

Pelatnas IESO Geologi Struktur 2013

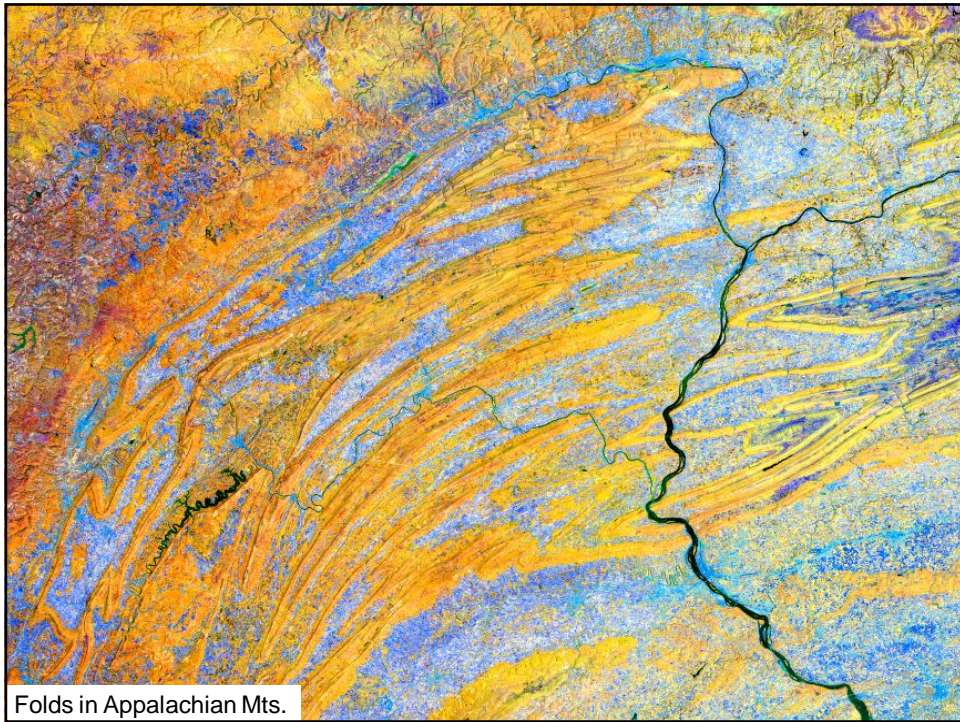
# Deformasi Liat

*Salahuddin Husein*

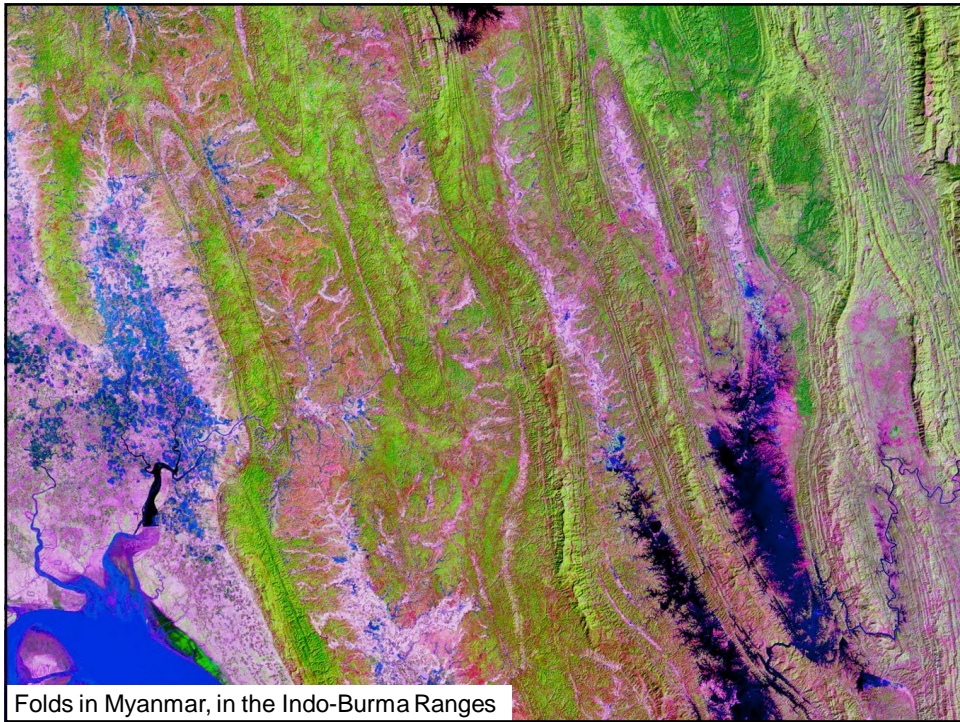


Jurusan Teknik Geologi  
Fakultas Teknik Universitas Gadjah Mada  
2013

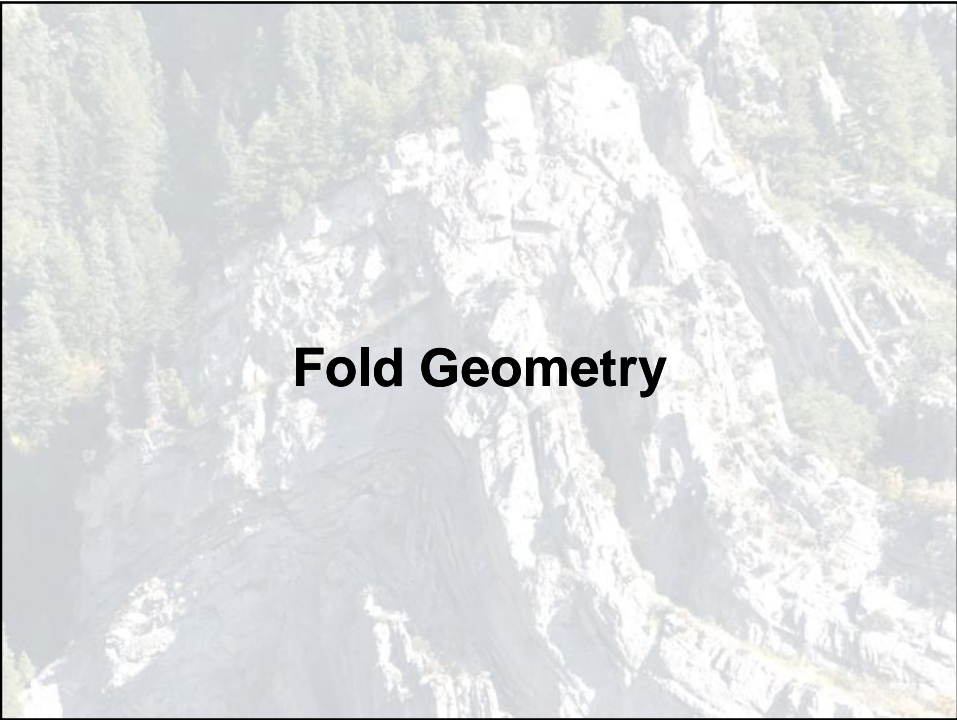




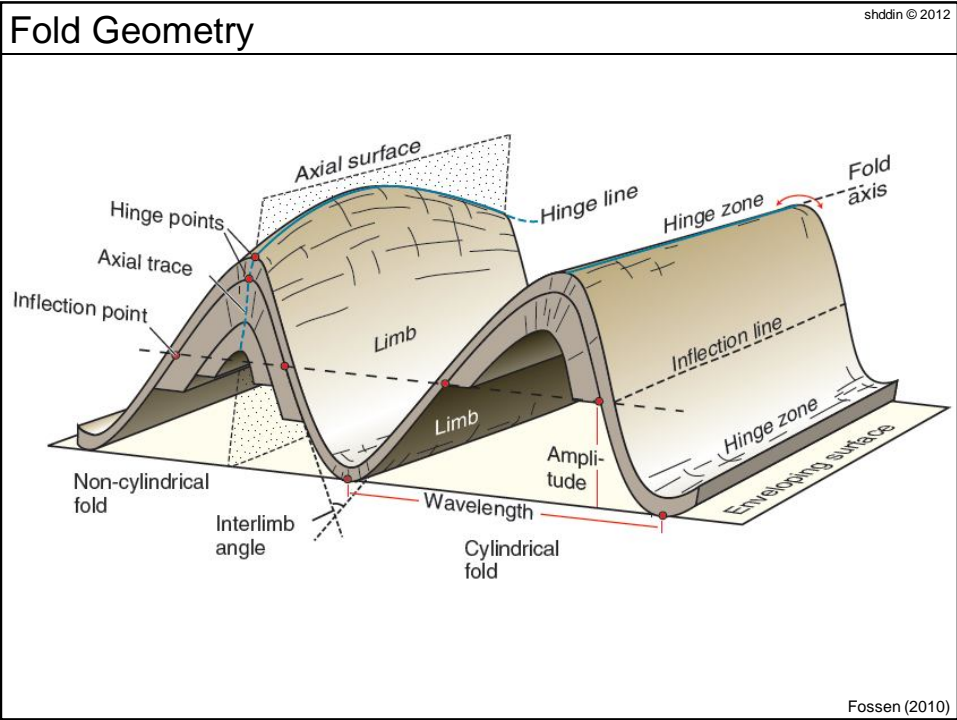
Folds in Appalachian Mts.



Folds in Myanmar, in the Indo-Burma Ranges



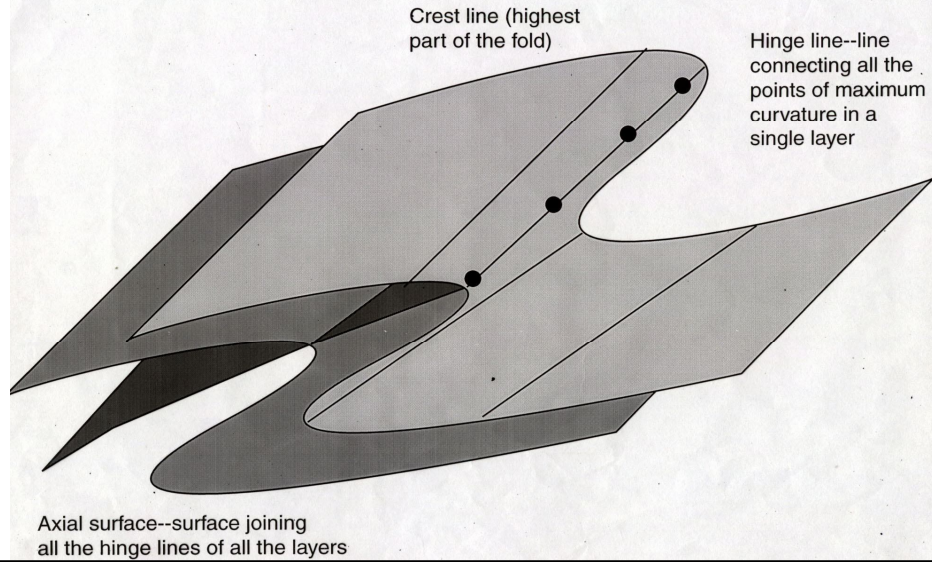
# Fold Geometry



## Fold Geometry

shddin © 2012

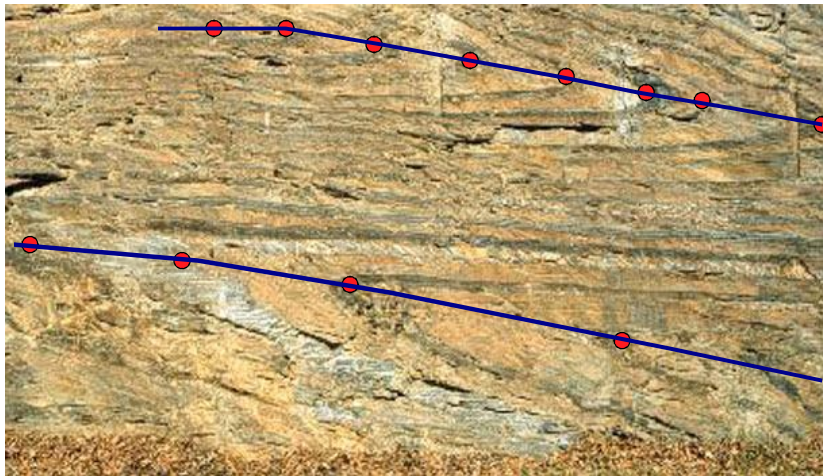
