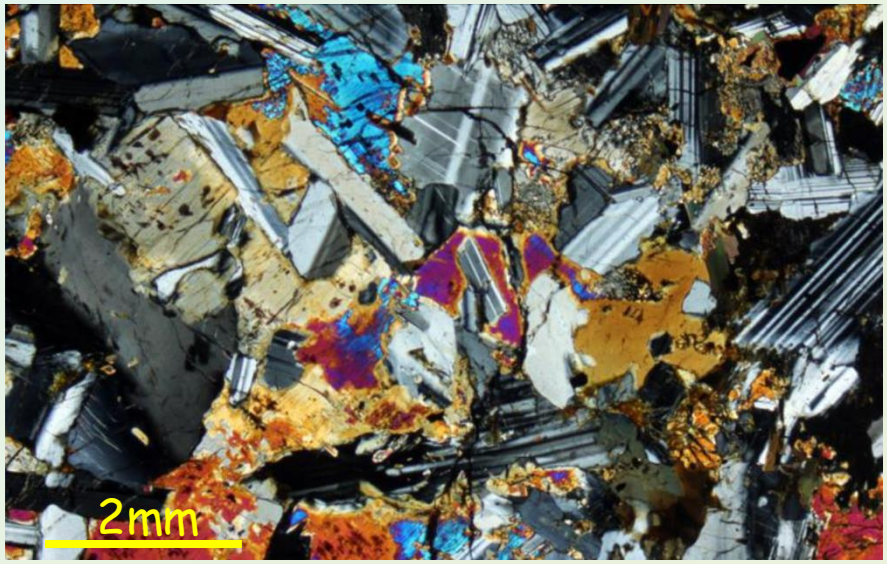
Gabbro



Gabbro hand specimen



Thin section of gabbro PPL

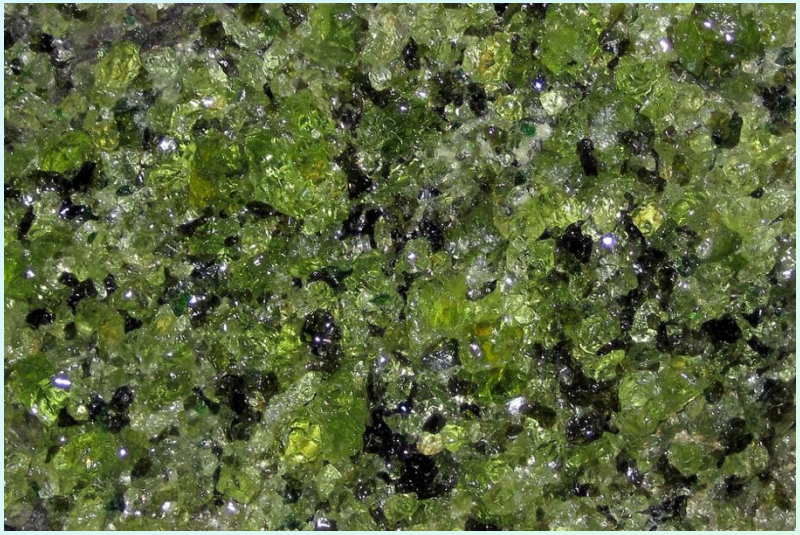


Thin section of gabbro XPL

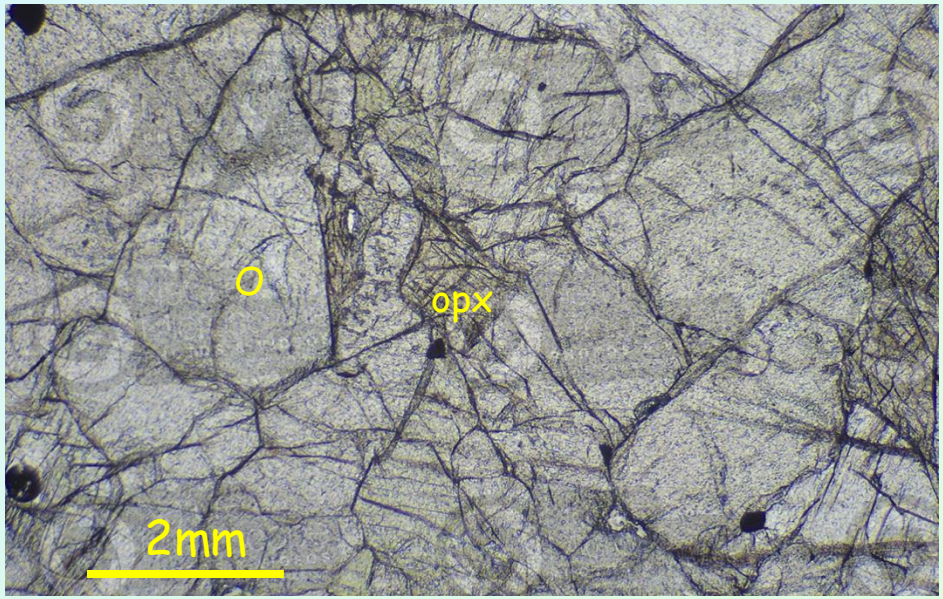
Peridotite

- Peridotite → group of ultrabasic igneous rocks containing >40% olivine with or without opx or cpx
- accessory mineral phases include garnet, spinel, plagioclase, ilmenite, chromite and magnetite
- peridotites comprise the bulk of the upper mantle and are present as xenoliths within basalt and ophiolites
- mantle peridotites are residues of partial melts. Peridotites can also form as cumulates in layered intrusions
- peridotite is the source rock of basalt magma → formed when peridotite partially melts

