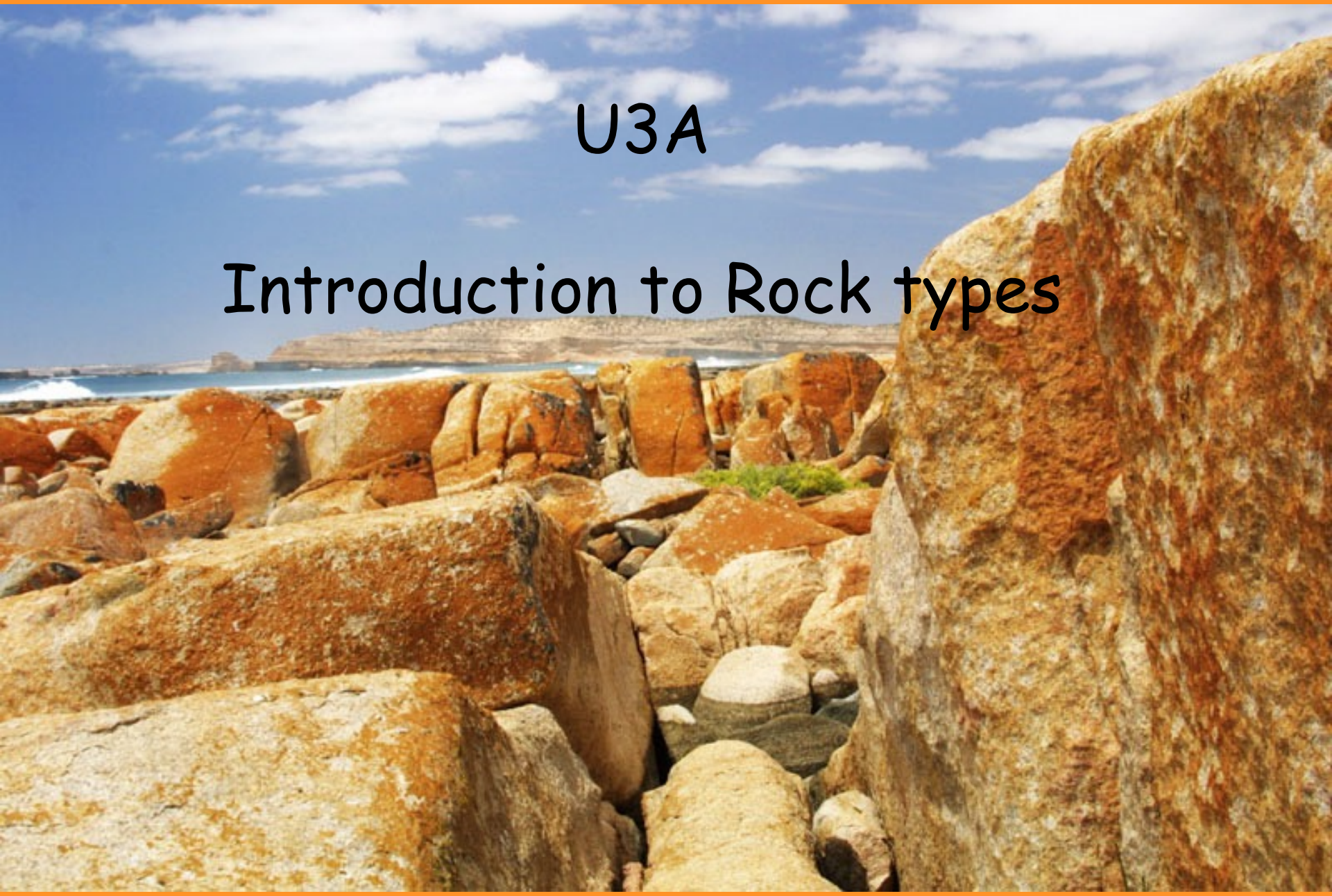


U3A

Introduction to Rock types

Rocks

- A rock is any naturally occurring aggregate of one or more minerals
- rocks don't normally contain a large number of different mineral species
- mostly these are silicate minerals, but they may be other minerals e.g. limestones are composed of carbonates,
- small amounts of other minerals (accessories) e.g. oxides, phosphates

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

Ambiguous rock types

Migmatite – mixture of igneous and metamorphic rocks

Wind deposited volcanic ash

Igneous rocks

- Igneous rocks are formed by the cooling and solidification (usually by crystallisation) of a melt
- molten rock material is called magma
- magmas are generated in the mantle and lower continental crust
- most magma produced is intruded into the Earth's crust

Granite

1cm

Magma generation

- Formed by partial melting

  (1) in upper mantle

  (2) lower continental crust

- strongly contrasting temperatures, rheologies and chemistry

- extruded magma (lava) → cools quickly → fine-grained rocks

  intruded magma → cools very slowly → coarse-grained rocks

Environments of igneous rock formation

- Extrusive or volcanic rocks
  - Formed from lava erupted onto the surface of the Earth
  - rapid cooling - fine grained textures ± vesicles

- Intrusive rocks
  - Formed by injection into other rocks - intrusions
  - crystallise beneath the surface of the Earth
  - slow cooling → coarse-grained textures
  - the deeper the intrusion → the slower the cooling rate

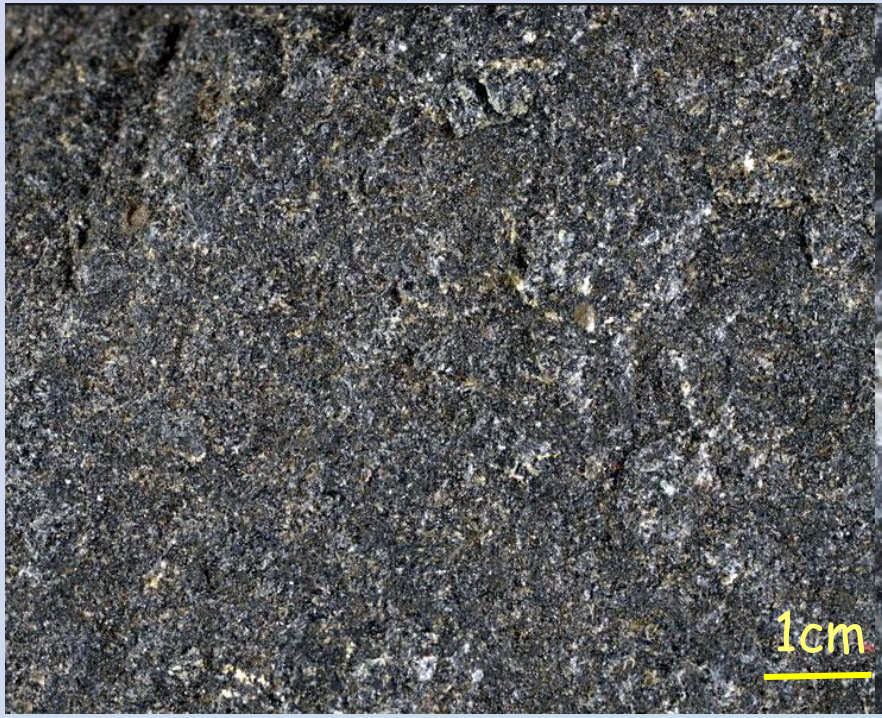
Grain-size is independent of composition

