

Ductile Shear Zones

Chapter 12 in



Earth Structure (2nd Edition), 2004
W.W. Norton & Co, New York
Slide show by Ben van der Pluijm

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Mylonites/Shear Zones

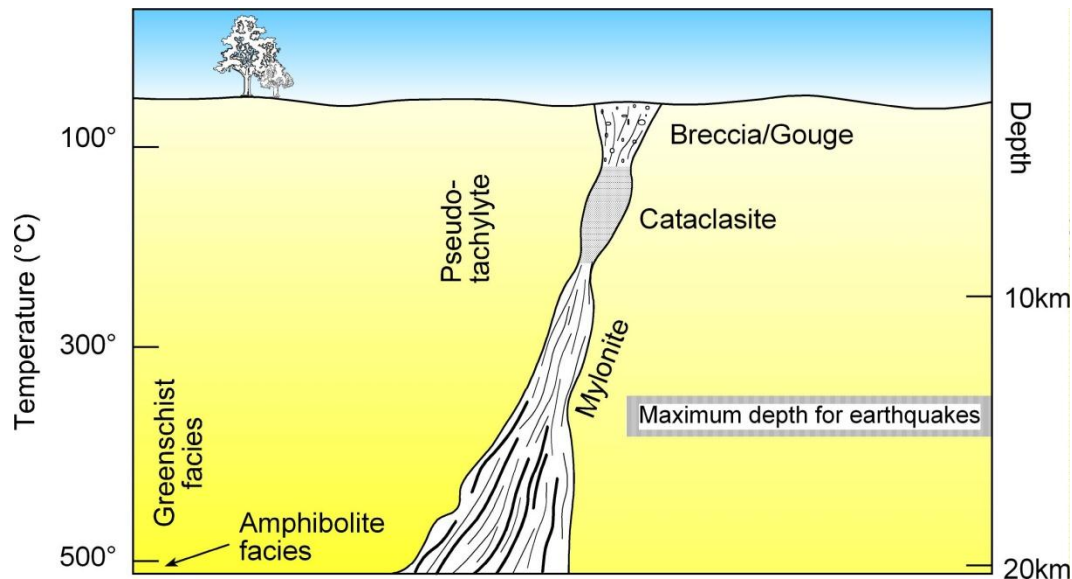


Mylonites

Narrow planar regions in which deformation is intense relative to that in adjacent rock.

Characteristics:

- fine-grained (relative to host rock)
- foliated (parallel to shear zone boundary)
- lineated (parallel to displacement direction)
- fold transposition (high strain)
- DPF: dimensional preferred fabric (dynamic recrystallization)
- CPF: crystallographic preferred fabric (dislocation creep)



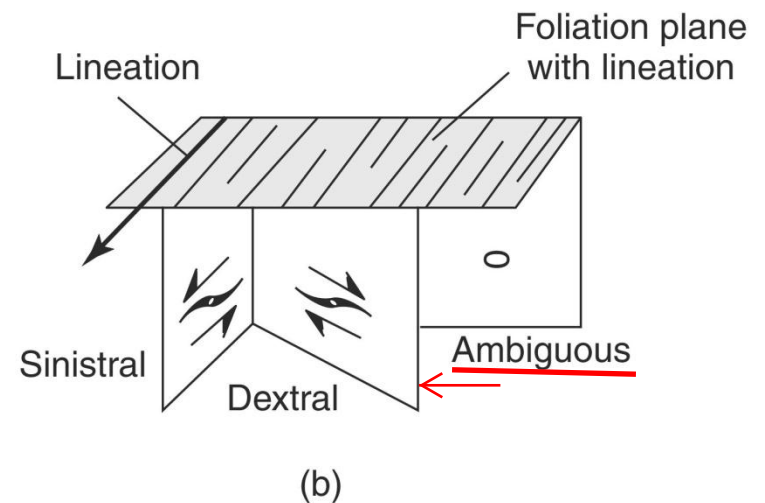
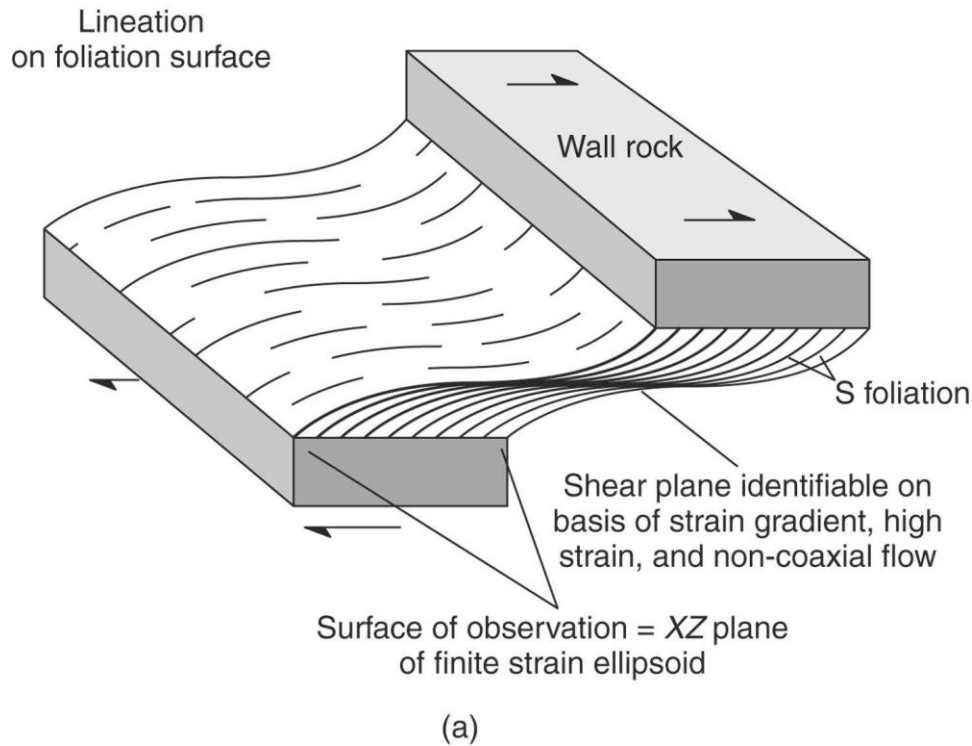
ES, 8-26