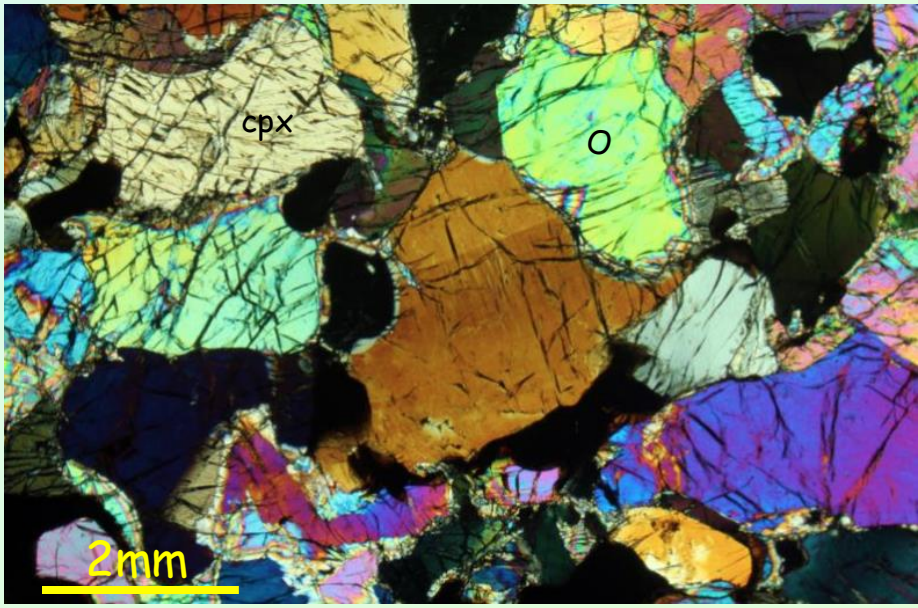
Peridotite



Peridotite hand specimen

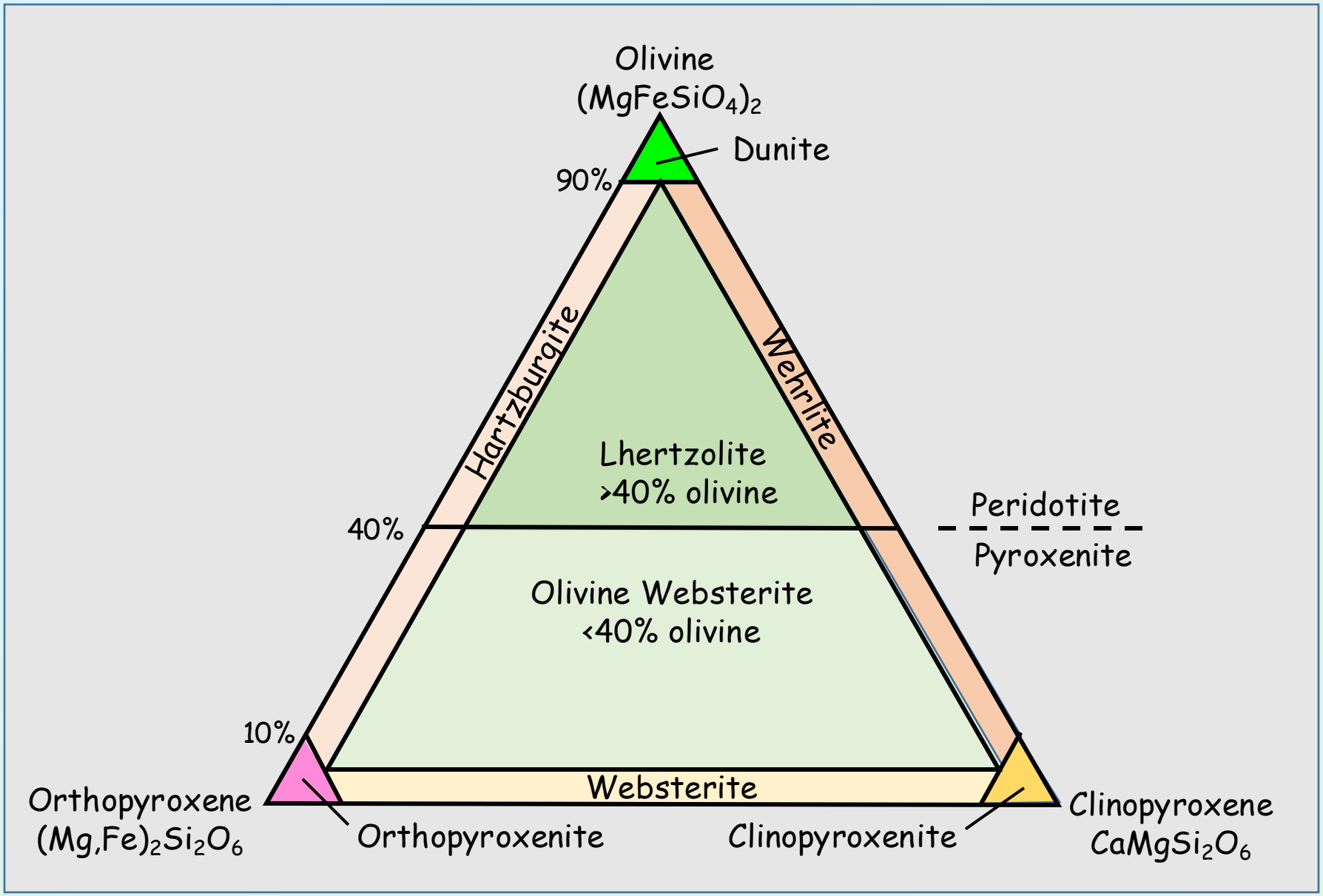


Thin section of peridotite PPL



Thin section of peridotite XPL

Classification of ultramafic rocks



Sedimentary Rocks

- Formed at the Earth's surface through interaction between the atmosphere, hydrosphere and crust and surface processes
- compose only ~5 – 10% of crust by volume but cover ~75% of Earth's surface → concentrated at or near Earth's surface
- preserve a record of erosion and deposition through time
- record information on ancient landscapes, environments and the history of life on Earth → fossil record
- host important fossil fuels, petroleum, coal and gas → all found within few km of Earth's surface

Types of sedimentary rocks

Clastic sedimentary rocks → rocks made up of rock and mineral fragments → breakup of pre-existing rocks e.g. conglomerate, sandstone

Organic sedimentary rocks → rocks made up of accumulated organic matter → plants, animals e.g. coal, fossiliferous limestone

Chemical sedimentary rocks → rocks formed as chemical precipitates → evaporative deposits e.g. gypsum , chert

Composite sedimentary rocks contain components of other types e.g. fossiliferous sandstone

Mudstone

- Mudstone → extremely fine-grained sedimentary rock consisting of a mixture of clay and silt-sized particles
- shale is used to describe mudstones that are hard and fissile
- claystone and siltstone → terms used to refer to rocks whose grain-size falls within a much narrower range
- mudstone and shale comprise ~65% of all sedimentary rocks
- mudstones can be separated into categories:

