



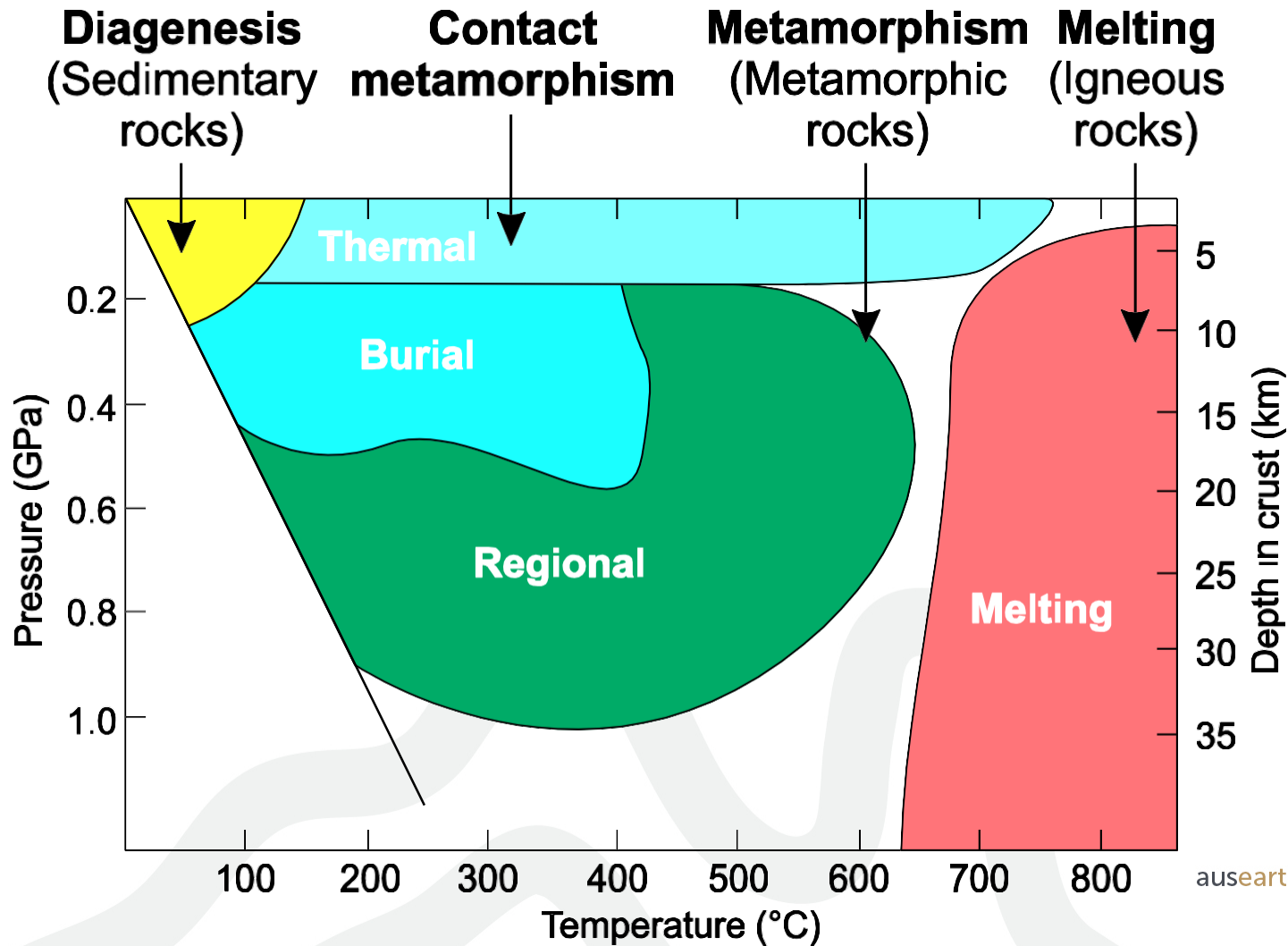
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# Metamorphic Rocks and Processes

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# Response of minerals to heating