Types of mylonites



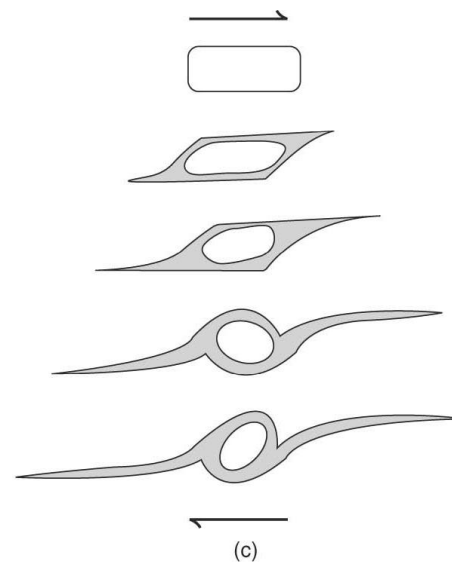
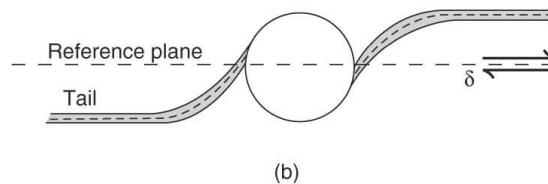
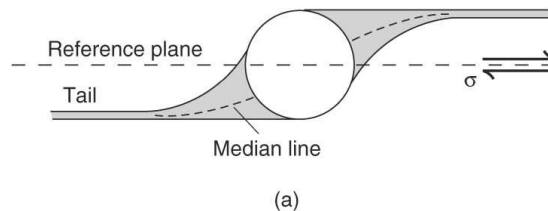
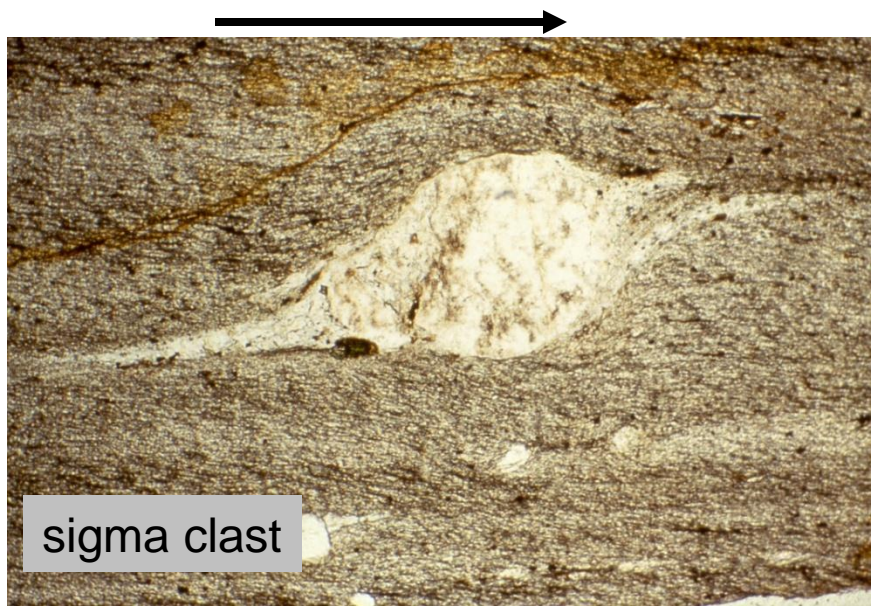
TABLE 12.2	TYPES OF MYLONITES
Blastomylonite	Mylonite that contains relatively large grains that grew during mylonitization [e.g., from metamorphic reactions or secondary grain growth].
Clastomylonite	Mylonite that contains relatively large grains or aggregates that remain after mylonitization reduced the grain size of most of the host rock [e.g., relatively undeformed feldspar grains or clumps of mafic minerals].
Phyllonite	Mica-rich mylonite.
Protomylonite	Mylonite in which the proportion of matrix is <50% [i.e., rocks in which only a minor portion of the minerals underwent grain-size reduction].
Ultramytonite	Mylonite in which the proportion of matrix is 90–100% [i.e., rocks in which mylonitization was nearly complete].

Terminology

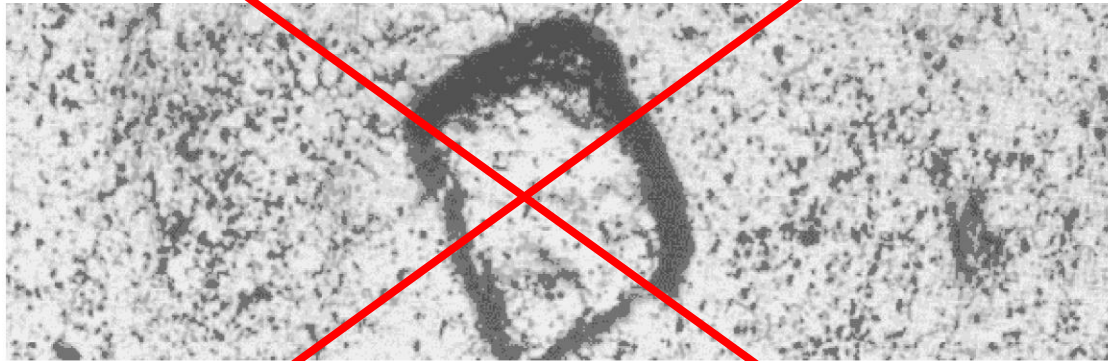


The plane of observation to determine the sense of shear must be oriented normal to mylonitic foliation and parallel to the mylonitic lineation.

Shear-sense Indicators - Grain-Tail Complexes



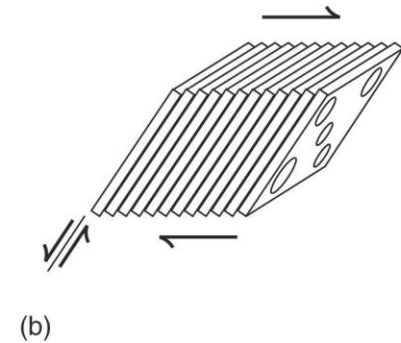
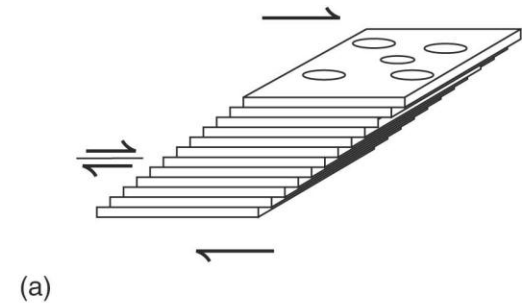
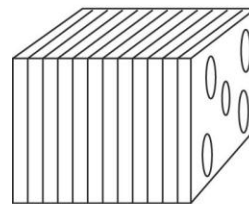
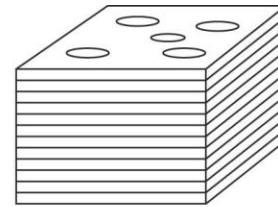
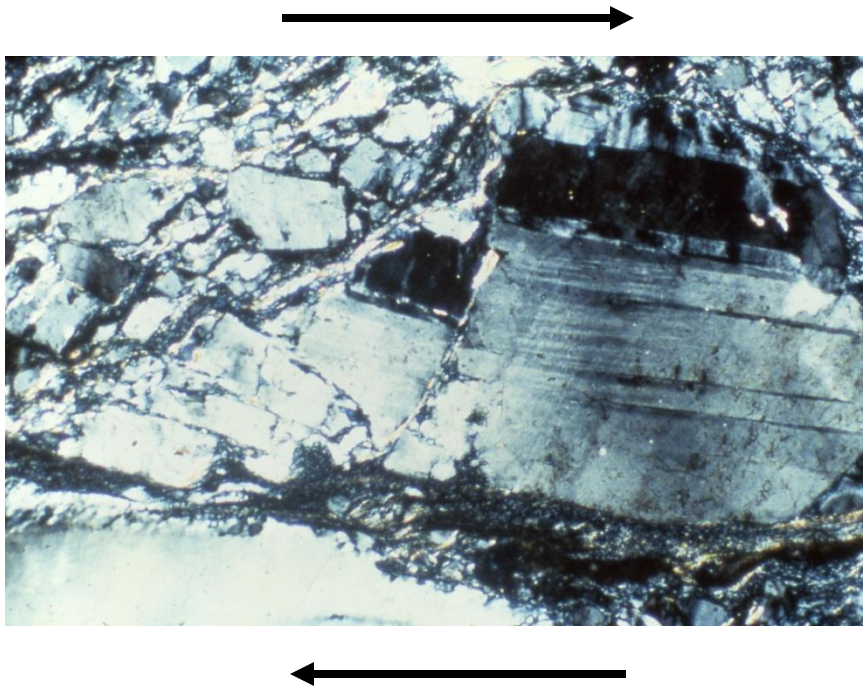
Porphyroclast