Siltstone - greater than half of composition is silt-sized particles

Claystone - greater than half of composition is clay-sized particles

Mudstone - hardened mud; a mix of silt and clay sized particles

Mudstone/shale

Mudstone hand specimen

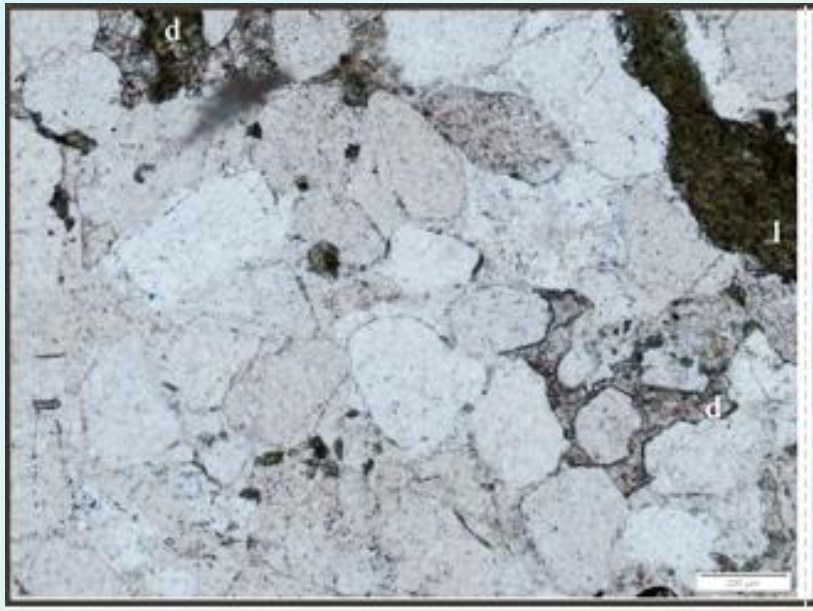
Thin section of shale PPL

Sandstone

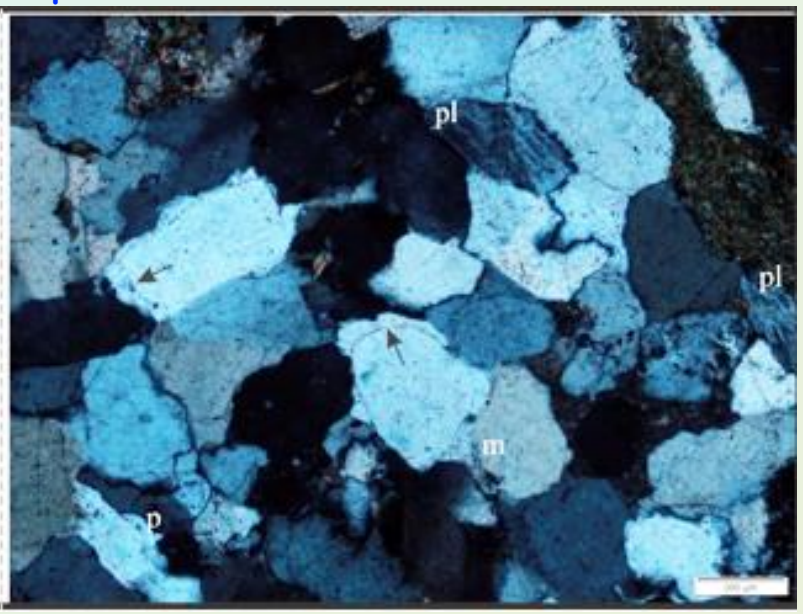
- Sandstone → clastic sedimentary rock composed of sand-sized grains (0.06-2mm) of quartz or feldspar
- second most common sedimentary rock after shale
- sandstone containing >90% quartz → quartzose sandstone
  sandstone containing >25% feldspar → arkose
- contain cementing material (e.g. silica, Fe-oxide, calcite) that cements grains together
- sediments that form sandstone → transported to sedimentary basins by rivers or deposited by waves or wind
- some grains may be organic particles such as shell debris

Sandstone

Sandstone hand specimen



Thin section of sandstone PPL



Thin section of sandstone XPL

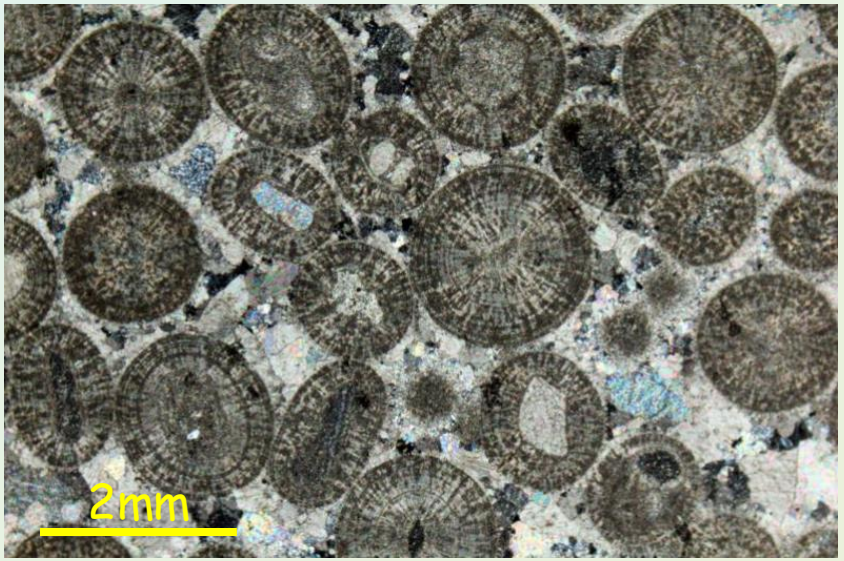
Limestone

- Limestone → sedimentary rock composed of calcium carbonate ($CaCO_3$) in the form of the mineral calcite
- forms from precipitation in warm, shallow seawater and accumulation of shell and other marine skeletal debris
- oolite is a limestone rock composed of rounded, sand-sized clasts called ooids (up to 2mm in diameter)
- ooids form from concentric accumulation of $CaCO_3$ around a nucleus (sand grain or shell fragment)
- form by inorganic precipitation of calcite around a nucleus while the clast is being rolled in wave-agitated waters

Oolitic limestone

Oolitic limestone hand specimen

Thin section oolitic limestone PPL



Thin section oolitic limestone XPL

Metamorphic rocks

- Rocks that are transformed from their original state due to prolonged exposure to physical conditions different from those at formation
- least common rocks seen at Earth's surface (~15%) → occupy much larger volume within Earth's crust
- two major types of metamorphism:

  contact metamorphism (relatively small scale)