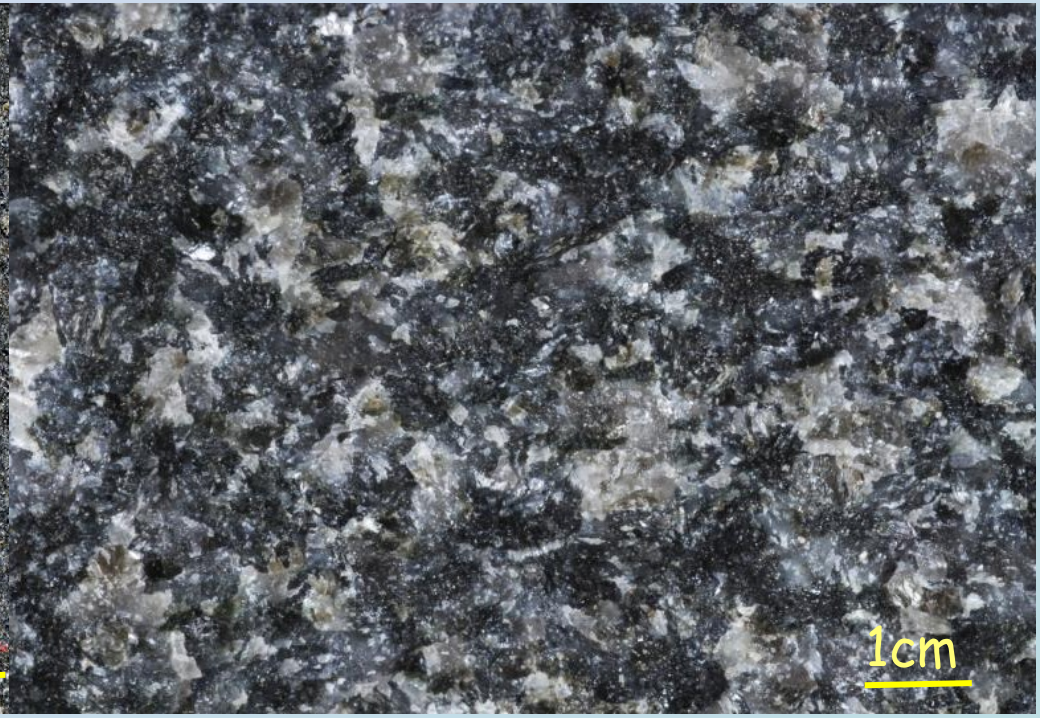
Grain-size → important parameter in classifying igneous rocks

Effect of cooling rate on grain-size

volcanic

intrusive





Basalt (fine-grained)

Gabbro (coarse-grained)

Classification of Igneous Rocks

Classification may be based on:

- Rock texture

  - Mainly based on the relative sizes of the grains

  → reflecting the mode of the formation of the rock

and

- Rock composition

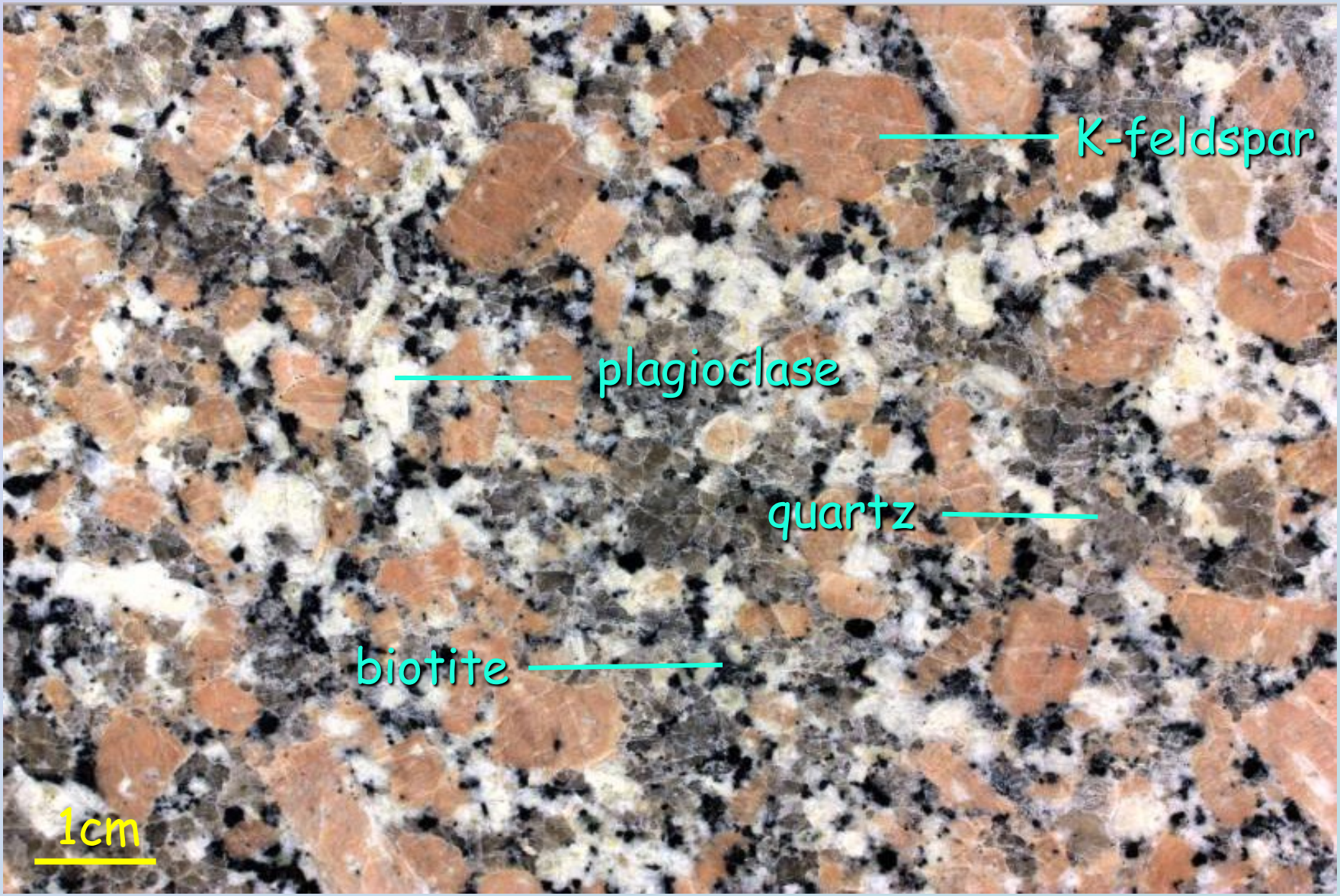
  - Mineral composition or,

  - chemical composition

Extrusive igneous rocks

Volcano erupting basaltic lava, Kilhauea, Hawaii

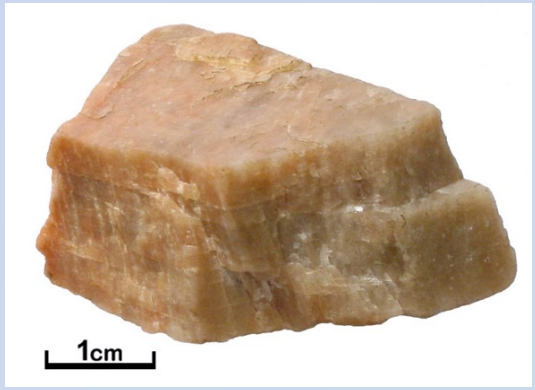
Intrusive igneous rocks



Igneous intrusive rock ⇒ granite

Common minerals in igneous rocks

plagioclase feldspar
$(Na,Ca)(Si,Al)_3O_8$



K-feldspar
$KAlSi_3O_8$

biotite mica
$K(Mg,Fe)_3(Si_3Al)O_{10}(OH,F)_2$

quartz
SiO_2

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

olivine
$(Fe,Mg)_2SiO_4$

Rocks undersaturated with respect to silica

There are a group of uncommon igneous rocks that have low silica contents that are undersaturated with respect to silica. These rocks contain one or more mineral species that are called feldpathoids