### Fold hinges and axial surfaces



## Fold Geometry

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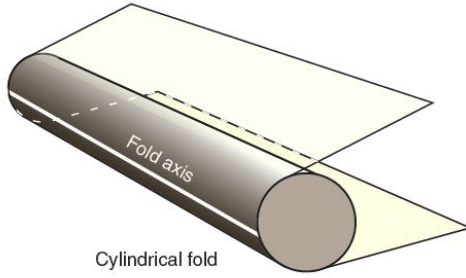
### Define hinge points



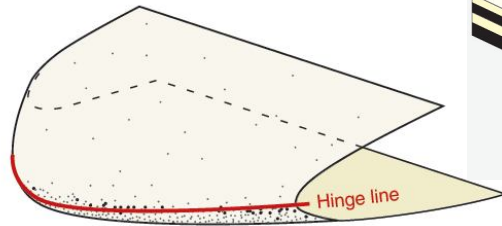
Join up hinge points to define axial trace

# Fold Geometry

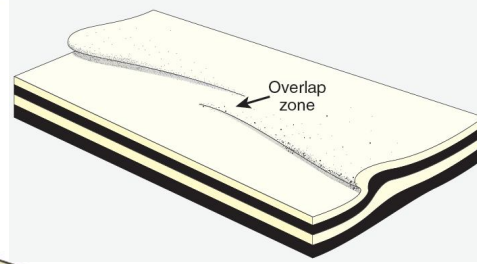
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Cylindrical fold



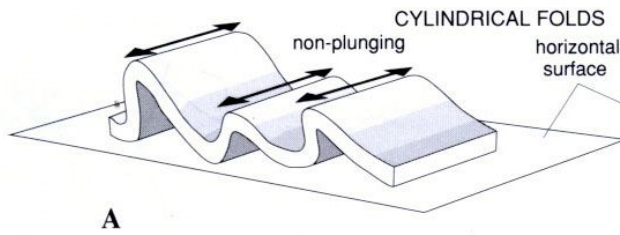
Non-cylindrical fold



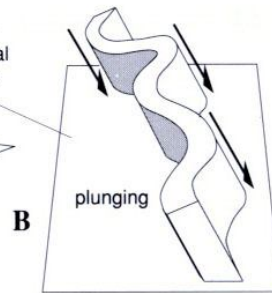
Fossen (2010)

# Fold Geometry

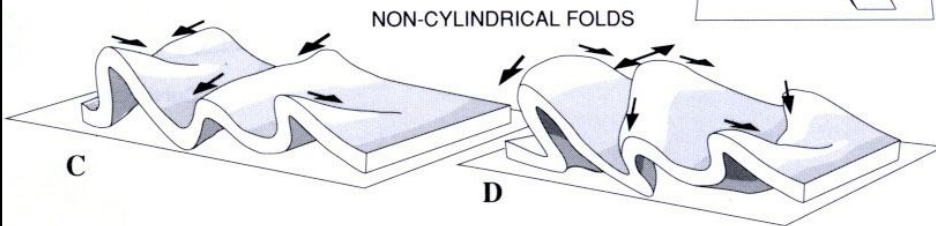
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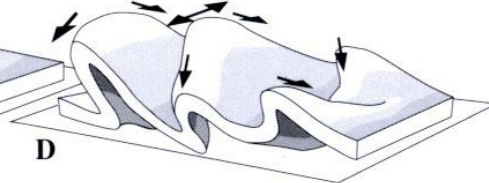
A



