Metamorphic Textures

Reading: Winter, Chapter 23

Metamorphic Textures

Textures are small-scale penetrative features

Relict Textures

- Inherited from original rock
- "Blasto-" = relict
- Any degree of preservation
- Pseudomorphs of minerals or pre-metamorphic textures/structures

Metamorphic Textures

The Processes of Deformation, Recovery, and Recrystallization

1. Cataclastic Flow
   - Mechanical fragmentation and sliding, rotation of fragments
   - Crush, break, bend, grind, kink, def^m^ twins, undulose extinction, shredding of micas, augen, mortar, etc.
   - Technically not metamorphic

Processes of Deformation, Recovery, and Recrystallization

2. Pressure Solution

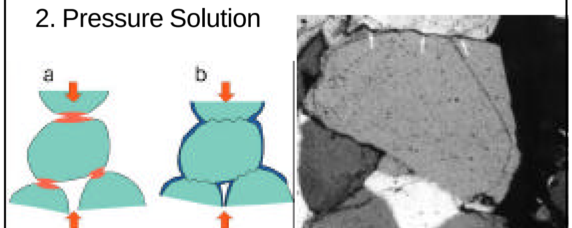

Figure 23-2 a. Highest strain in areas near grain contacts (hatch pattern). b. High-strain areas dissolve and material precipitates in adjacent low-strain areas (shaded). The process is accompanied by vertical shortening. c.Pressure solution of a quartz crystal in a deformed quartzite (s_1 is vertical). Pressure solution results in a serrated solution surface in high-strain areas (small arrows) and precipitation in low-strain areas (large arrow). ~ 0.5 mm across. The faint line within the grain is a hematite stain along the original clast surface. After Hibbard (1995) *Petrography to Petrogenesis* . Prentice Hall.

Metamorphic Textures

3. Plastic Intracrystalline Deformation
   - No loss of cohesion
   - Several processes may operate simultaneously
     - Defect migration
     - Slip planes
     - Dislocation glide
     - Deformation twinning

Metamorphic Textures

4. Recovery
   - Loss of stored strain energy by vacancy migration, dislocation migration and annihilation
   - Polygonization- general term for formation of low-strain subgrains

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5. Recrystallization
   - Grain boundary migration
   - Subgrain rotation
   - Solid-state diffusion creep at higher T
   - Crystalplastic deformation (general term)
     - Grain boundary sliding and area reduction

Coalescence- recovery and recrystallization by which large grains form by the addition of smaller strained grains by grain boundary migration

Dislocation migration forms two strain-free subgrains

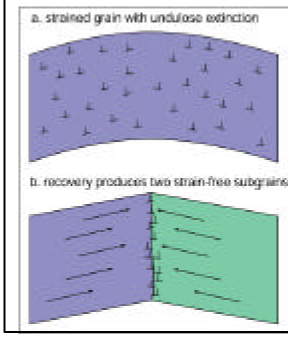


Figure 23-5. Illustration of a recovery process in which dislocations migrate to form a subgrain boundary. Winter (2001)

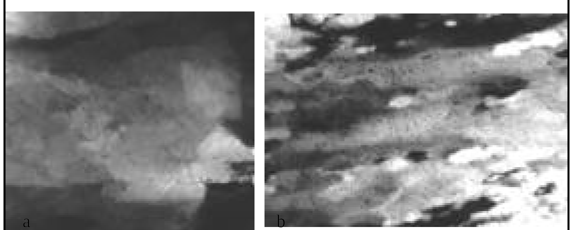


Figure 23-4 a. Undulose extinction and (b) elongate subgrains in quartz due to dislocation formation and migration Winter (2001)

Recrystallization by grain boundary migration and sub-grain rotation

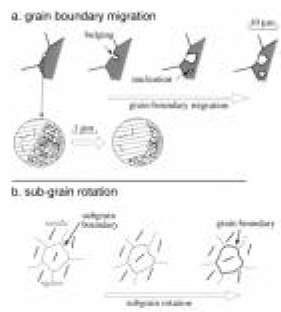
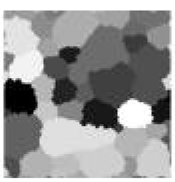


Figure 23-6. Recrystallization by (a) grain-boundary migration (including nucleation) and (b) subgrain rotation. From Passchier and Trouw(1996) *Microtectonics*.

Figure 23-7a. Recrystallized quartz with irregular (sutured) boundaries, formed by grain boundary migration. Width 0.2 mm. From Borradaile *et al*. (1982).