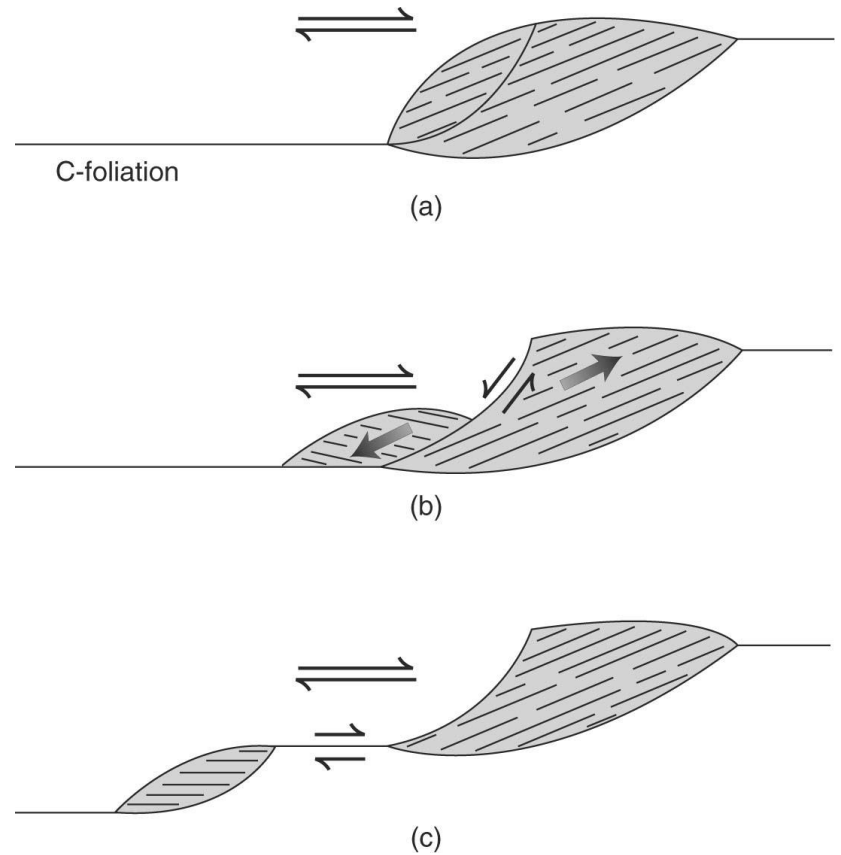
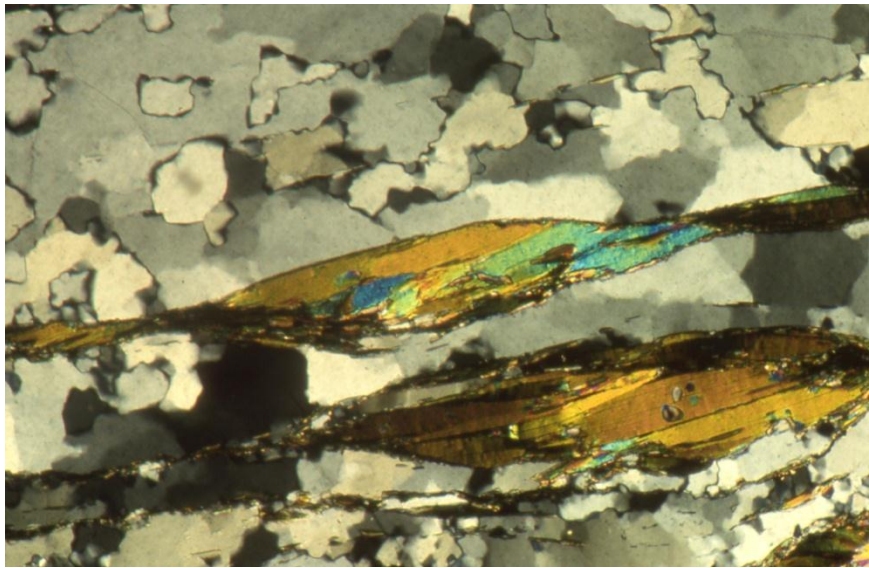
camphor clast in a matrix of OCP grains

Ten Brink, 2000

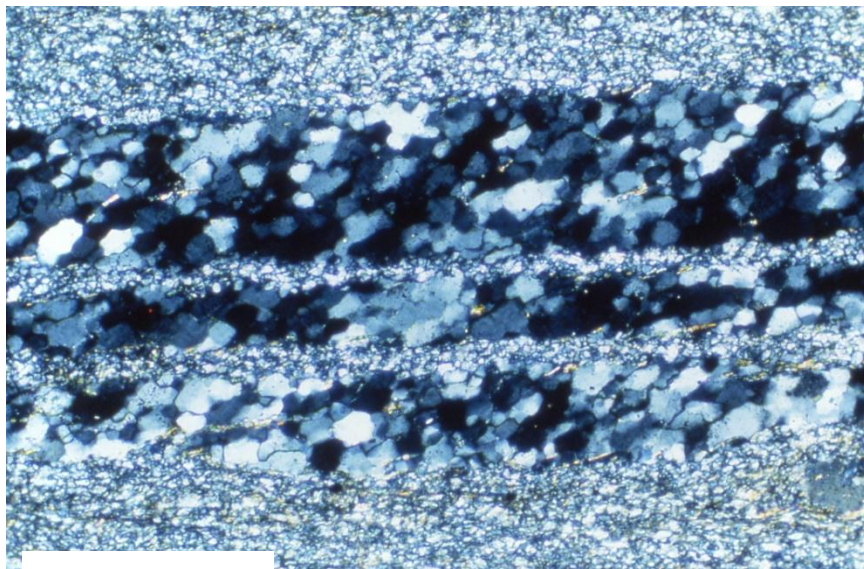
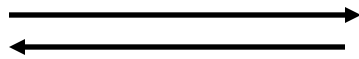
Shear-sense Indicators – Fractured Grains



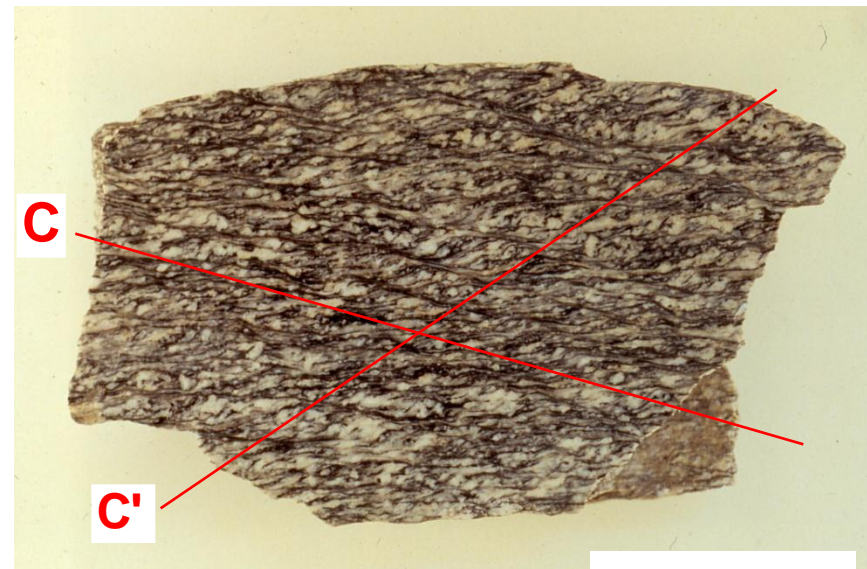
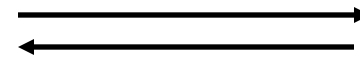
Shear-sense Indicators – Mica Fish