B



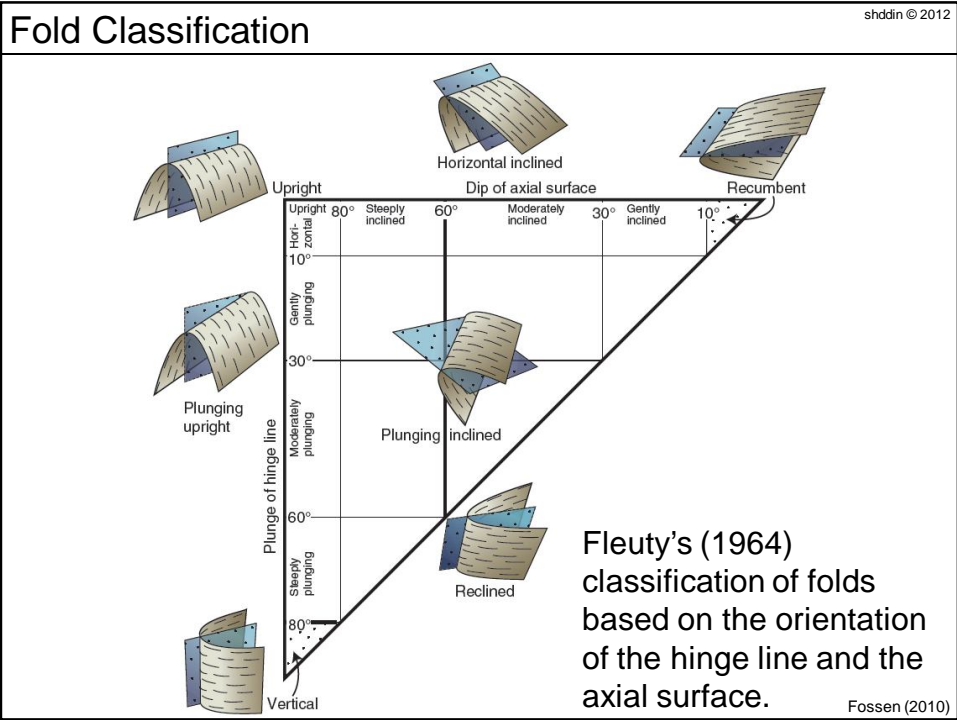
C

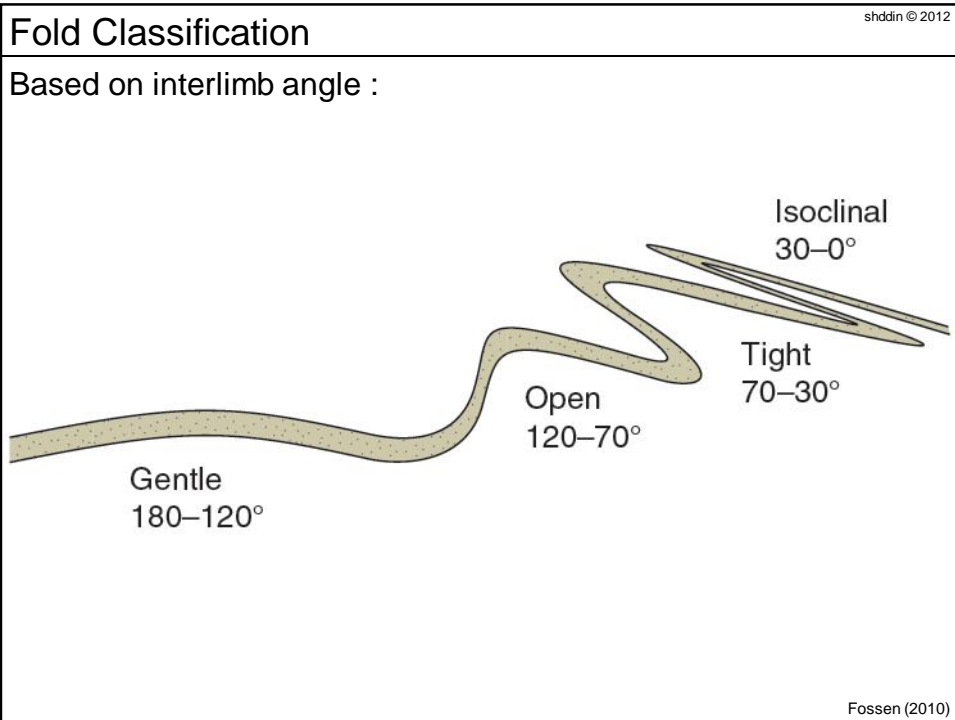
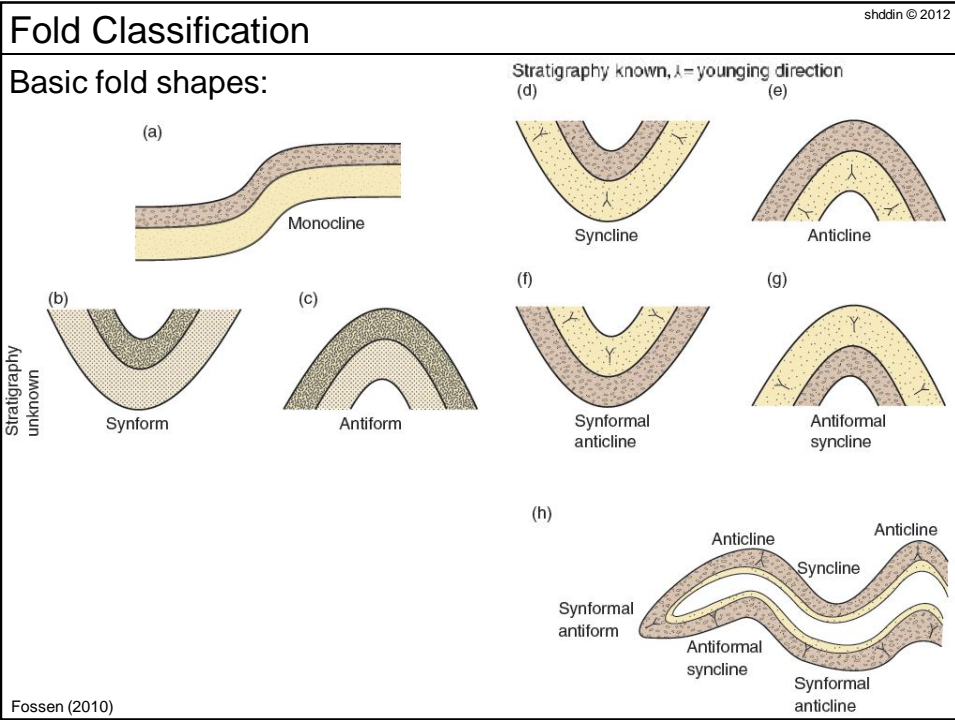