- Dehydration = loss of water



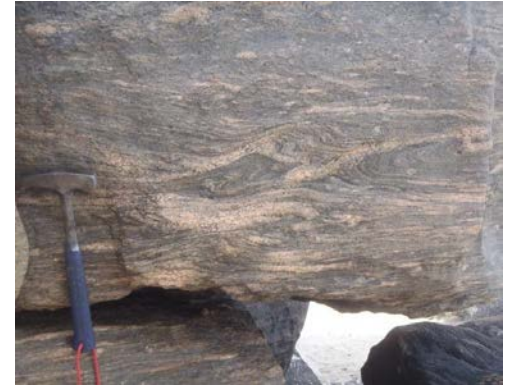
# Response of minerals to heating

- Dehydration = loss of water
- Decarbonation = loss of carbon dioxide

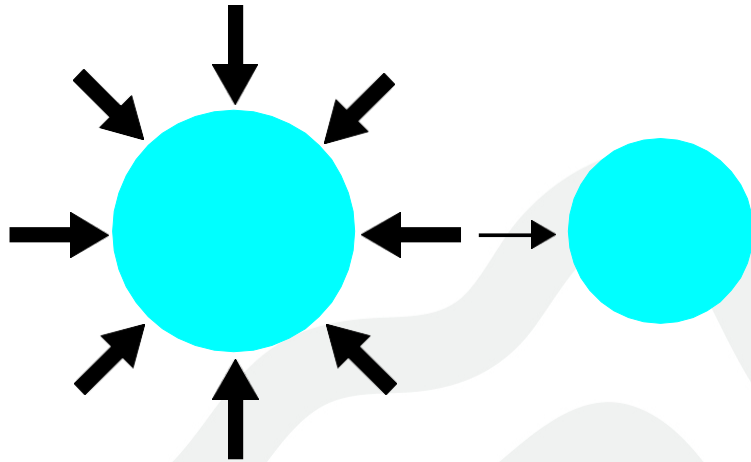


# Response of minerals to pressure

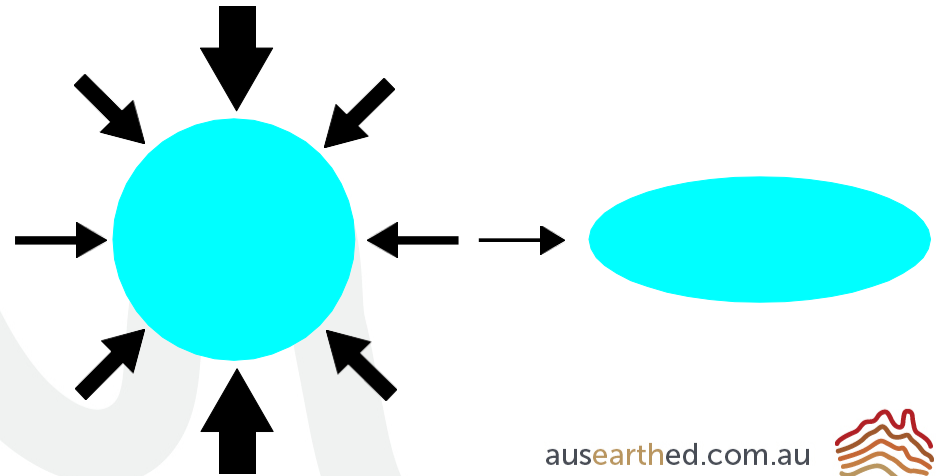
- Changed shape



**A. Load pressure**

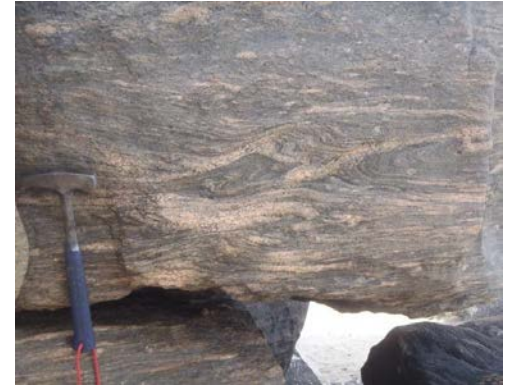


**B. Directed pressure**

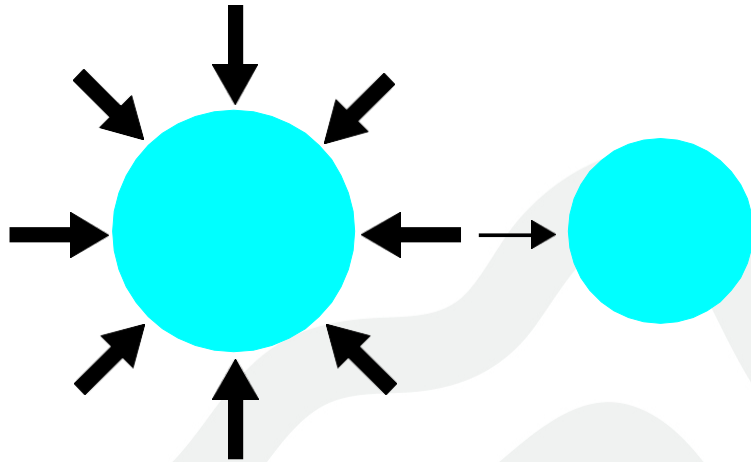


# Response of minerals to pressure

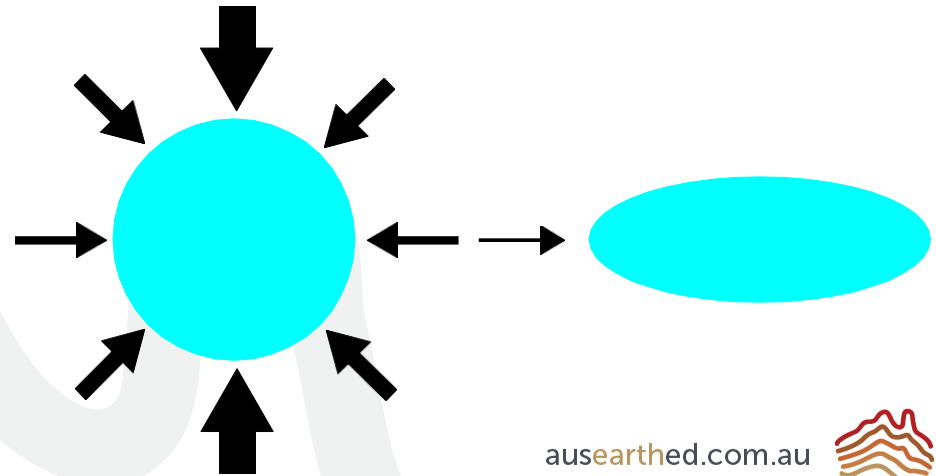
- Changed shape
- Changed size



**A. Load pressure**



**B. Directed pressure**



# Regional Metamorphism

- Heat and pressure