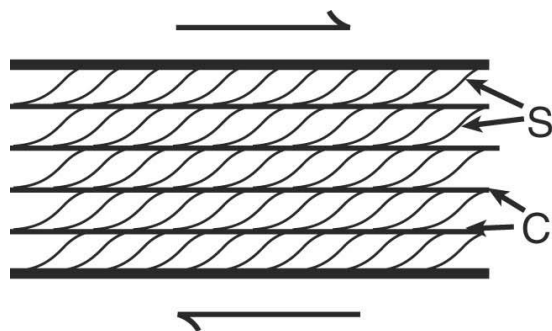
Shear-sense Indicators - Fabrics



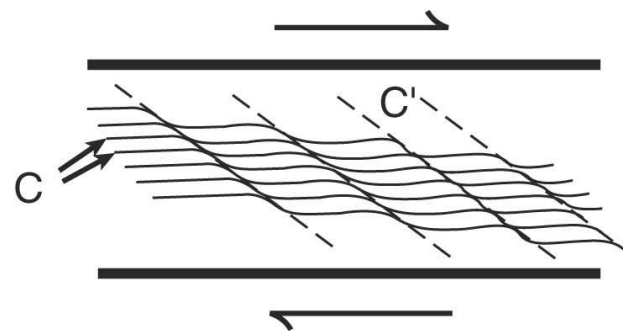
S-C fabric



C-C' fabric

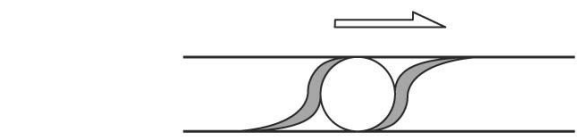


(a)



(b)

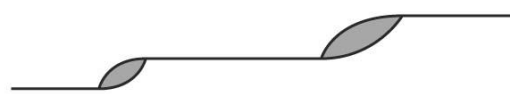
Shear-sense Indicators - Summary



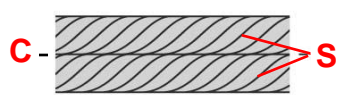
δ -type



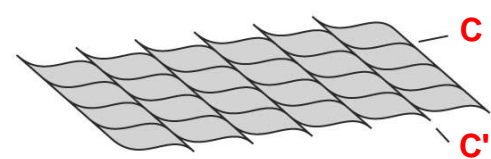
σ -type



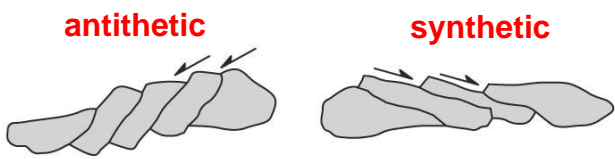
Mica fish



C-S fabric

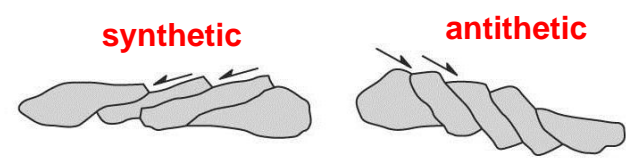
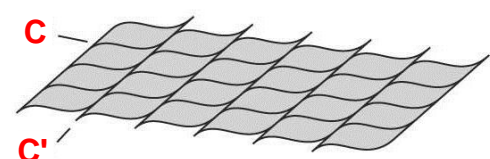
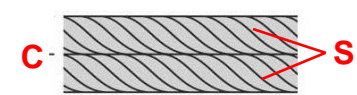
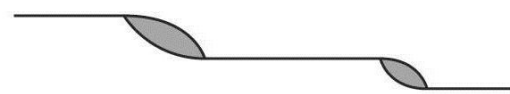
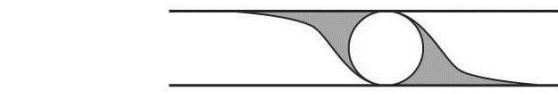
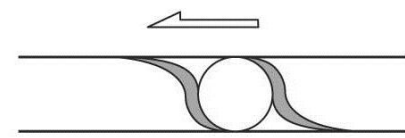


C-C' fabric



Fractured grains

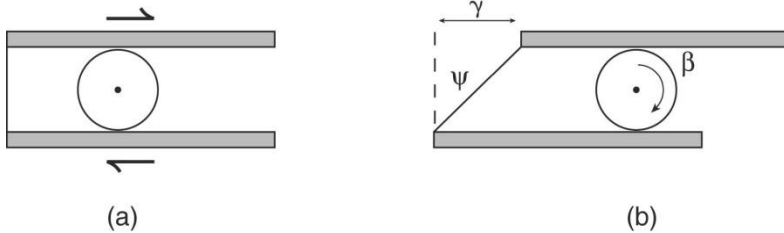
Dextral Shear



Sinistral Shear

Strain – Rotation

All the next slides will be considered on the "PETROFABRICS" course.



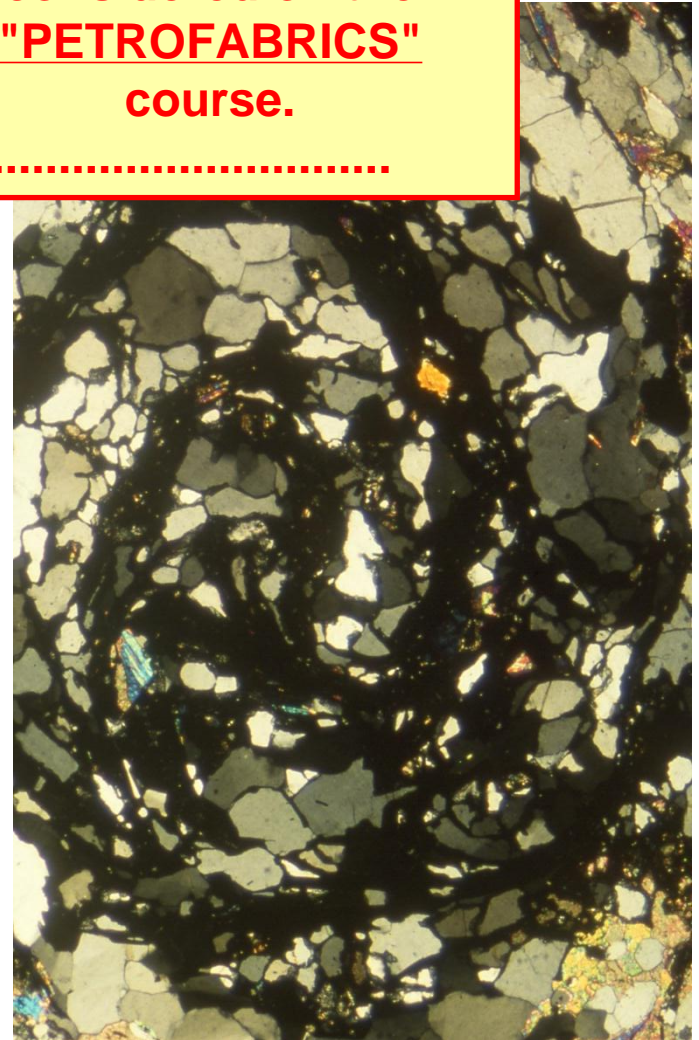
$$\beta = \Omega \tan \psi = \Omega \gamma$$

β is rotation angle in radians (1 radian is 180°)

