Recording features of metamorphic rocks

A **metamorphic rock** is a result of a transformation of a pre-existing **rock**. The original **rock** is subjected to heat and pressure, which cause obvious physical and/or chemical changes.

Types of metamorphism

- Regional extent (over a wide area)

- Orogenic metamorphism (T, P, active fluids)
- Ocean floor metamorphism (T)
- Subduction zone metamorphism (HP/LT)
- Burial metamohism (LT/LP)

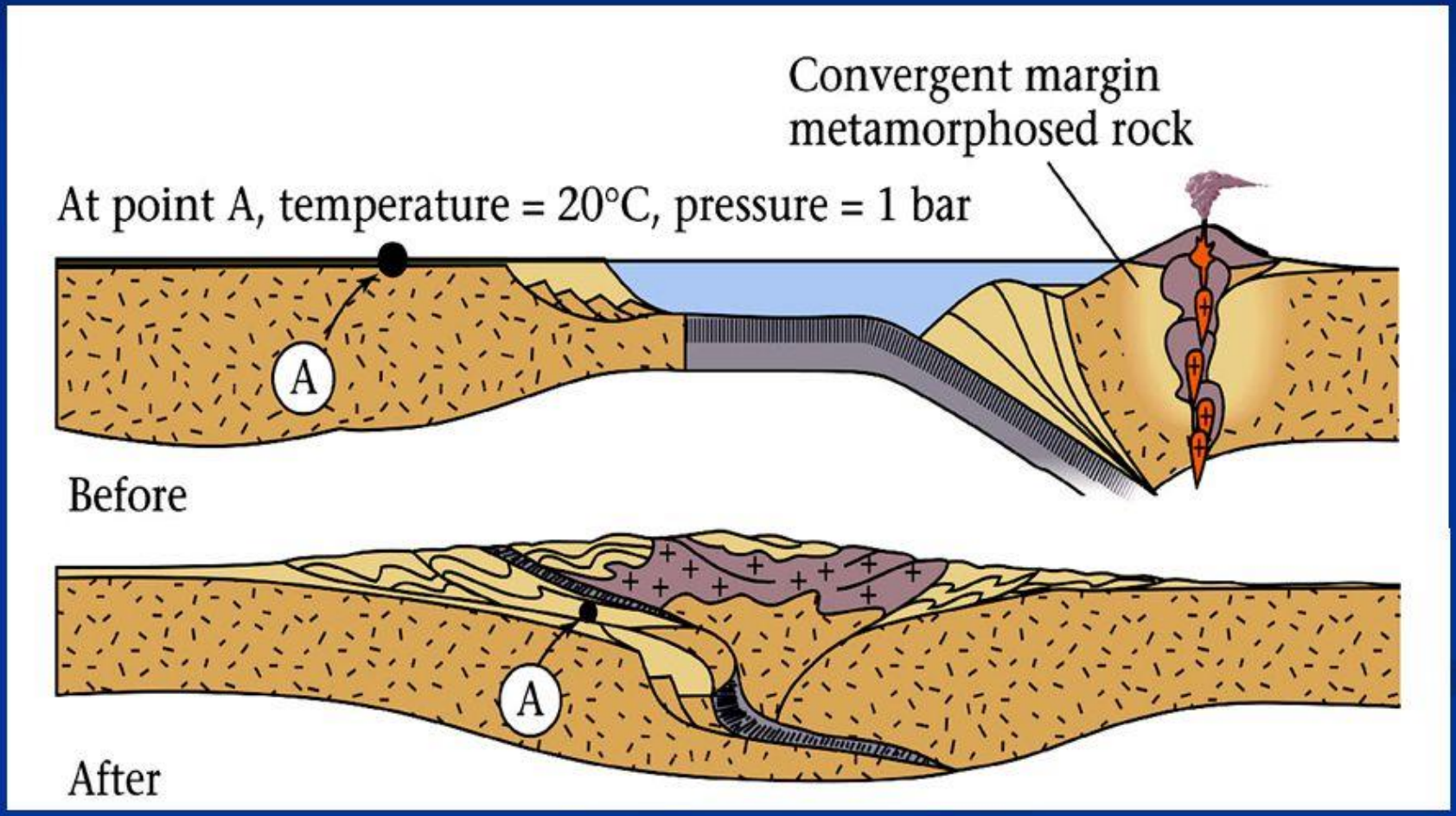
- Local extent (local area)

- Contact or thermal metamorphism (T)
- Cataclastic or shear zone metamorphism (P)
- Hydrothermal metamorphism (active fluids)
- Impact or shock metamorphism (extreme P-T)

