Classification of Metamorphic Rocks; Metamorphic Facies

GEOL 13.53

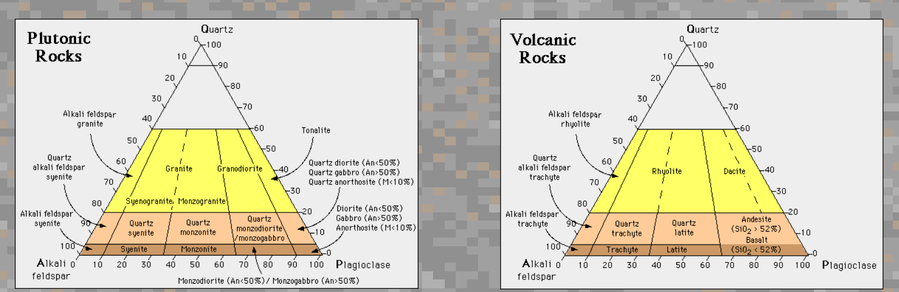
Metamorphic Lecture 2

Rock Classification Schemes

- **In general, there are two key variables associated with classification of any rock:**
  - **Composition**
  - **Environment of formation**

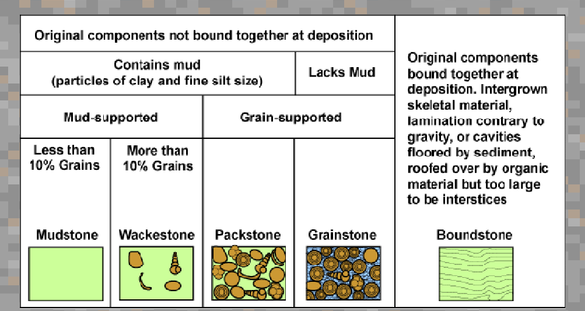
Rock Classification Schemes

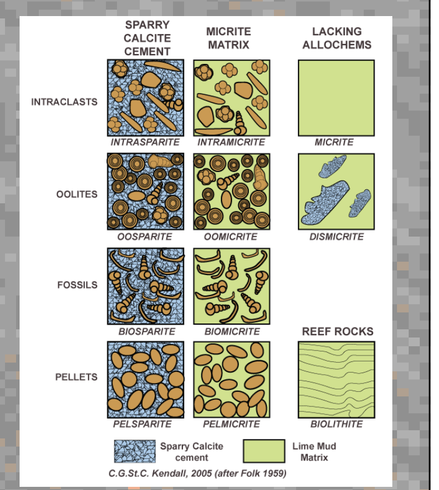
- For IGNEOUS rocks:
  - Composition of magma
    - Felsic, Intermediate, Mafic, Ultramafic
  - Environment of formation
    - Earth's interior (plutonic) or surface (volcanic)



Rock Classification Schemes

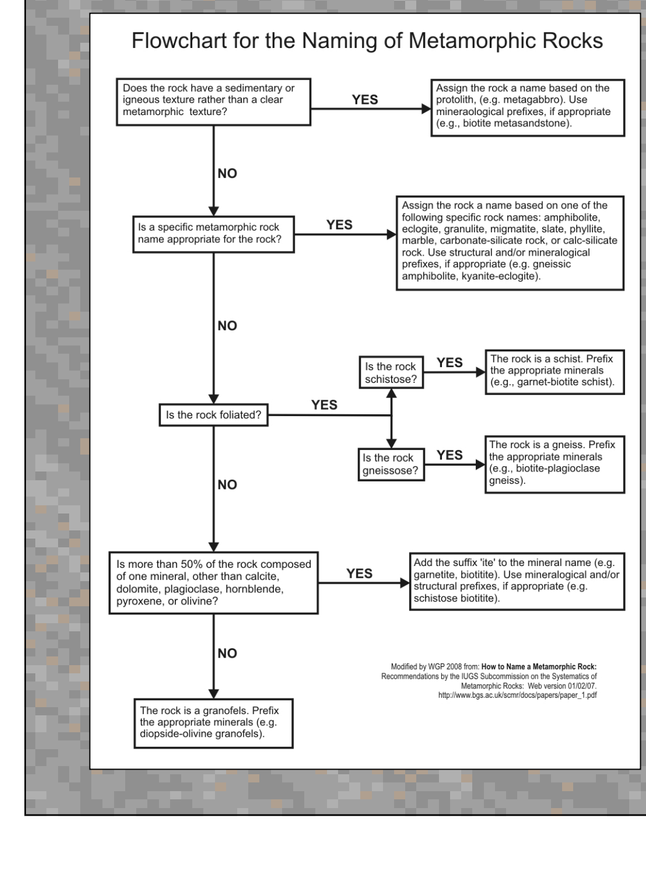
- For SEDIMENTARY rocks:
  - Composition of sediments
    - Quartz, feldspar, clay, carbonates
  - Environment of formation
    - E.g., River, deep sea, lagoon, beach