High-Strain Metamorphic Textures (shear zones)

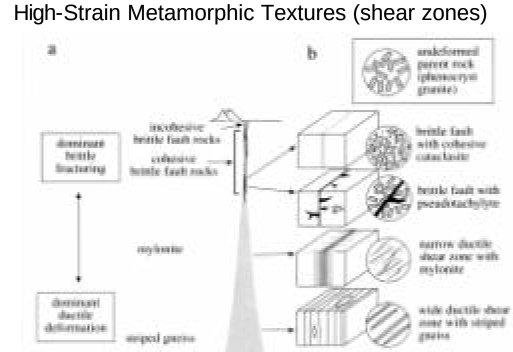


Figure 22-2. Schematic cross section through a shear zone, showing the vert ical distribution of fault -related rock types, ranging from non-cohesive gouge and breccia near the surface through progressively more cohesive and foliated rocks. Note that the width of the shear zone increases with depth as the shear is distributed over a larger area and becomes more ductile. Circles on the right represent microscopic views or textures. From Passchier and Trouw (1996) *Microtectonics*, Springer -Verlag, Berlin.

High-Strain Metamorphic Textures

- Concentrate on cataclastic > ductile (shallower)
  - Break, crack, bend, crush, rotate
  - Slip and shredding of phyllosilicates
  - Clasts- broken remnants
  - Porphyroclast- larger remnant in finer crush matrix
    - Mortar texture
    - Ribbons
  - Pseudotachylite

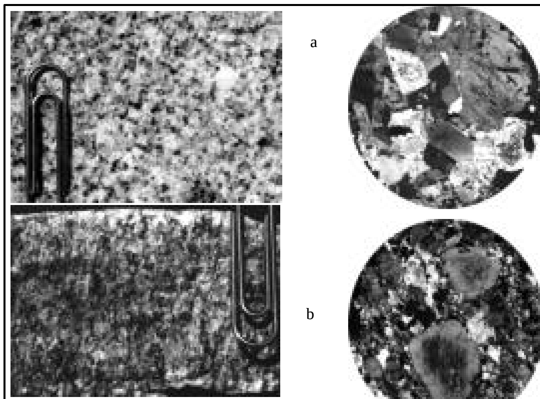


Figure 23-15. Progressive mylonitization of a granite. From Shelton (1966). *Geology Illustrated.* Photos courtesy© John Shelton.

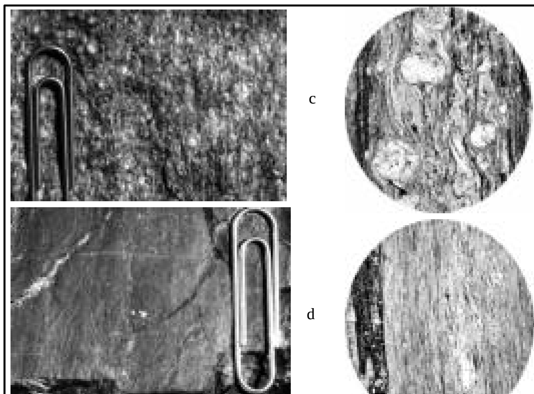


Figure 23-15. Progressive mylonitization of a granite. From Shelton (1966). *Geology Illustrated.* Photos courtesy© John Shelton.

Table 22-1. Classification of High-Strain Fault Zone Rocks

% fine matrix	Rocks without primary cohesion	Rocks with primary cohesion			
		Non-foliated	Foliated		Glass in matrix
50	Fault breccia	Microbreccia	Protomylonite	Blastomylonite (if significantly recrystallized)	Pseudotachylite
70			Mylonite		
90	Fault gouge	Cataclasite	Ultramylonite		

After Higgins (1971)

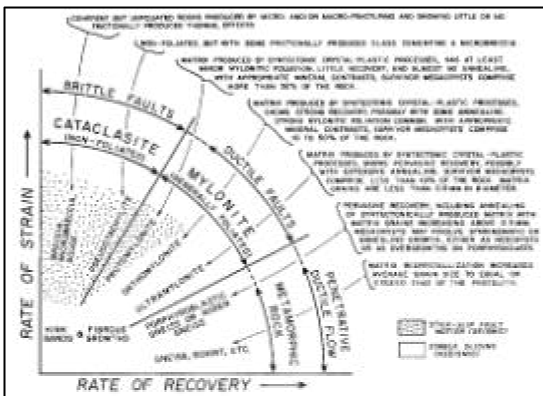
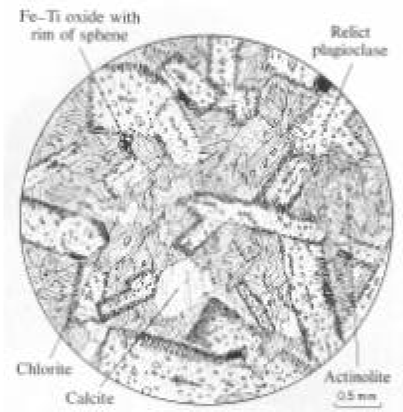


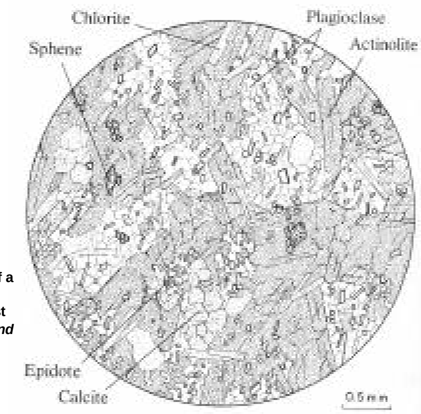
Figure 22-3. Terminology for high-strain shear-zone related rocks proposed by Wise *et al.* (1984) Fault-related rocks: Suggestions for terminology. *Geology*, 12, 391-394.