Orogenic metamorphism

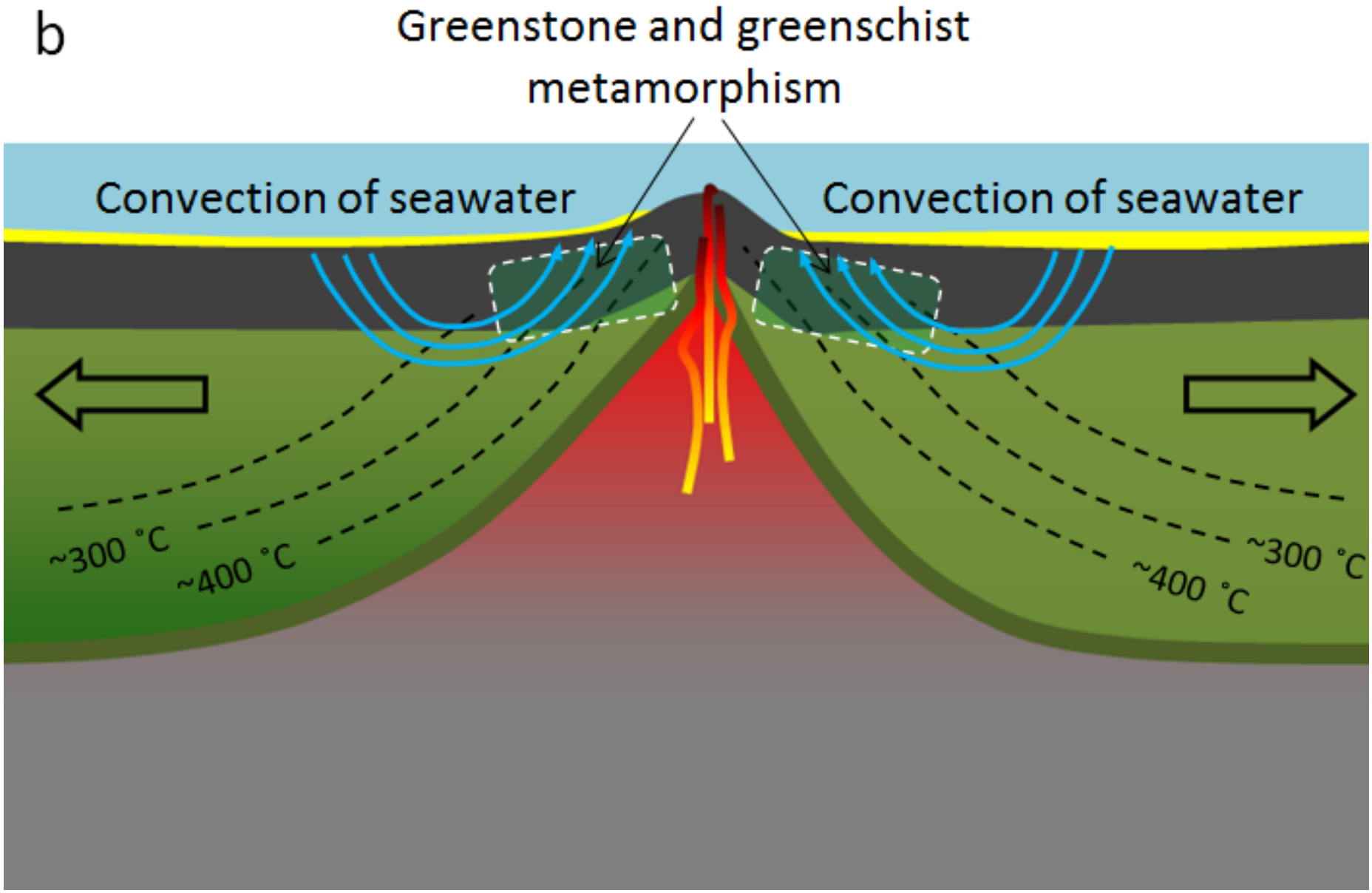
Is the most common type of **metamorphism**. It commonly occurs in island arcs and near continental margins because **orogenic** belts typically form at convergent plates boundaries. Understanding **orogenic metamorphism** leads to the understanding of the thermal, burial and erosion cycle of any **orogeny**.