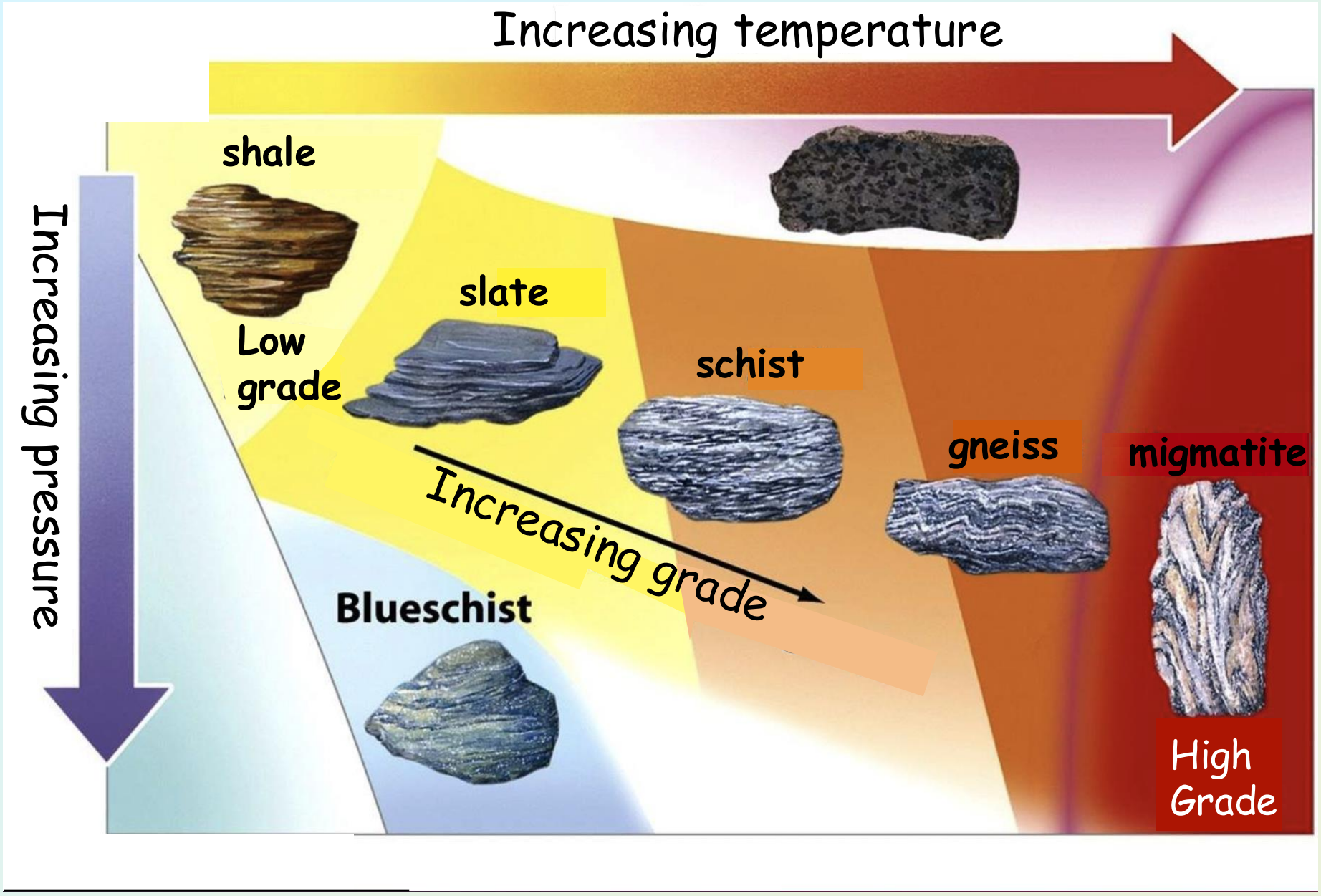
  regional metamorphism (extensive e.g. thousands of km long)
- pre-metamorphosed rock → protolith

Protolith —metamorphism→ metamorphic rock

Metamorphic rock features

- Metamorphic rocks are crystalline rocks
- recrystallisation occurs in the solid state
- new mineral assemblages and/or textures may develop in response to changed conditions
- regional metamorphic rocks commonly contain superimposed structural features due to deformation in the Earth's crust
- changed environment → variety of different rock types
  → hornfels, marble, quartzite (contact)
  → slate, phyllite, schist, gneiss, marble, quartzite (regional)

Metamorphic grade



Metamorphic facies

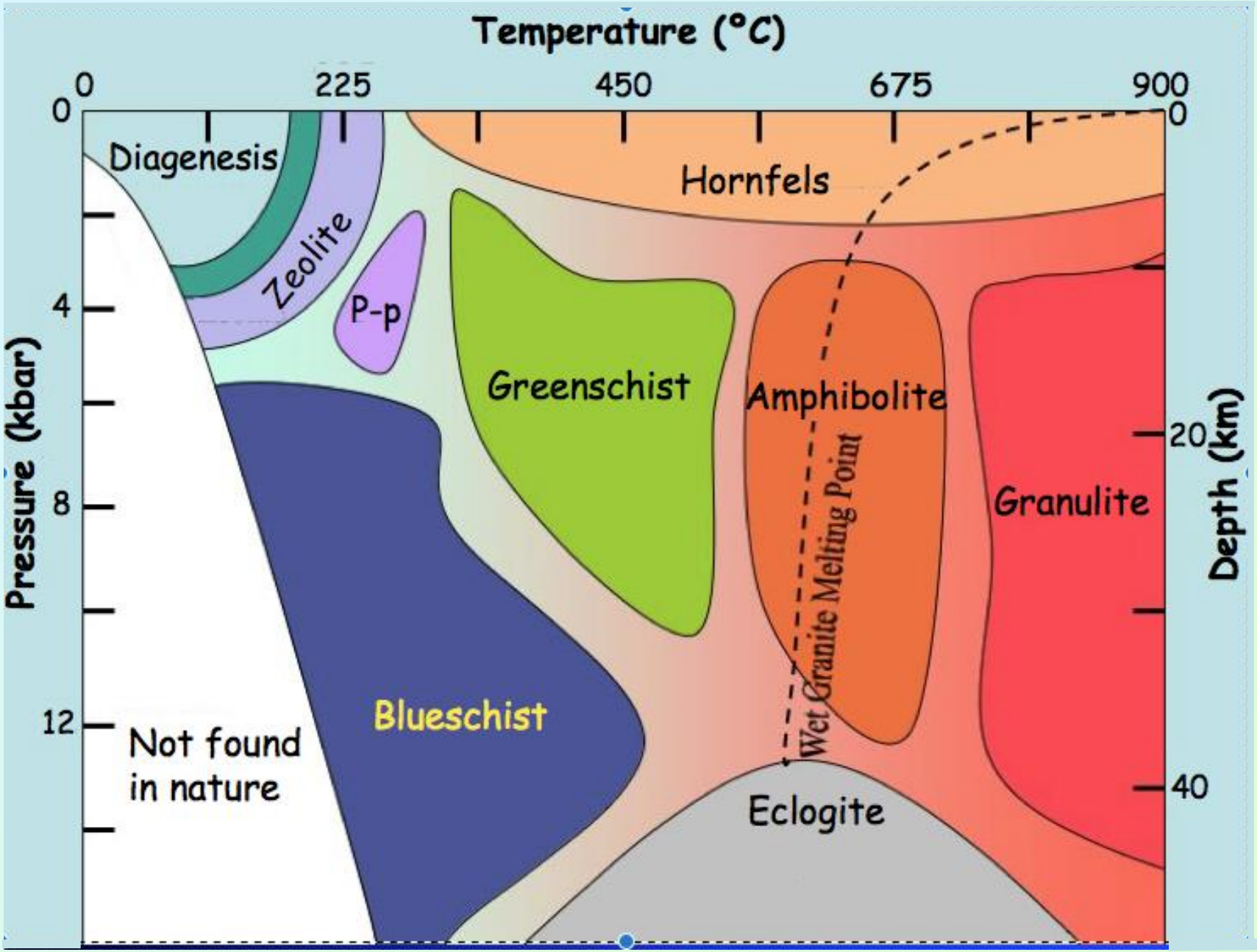
- Metamorphic grade can be defined because of occurrence of certain minerals that form at a specific metamorphic grade → index minerals