D



# Fold Classification





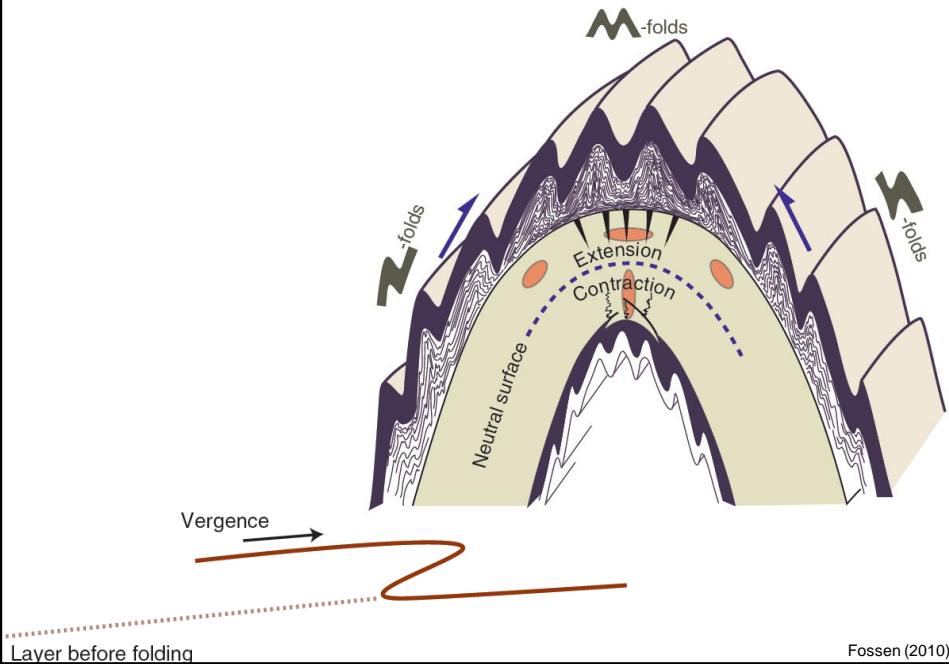
# Isoclinal Fold

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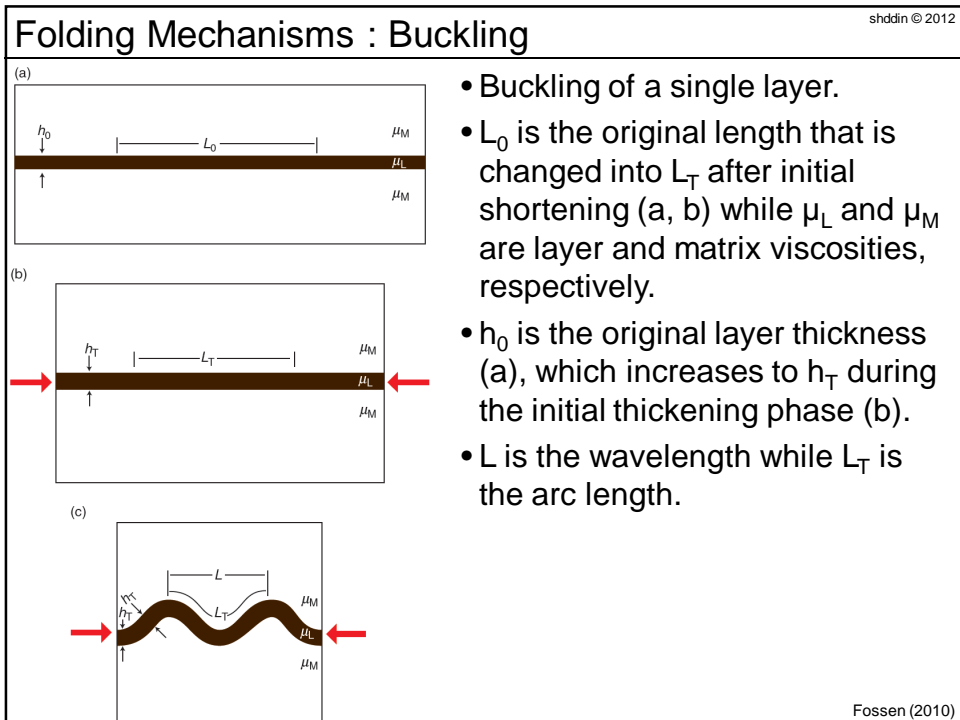
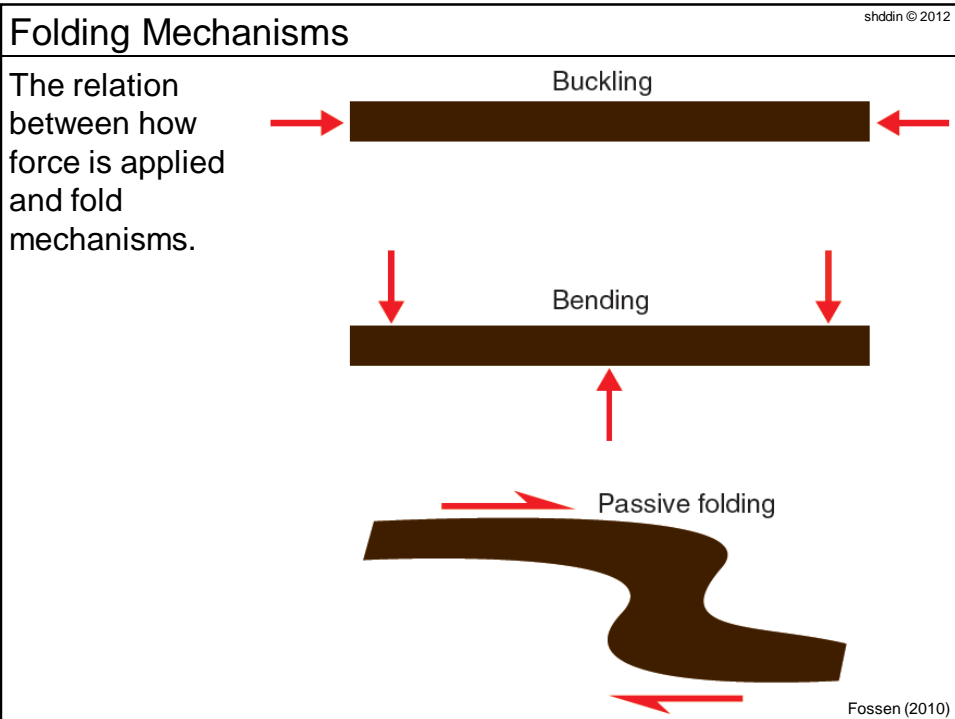
# Fold Symmetry and Vergence

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Fossen (2010)


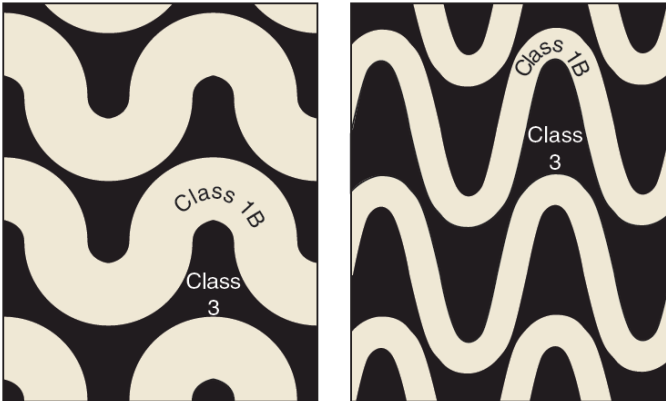




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## Folding Mechanisms : Buckling

Buckling occurs or **active folding** when a competent layer in a less competent matrix is shortened parallel to the length of the layer.

