

Lecture SIX
***Metamorphic Grade and
Facies***

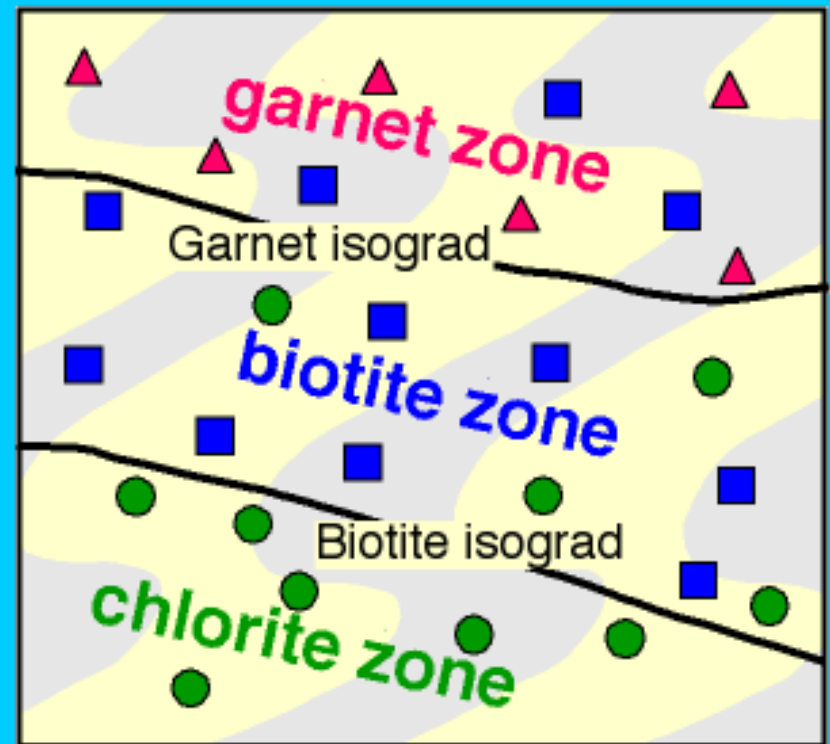
Metamorphic grade and Facies

Systematic spatial distribution in mineral assemblages that formed during metamorphism in metamorphic terrains allow to delineate mineral zonation, using index minerals (e.g. chlorite, biotite, garnet, staurolite, cordierite, sillimanite, andalusite, wollastonite, diopside... etc.)

- **Mineral zone**: Zones in the field, which mark the first appearance of an index mineral, such as chlorite zone, garnet zone.

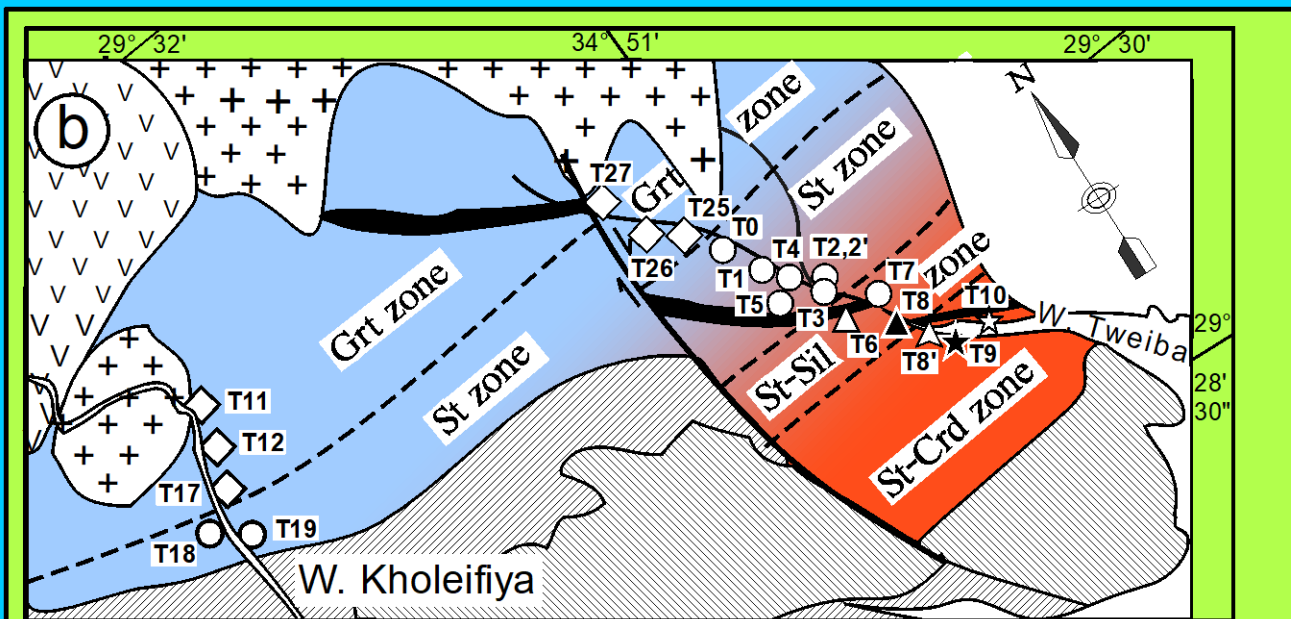
- **Mineral isograd**: boundary marked between two mineral zones, which include:

- Mineral-in: first app
- Mineral-out: the last appearance of



- chl-mus-qtz
- bio-chl-mus-qtz
- ▲ gt-bio-chl-mus-qtz

Example: Wadi Tweiba (S. Sinai) mineral zones



Mineral assemblages

- ◇ grt
- grt+st
- △ grt+st+sil
- ▲ grt+st+and+sil
- ★ grt+st+crd
- ★ grt+st+crd+and+sil
- △ st+crd
- grt+sil
- ▽ grt+crd
- ▷ st+crd+sil

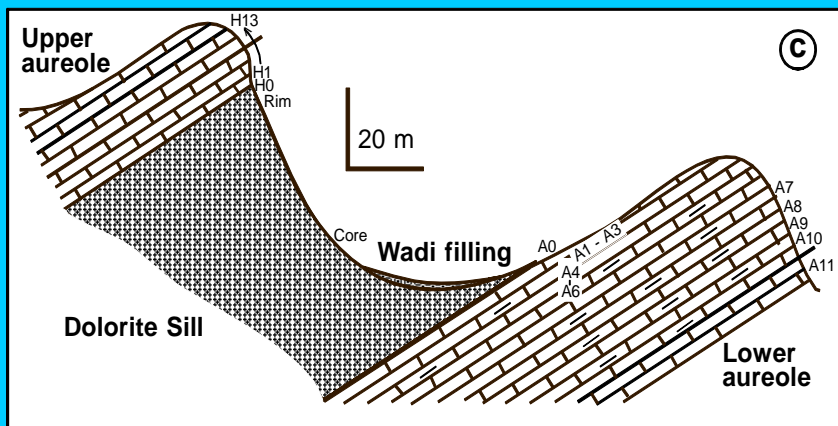
Unmetamorphosed igneous rocks

- ++ (Younger) Granites
- [Grid] (Older) Quartz-diorite
- [V V] Andesite-rhyolite (Dokhan) Volcanics