$$KAlSi_3O_8 - SiO_2 \rightarrow KAlSi_2O_6$$

orthoclase leucite

$$NaAlSi_3O_8 - SiO_2 \rightarrow NaAlSi_2O_6$$

albite nepheline

Characteristic features of igneous rocks

(1) Zoned crystals

(2) porphyritic texture

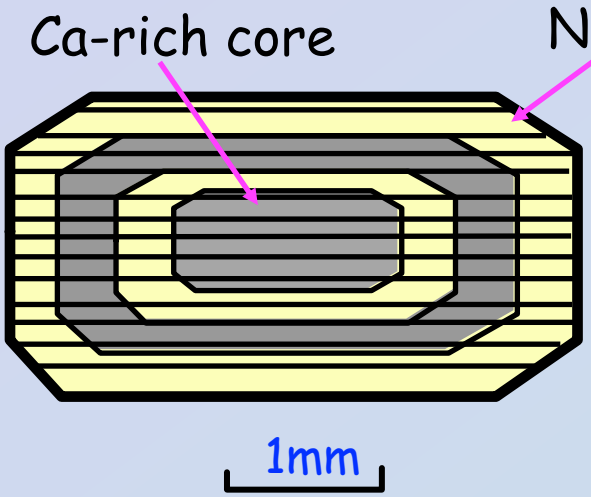
(3) even distribution of coarse interlocking crystals

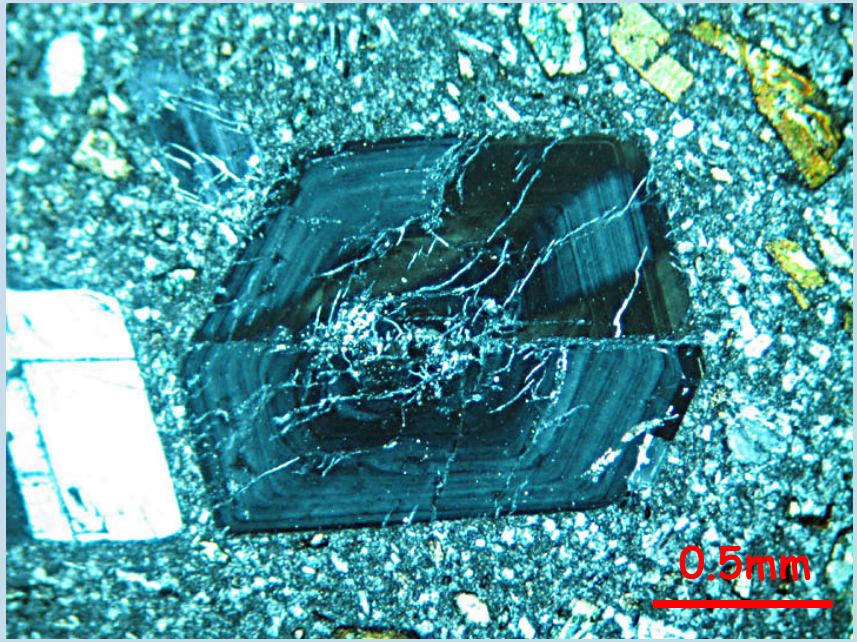
(4) gas bubbles (vesicles)