Orogenic Metamorphism



Ocean floor metamorphism

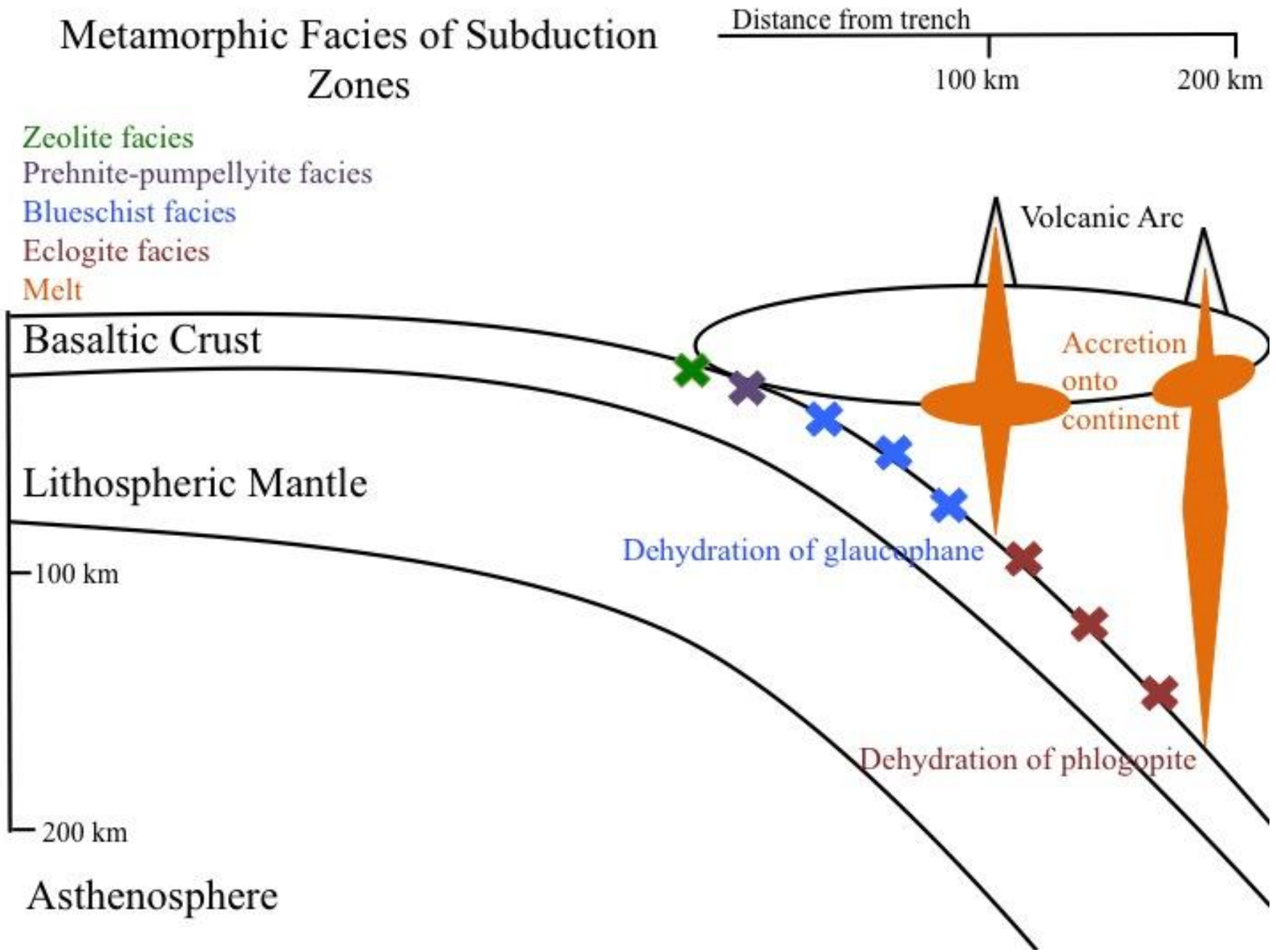
is a concept that has arisen from recent studies of present oceanic ridges and fracture zones where new crust is being generated, altered, and deformed. Recognition of on-land ophiolite suites as ancient examples of oceanic crust and mantle provide insights into the thermal and dynamothermal regimes that characterize ocean floors.