Metamorphic complex

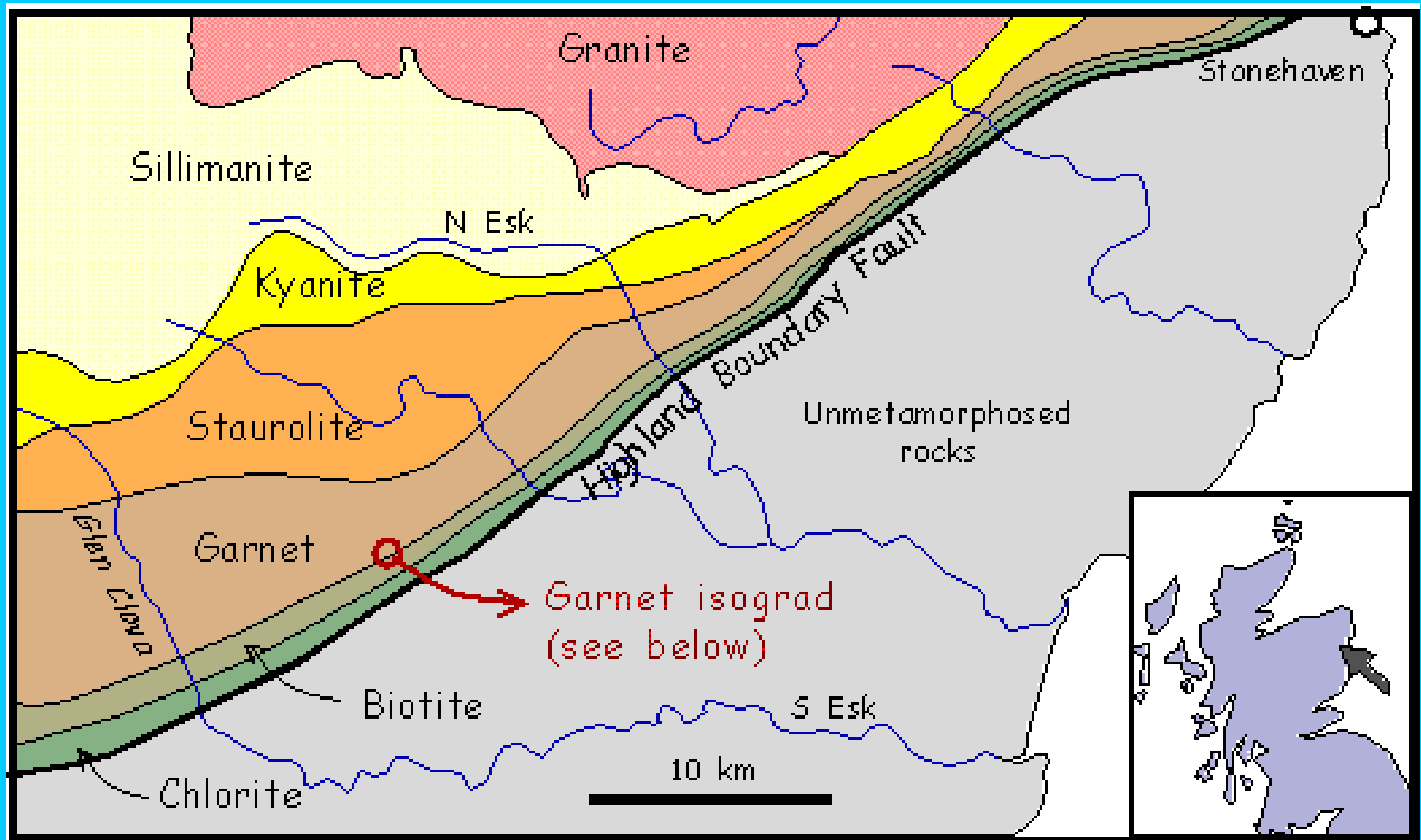
- [Horizontal lines] Undifferentiated orthogneisses
 - [Diagonal lines /] Type-VI
 - [Diagonal lines \] Type-III
 - [Vertical lines] Type-I
- [Grid] Migmatites
- [Black] Metagabbros-metadiorite/metabasites
- [Light blue] Pelitic schists

Gabal Yelleq (Sinai) contact aureole mineral zones



Aureole	S. No.	Distance (m)	Mineral assemblage	Metamorphic zone
Upper aureole	H10	7.00	Cal	Slightly metamorphosed
	H9	6.00	Cal + Grt + Wo	Garnet
	H8	5.00	Cal + Wo + Grt	
	H7	4.00	Cal + Wo + Grt	
	H6	3.00	Cal + Grt	
	H5	2.00	Cal + Grt + Wo + Cpx + Aph	Clinopyroxene
	H4	1.00	Cal + Grt + Wo + Cpx	
	H3	0.40	Cal + Grt + Cpx	
	H2	0.20	Cal + Grt + Cpx	
	H1'	0.10	Cal + Grt + Cpx	Zeolite minerals
	H1	0.05	Cal + Withr + Grt + Aph	
H0	0.00	Ntr + Thom		
Dolerite		B1.2	Ca-Pl + Cpx + Ol + opaques	
Lower Aureole	A0	0.00	Cal + Grt + Wo + Cpx	Clinopyroxene
	A1	0.50	Cal + Wo + Grt + Cpx	
	A2	1.50	Cal + Wo + Grt + Cpx	
	A3	2.50	Cal + Wo + Grt + Cpx	
	A4	4.00	Cal + Wo + Grt + Cpx	Garnet
	A5	6.00	Cal + Wo + Grt	
	A6	8.00	Cal + Grt	
	A7	10.00	Cal + Wo	Wollastonite
	A8	13.00	Cal + Wo	Slightly metamorphosed
	A9	18.00	Cal	
	A10	25.00	Cal	
A10-1	26.00	Cal		
A10-2	27.00	Cal	Un-metamorphosed	
Matulla limestone	A11	28.00		Yellowish limestone
	A12	29.00		Yellowish limestone
	A13	33.00		Yellowish limestone
	A14	42.00	Yellowish limestone	