(5) glassy textures

Zoned crystals

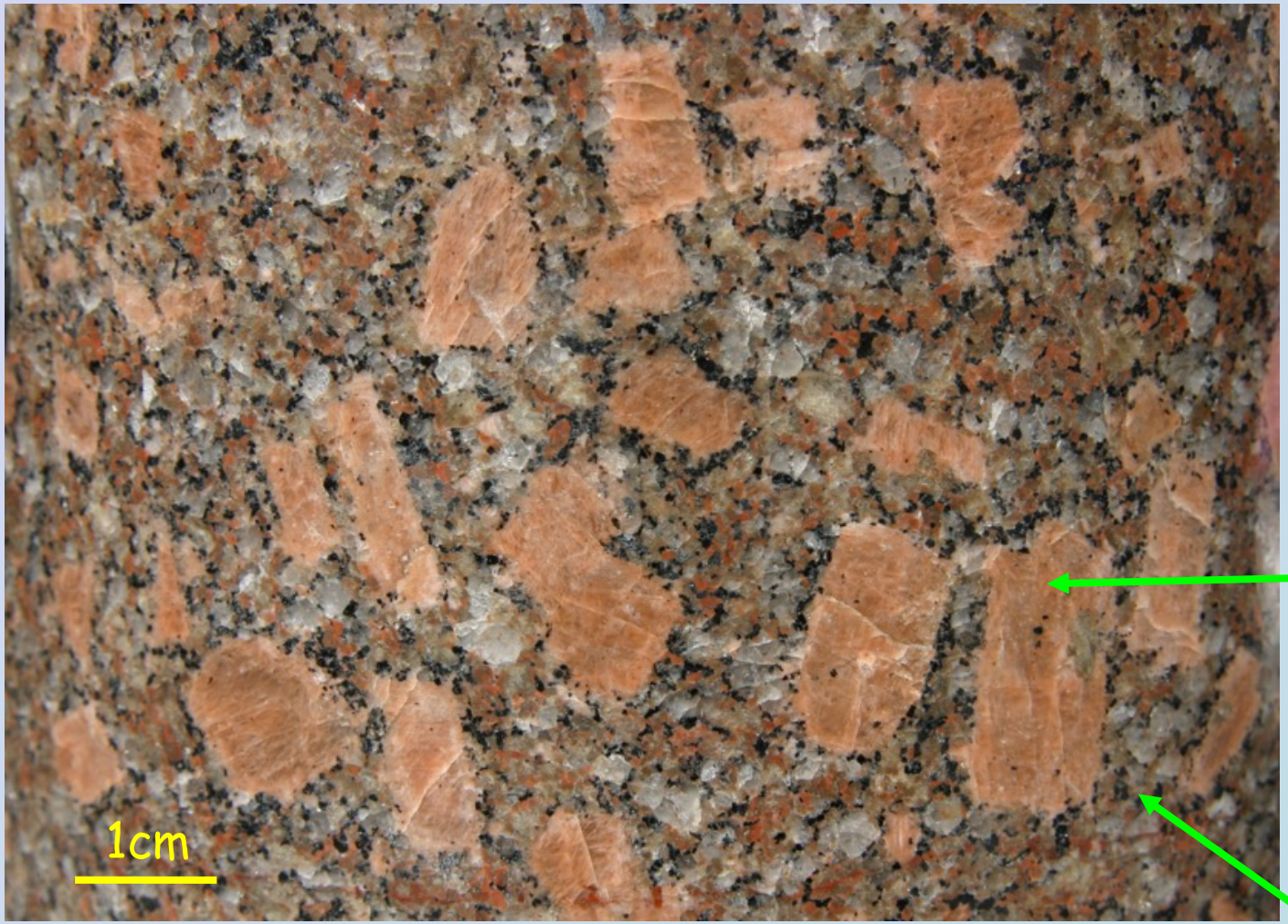
e.g. zoned plagioclase





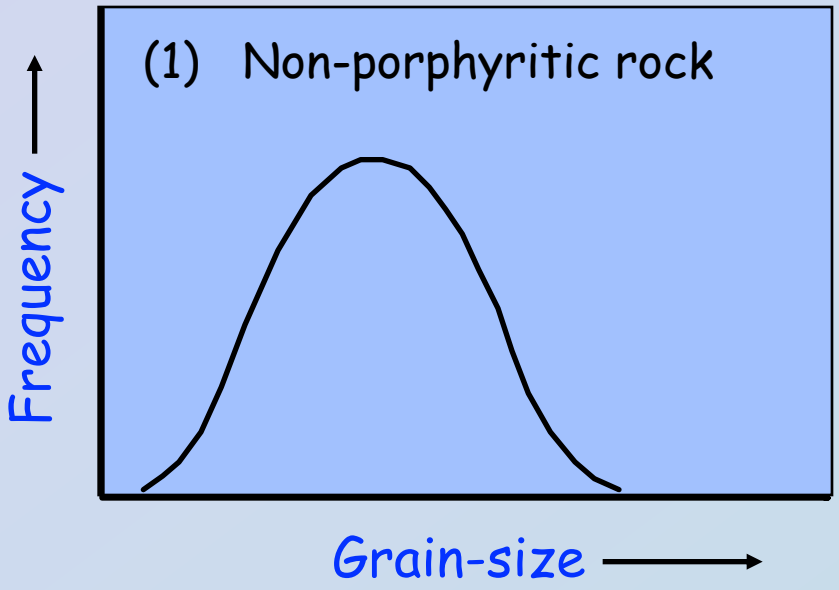
Photomicrograph zoned plagioclase
Crystal. Crossed polars