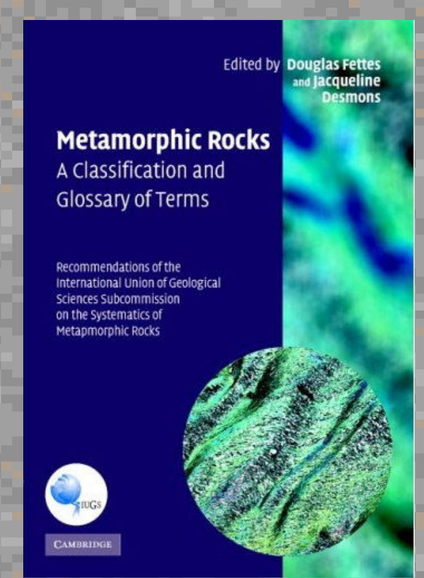


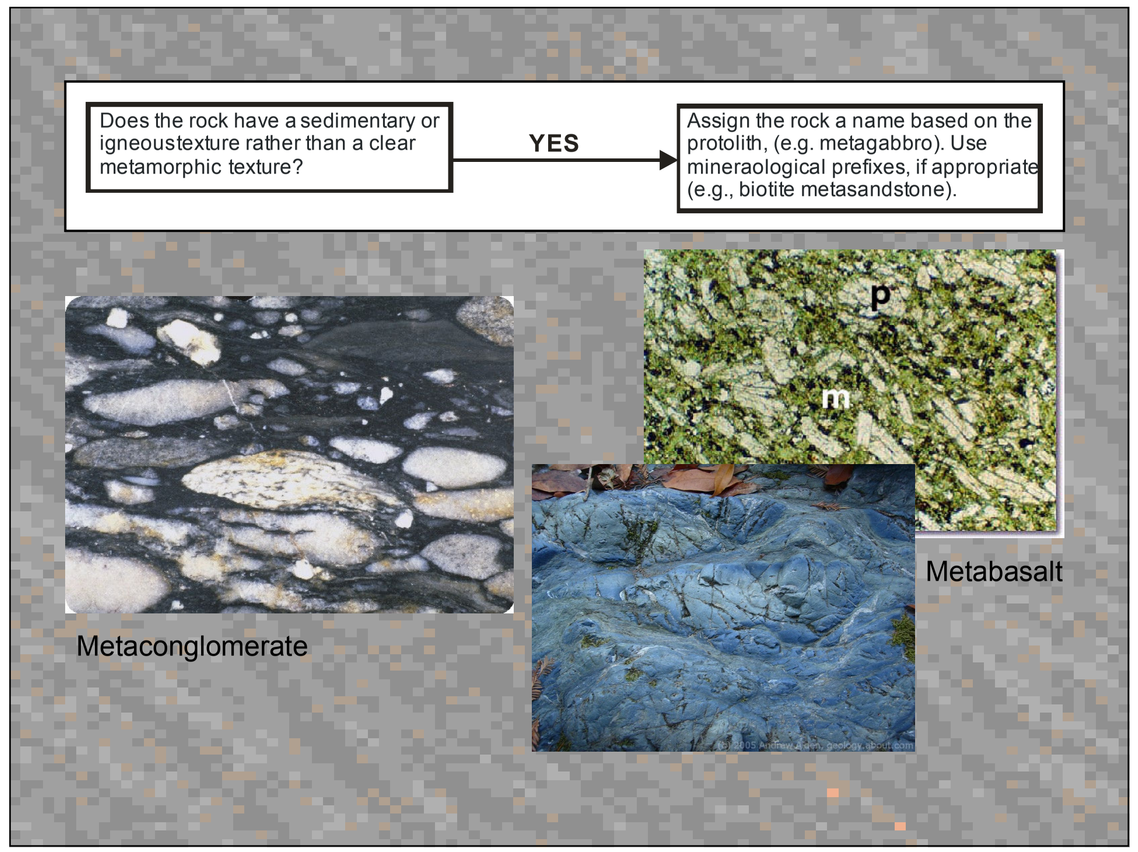


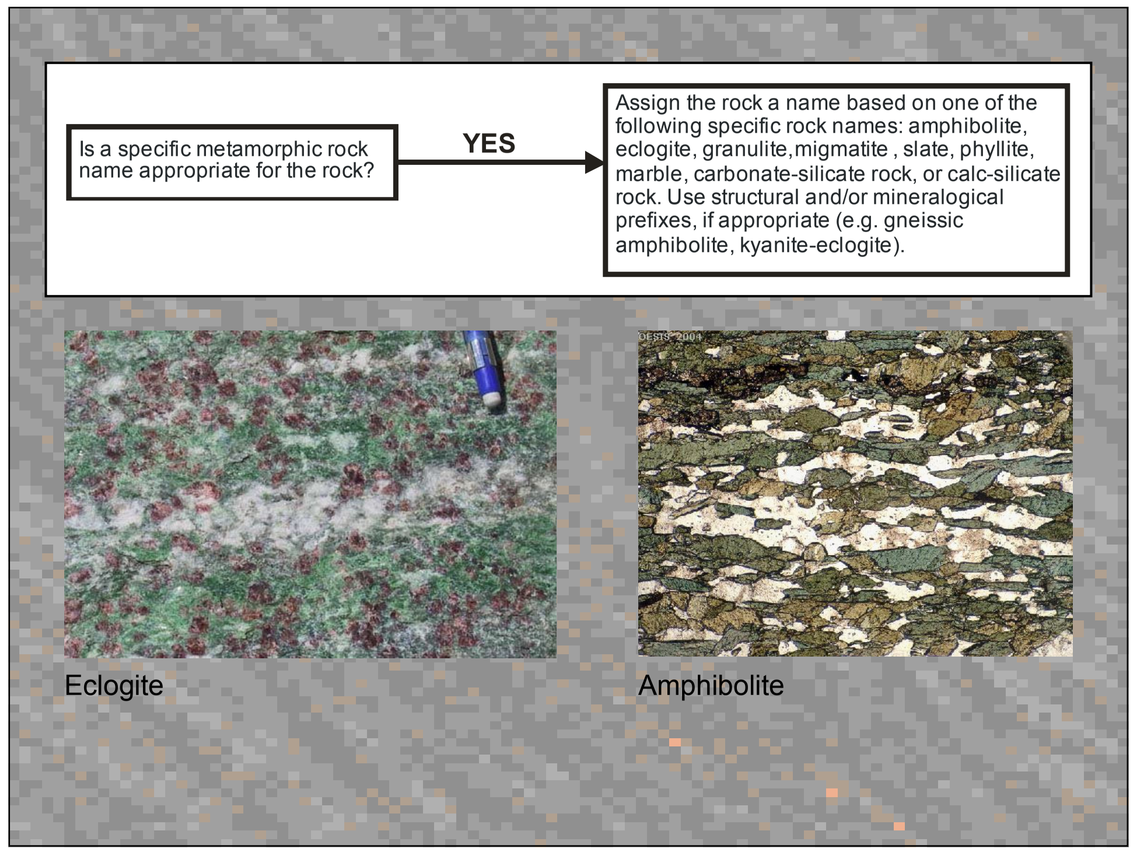
Rock Classification Schemes

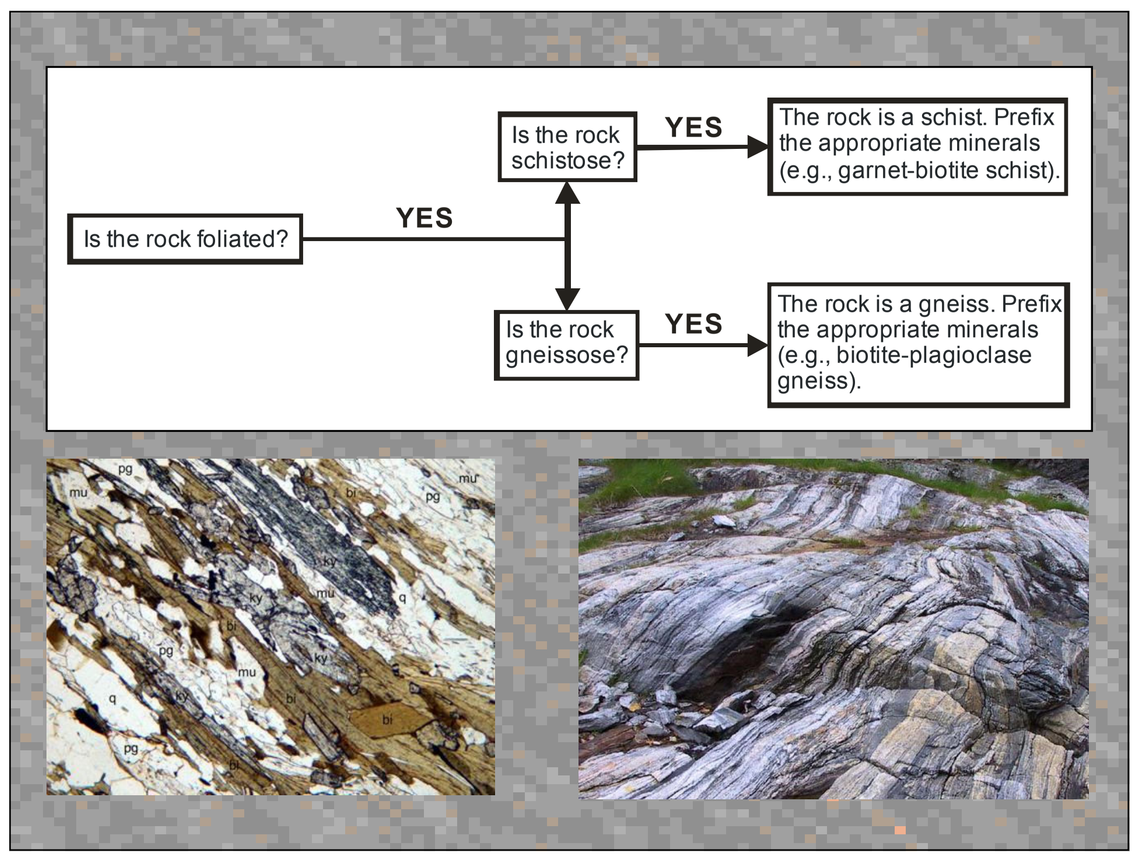
- For METAMORPHIC rocks:
  - Chemical composition of *protolith* (type of rock that was metamorphosed)
    - Shale, limestone, sandstone, mafic igneous rock, ultramafic igneous rock
  - Mineralogical composition of metamorphic rock
    - Amphibolite, quartzite, blueschist
  - Textural composition of metamorphic rock
    - Schist, gneiss, cataclasite
  - Environment of formation
    - Contact or regional metamorphism
    - Conditions of metamorphism (P/T)