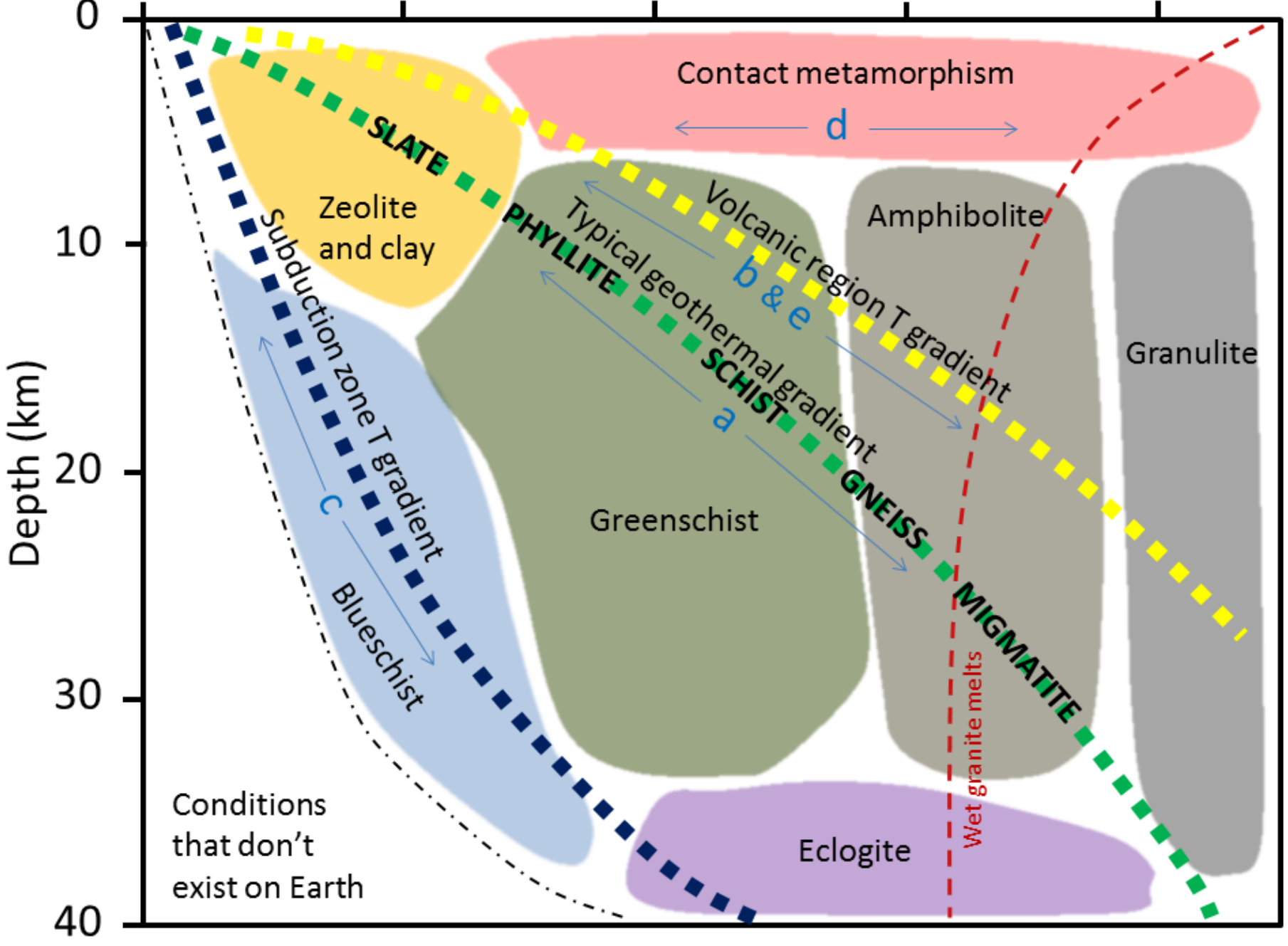

b
Greenstone and greenschist metamorphism
Convection of seawater
Convection of seawater
~300 ˚C
~400 ˚C
~300 ˚C
~400 ˚C

Subduction zone metamorphism

- Subduction zone metamorphism is characterized by a low temperature, high-ultrahigh pressure metamorphic path through the zeolite, prehnite-pumpellyite, blueschist, and eclogite facies stability zones of subducted oceanic crust

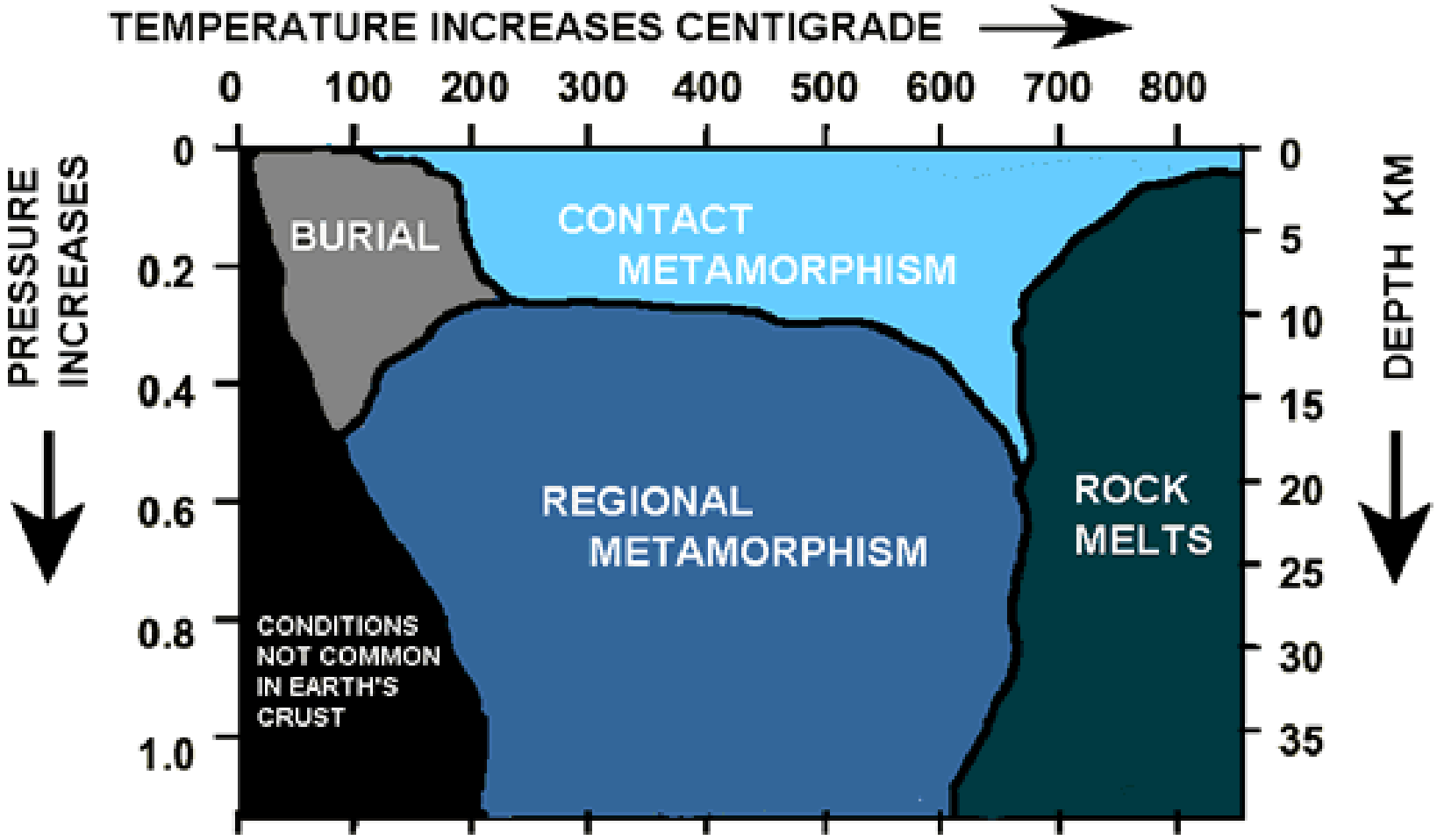
Metamorphic Facies of Subduction Zones




Depth (km)
0
10
20
30
40
Contact metamorphism
d
SLATE
Zeolite
and clay
Volcanic region T gradient
Typical geothermal gradient
b & e
PHYLLITE
Amphibolite
Granulite
SCHIST
a
GNEISS
Greenschist
MIGMATITE
Subduction zone T gradient
c
Blueschist
Wet granite melts
Eclogite
Conditions
that don't
exist on Earth