# Regional Metamorphism

- Heat and pressure
- Common at convergent margins





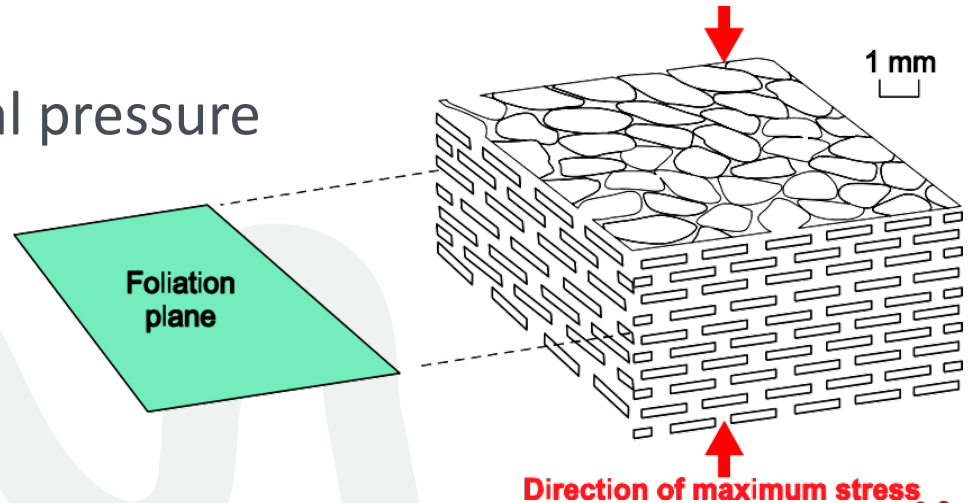
# Regional Metamorphism

- Heat and pressure
- Common at convergent margins
- Very large areas



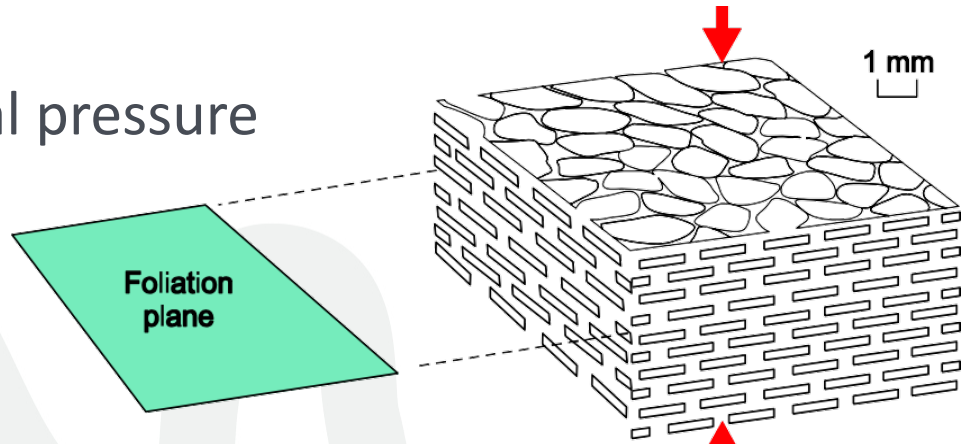
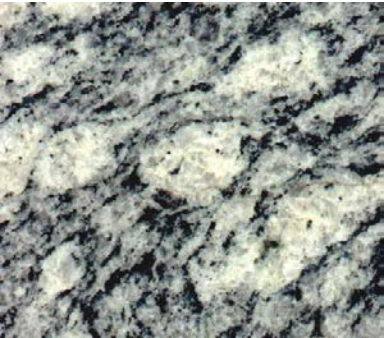
# Regional Metamorphism

- Heat and pressure
- Common at convergent margins
- Very large areas
- Foliated due to directional pressure



# Regional Metamorphism

- Heat and pressure
- Common at convergent margins
- Very large areas
- Foliated due to directional pressure
- Often coarser grained