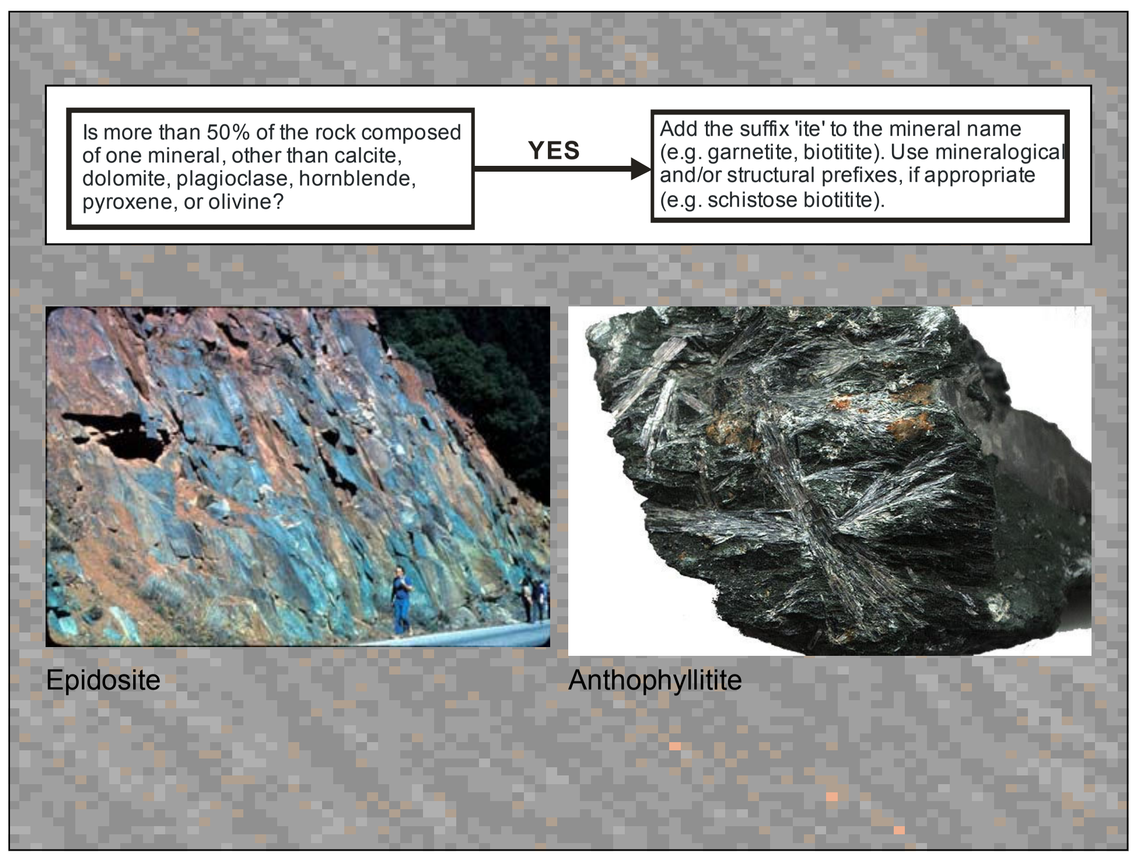






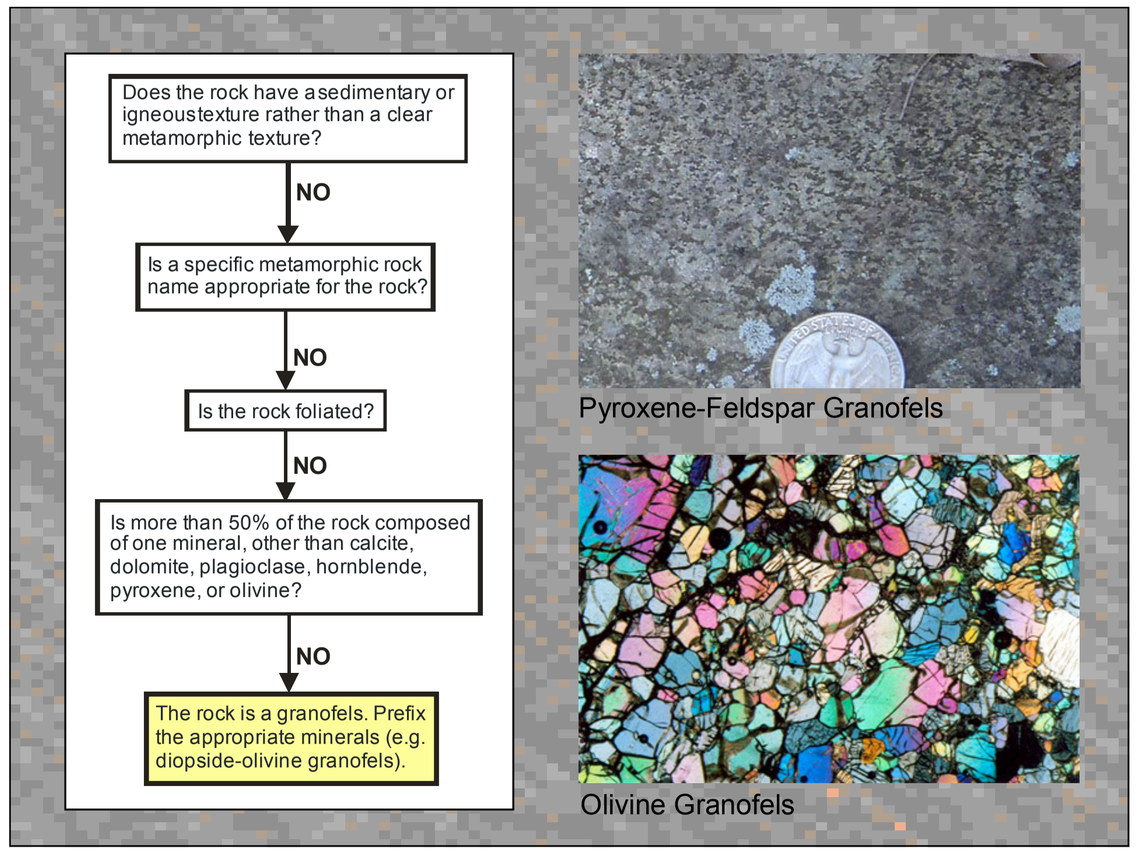






Epidosite

Anthophyllitite

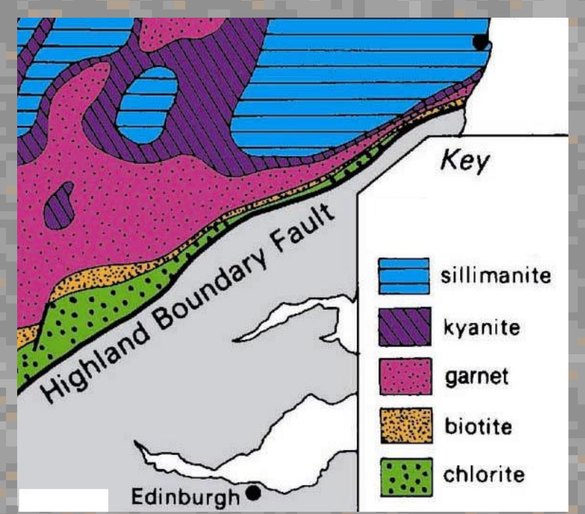


Pyroxene-Feldspar Granofels

Olivine Granofels

Metamorphic Zones and Facies

Mineral Zones of G.W. Barrow (1893)