  e.g. with increasing temperature and pressure in shale

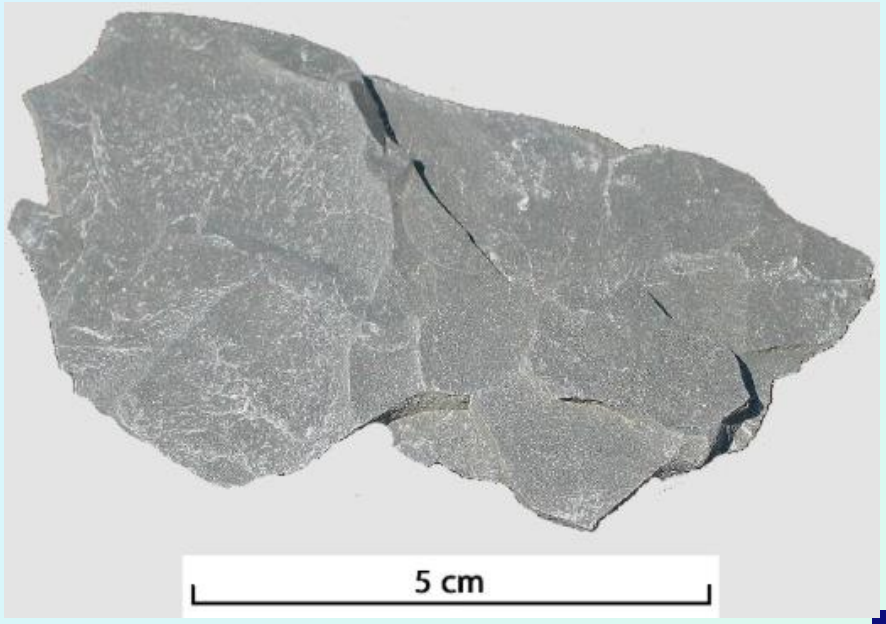
  chlorite → biotite → garnet → staurolite → kyanite → sillimanite

- metamorphic facies is defined by the set of mineral assemblages found in rocks of diverse composition but similar metamorphic grade