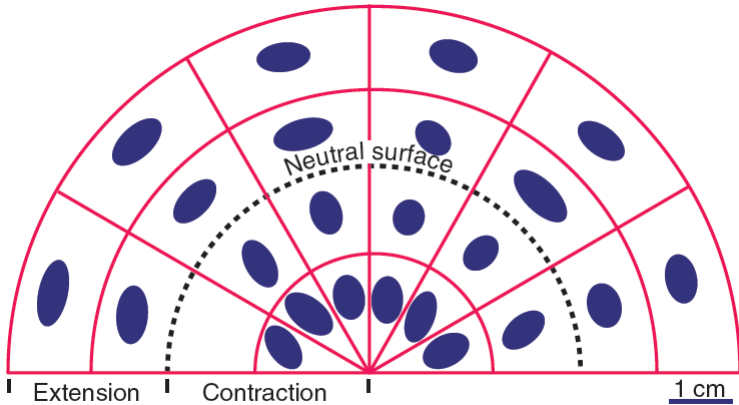



Fossen (2010)

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## Folding Mechanisms : Buckling

- Strain distribution in the hinge zone of a folded limestone layer in shale.
- Outer-arc stretching is separated from inner-arc shortening by a neutral surface.



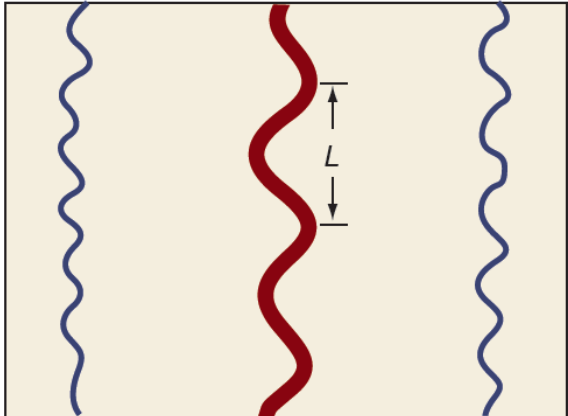
Fossen (2010)

shddin © 2012


### Folding Mechanisms : Buckling

- Folding of multilayered rocks.
- Far-apart layers act as individual layers.
- The closer they get, the more they behave as a single layer with thickness larger than that of the thickest of the individual layers.


$L_d = 5 \text{ mm}$



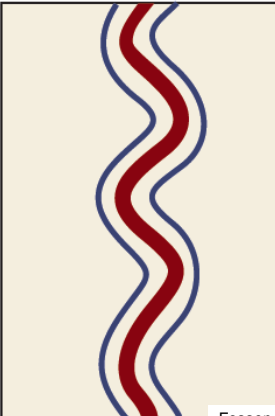
12 mm



6.3 mm



$L_d = 13 \text{ mm}$




Fossen (2010)

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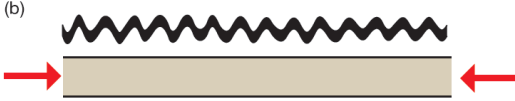
### Folding Mechanisms : Buckling

- Illustration of how folding initiates in thin layers.
- Once the thicker layer starts to fold, the smaller folds in the thin layer become parasitic and asymmetric due to flexural flow


(a)




(b)



(c)



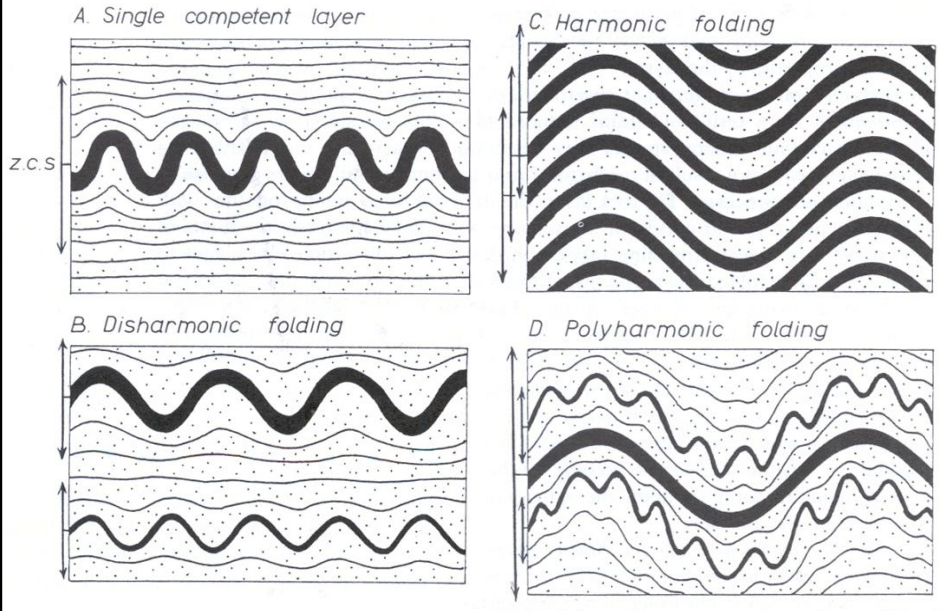


Fossen (2010)

# Folding Mechanisms : Buckling

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## Effects of multi-layers - different spacing and layer thicknesses



## Disharmonic Folding

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## Polyharmonic Folding

shadin © 2012



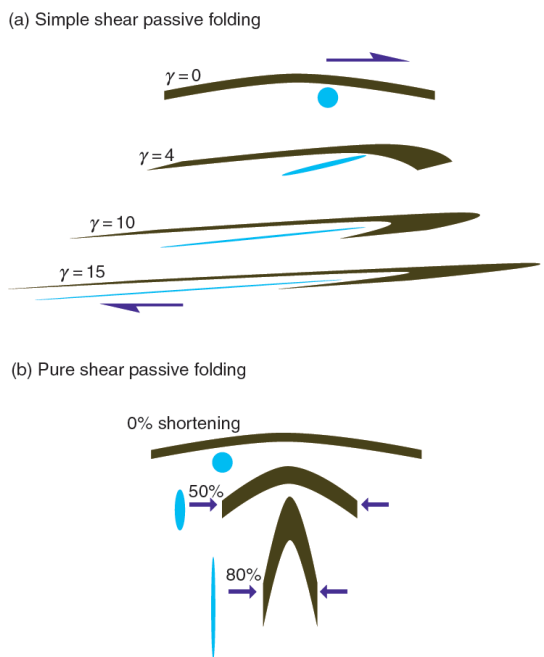
## Harmonic Folding

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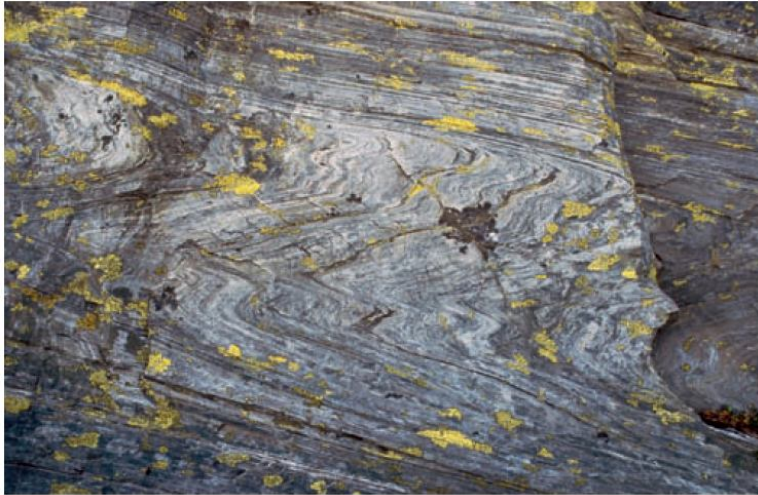
Folding Mechanisms : Passive Folding shddin © 2012

- Formation of Class 2 folds by (a) simple shearing (known as **shear fold**) and (b) pure shearing of a gently curved layer.
- No viscosity contrast is involved, meaning that the folds can be regarded as **passive**.
- Passive folds generated by simple shearing are perfectly **similar folds**.



Folding Mechanisms : Passive Folding shddin © 2012

- Passive folding produces harmonic folds where the layering plays no mechanical role and therefore no influence on the fold shape.



- Passive harmonic folding of quartzite in a mylonite zone. The similar geometry of this Z-fold indicates that it is a **shear fold**.