**Direction of maximum stress**



# Rocks from regional metamorphism

## slate



# Rocks from regional metamorphism

slate



phyllite



# Rocks from regional metamorphism

slate



phyllite



schist



# Rocks from regional metamorphism

slate



phyllite



schist



gneiss



# Rocks from regional metamorphism

slate



phyllite



schist



gneiss



amphibolite





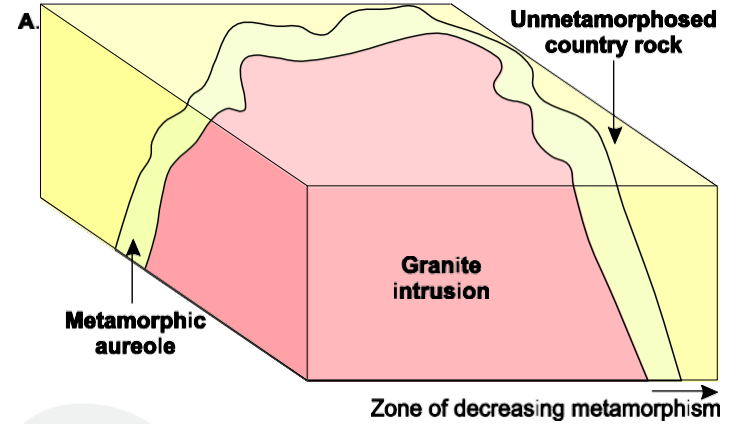
# Contact metamorphism

- Heat



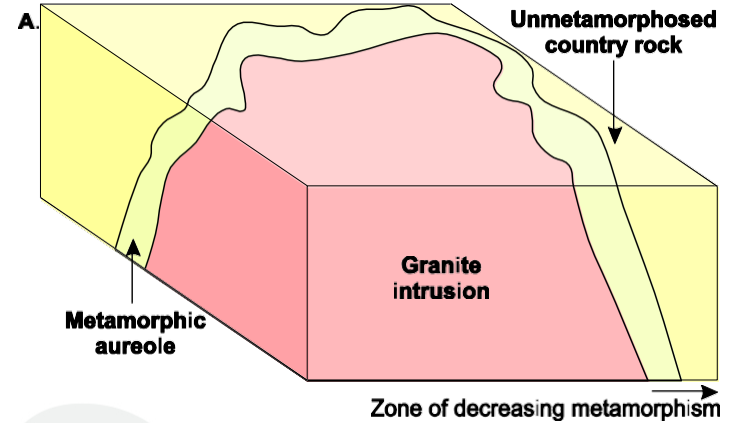
# Contact metamorphism

- Heat
- Common around igneous intrusions



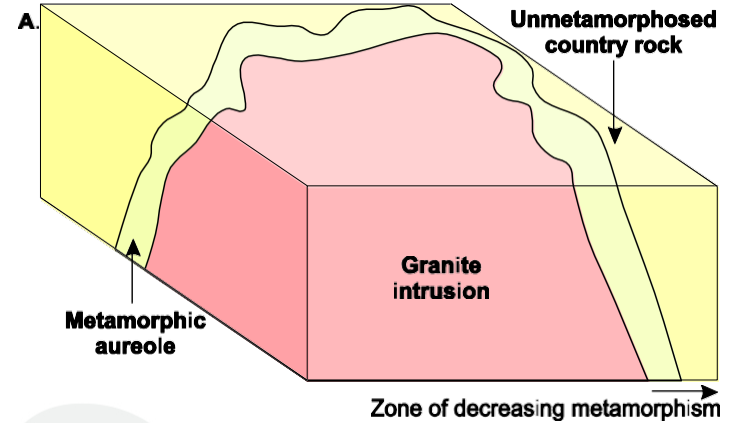
# Contact metamorphism

- Heat
- Common around igneous intrusions
- Size depends on the extent & heat of the intrusion



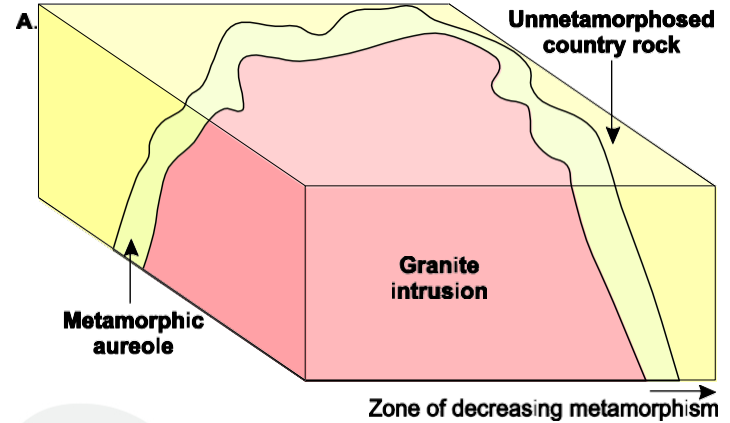
# Contact metamorphism

- Heat
- Common around igneous intrusions
- Size depends on the extent & heat of the intrusion
- Often fine-grained



# Contact metamorphism

- Heat
- Common around igneous intrusions
- Size depends on the extent & heat of the intrusion
- Often fine-grained
- Weak or no foliation



# Rocks from contact metamorphism

Limestone



# Rocks from contact metamorphism

Limestone



Marble



# Rocks from contact metamorphism

Limestone



Marble

Sandstone





# Rocks from contact metamorphism

Limestone



Marble

Sandstone



Quartzite

Hornfels (B Gray)