Metamorphic facies

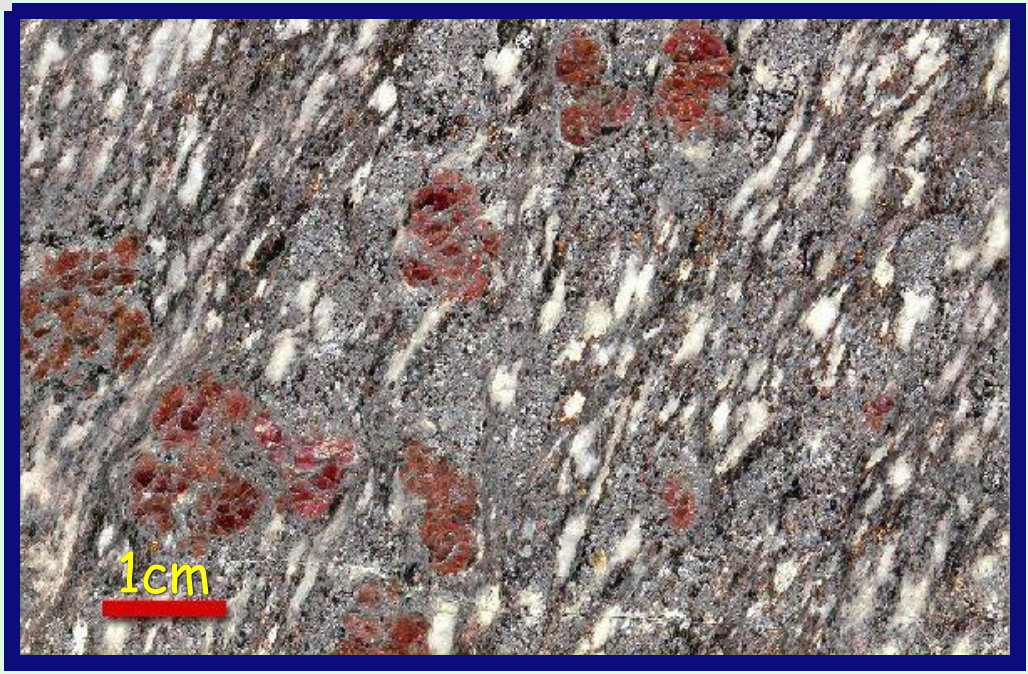


Mudstone → metamorphism → garnet gneiss



mudstone

garnet gneiss

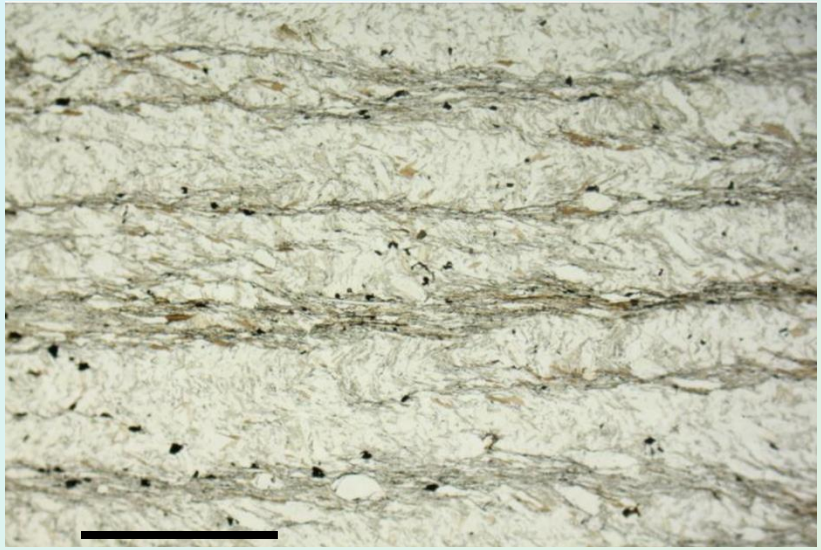


Slate

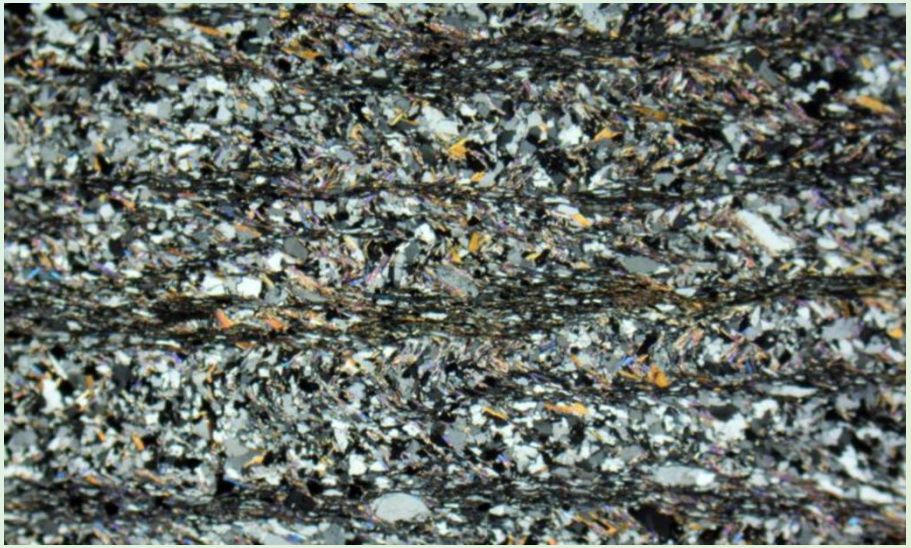
- Slate → low-grade, regional metamorphic rock formed by metamorphism of mudstone, shale or sometimes volcanic ash
- slate → characterised by foliation along which it breaks to leave smooth flat surface called slaty cleavage
- slate is mainly composed of quartz and muscovite and illite
- other minerals that may be present in slate include biotite, chlorite, hematite and pyrite
- slates may be black, blue, red, green or grey due to presence of graphite (black), hematite (red, purple) and chlorite (green)

Slate

Slate hand specimen



TS of slate PPL



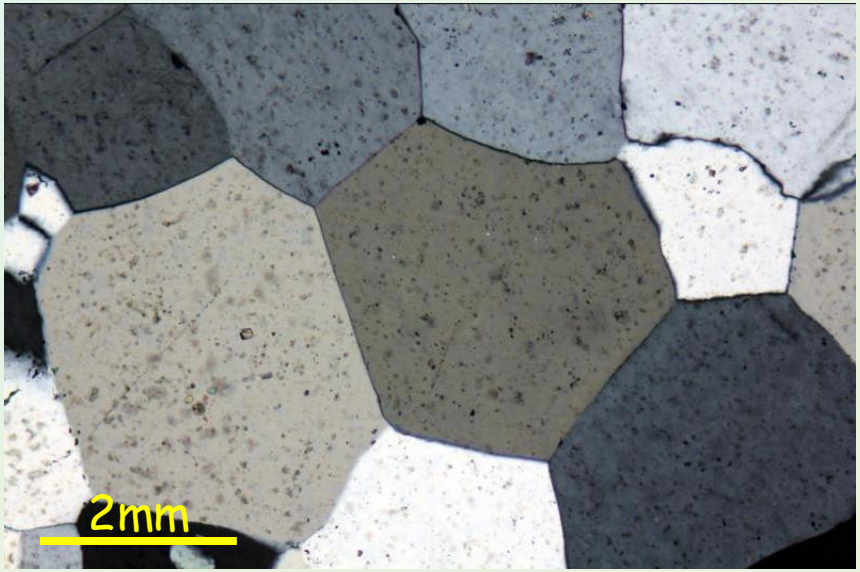
TS of slate XPL

Quartzite

- Quartzite → hard, non-foliated, contact or regional metamorphic rock that forms from a pure quartz sandstone or chert protolith
- metamorphism recrystallises the sand grains and silica cement that binds them together
- the result is a network of interlocking grains that form a hard, durable rock that breaks through quartz grains rather than along grain boundaries
- quartzite is usually white or grey in colour but impurities can produce red (Fe), orange, brown, green or blue