ψ is angular shear

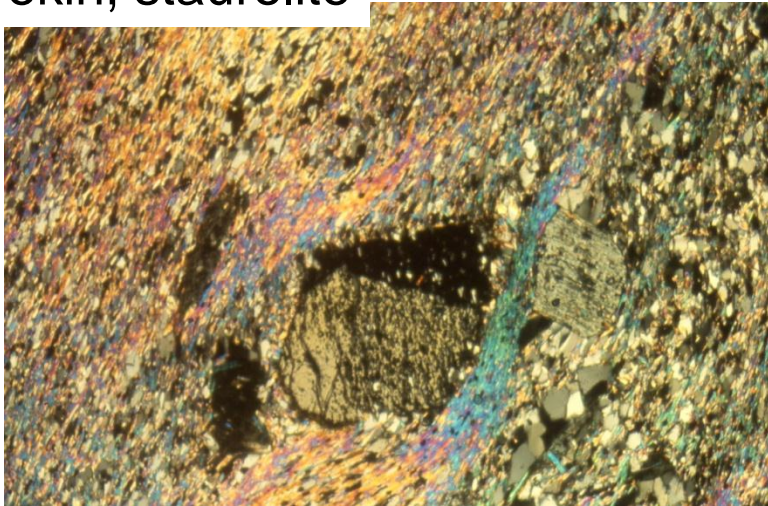
γ is shear strain

Ω is mechanical coupling

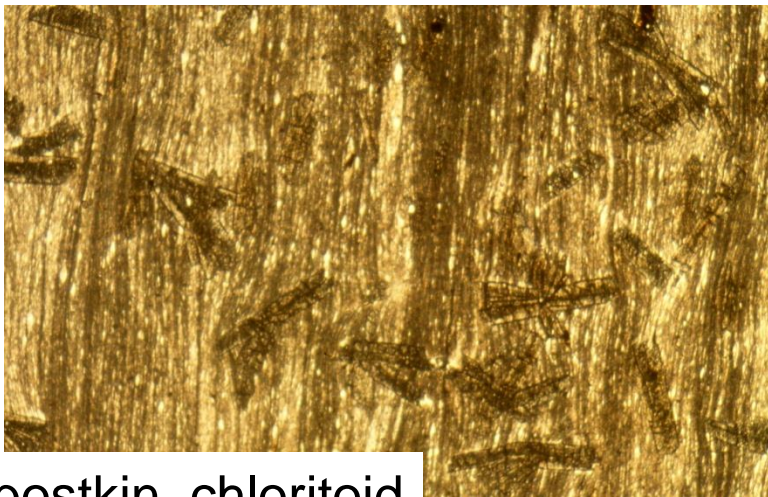
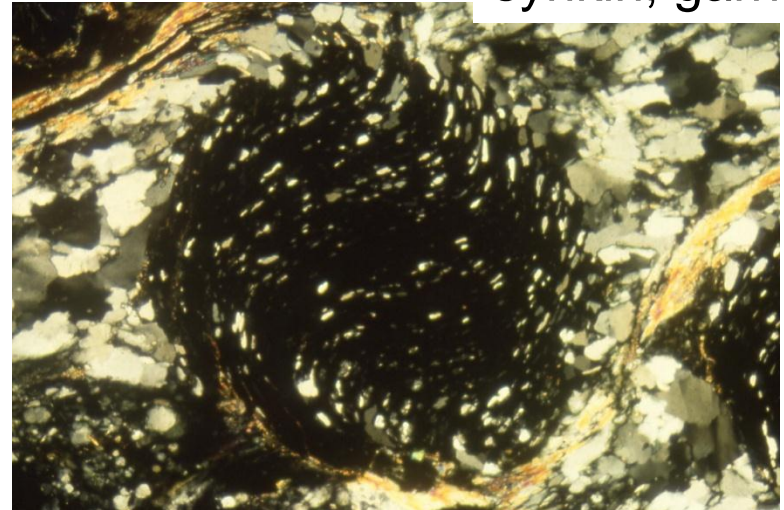


Digression: Porphyroblastesis

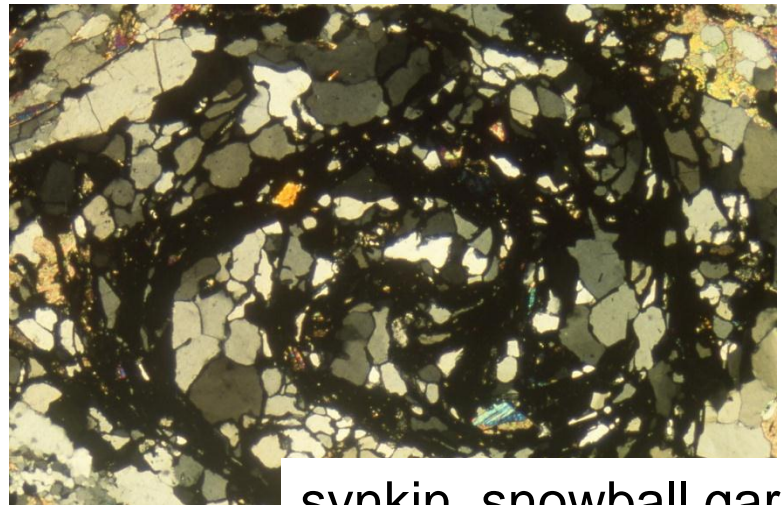
prekin, staurolite



synkin, garnet

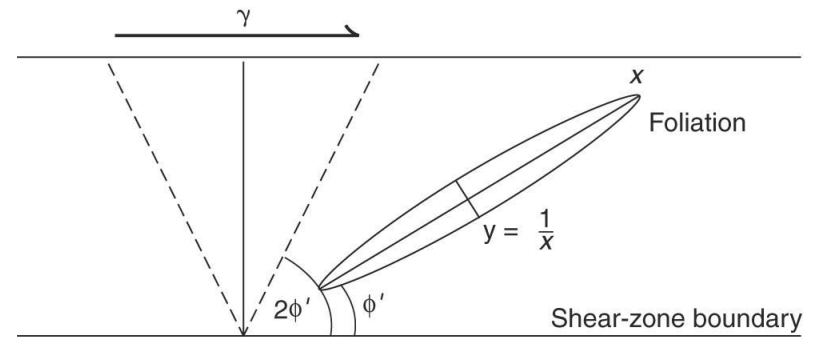
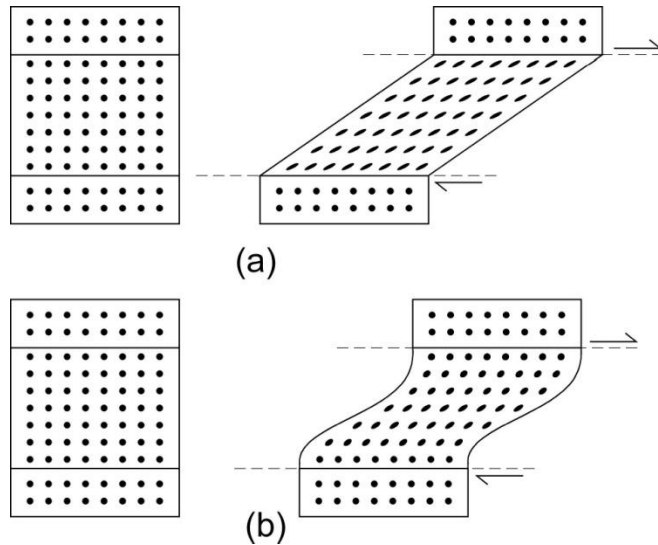


postkin, chloritoid

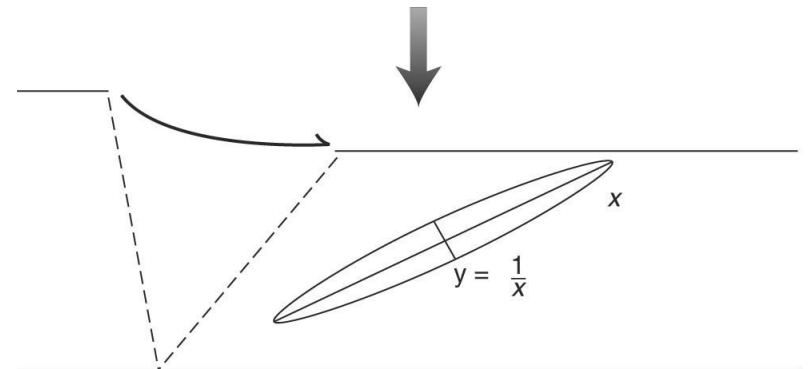


synkin, snowball garnet

Shear zones and Strain



(a)



(b)