Textures of Contact Metamorphism

- Typically shallow pluton aureoles (low-P)
- Crystallization/recrystallization is near-static
  - Monomineralic with low D surface energy form granoblastic polygonal
  - Larger D S.E. form decussate
- Isotropic textures (hornfels, granofels)
- Relict textures are common



Progressive thermal metamorphism of a diabase (coarse basalt). From Best (1982). *Igneous and Metamorphic Petrology*. W. H. Freeman. San Francisco.



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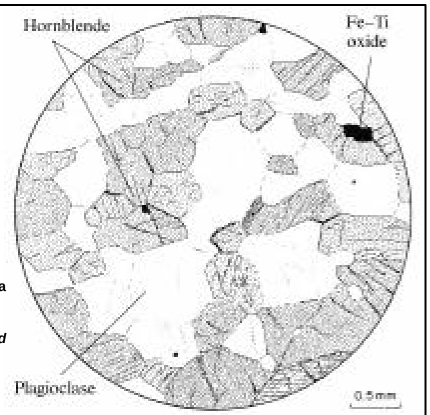

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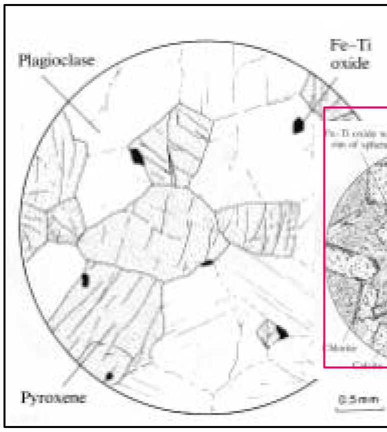

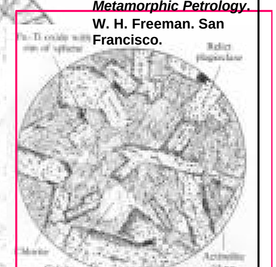

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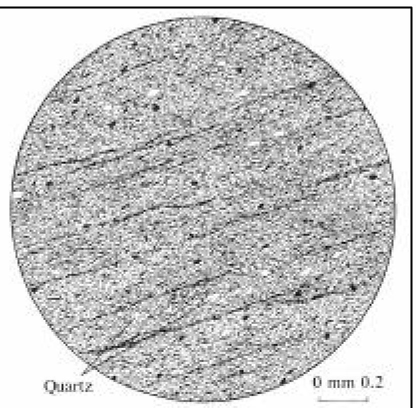
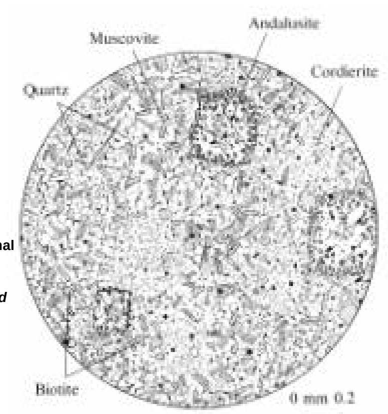
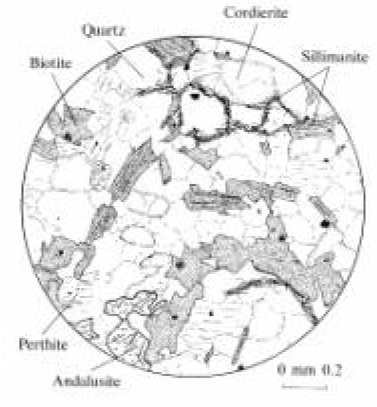


Progressive thermal metamorphism of slate. From Best (1982). *Igneous and Metamorphic Petrology*. W. H. Freeman. San Francisco.



Progressive thermal metamorphism of slate. From Best (1982). *Igneous and Metamorphic Petrology*. W. H. Freeman. San Francisco.



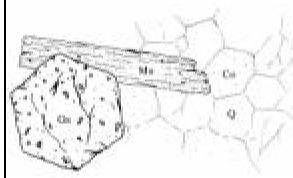
Progressive thermal metamorphism of slate. From Best (1982). *Igneous and Metamorphic Petrology*. W. H. Freeman. San Francisco.