Metapelites metamorphic zones (Scotland)



Metamorphic mineral zones in NE Scotland, after Barrow and Tilley

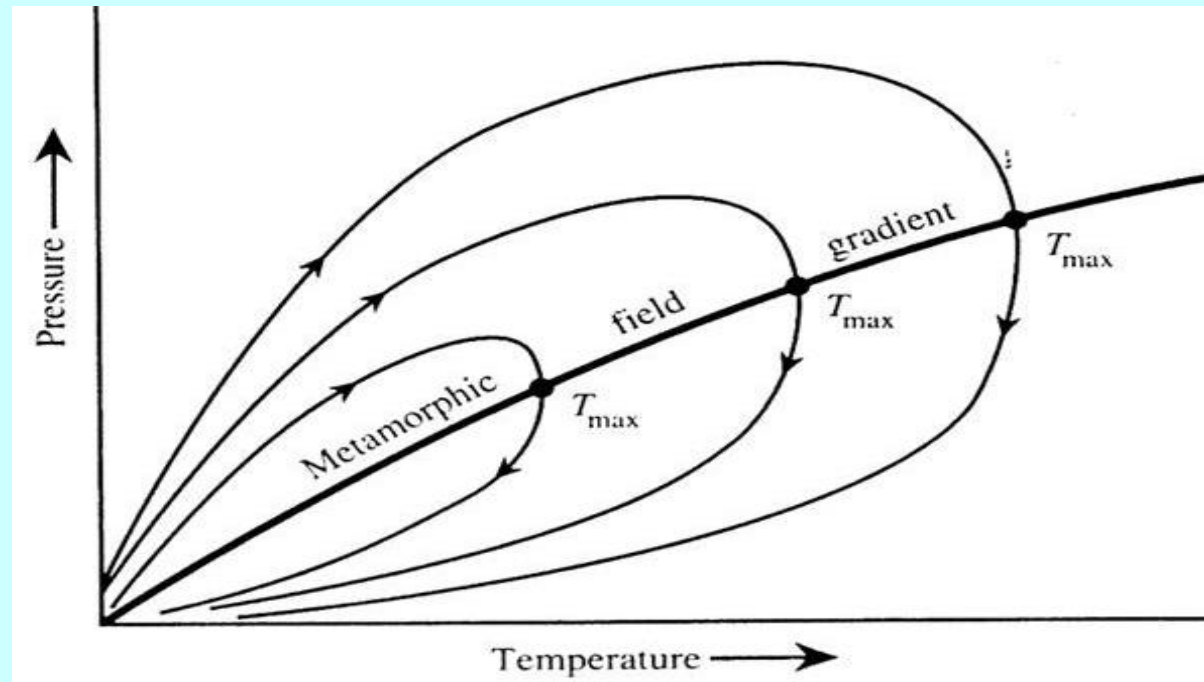
Distribution of minerals within metamorphic zones

	Metamorphic Zones					
	Chlorite	Biotite	Garnet	Staurolite	Kyanite	Sillimanite
Chlorite	—————					
Muscovite	—————					
Biotite	—————					
Garnet		—————				
Staurolite			—————			
Kyanite				—————		
Sillimanite					—————	
Plagioclase	—————					
Quartz	—————					

Metamorphic grades

Metamorphic grades is a general term for describing the relative P-T conditions under which the metamorphic rocks form. The grades could subdivided into:

- Very low grade
- Low grade
- Medium grade
- High grade
- Very high grade

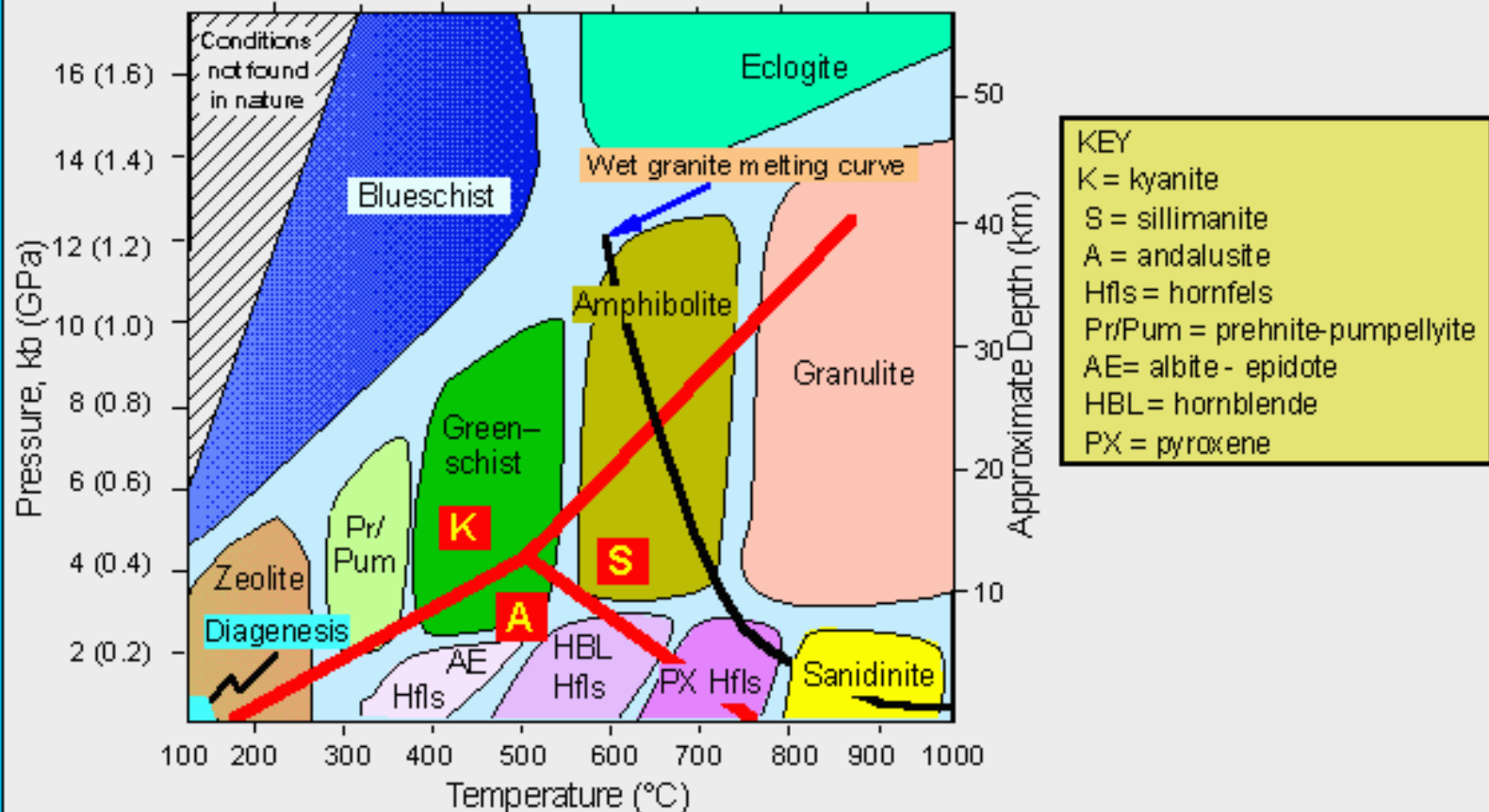


The boundaries between the grades are chosen to correspond to important discontinuous reactions (could recognized as major isograd), and they correlate with the scheme of metamorphic facies.

Metamorphic facies

Metamorphic facies is defined as a set of metamorphic mineral assemblage, repeatedly associated in space and time.