# Rocks from contact metamorphism

Limestone



Marble

Sandstone



Quartzite

Mudstone or  
other parent



# Rocks from contact metamorphism

Limestone



Marble

Sandstone



Quartzite

Mudstone or  
other parent



Hornfels

*Hornfels (B Gray)*



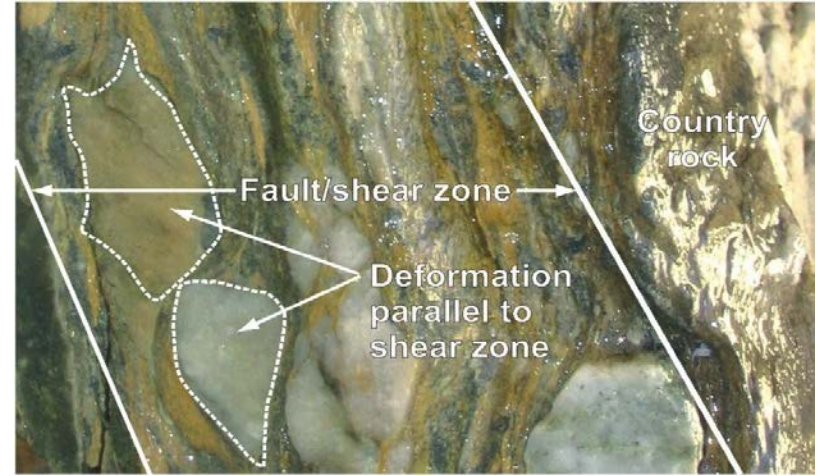
# Dynamic metamorphism

- Pressure



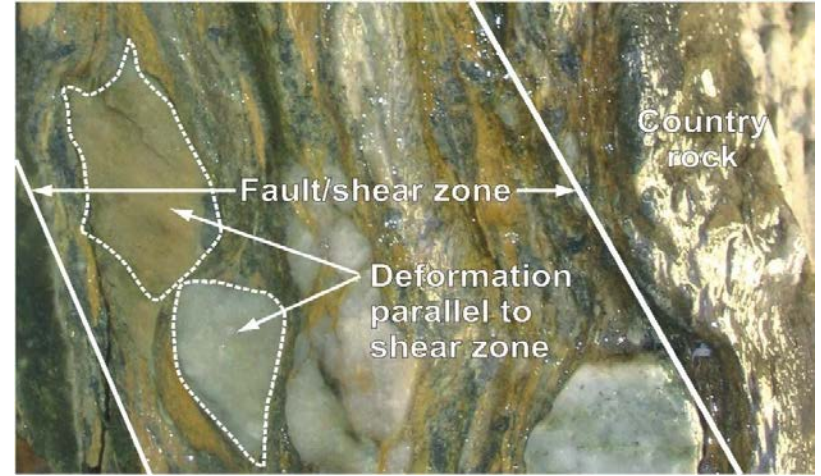
# Dynamic metamorphism

- Pressure
- Common at fault and thrust zones



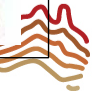
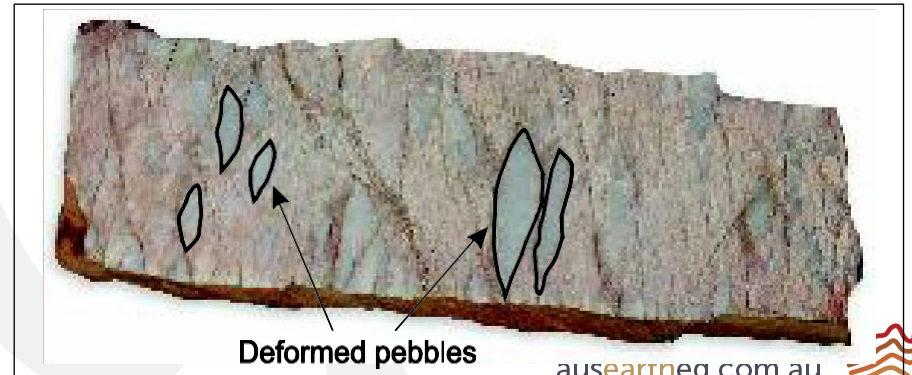
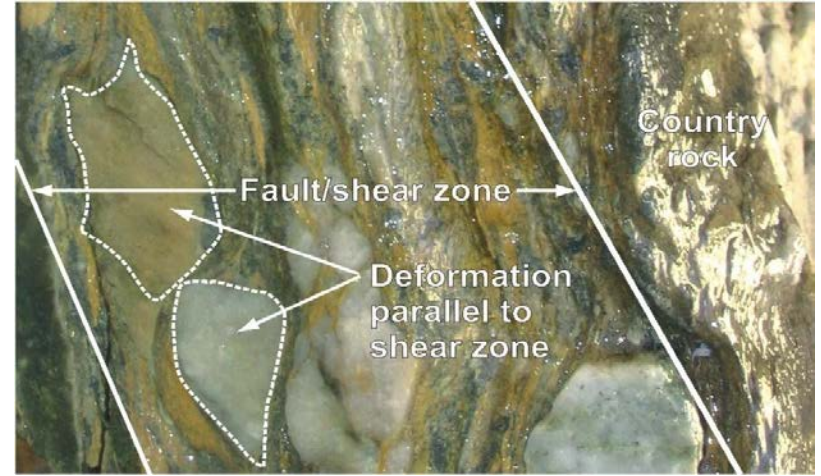
# Dynamic metamorphism