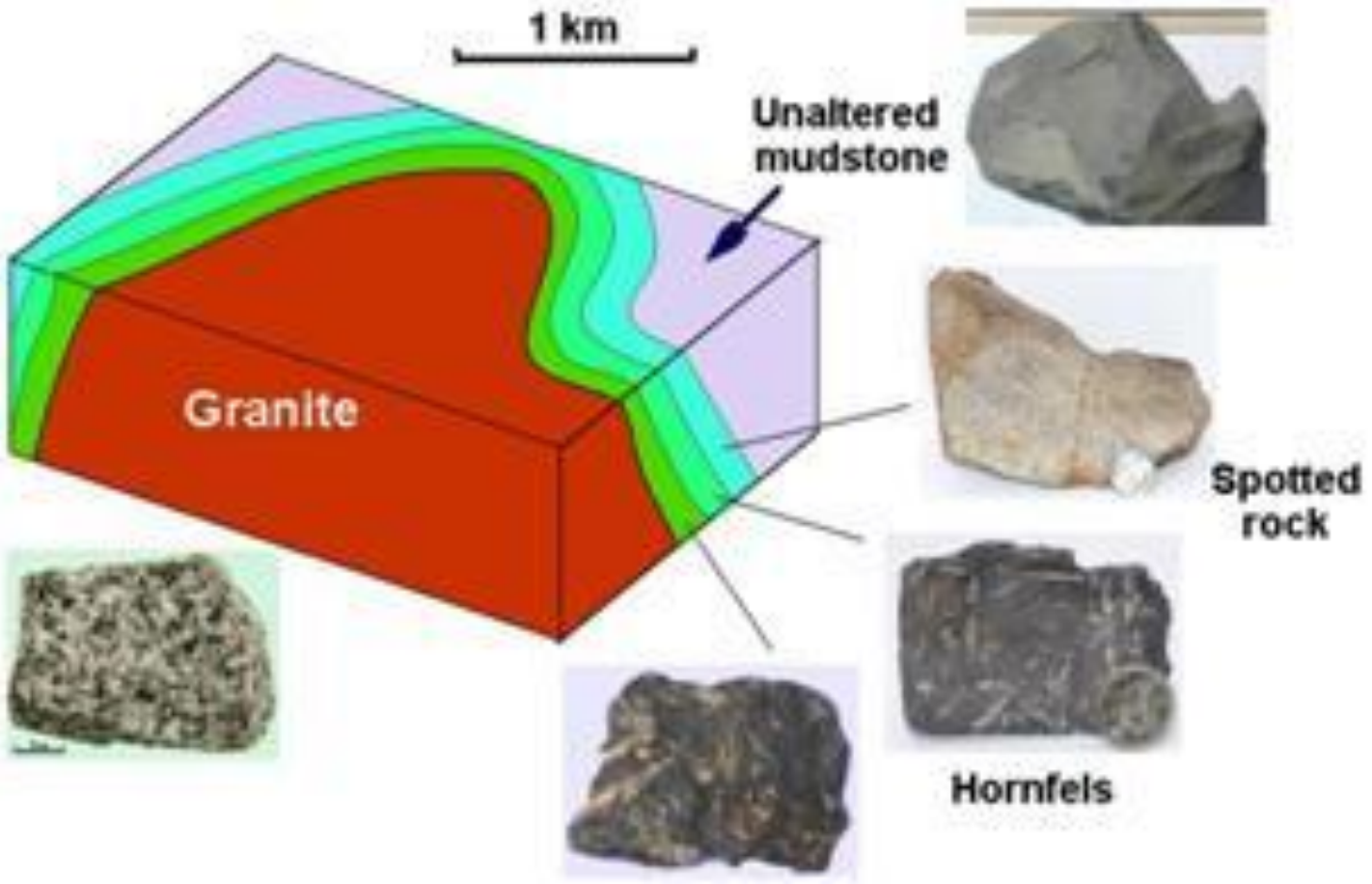
Burial metamorphism

- occurs when sedimentary rocks that had undergone diagenesis are buried even deeper. Diagenesis grades into **burial metamorphism**, a relatively mild type of **metamorphism** resulting from the heat and pressure exerted by overlying sediments and sedimentary rocks.


TEMPERATURE INCREASES CENTIGRADE
0
100
200
300
400
500
600
700
800
PRESSURE INCREASES
0
0.2
0.4
0.6
0.8
1.0
DEPTH KM
0
5
10
15
20
25
30
35
BURIAL
CONTACT METAMORPHISM
REGIONAL METAMORPHISM
ROCK MELTS
CONDITIONS NOT COMMON IN EARTH'S CRUST