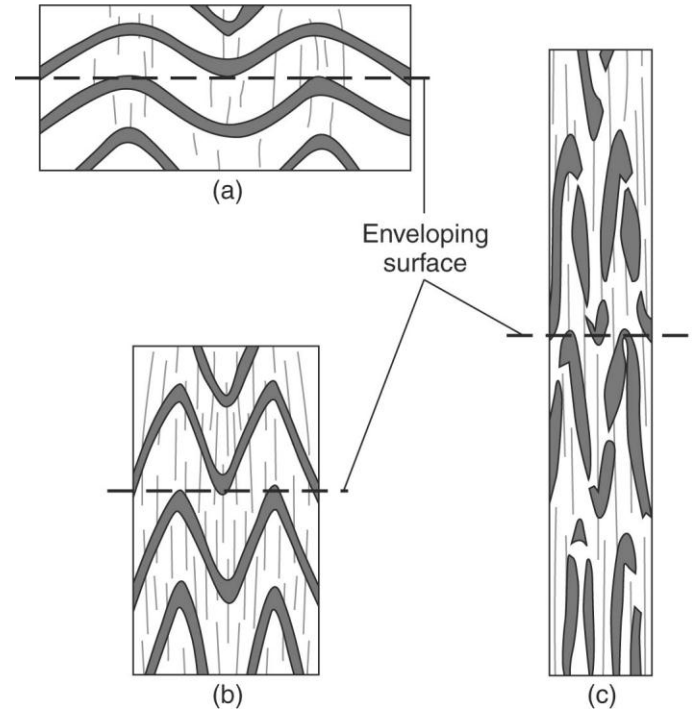
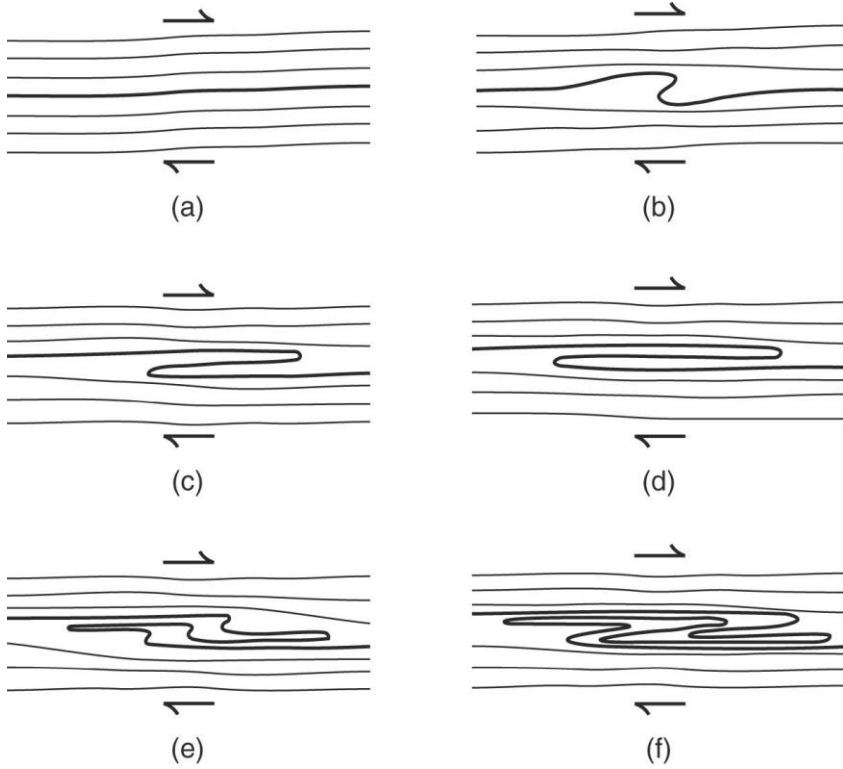
$$\gamma = 2/\tan 2\phi'$$

ϕ' is angle between foliation and shear-zone boundary

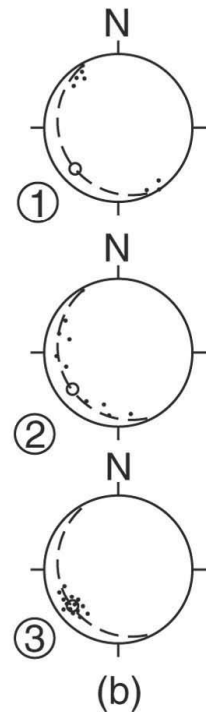
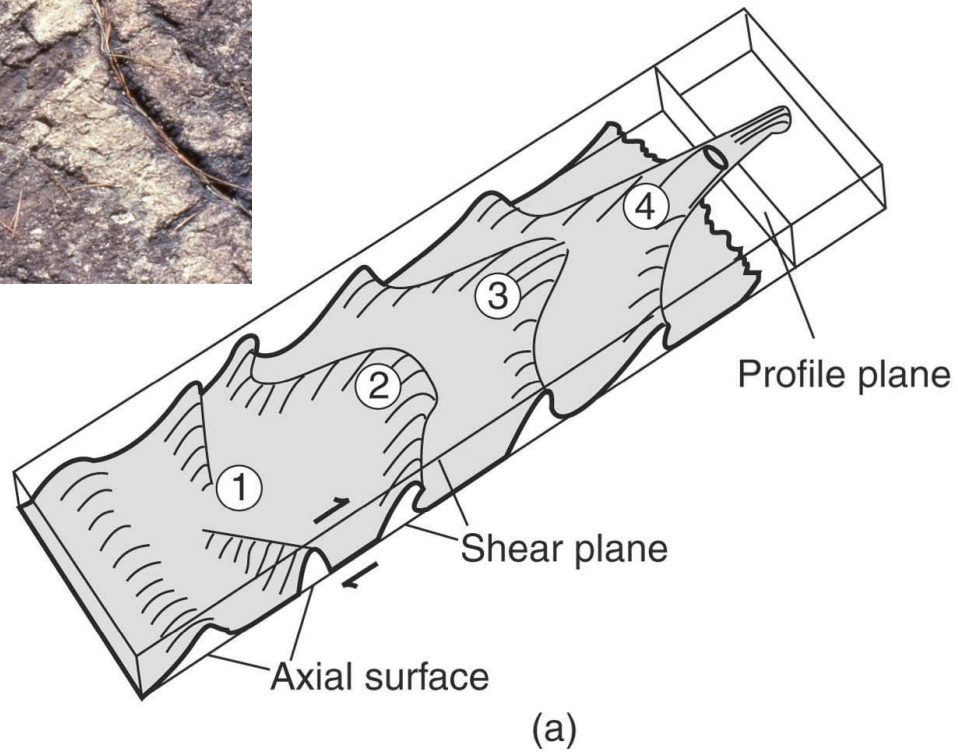
High Strain Regions and Transposition