- Pressure
- Common at fault and thrust zones
- Often localised



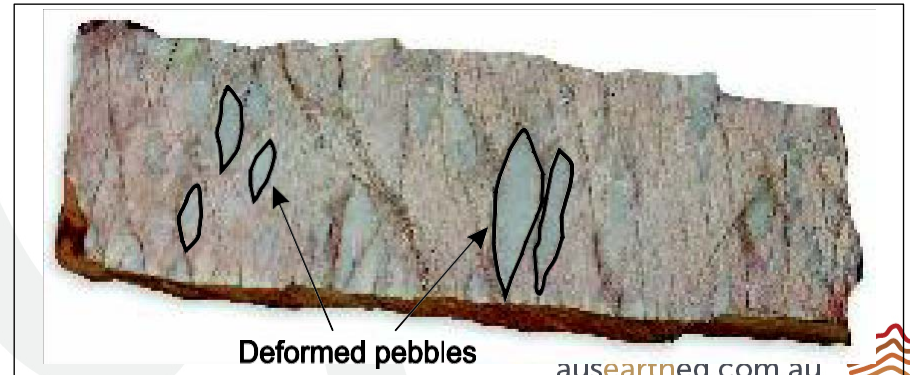
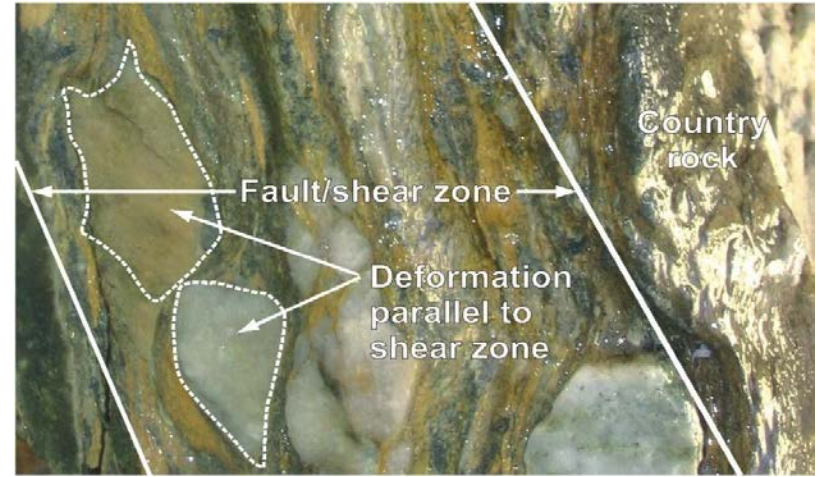
# Dynamic metamorphism

- Pressure
- Common at fault and thrust zones
- Often localised
- Deformed or angular fragments
- Rock 'flour'



# Dynamic metamorphism

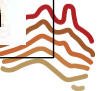
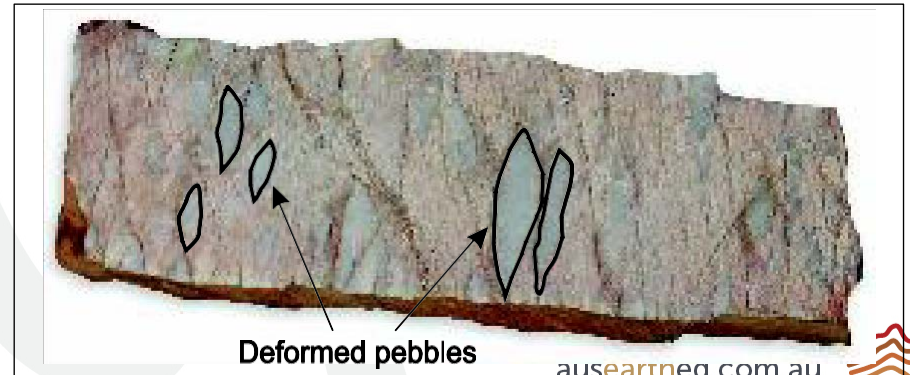
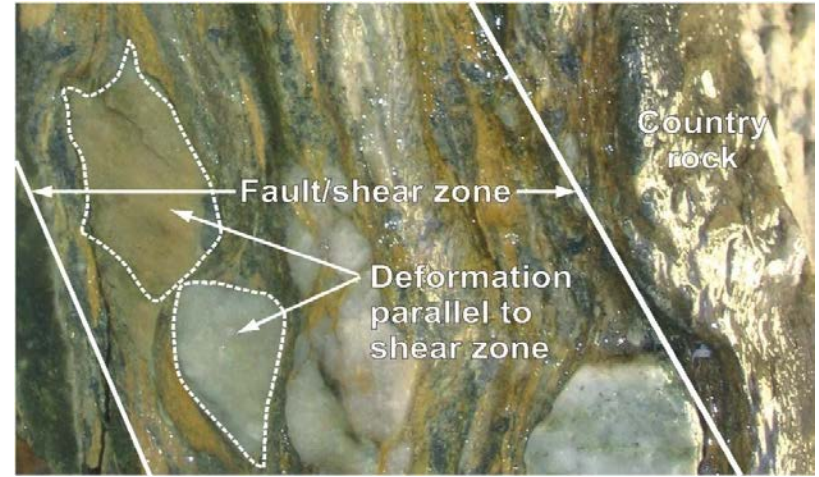
- Pressure
- Common at fault and thrust zones
- Often localised
- Deformed or angular fragments
- Rock 'flour'
- Partial recrystallisation