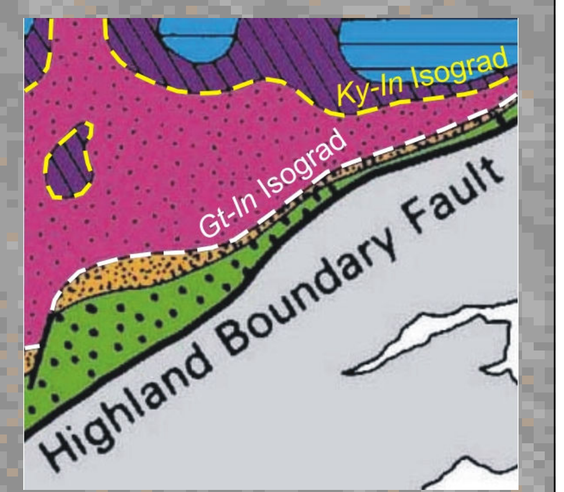


Excerpted From Gillen (1982) *Metamorphic Geology. An Introduction to Tectonic and Metamorphic Processes.*

- Barrow noted that pelitic rocks of the Scottish Highlands had distinct mineral zones (Gt, Ky, Sil)
- He concluded that this was the result of increasing metamorphic grade (T)
- Tilley (1925) added the low-grade Biotite and Chlorite zones
- Bt, Gt, St, Ky, and Sil are **Index Minerals** in metapelitic rocks

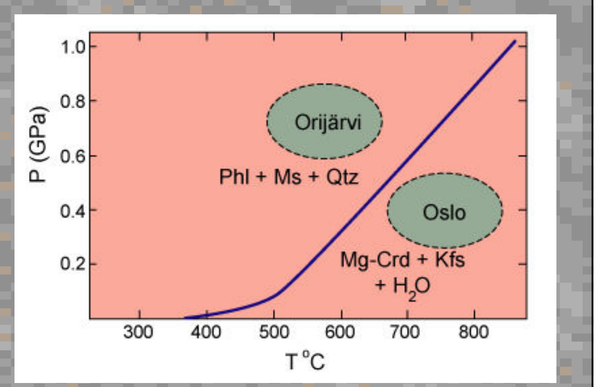
Index Mineral Isograds

- The line that defines the first appearance of an index mineral corresponds to a line of equal metamorphic grade
- Introduction of the concept of an **isograd**



Eskola and Metamorphic Facies

- Eskola (1914, 1915) noted that metapelitic rocks in southern Finland (Orijärvi) contained the assemblage Bt-Ms whereas near Oslo, rocks contained the compositionally equivalent mineral assemblage Kf-Cd
- If rocks are the same composition, then the mineralogical difference must be due to a difference in physical conditions



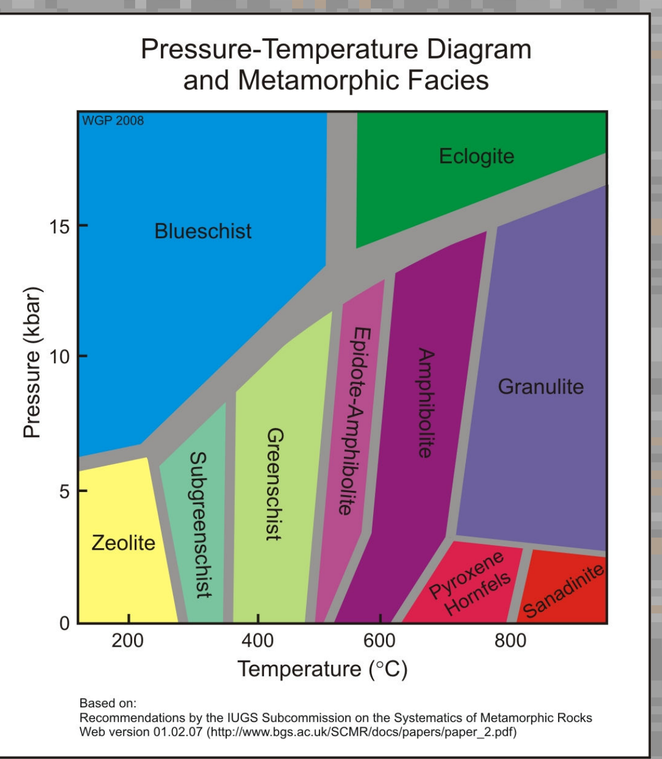
$$2\ KMg_3AlSi_3O_{10}(OH)_2 + 6\ KAl_2AlSi_3O_{10}(OH)_2 + 15\ SiO_2 \leftrightarrow 3\ Mg_2Al_4Si_5O_{18} + 8\ KAlSi_3O_8 + 8\ H_2O$$