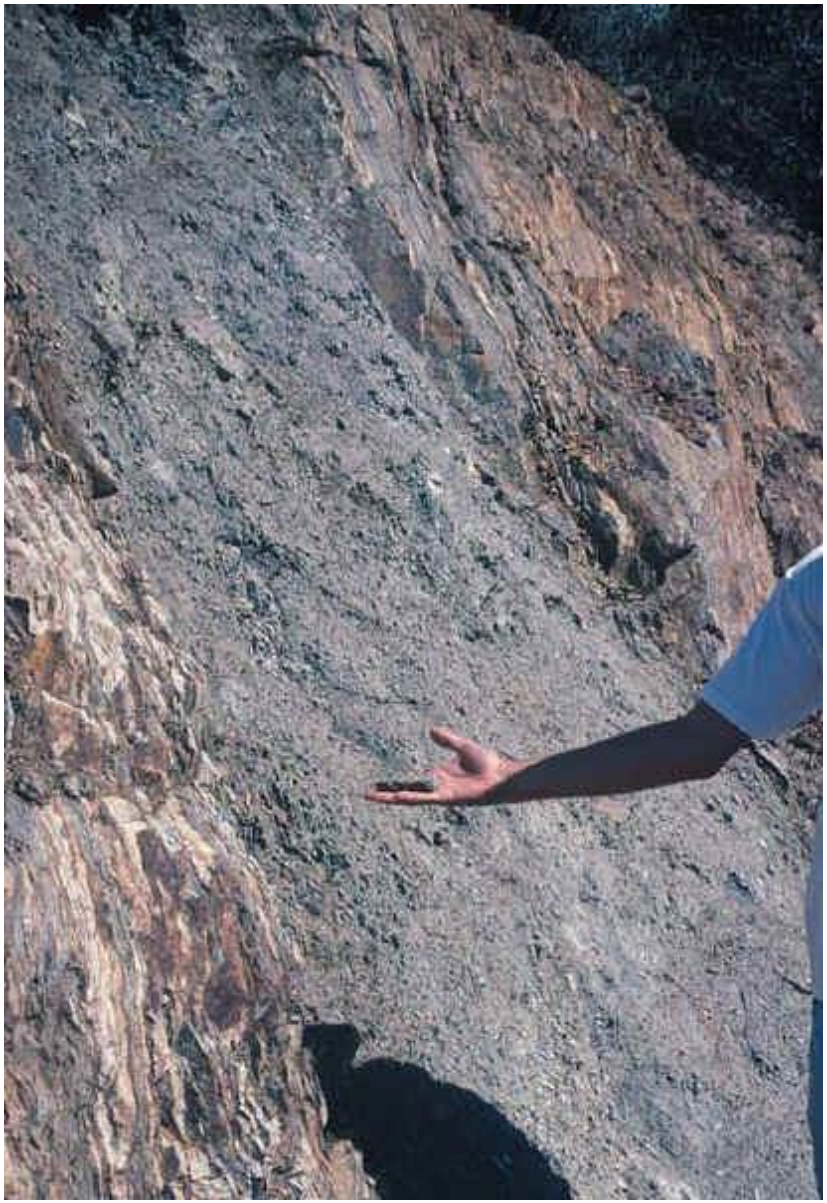
Contact or thermal metamorphism

Is a type of **metamorphism** where rock minerals and texture are changed, mainly by heat, due to **contact** with magma.


1 km
Unaltered mudstone
Granite
Spotted rock
Hornfels

Cataclastic or shear zone metamorphism

- Restricted to the vicinity of faults of overthrusts in the upper crust level (brittle deformation