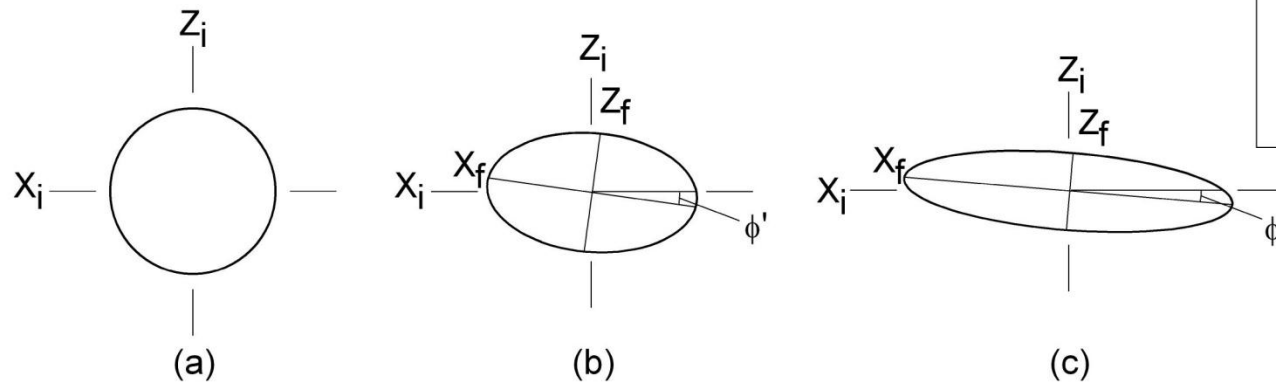
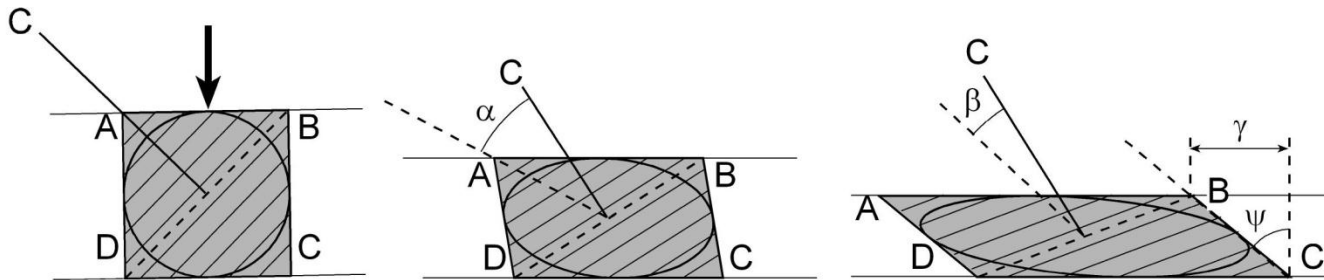
Fold Transposition



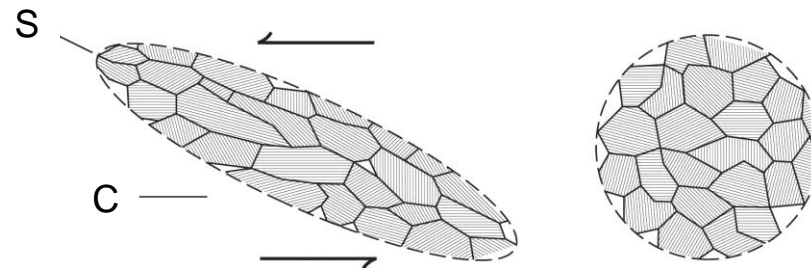
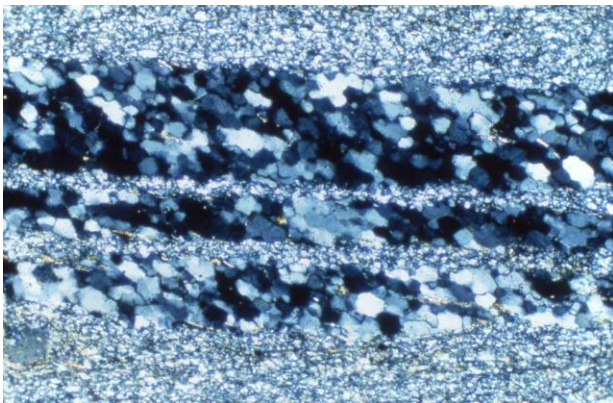
Sheath Folds



Crystallographic Fabrics



x_i, z_i = instantaneous strain
 x_f, z_f = finite strain
 C = basal plane pole



Symmetry Principle (Curie Principle, 1894)

The effect may have the **same or a higher** symmetry than the cause.
The cause cannot have a higher symmetry than the effect produced.

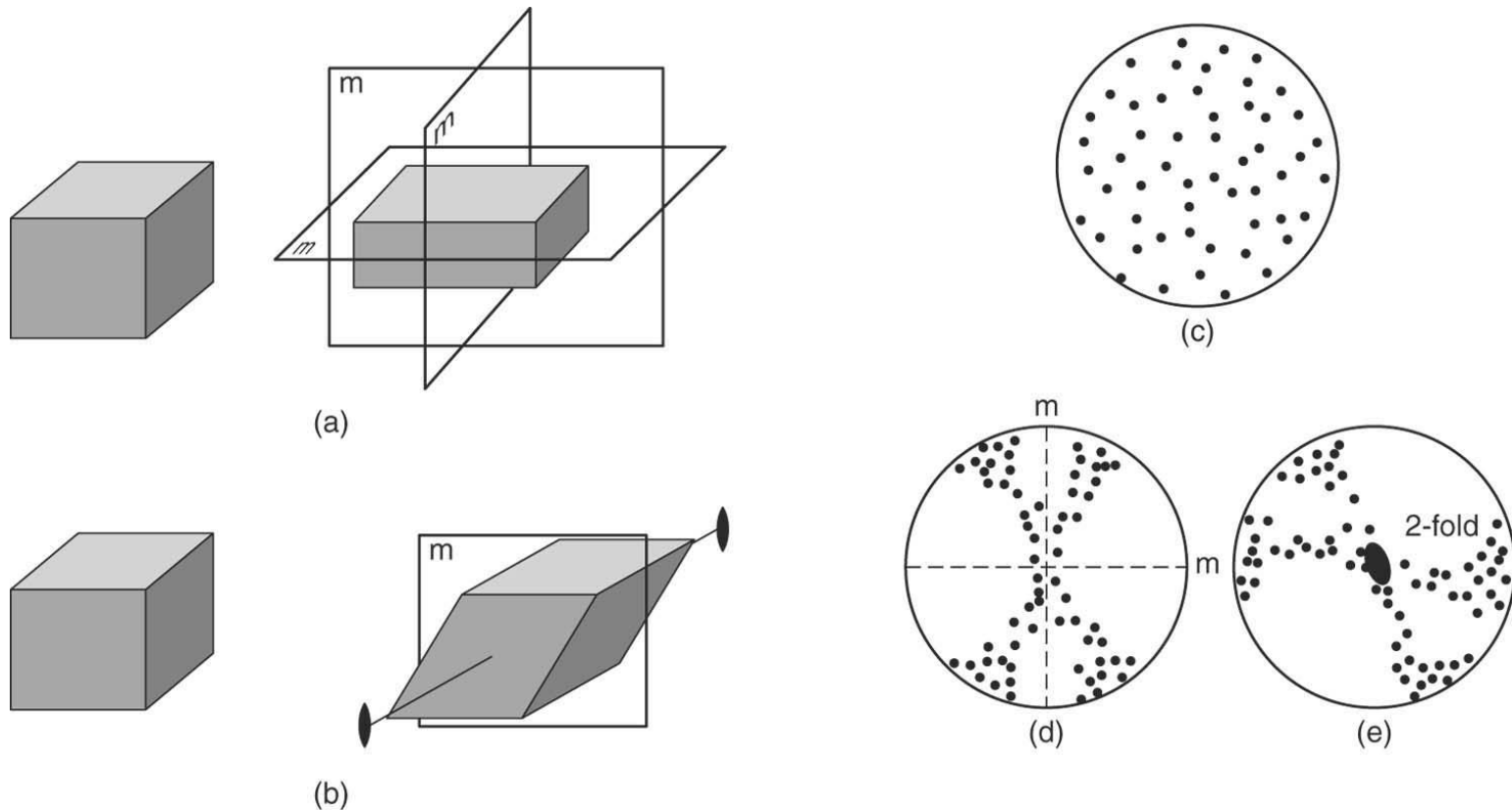
Example:

Monoclinic c-axis fabric cannot be produced by coaxial (=orthorhombic) strain.
But, the reverse can be true

TABLE 12.3		CRYSTAL SYSTEMS IN ORDER OF INCREASING SYMMETRY	
System	Symmetry	Crystal Axes ¹	
Triclinic	1 one-fold axis or center of symmetry	$a \neq b \neq c, \alpha \neq \beta \neq \gamma \neq 90^\circ$	
Monoclinic	1 two-fold axis or 1 symmetry plane	$a \neq b \neq c, \alpha = \gamma = 90^\circ, \beta \neq 90^\circ$	
Orthorhombic	3 two-fold axes or 3 symmetry planes	$a \neq b \neq c, \alpha = \beta = \gamma = 90^\circ$	

¹a, b, and c describe the lengths of the crystal axes; α is the angle between b and c; β is the angle between a and c; γ is the angle between a and b.