Fossen (2010)

shddin © 2012

### Folding Mechanisms : Bending

- Examples of bending in various settings and scales:
  - (a) between boudins;
  - (b) above thrust ramps;
  - (c) above reactivated faults;
  - (d) above shallow intrusions or salt diapirs.

Fossen (2010)

shddin © 2012

### Folding Mechanisms : Bending

- Bending occurs when forces act across layers, and may involve more than one mechanism.

Passive folding of layers between boudins.

Fossen (2010)

## Folding Mechanisms : Slip and Flow

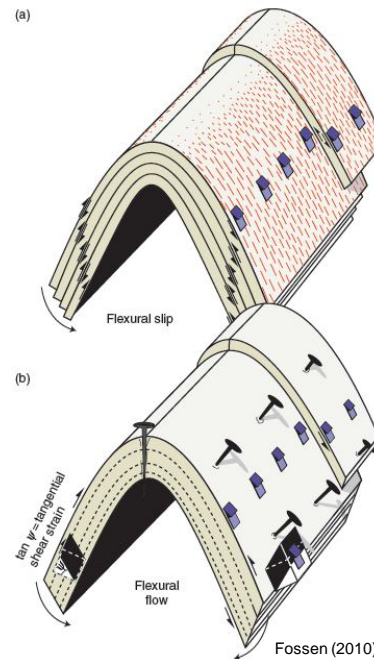
shddin © 2012

(a) Flexural **slip**, showing opposite sense of slip on each limb, decreasing towards the hinge zone.

(b) Flexural **flow**, where fold limbs are being sheared.

- Ideally, layer thickness is preserved in both models.

- **Slickenlines** on folded weak layers and constant bed thickness reveal flexural slip.



## Flexural Slip : Striation

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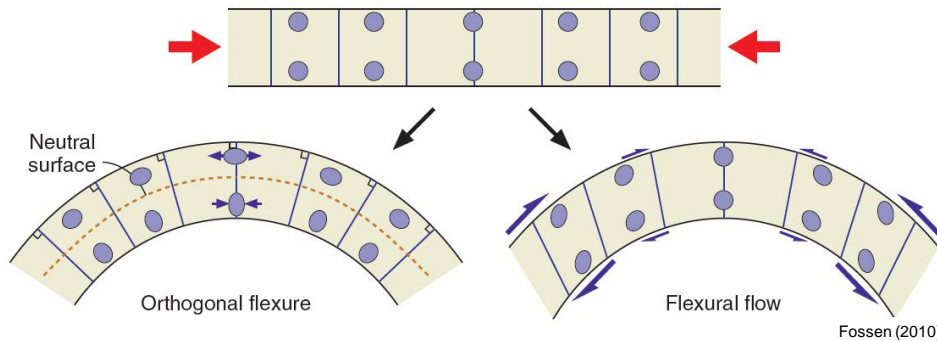
## Flexural Slip : Striation



## Folding Mechanisms : Orthogonal Flexure

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- Layer-parallel shortening resulting in orthogonal flexure and flexural flow.
- Pure flexural flow folds have no neutral surface, and strain increases away from the hinge zone.
- In orthogonal flexure, all lines originally orthogonal to the layering remain so throughout the deformation history.
- Orthogonal flexure produces parallel folds with a neutral surface.



## Folding Mechanisms : Kinking

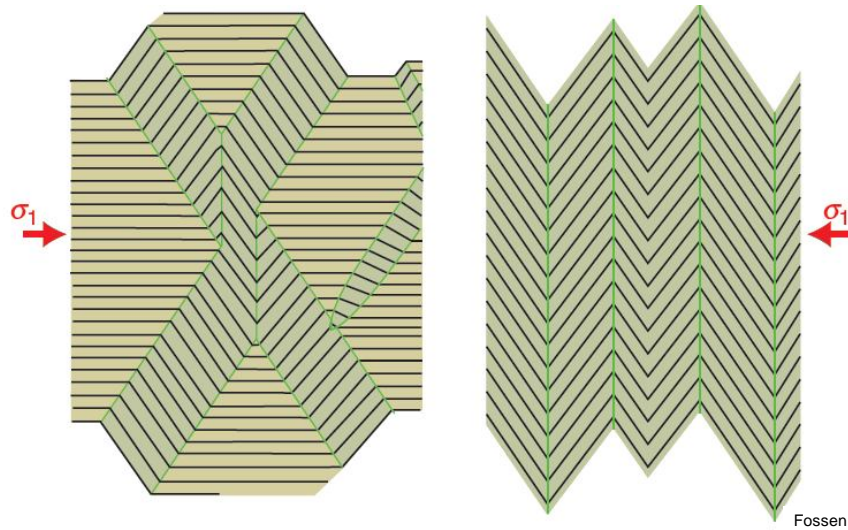
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## Folding Mechanisms : Kinking

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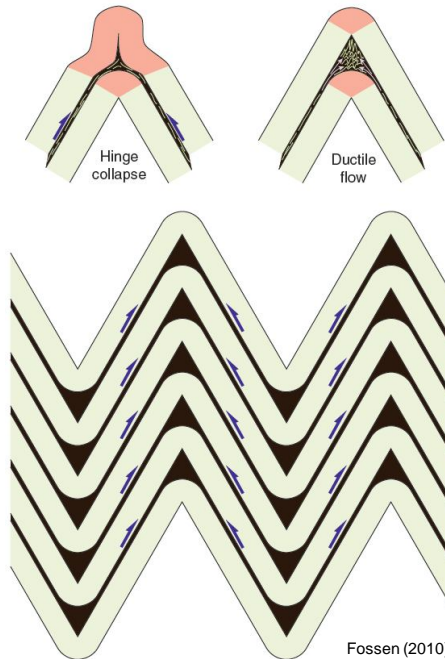
- The orientation of  $s_1$  can be determined from the orientation of conjugate sets of kink bands.
- Continued kink band growth can produce **chevron folds**.



## Folding Mechanisms : Kinking

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- Chevron folds forming by the flexural slip mechanism imply a **space problem** in the hinge zone that is resolved by ductile flow of the incompetent (dark) layers or collapse of the competent layers in the hinge zone.
- Strained parts of competent layers are marked in red, showing that layer thickness is maintained on the limbs.