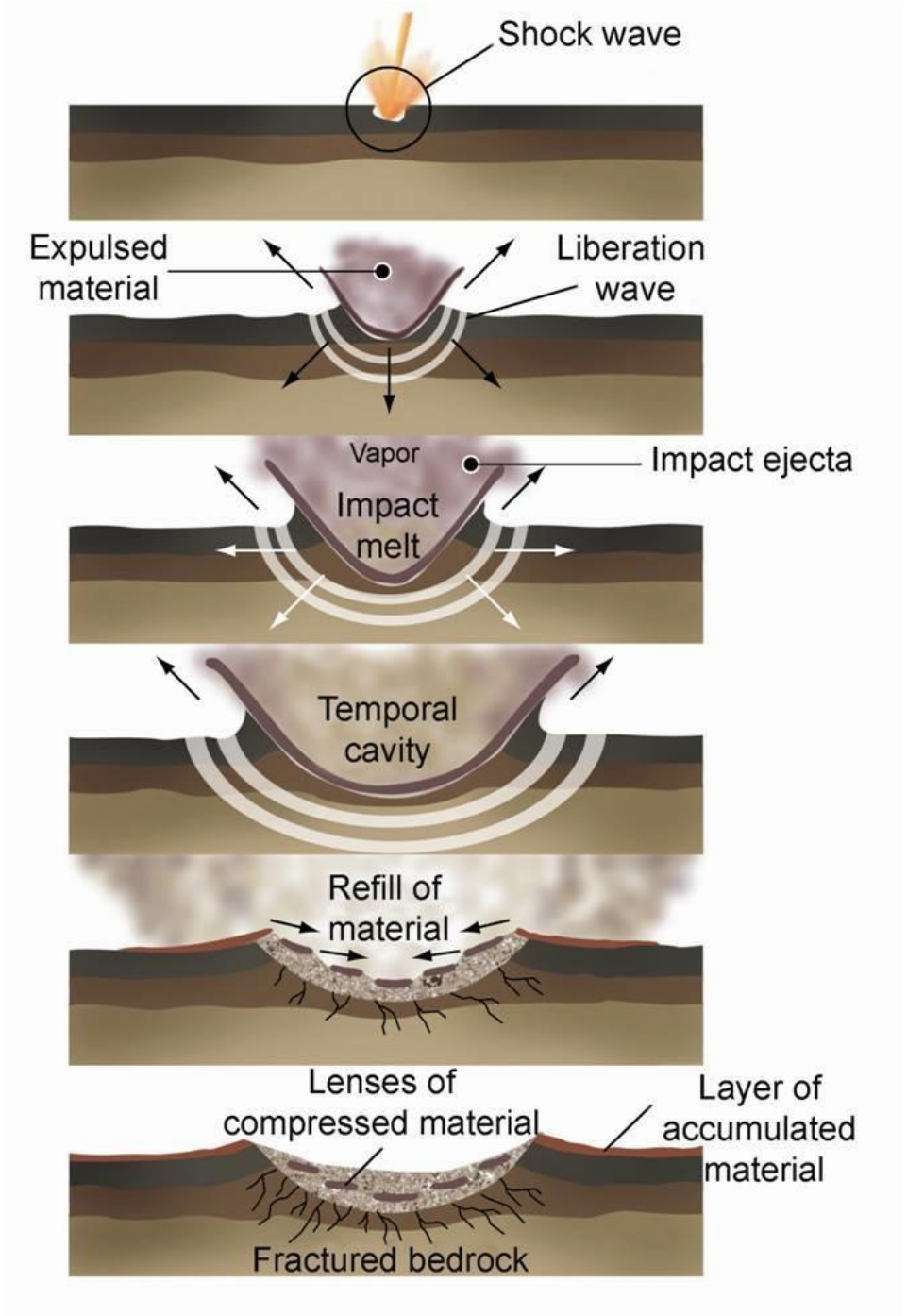


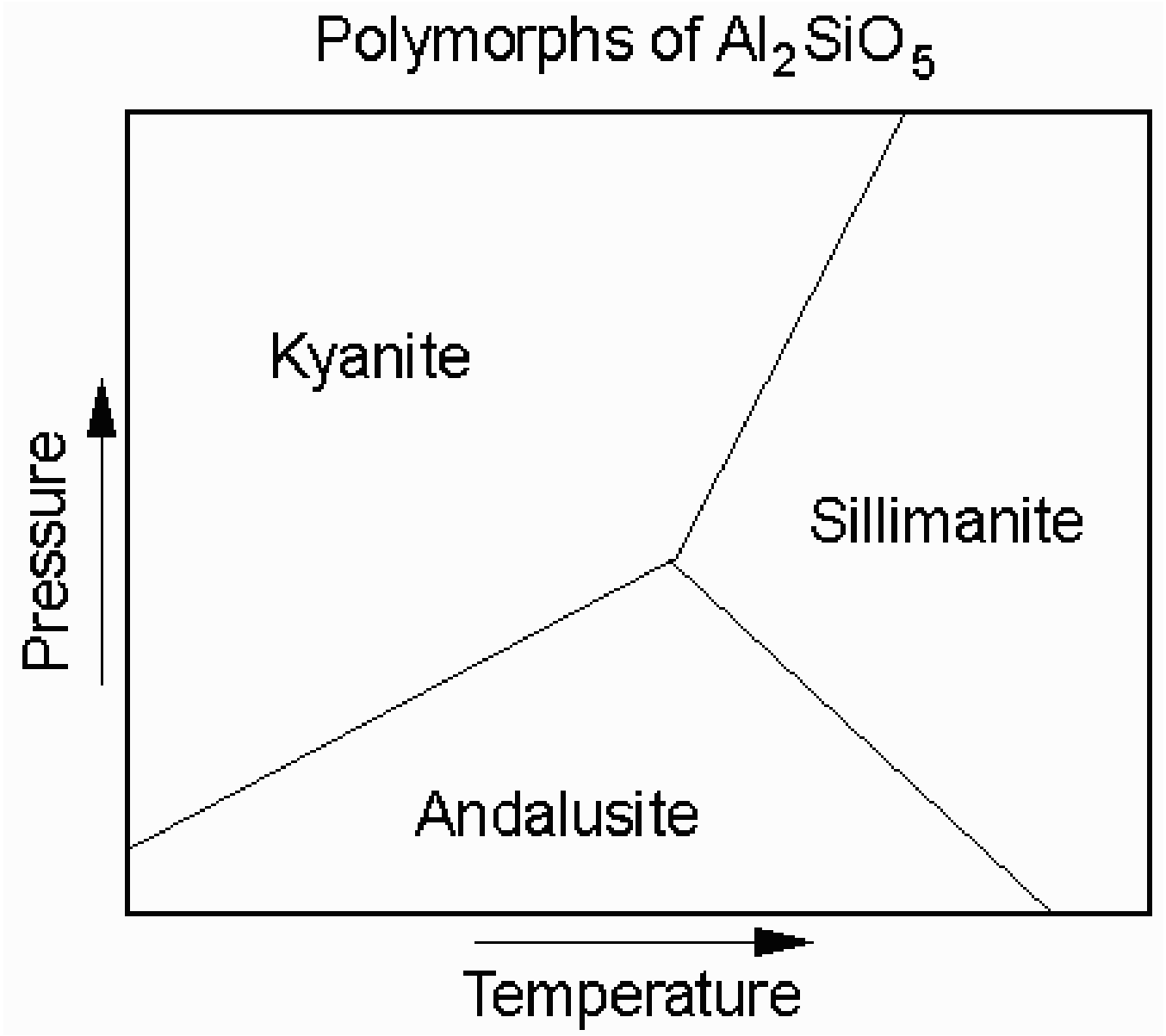
Hydrothermal metamorphism

occurs when hot, chemically active, mineral laden waters interact with a surrounding pre-existing rock (called the country rock).