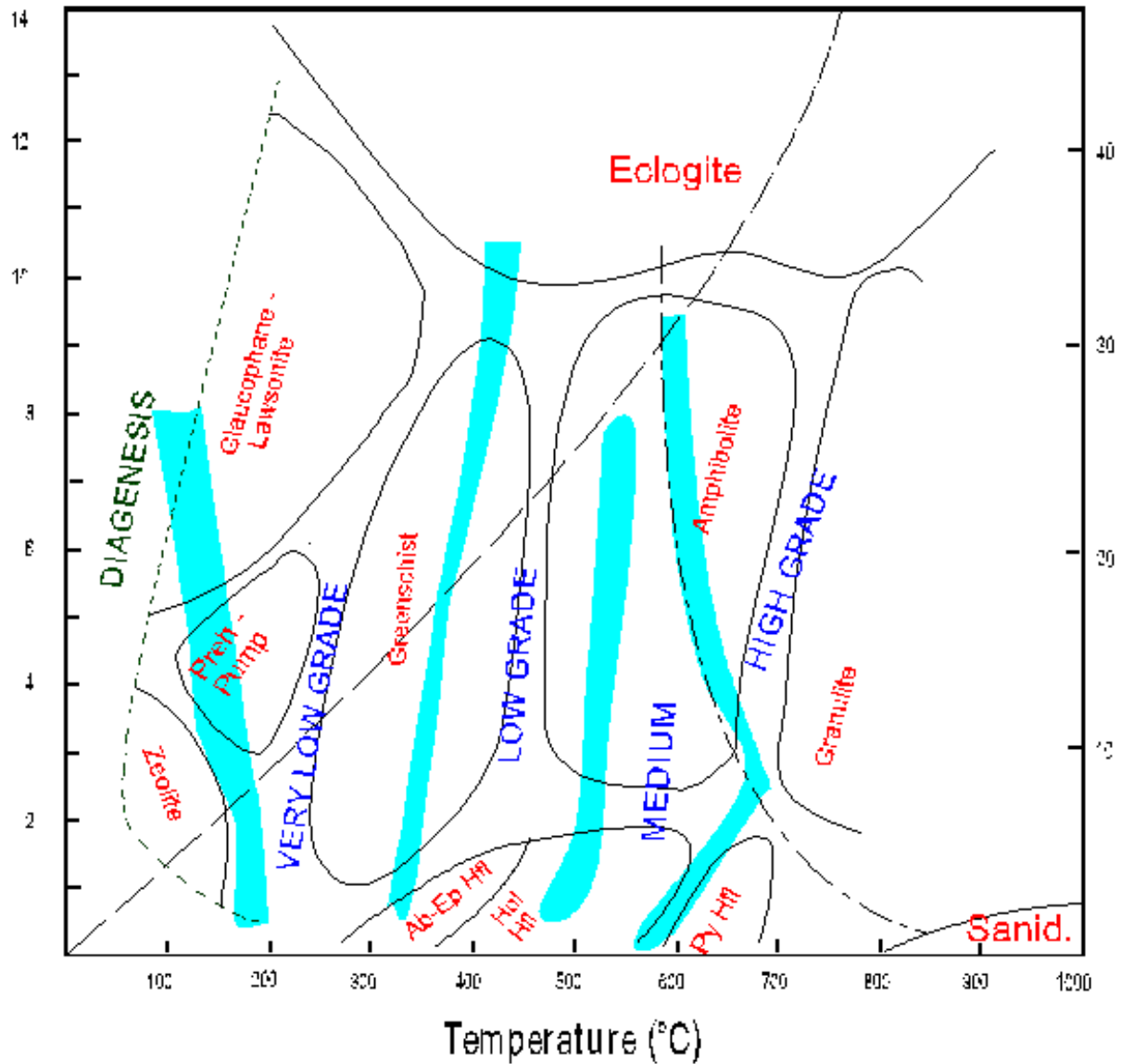
Generalized Metamorphic Facies Boundaries (after Yardley, 1988)



Metamorphic grades and facies

Metamorphic grade	Metamorphic facies	Index mineral assemblages	
		Pelitic rocks	Metabasalt
Very low grade	<i>Zeolite</i>	Mixed layer clays, sericite	Laumonite, analcite, heulandite, wairakite
	<i>Prehnite-pumpellyite</i>	Illite-muscovite, Chl, Ab, Pyr,	- prehnite-pumpellyite, Chl. Ab, Ep, Act, Law.
	<i>Blue schist</i>	Chl, Tlc, Ms, Grt, Chld	Glu, Law
Low grade	<i>Greenschist</i>	Chl, Ms, Ab, Bt, Grt	Act, Ep, Ab, Chl, Act, Grt, Hbl
	<i>Albite-epidote hornfels</i>	Ms, Bt, Chl	Pl, Ep, Act, Chl
Medium grade	<i>Amphibolite</i>	Grt, St, And, Ky, Sill, Ms, Crd	Hbl, Pl, Ep, Grt
	<i>Hornblende hornfels</i>	Crd, Chl, bt, Ms, And	Hbl, Pl, Cumm
High grade	<i>Granulite</i>	Crd, Grt, Kfs, Sill, Ky, Hy, Sap.	Cpx, Grt, Opx, Pl, Ol, Hbl
	<i>Pyroxene honfels</i>	Crd, And, Kfs	Cpx, Opx, Pl, Ol, Hbl
	<i>Sanidinite</i>	Cor, Mgt, An, glass	Not well defined
Very high grade	<i>Eclogite</i>	Tlc, ky, Grt, Ms	Omph (Cpx), grt

Metamorphic grades and facies



Metamorphic series