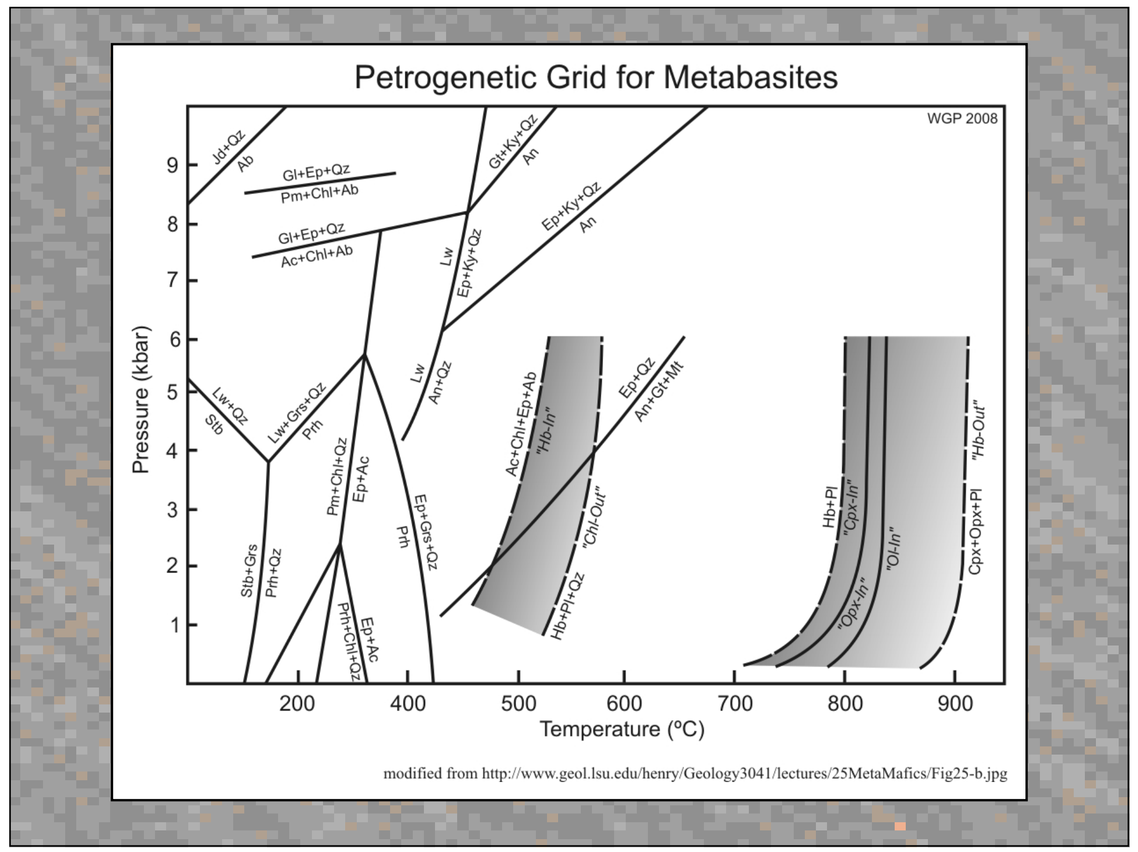
Eskola and Metamorphic Facies

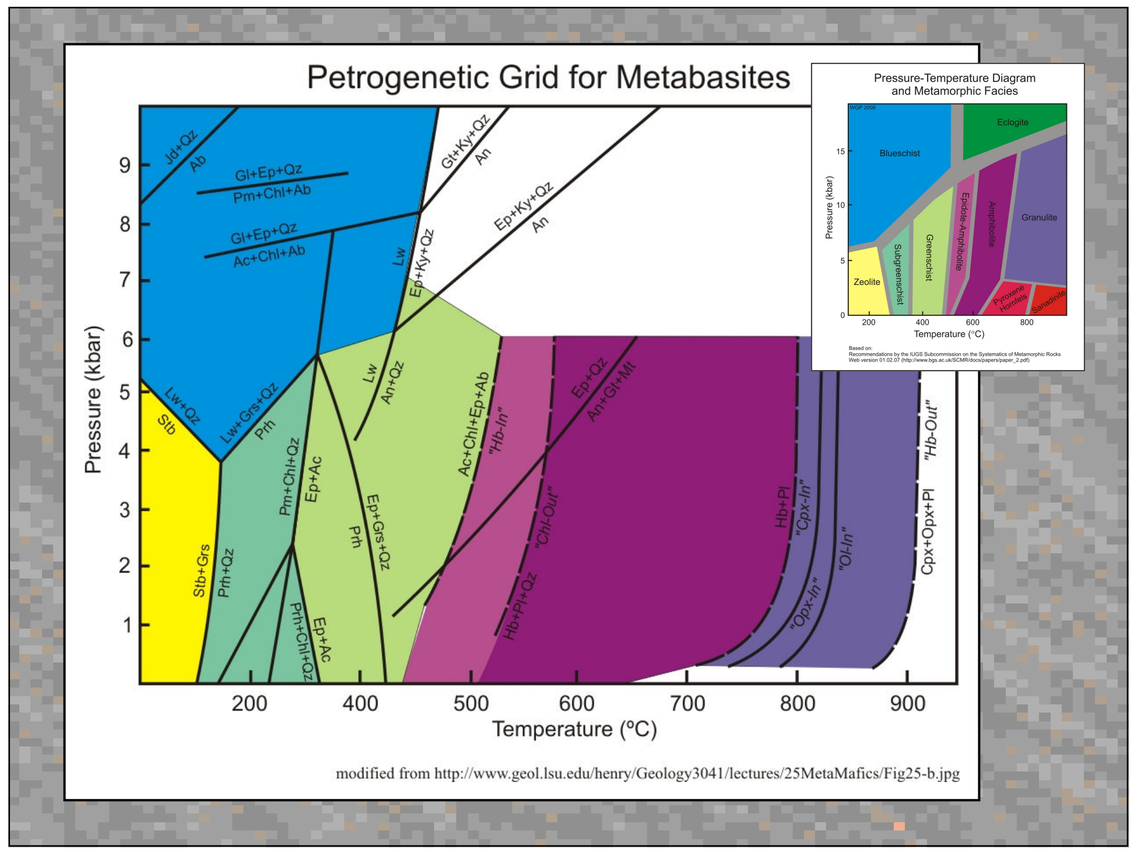
- Eskola (1915) introduced the concept of **metamorphic facies**:
  - "In any rock or metamorphic formation which has arrived at a chemical equilibrium through metamorphism at constant temperature and pressure conditions, the mineral composition is controlled only by the chemical composition."
- A **metamorphic facies** is a set of repeatedly associated metamorphic mineral assemblages
- If you find a specified mineral assemblage, then you can assign a metamorphic facies to the area, and thereby assign a range of pressure and temperature conditions.