Impact or shock metamorphism

- occurs when high heat and pressures generated during an **impact** deform the underlying rock layers.


Shock wave
Expulsed material
Liberation wave
Vapor
Impact ejecta
Impact melt
Temporal cavity
Refill of material
Lenses of compressed material
Layer of accumulated material
Fractured bedrock


Polymorphs of Al_2SiO_5
Kyanite
Sillimanite
Andalusite
Pressure
Temperature

Textures

Careful observation in the field can help build an early understanding of complex rocks, avoid misleading assumptions and help with both sampling and collection of field data.

Banding

- Primary banding, i.e., *cross - lamination*
- Secondary banding

Grain textures

A key observation is whether the rock displays orientated crystals (typical of deformed, regionally metamorphosed rocks), or granular texture. The latter may indicate contact metamorphism caused by a nearby igneous body

Reaction textures

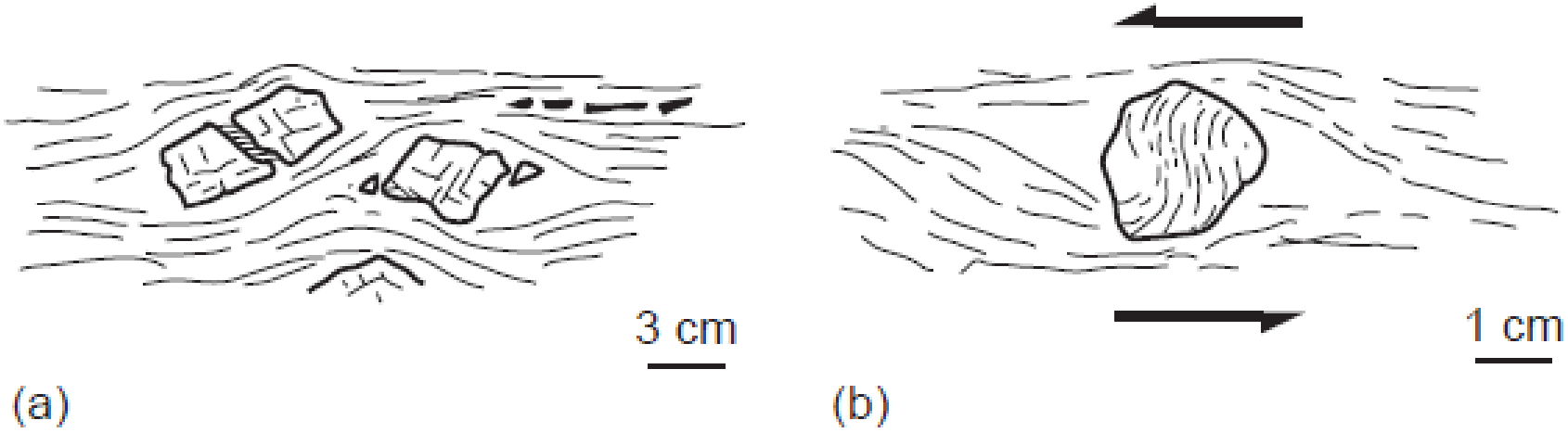
- **Pseudomorphs** are aggregates of new mineral grains that have formed by alteration or replacement of a pre – existing porphyroblast. In many cases, the aggregate retains the form of the original crystal.
- **Coronas** may indicate partial replacement of a mineral by another, or represent a rim of new mineral formed at the interface between two others.

Identifying common metamorphic minerals

Pressure/ temperature conditions	Pelitic (mudstone)	Mafic (basalt)	Felsic (granite)	Ultramafic (peridotite)	Calc-silicate (impure limestone)
LT	Chlorite	Chlorite	Chlorite, epidote	Serpentine	Talc
LP	Andalusite, cordierite No garnet	Pyroxenes, olivine No garnet	Andalusite		
MP/T	Chloritoid, staurolite	Actinolite, epidote, zoisite		Talc (abundant)	Tremolite
HP	Kyanite, talc, rutile No plagioclase	Lawsonite, Na-pyroxene, rutile, glaucophane No plagioclase	Na-pyroxene, kyanite No plagioclase		Zoisite
HT	Sillimanite, spinel, orthopyroxene No muscovite	Clinopyroxene, orthopyroxene	Orthopyroxene, cordierite, sillimanite	Orthopyroxene	Wollastonite, Mg-olivine, Ca-pyroxene, spinel
Wide P and T ranges	Muscovite, biotite, garnet, quartz, plagioclase	Garnet, hornblende, plagioclase, biotite, quartz, titanite	Quartz, biotite, K-feldspar, plagioclase, muscovite	Olivine, chlorite, magnesite	Calcite, dolomite, plagioclase, Ca-garnet, hornblende, chlorite, epidote

Syn-, Pre - kinematic features

- Early porphyroblasts are commonly wrapped by later tectonic foliations. Pre - kinematic grains or clasts may be cracked, bent or even pulled apart



a) Pre - kinematic, broken K - feldspar grains and a boudinaged tourmaline crystal (top right), wrapped by a high - strain foliation. (b) Syn - kinematic garnet with curved inclusion trails, showing inferred shear sense.

Post- kinematic features

- Post - kinematic features generally show random orientation, indicating static, post - kinematic development.