Quartzite

Quartzite hand specimen



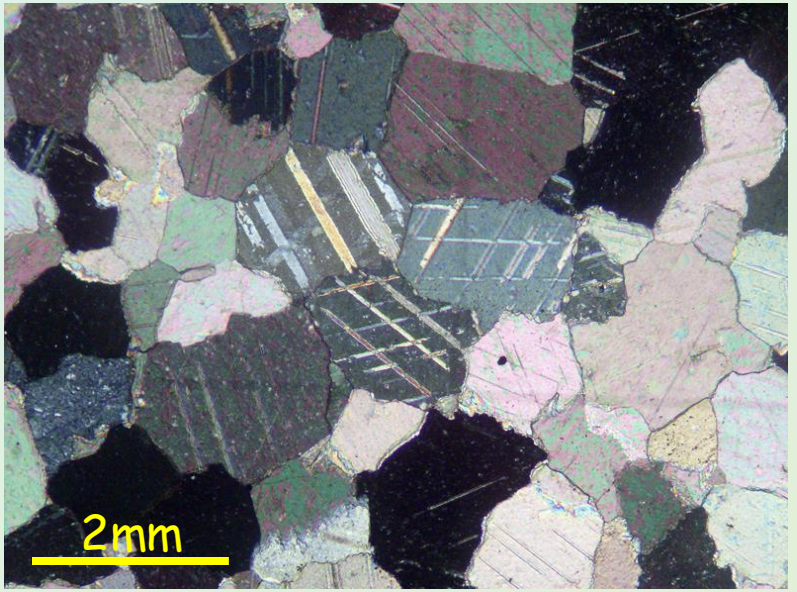
Thin section of quartzite XPL

Marble

- Marble → regional or contact metamorphic rock formed by recrystallisation of limestone or dolostone [$CaMg(CO_3)_2$]
- in early stages of limestone to marble transformation, calcite crystals in the rock are very small
- as metamorphism progresses, crystals grow larger to easily recognisable interlocking crystals
- recrystallisation usually obscures original fossils (if present) and sedimentary structures in protolith
- impurities in limestone can recrystallise during metamorphism resulting in mineral impurities (e.g. graphite, pyrite, quartz and Fe-oxides) or minor new minerals e.g. wollastonite (CaS)

Marble

Marble hand specimen



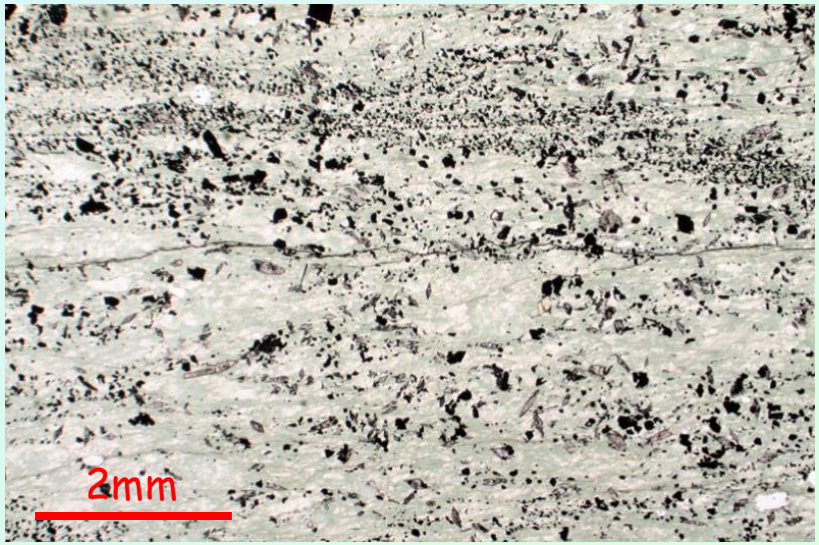
Thin section of marble XPL

Chlorite schist

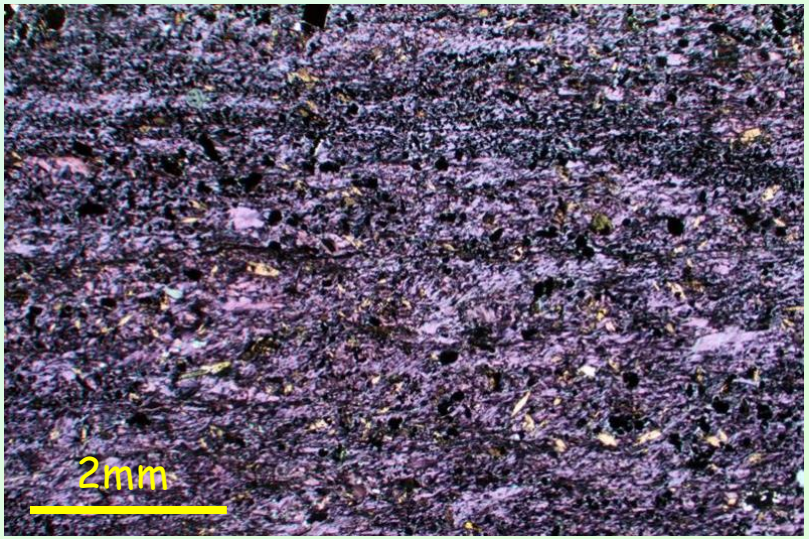
- Schist is a medium-grade, foliated regional metamorphosed shale, mudstone or mafic igneous rock
- chlorite schist→ medium-grade strongly foliated rock composed mainly of chlorite → green colour and platy texture
- can split into thin flakes or slabs due to well developed parallelism of >50% of minerals present
- individual minerals are discernible with the naked eye, distinguishing it from slate
- chlorite schist → typically formed by regional metamorphism of mafic igneous rocks e.g. basalt