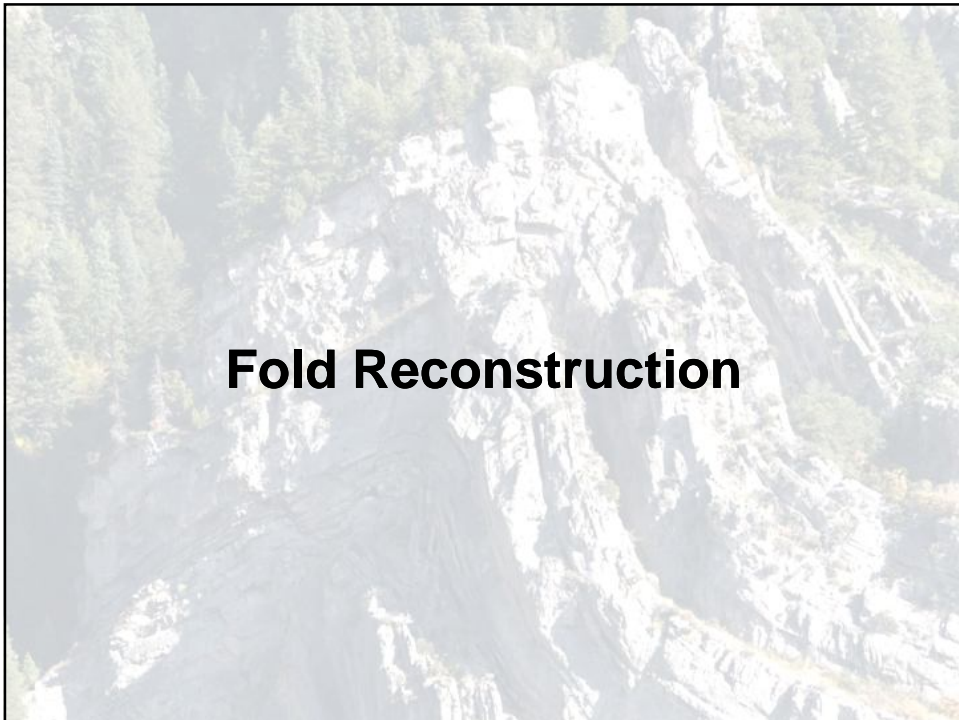
## Chevron Fold

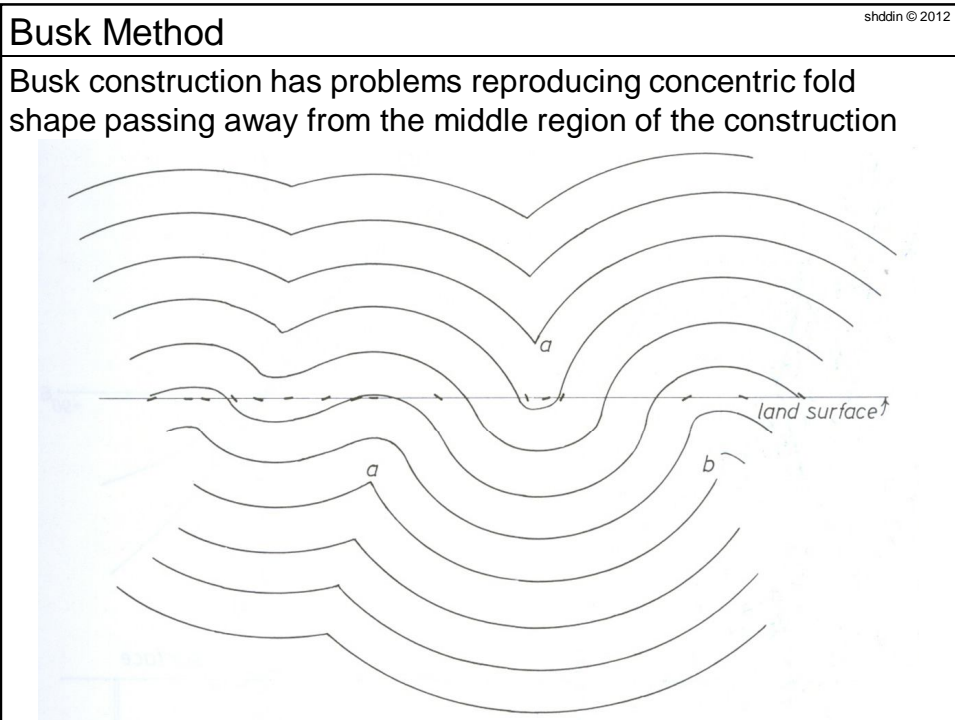
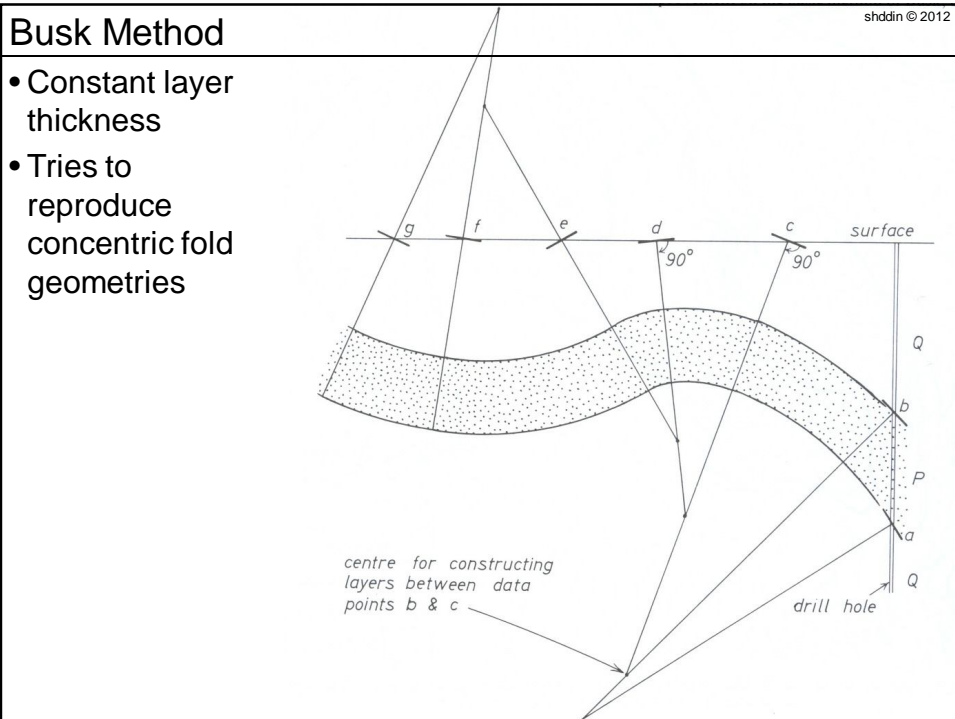
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## Chevron Fold

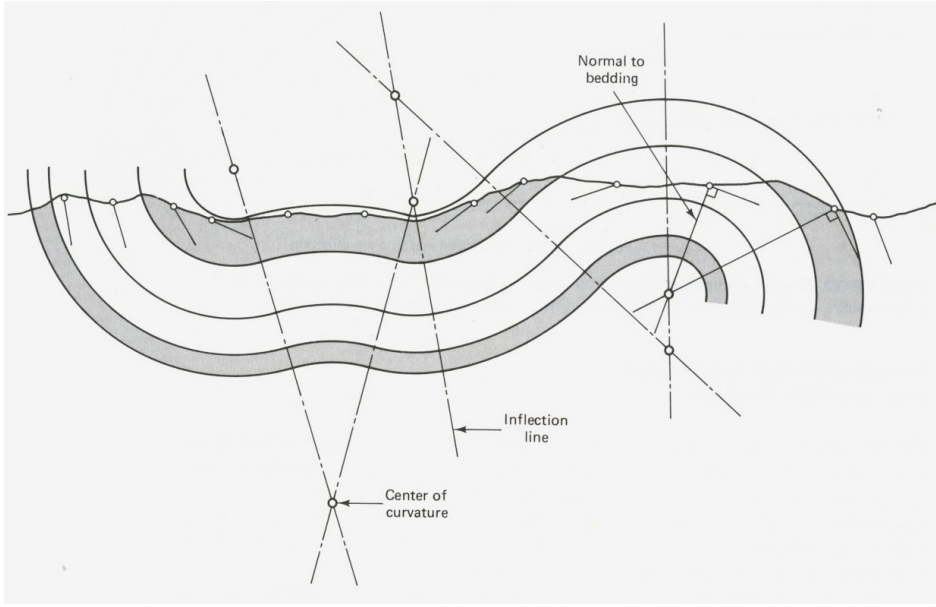
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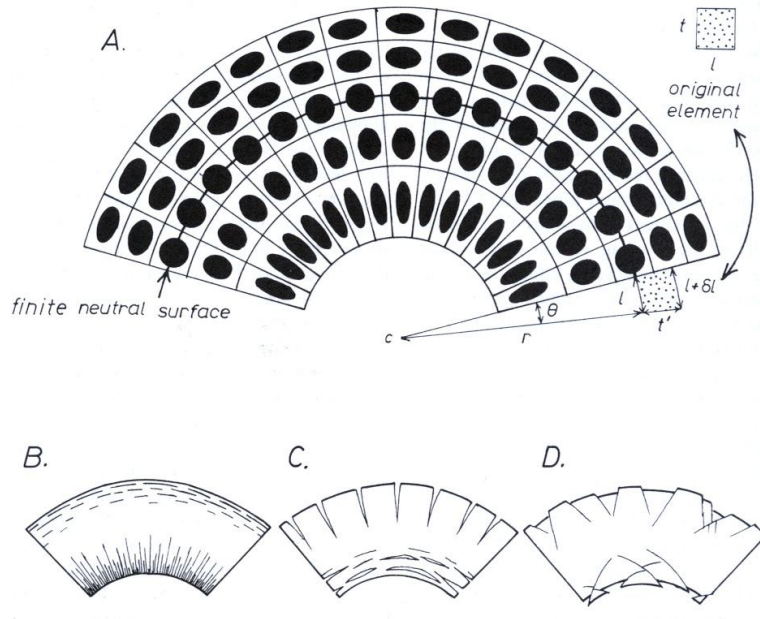
# Busk Method