The Crystalloblastic Series

Most Euhedral

- Titanite, rutile, pyrite, spinel
- Garnet, sillimanite, staurolite, tourmaline
- Epidote, magnetite, ilmenite
- Andalusite, pyroxene, amphibole
- Mica, chlorite, dolomite, kyanite
- Calcite, vesuvianite, scapolite
- Feldspar, quartz, cordierite

Least Euhedral



Differences in development of crystal form among some metamorphic minerals. From Best (1982). *Igneous and Metamorphic Petrology*. W. H. Freeman. San Francisco.

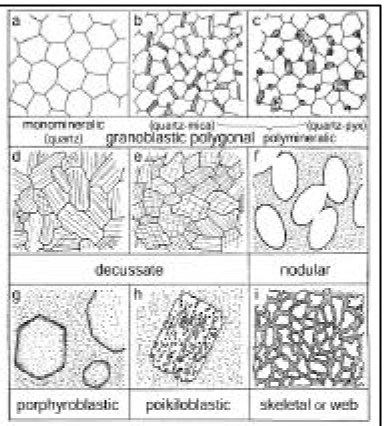
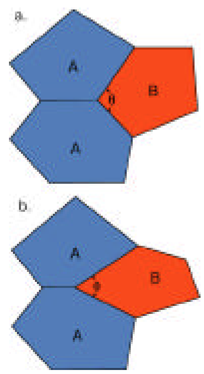


Figure 23-9. Typical textures of contact metamorphism. From Spry (1969) *Metamorphic Textures*. Pergamon. Oxford.

Fig. 23-10 Grain boundary energy controls triple point angles



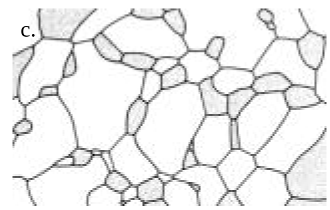
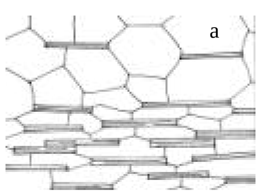
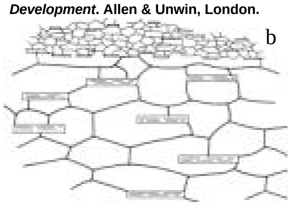


Figure 23-10. a. Dihedral angle between two mineral types. When the A-A grain boundary energy is greater than for A-B, the angle q will decrease (b) so as to increase the relative area of A-B boundaries. Winter (2001) c. Sketch of a plagioclase (light)-clinopyroxene (dark) hornfels showing lower dihedral angles in clinopyroxene at most cpx-plag-plag boundaries. (c. from Vernon, 1976) *Metamorphic Processes: Reactions and Microstructure Development*. Allen & Unwin, London.

Figure 23-11. Quartz-mica schists. a. Closer spacing of micas in lower half causes quartz grains to passively elongate causing quartz-quartz boundaries to meet mica (001) faces at 90°. From Shelley (1993). b. Layered rock in which growth of quartz has been retarded by grain boundary "pinning" by finer micas in the upper layer. From Vernon, 1976) *Metamorphic Processes: Reactions and Microstructure Development*. Allen & Unwin, London.





Metamorphic Textures

- Contact overprint on earlier regional events are common
  - Thermal maximum later than deformational
  - Separate post-orogenic (collapse) event
- Nodular overprints
- Spotted slates and phyllites

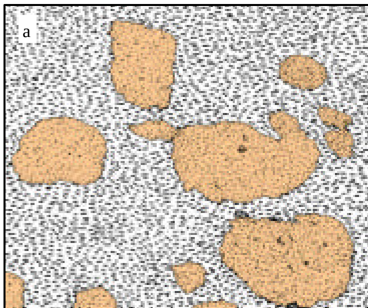
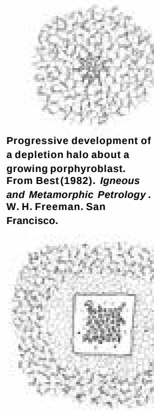


Figure 23-14. Overprint of contact metamorphism on regional. a. Nodular texture of cordierite porphyroblasts developed during a thermal overprinting of previous regional metamorphism (note the foliation in the opaques). Approx. 1.5 x 2 mm. From Bard (1986) *Microtextures of Igneous and Metamorphic Rocks*. Reidel Dordrecht. b. Spotted phyllite in which small porphyroblasts of cordierite develop in a preexisting phyllite. Winter (2001)

Depletion haloes



Progressive development of a depletion halo about a growing porphyroblast. From Best (1982). *Igneous and Metamorphic Petrology*. W. H. Freeman. San Francisco.

Depletion halo around garnet porphyroblast. Boehls Butte area, Idaho