Chlorite schist

Chlorite schist hand specimen



TS chlorite schist PPL



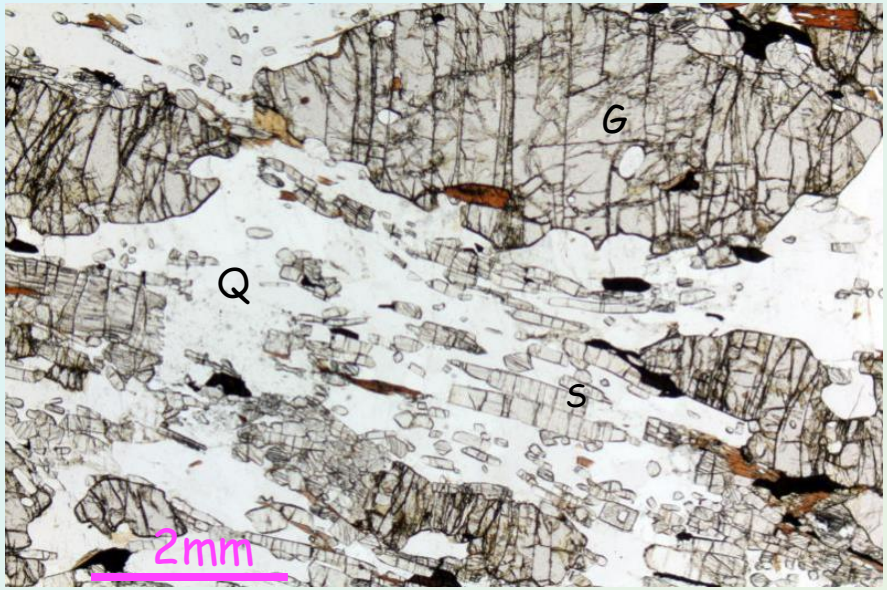
TS chlorite schist XPL

Garnet-sillimanite gneiss

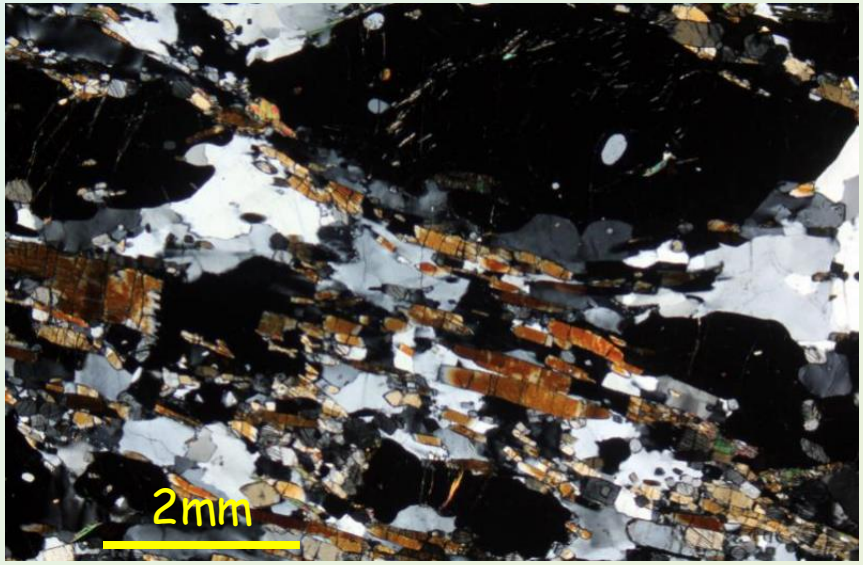
- Gneiss is a coarse-grained, medium to high-grade, regional metamorphic rock
- unlike schists, gneisses commonly show distinct compositional banding and a paucity of platy minerals
- garnet-sillimanite gneiss forms at high temperature (>600°C) and high pressure (>6Kb)
- protolith is shale or siltstone

Garnet-sillimanite gneiss

Garnet-sillimanite-gneiss hand specimen



Thin section of garnet-sillimanite gneiss PPL



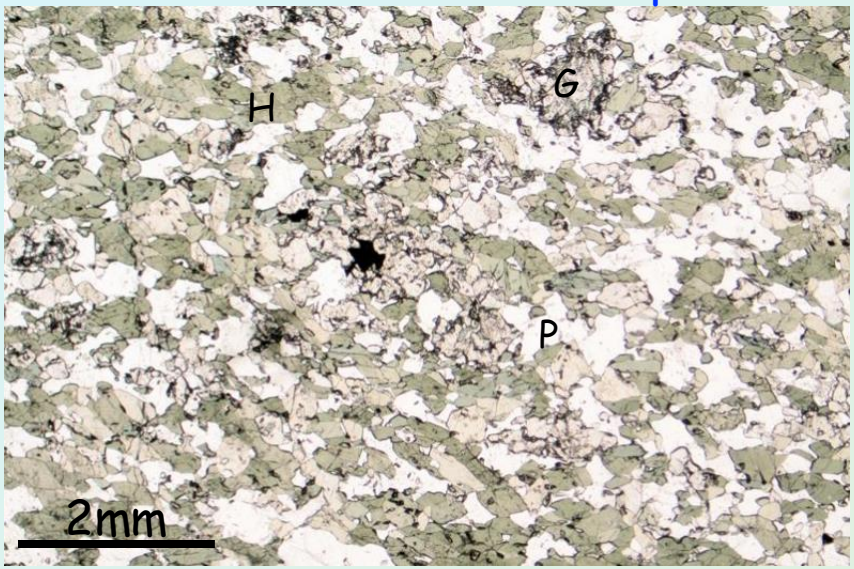
Thin section of garnet mica schist XPL

Amphibolite

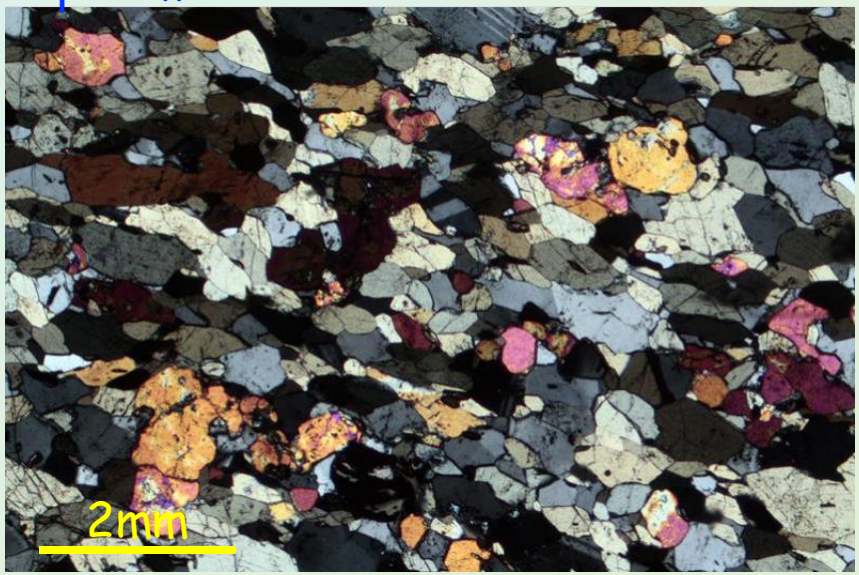
- Amphibolite → medium to coarse-grained regional metamorphic rock composed dominantly of minerals of the amphibole group (e.g. hornblende) and plagioclase
- may contain minor amounts of other metamorphic minerals such as biotite, epidote, garnet, wollastonite, andalusite, staurolite
- it is typically dark coloured with a weak foliation but may have a prominent lineation
- it can be produced through the metamorphism of mafic rocks such as basalt or from metamorphism of clay-rich sedimentary rocks
- amphibolite as a rock defines a particular set of temperature and pressures → amphibolite facies

Amphibolite

Amphibolite hand specimen



Thin section of garnet amphibolite PPL



Thin section of garnet amphibolite XPL