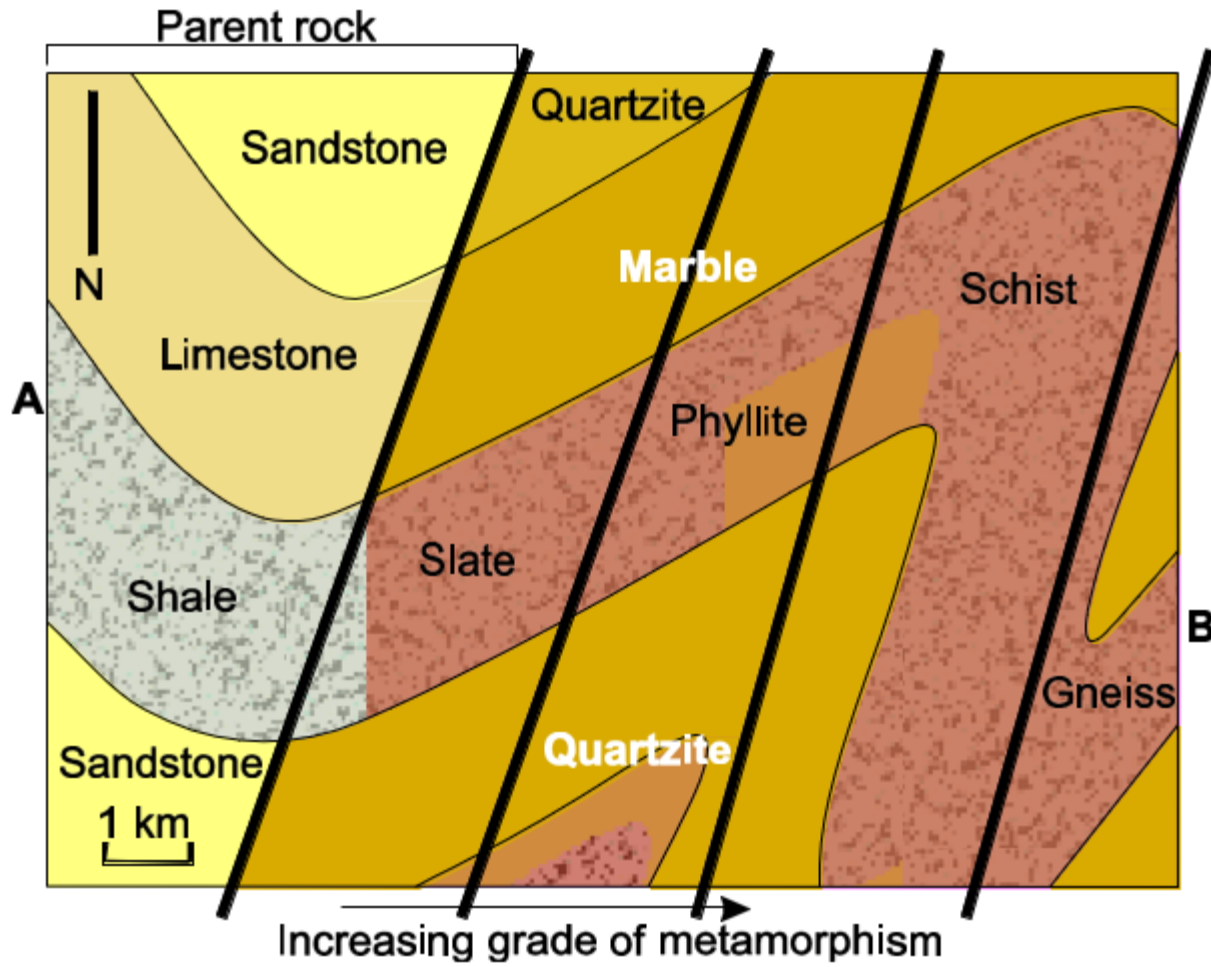




# Dynamic metamorphism

- Pressure
- Common at fault and thrust zones
- Often localised
- Deformed or angular fragments
- Rock 'flour'
- Partial recrystallisation
- Mylonite