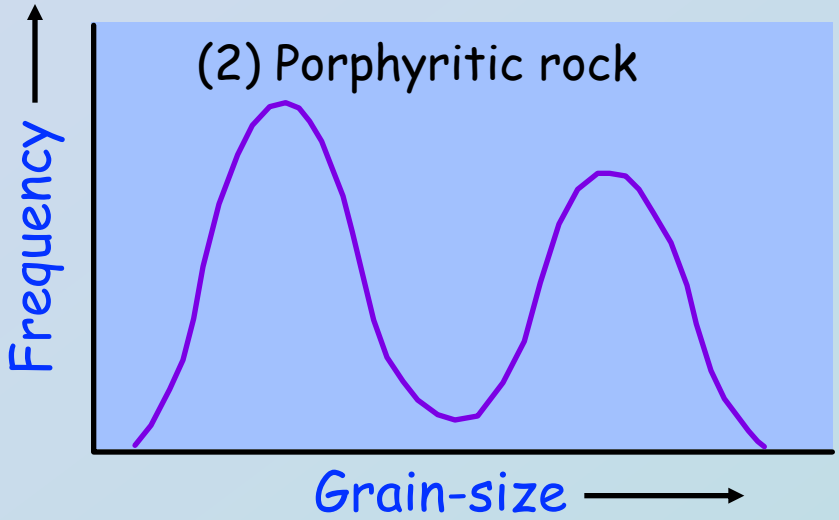
Porphyritic texture



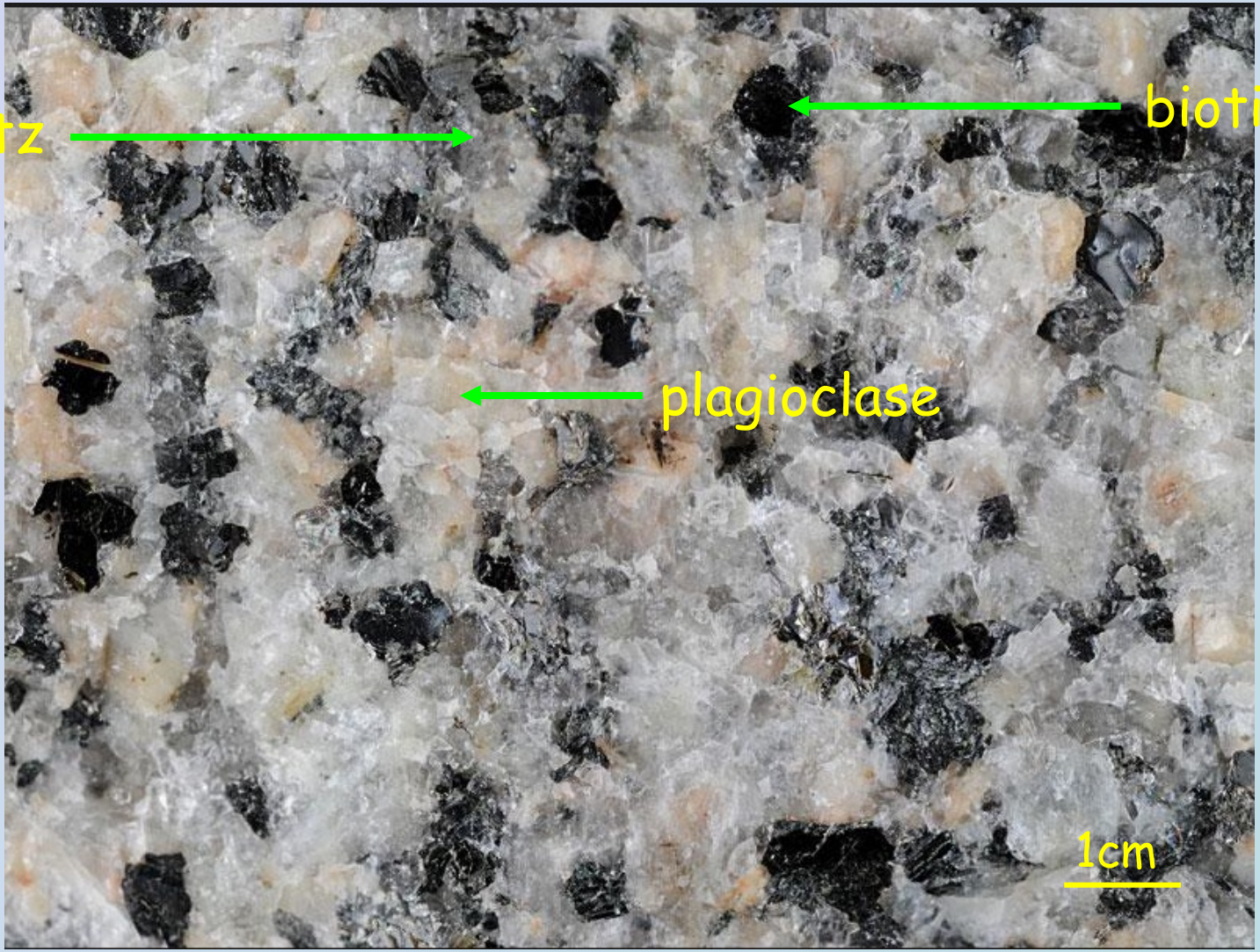
Porphyritic granite

Distribution of grain-size in igneous rocks





Even distribution of coarse interlocking crystals



Tonalite

Vesicles

Vesicular olivine basalt

Glassy textures

Obsidian

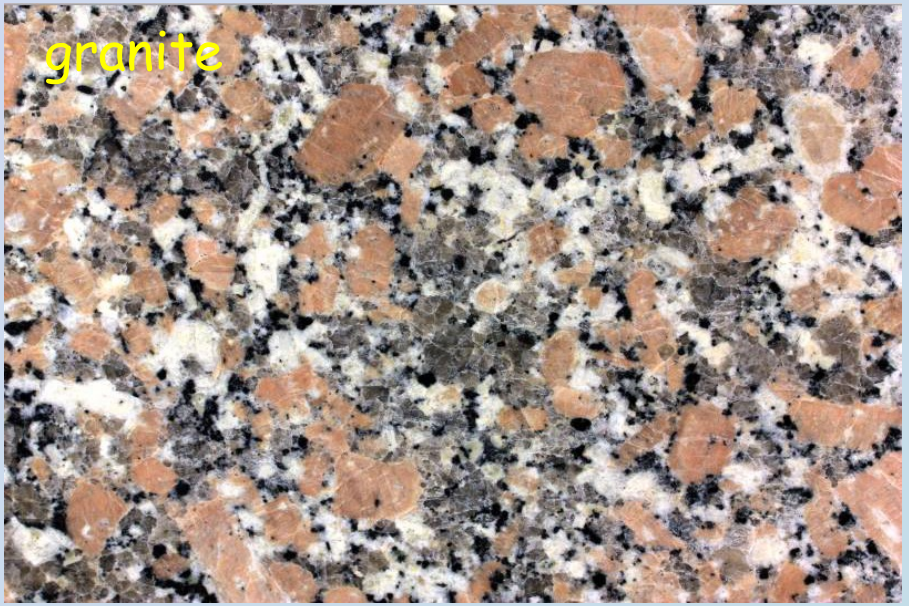
Grain-size

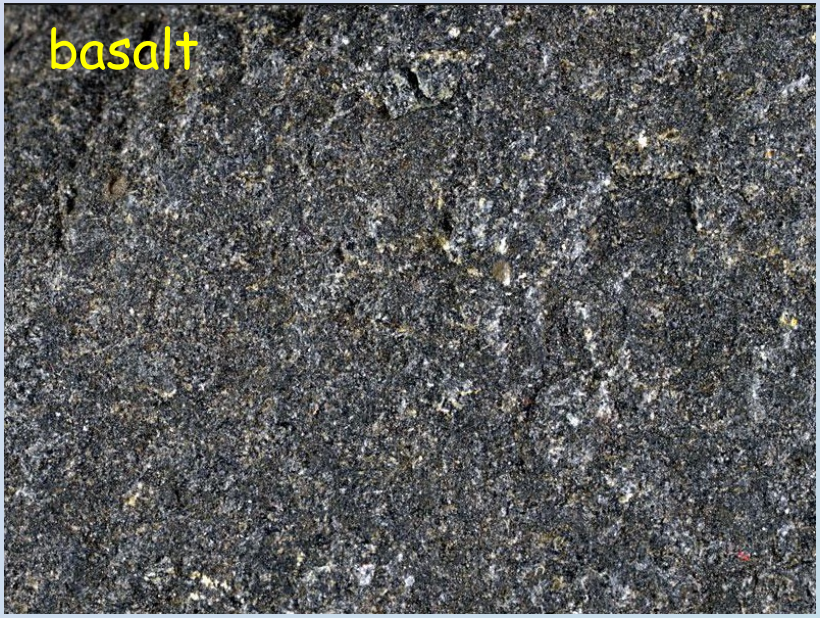
Grain-size implies the cooling history of the rock

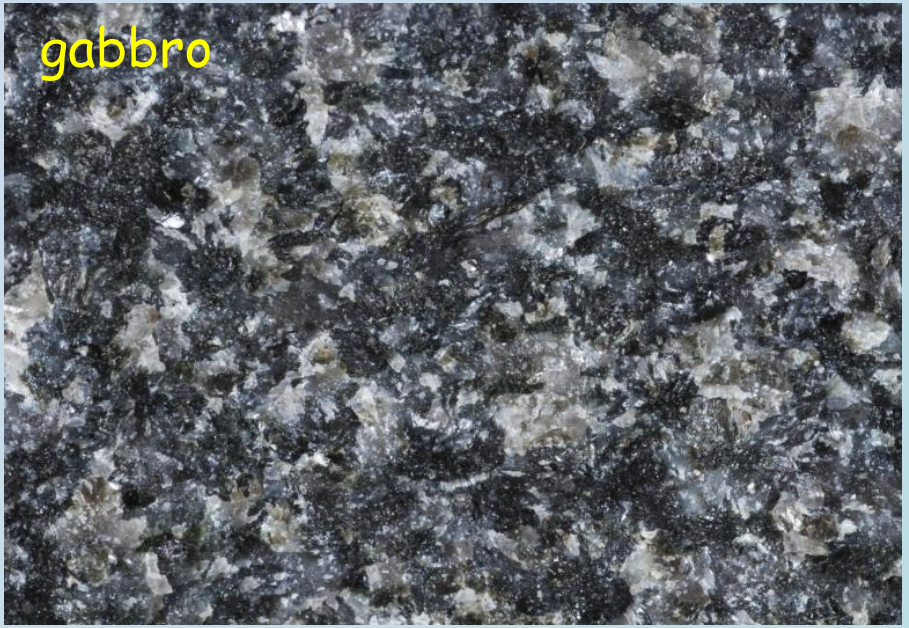
glass	→	extremely rapid cooling
fine crystals	→	rapid cooling
coarse crystals	→	slow cooling
porphyritic texture	→	dual cooling history

Description	Grain-size
Very-coarse grained	>2cm
Coarse-grained	5mm - 2cm
Medium-grained	1 - 5mm
Fine-grained	<1mm

Grain-size contrast







Mineral composition

Mineral species and their abundances are used in the classification of igneous rocks

(a) Abundance of quartz

(i) Rocks containing quartz are oversaturated with respect to silica (SiO_2)

(ii) Rocks containing feldspathoids are undersaturated

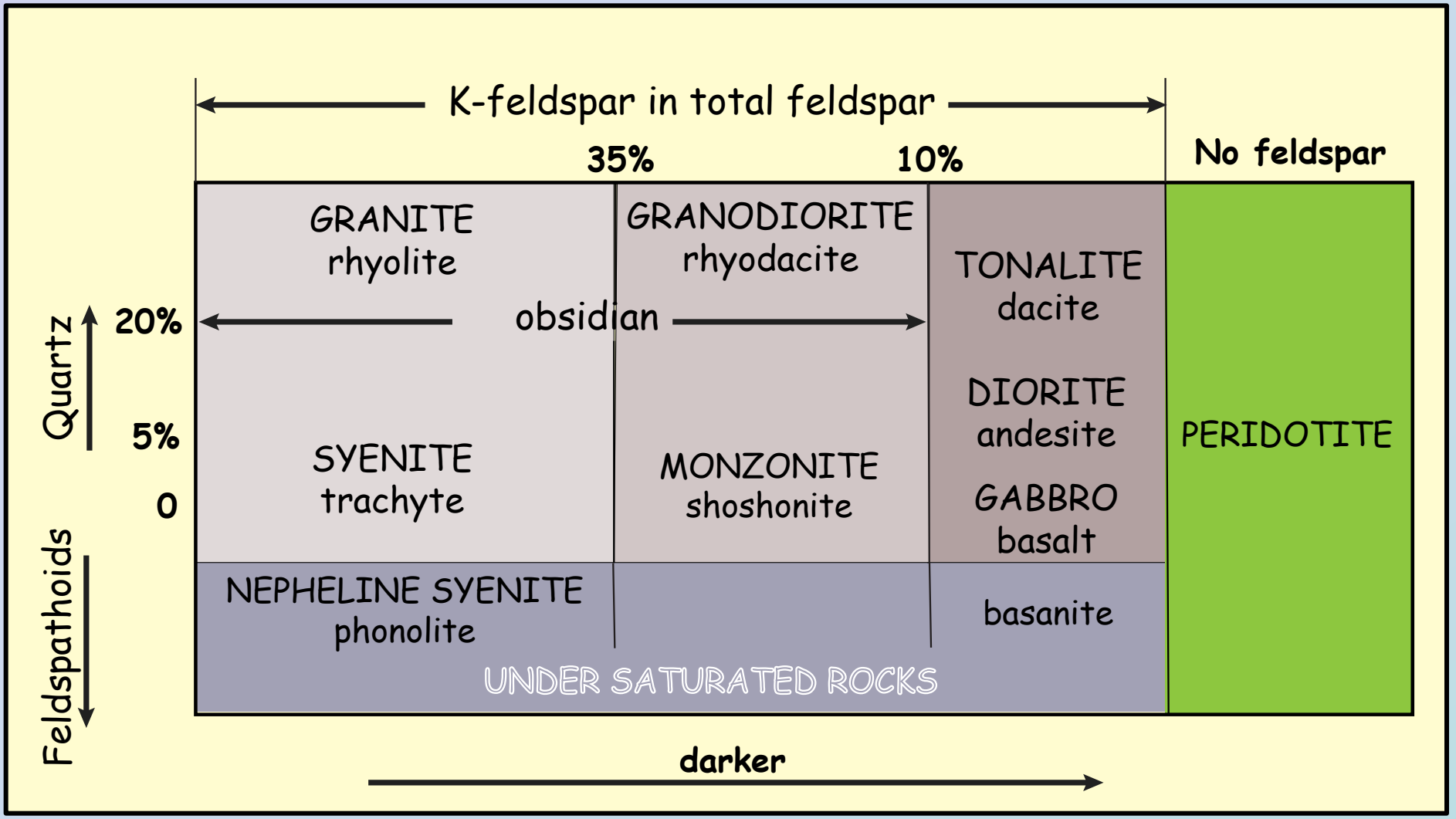
(iii) Olivine does not occur with quartz