Eskola and Metamorphic Facies

- In 1920, Eskola introduced five metamorphic facies that were defined by mineral assemblages in metabasites:
  - Greenschist
  - Amphibolite
  - Hornfels
  - Sanidinite
  - Eclogite
- In 1939, Eskola added an additional 3 metamorphic facies:
  - Granulite
  - Epidote-amphibolite
  - Glaucophane-schist (now called Blueschist)
- In 1959 and 1960, Coombs added two additional metamorphic facies:
  - Zeolite
  - Prehnite-Pumpellyite (now called Subgreenschist)







Metamorphic Facies and their Characteristic Minerals and Mineral Assemblages

FACIES	**Metabasites**	**Metapelites**	**Marbles***	**Metaperidotites***
Zeolite	Zeolites such as laumontite and heulandite etc. (in place of other Ca-Al silicates such as Prh, Pm, and Ep)	Mixed-layer clays (XRD)	Cc-Do-Qz	Srp (Chrysotile)
Subgreenschist	Prh-Pm, Pm-Ac, Prh-Act (Prh and Pm are the diagnostic Ca-Al silicates rather than minerals of the epidote or zeolite groups)	Illite-Chl-Ab-Qz	Cc-Do-Qz	Srp (Chrysotile)
Greenschist	Ac-Ep-Chl-Ab (an epidote group mineral is the diagnostic Ca-Al silicate rather than Prh or Pm)	Chl-Ms-Ab (low T) Bt-Chl-Ms-Ab (high T)	Cc-Do-Qz	Brucite-Srp, Srp-Fo
Epidote-Amphibolite	Hb-Ab-Ep(-Chl)	Gt-Bt-Chl-Ms-Ab		
Amphibolite	Hb-Pl (plagioclase more calcic than An_{17})	St-Als-Ms (Low T) Sil-Kf-Ms(-Gt or Cd) Sil-Gt-Cd (no Kf) (High T)	Cc-Do-Tr, Cc-Do-Di, Cc-Do-Fo	Fo-Tr-Srp, Fo-Tlc, Fo-Tr-En, En-Tr-Qz
Granulite	Cpx-Opx-Pl (Ol not stable with Pl or with Gt)	Cd-Gt-Kf-Sil (mod P), Ky-Kf (high P)		
Pyroxene Hornfels	Cpx-Opx-Pl (Ol stable with Pl)	Cd-And-Kf	Cc-Fo, Di-Gt-Wo	Anthophyllite-Fo
Sanadinite	Distinguished from pxn hornfels facies by especially high-T minerals (e.g. pigeonite, K-rich labradorite)	Corundum-An-Mt (no Qz)	Wo-An-Di	
Blueschist	Gl-Ep(-Gt), Gl-Lw(-Jd)	Ms-Gt-(Tc or Chl) (no Bt)	Aragonite	
Eclogite	Omphacite-Gt-Qz (no Pl or Ol stable with Gt)	Tc-Ky(-Gt-Ms)		