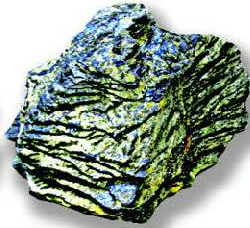






**Chlorite**

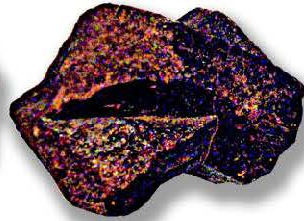
(low temperatures  
and pressures)



**Biotite**



**Garnet**



**Staurolite**



**Kyanite**



**Sillimanite**

(high temperatures  
and pressures)





**Chlorite**

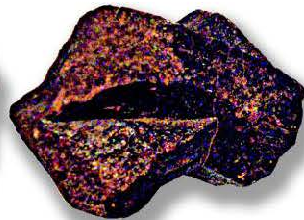
(low temperatures  
and pressures)



**Biotite**



**Garnet**



**Staurolite**



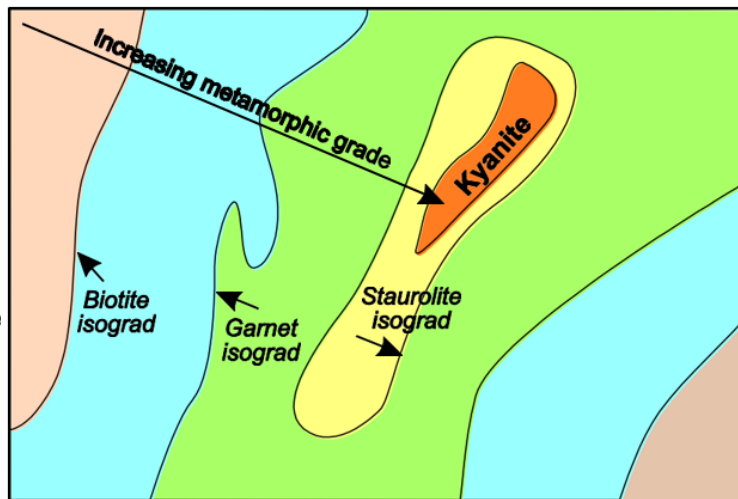
**Kyanite**



**Sillimanite**

(high temperatures  
and pressures)

-  Chlorite zone
-  Biotite zone
-  Garnet zone
-  Staurolite zone
-  Kyanite zone



# Hydrothermal processes

- Hot fluids percolate through rocks



# Hydrothermal processes

- Hot fluids percolate through rocks
- Minerals are chemically altered and may be completely replaced



# Hydrothermal processes

- Hot fluids percolate through rocks
- Minerals are chemically altered and may be completely replaced
- Metamorphic or igneous source of fluids



# Copper

- Intrusion of water-rich magma





# Copper

- Intrusion of water-rich magma
- Residual liquid crystallises on edges



# Copper

- Intrusion of water-rich magma
- Residual liquid crystallises on edges
- Metals such as copper are concentrated here



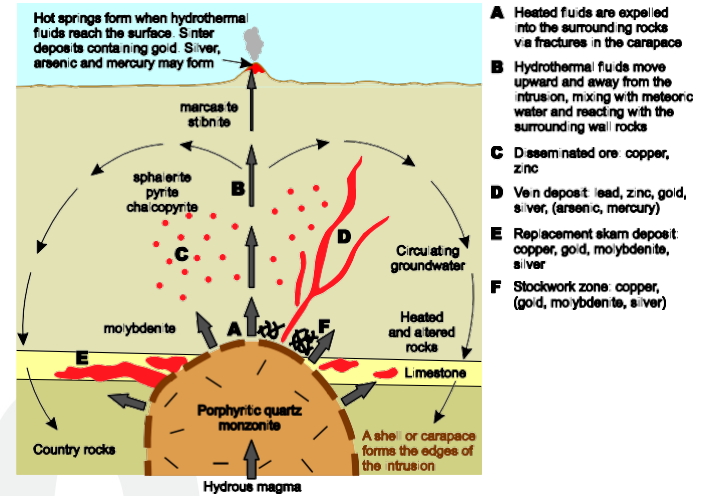
# Copper

- Intrusion of water-rich magma
- Residual liquid crystallises on edges
- Metals such as copper are concentrated here
- Pressure increase forces super-heated fluids into country rocks



# Copper

- Intrusion of water-rich magma
- Residual liquid crystallises on edges
- Metals such as copper are concentrated here
- Pressure increase forces super-heated fluids into country rocks
- Cools and precipitates out metal rich minerals



# Gold

- Hydrothermal gold vein deposits – Eastern Goldfields
- Hot saline fluids (metamorphic origin) leached out gold and other metals moving up through country rock
- Move through faults, fractures and brittle rocks
- Cools and precipitates out (often in and around quartz veins)



# References

- Hornfels photograph, Bobby Gray, accessed at <http://www.texasbeyondhistory.net/transp/nature/images/hornfels.html>, on May 15, 2012.

Unless otherwise stated all information and graphics are from:

- Tompkins, D.E. (Ed.), 2011, Exploring Earth and Environmental Science Stages 1, 2 and 3, Earth Science Western Australia
- ESWA photo/graphic library





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