Quartz is vitreous, lacks cleavage usually appears grey.

(b) Relative proportions of plagioclase feldspar and alkali feldspar

(c) Dark (mafic) mineral content (olivine, pyroxenes, amphiboles, biotite)

Igneous rock classification chart



Sedimentary rocks

Sedimentary rocks form at the Earth's surface by surface processes under low temp/press. conditions. They can be aggregates deposited by a transporting medium such as water, wind, ice or deposits of organic material or chemical precipitates

Coarse sandstone

1cm

Categories of sedimentary rocks

Sedimentary rocks are classified by texture and, the composition of the constituent particles

- Clastic sedimentary rocks
  - Rocks made up of rock and mineral fragments
  - sub-divided by grain-size: gravel, sand, silt, clay
- Organic rocks

  Rocks made up of accumulated organic matter

  e.g. fossiliferous limestone, coal
- Chemical rocks

  Rocks formed as chemical precipitates

  e.g. evaporites (halite, gypsum)

Types of sedimentary rocks

Detrital (clastic) sedimentary rocks

e.g. conglomerate, breccia, sandstone, mudstone

Chemical sedimentary rocks

e.g. halite, limestone, dolostone, gypsum, chert

Organic sedimentary rocks

e.g. coal, fossiliferous limestone, chert

Hybrid sedimentary rocks

e.g. Fossiliferous calc arenite

Quaternary conglomerate, Cyprus

Layers of shale interbedded with sandstone, Stirling, UK

Organic Rocks

Organic rocks differ in composition and texture from clastic sedimentary rocks

- Organic limestone
  - most common of organic rocks
  - composed of shells and skeletal material made up of calcium carbonate ($CaCO_3$) - fossil material
  - most common non-clastic, sedimentary rock type
  - some limestones are clastic – fragmental debris
  - organic limestones → great variety of textures

Fossiliferous limestone, Yass, NSW

Organic limestone – White Cliffs of Dover

Organic Rocks

- Coal

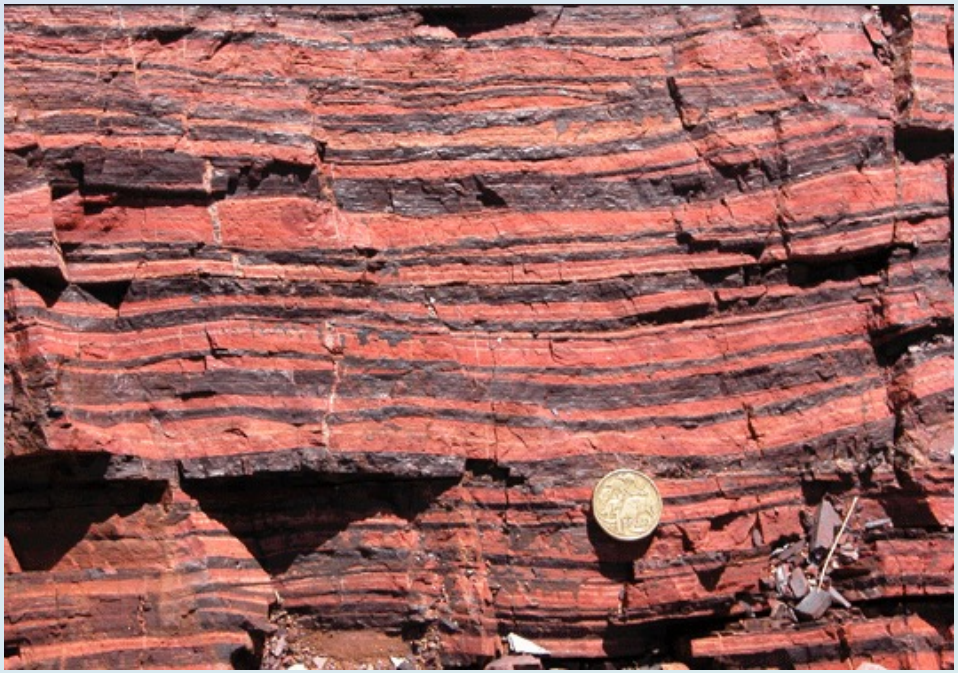
  - formed of accumulated plant material in shallow water conditions
  - accumulates in anoxic swamps with little input of clastic materials
  - slow subsidence contemporaneous with deposition required for thick sequences to form
  - important fossil fuel, especially for power generation

Chemical sedimentary rocks

- Chemical limestones
  - can form in warm, shallow seas
  - evaporation leads to precipitation of fine lime mud
  - can also form as dripstone in limestone caves (stalagtites, stalagmites, flowstone) and around springs (travertine, tufa)
- Silica rocks
  - form as precipitates around hot springs in volcanic areas e.g. Pamukkale, Turkey; precipitation in very deep ocean
- Evaporites
  - a group of chemical precipitates formed by evaporation of sea water or in salt lakes
  - include halite (NaCl) and gypsum ($CaSO_4.2H_2O$)
  - important indicators of hot climates

Gypsum deposited in saline lake,

Lake Torrens, South Australia



Banded iron formation, Pilbara region, WA

Origin of clastic sedimentary rocks

- Weathering
  - the chemical and mechanical breakdown of rocks

- Transport
  - the movement of sediment over the face of the Earth
  - involves a transporting medium - wind, water or ice

- Deposition
  - the process whereby sediment is laid down
  - occurs in a wide variety of sedimentary environments

- Compaction and cementation
  - processes that occur after deposition to transform loose sediment into solid rock
  - due to pressure of overlying sediment, and chemical action within pore fluids