CPF and Symmetry

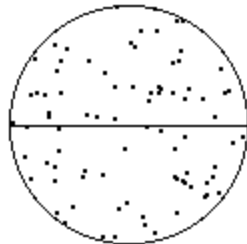
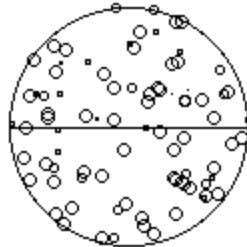
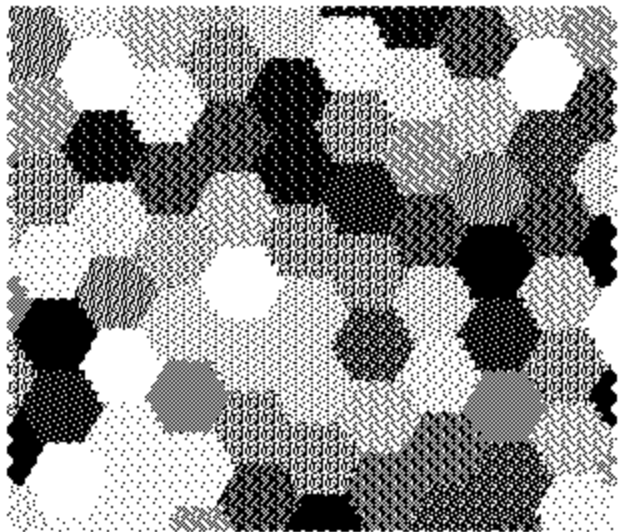


Symmetry Principle.

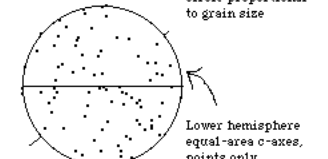
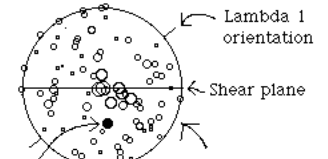
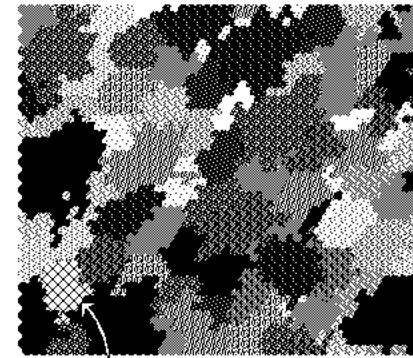
(a) orthorhombic, (b) monoclinic symmetry.

(c) Random distribution of c-axes reorganizes into (d) high-symmetry (orthorhombic) and (e) low-symmetry (monoclinic) pattern.

Low Temperature Fabric - DPF and CPF

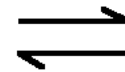


INC= 0 B/B+P=.50 MOB=.00 PNUKE=.000 ANGNUKE=.0 GAMMA=.00

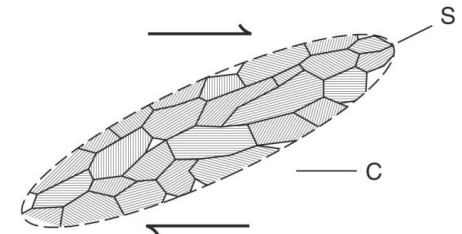
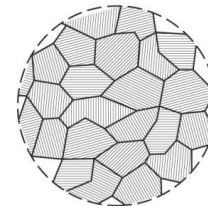


INC= 2 B/B+P=.00 MOB= 5.00 PNUKE=.000 ANGNUKE=.0 GAMMA=.40

Example Image



Grain shape fabric assumes crossed-polars parallel to boundaries. (Material that goes off left due to straining reappears on right.)

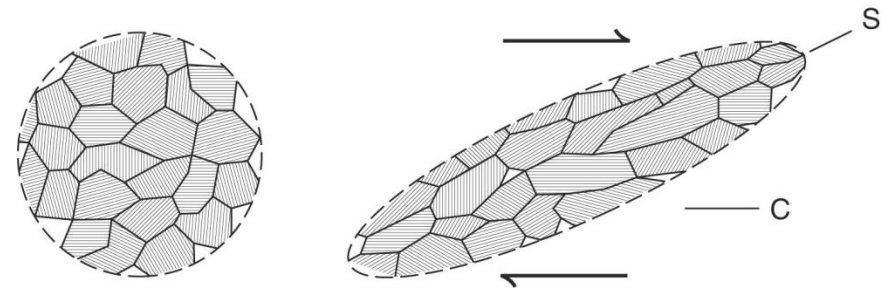
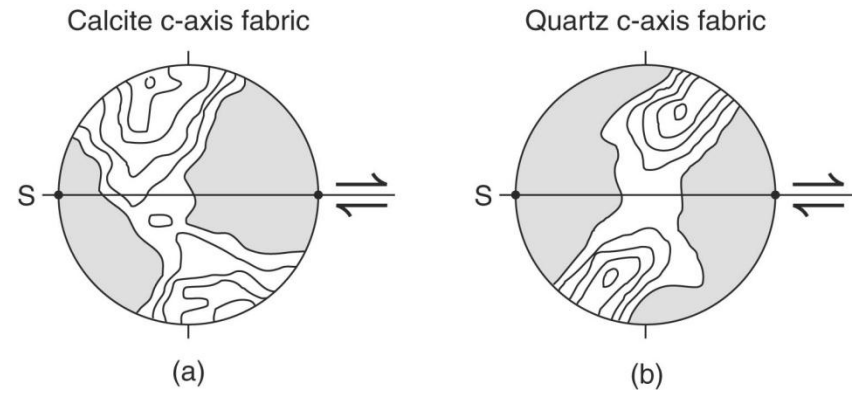
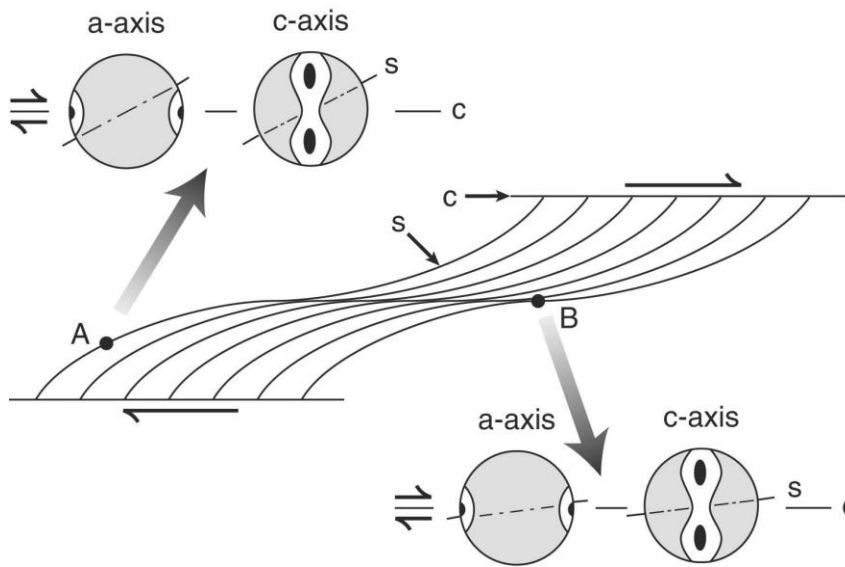


Low T_h , i.e. single glide system (exponential creep)

This is homologous temperature: $T/T_{melting}$ (in K)

Jessell and Bons, 2002

Fabrics in shear zones



Relationship between shape, crystallographic fabric, mylonitic foliation (S) and shear plane (C) in a grain aggregate.

Crustal Fault Model