Gravel deposits in braided stream, Waimakariri, NZ

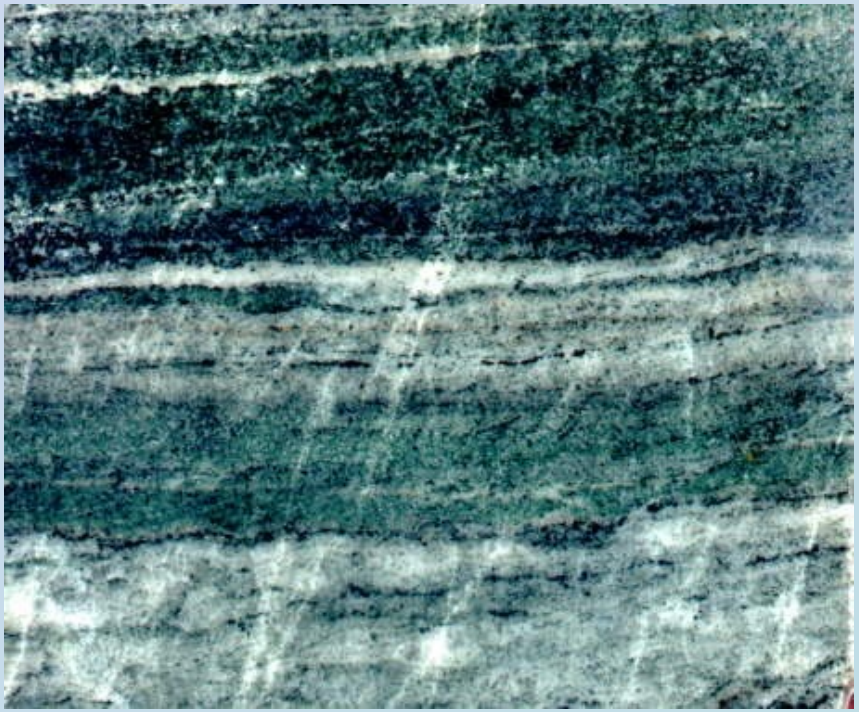
Metamorphic rocks

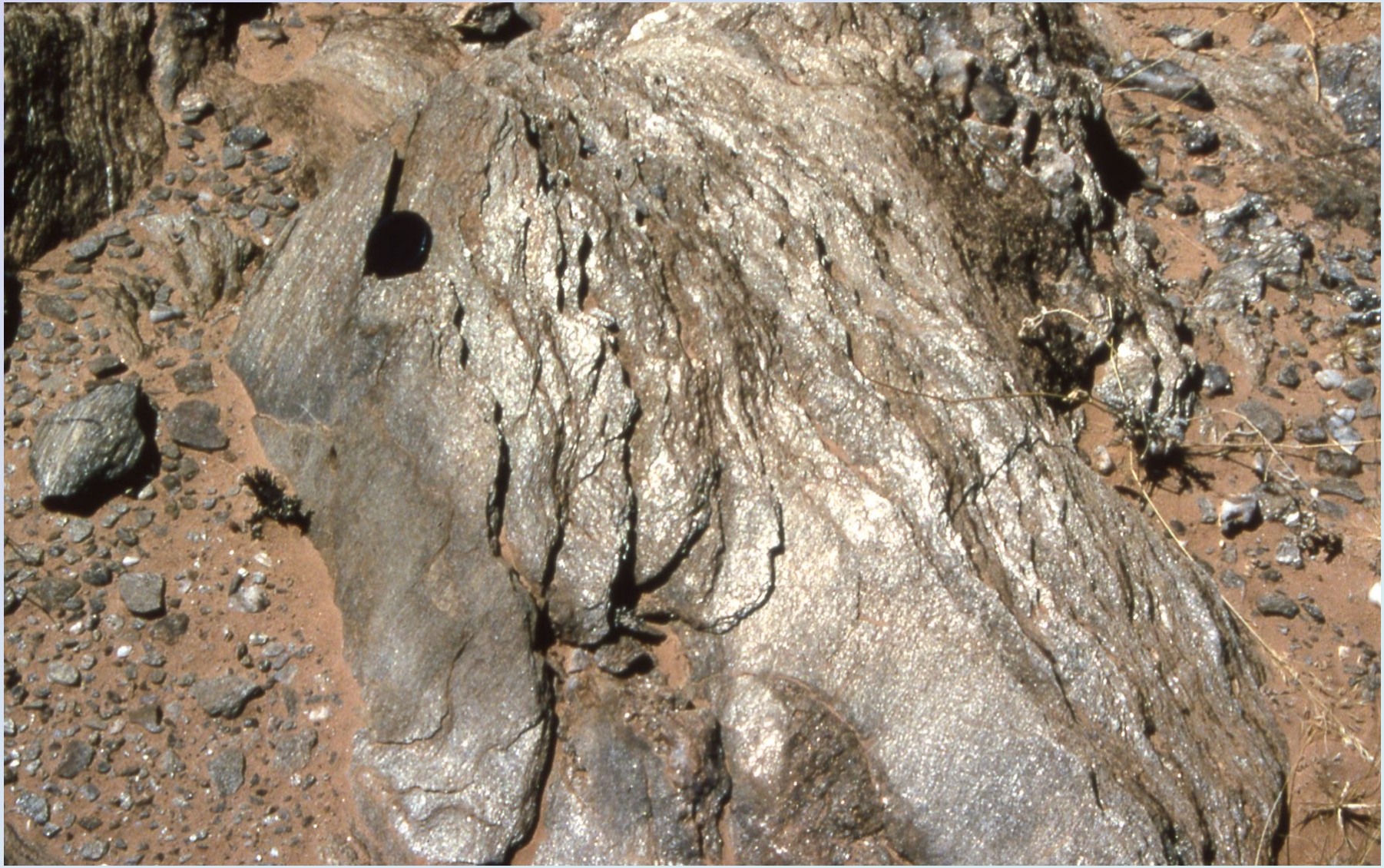
- Metamorphic rocks form from the transformation of pre-existing rocks as a result of prolonged exposure to temperature and pressure conditions different to those at which they originally formed
- mineral transformations are common with change in the physical environment
- great variety of metamorphic rocks → reflects range in physical conditions
- original features of protolith often completely obliterated

Metamorphic rocks

Metamorphic rocks form chiefly by solid-state changes due to recrystallisation and deformation of pre-existing rocks under high temperature and pressure conditions. Often accompanied by new mineral growth

Gneiss





Mica schist outcrop, Namibia

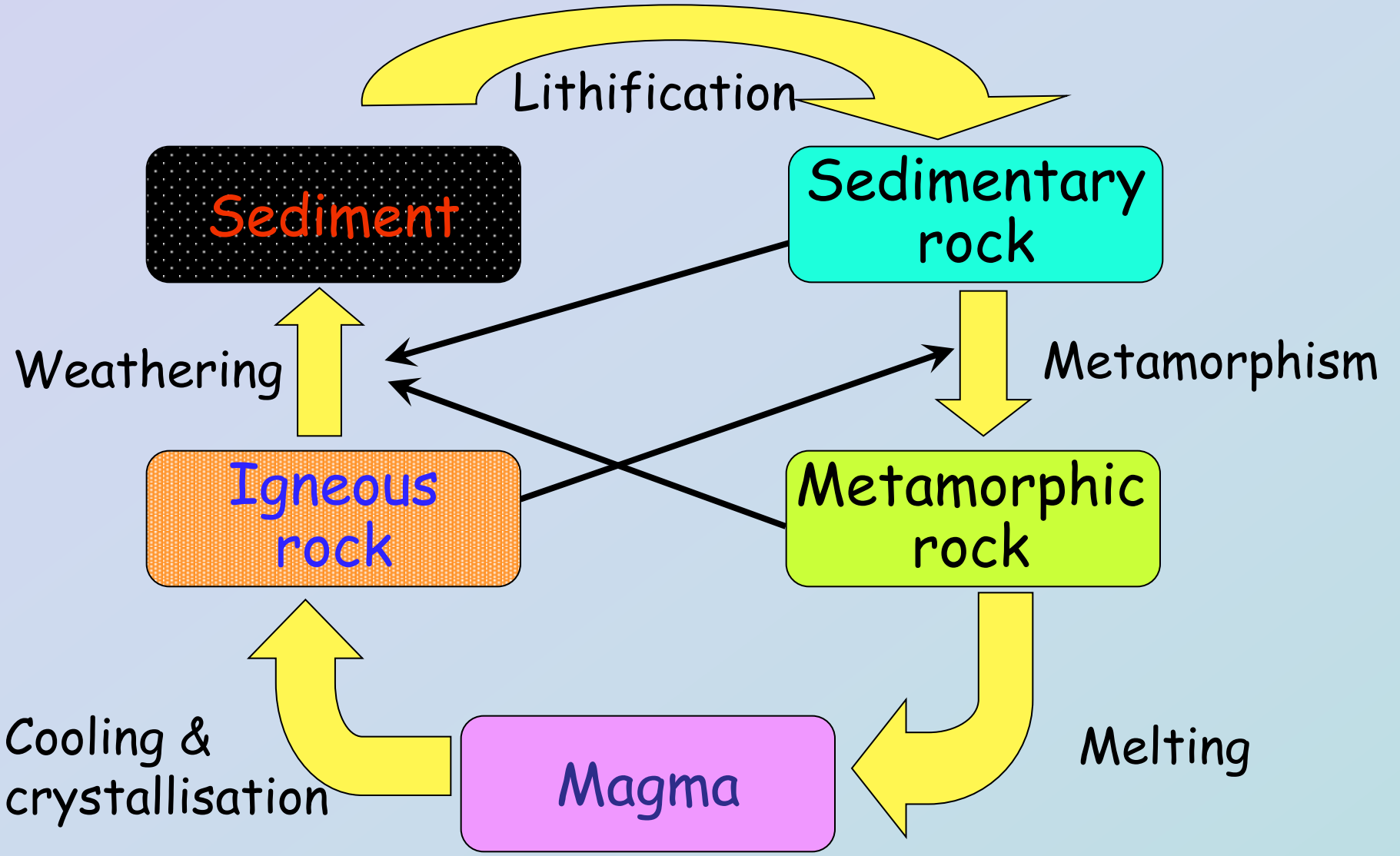
Garnet gneiss, Agucha, India

Migmatitic gneiss, Wyoming, USA

The rock cycle

- All of the rock groups are related in a broad cycle
- all newly formed rocks are produced from the recycling of older rocks
- the basic rock groups may form from each other in response to changes in their physical environment
- the cycle can be repeated but not all rocks go through the entire cycle

The rock cycle



Sediment to igneous rock

- Build up of sedimentary pile → deep burial → temperature and pressure increase → recrystallisation and clay minerals transform into new minerals (e.g. chlorite, micas, aluminosilicates) → metamorphic rock → deeper burial → further heating → partial melting → generation of magma → igneous rock

- melting also occurs in mantle (100-300km depth) → basaltic magma

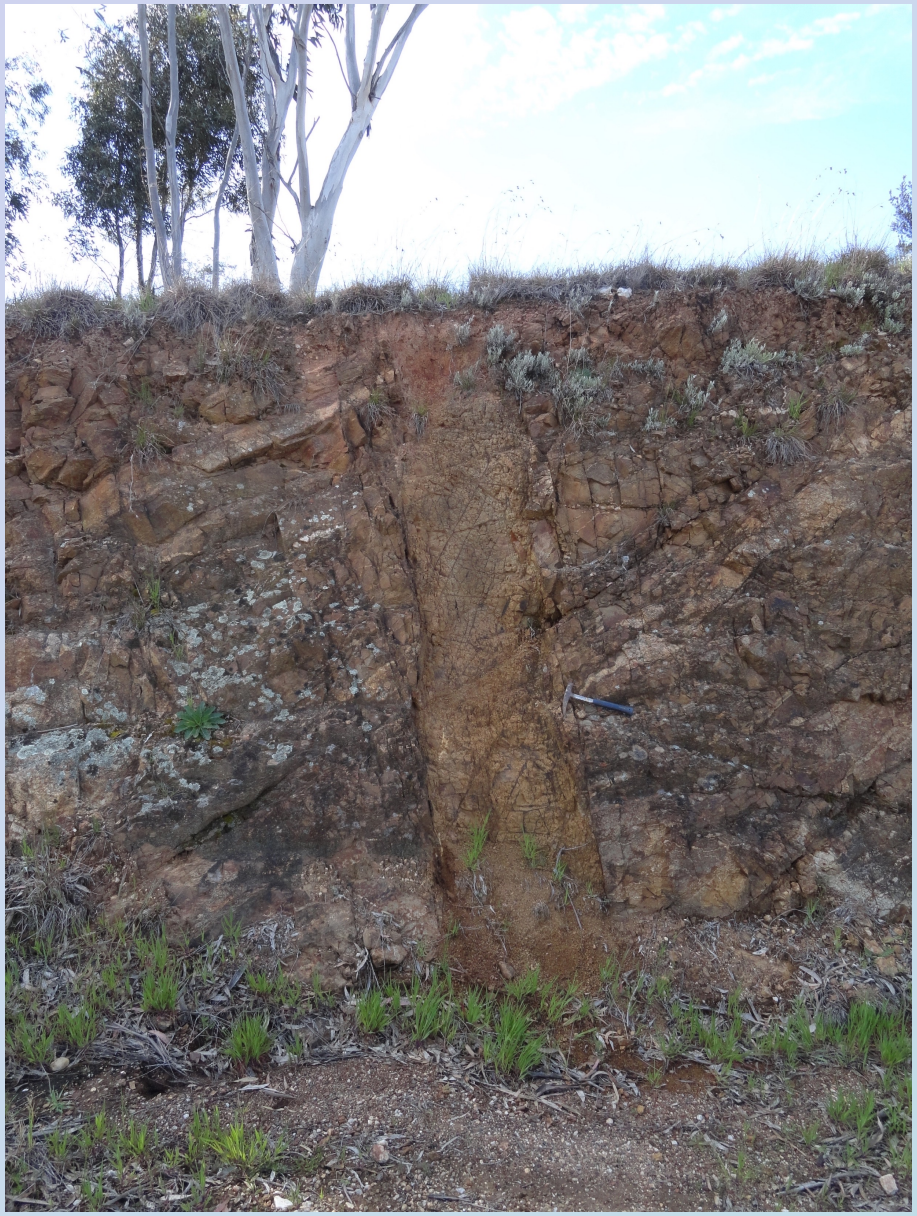
Distinction of fundamental types

Three main ways of discriminating between rock types:

- Field Relationships
  - eg. sedimentary layering/metamorphic layering
  - cross-cutting relationships of intrusive igneous rocks
- Mineralogy
  - eg. high temperature minerals typically igneous rocks
  - low temperature minerals $\Rightarrow$ sedimentary rocks
  - certain minerals only occur in metamorphic rocks
  - zoned crystals largely confined to igneous rocks
- Grain relationships (rock textures)
  - eg. crystals forming from melt $\Rightarrow$ good crystal shapes
  - metamorphic rocks often have poorly shaped crystals

Sedimentary layering in Grand Canyon sequence, USA

Compositional layering in gneiss, Kangaroo Is., S Aust



Tertiary basalt dyke cutting Ordovician sedimentary rocks, Benambra, Vic