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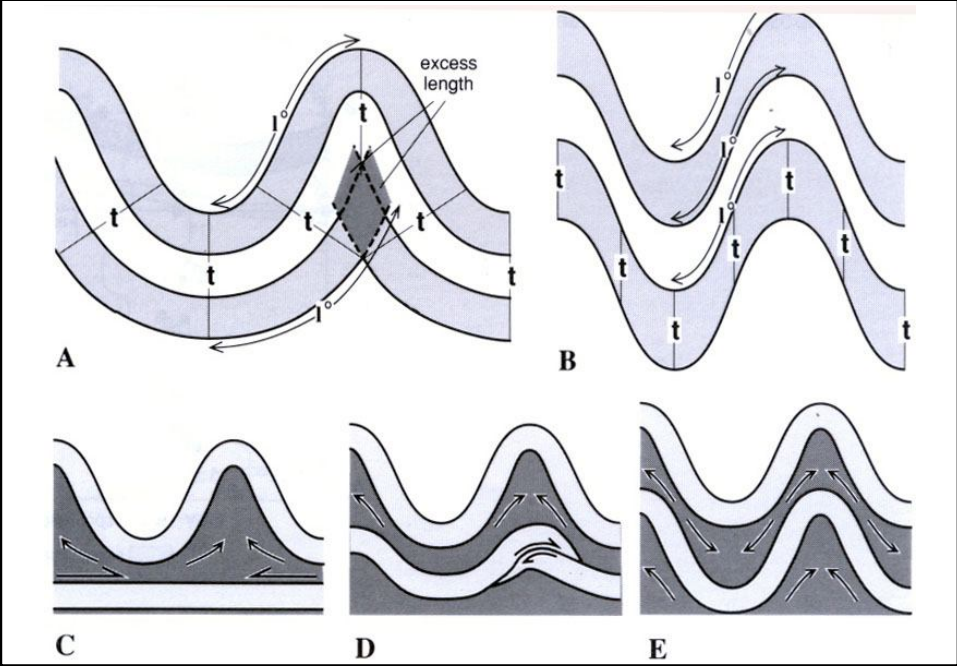
# Busk Method : Room Problems

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# Busk Method : Room Problems

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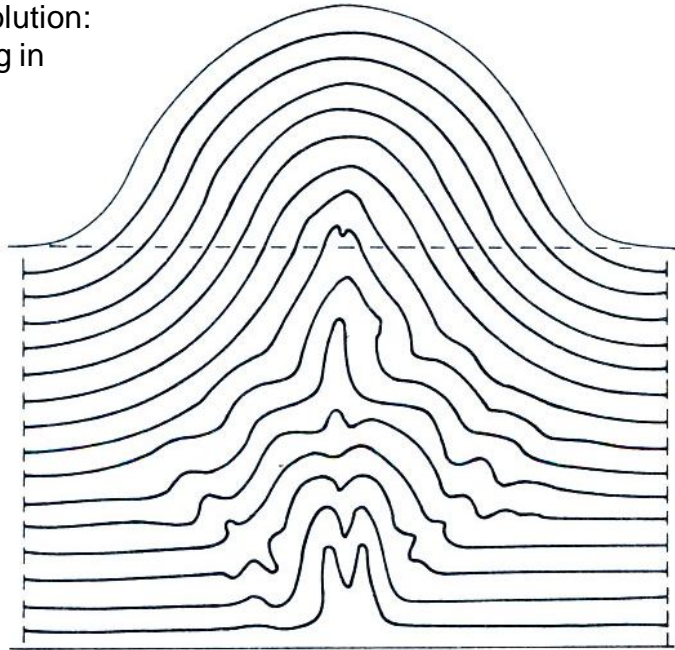
# Complicated Room Problems



## Room Problems : Goguel's Solution

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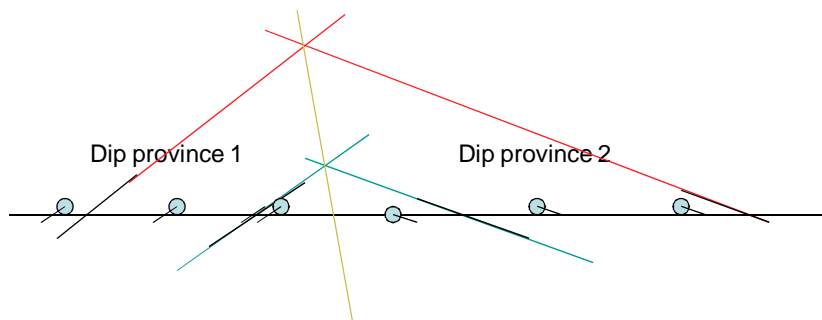
Goguel's (1952) solution:  
disharmonic folding in  
the fold core



## Kink Band Method

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- 1) In the simplest case constant layer thickness is assumed
- 2) A section is divided into dip panels which are areas of constant dip. They are separated by kink band surfaces

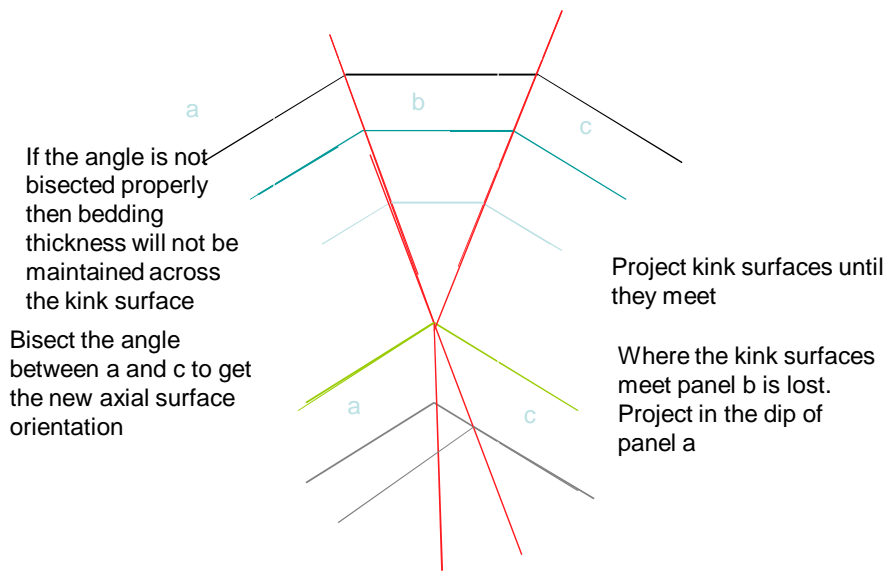


- 3) Project the dips of the different provinces for known horizons
- 4) Where the dips intersect construct a kink surface that bisects equally both dip provinces



## Kink Band Method

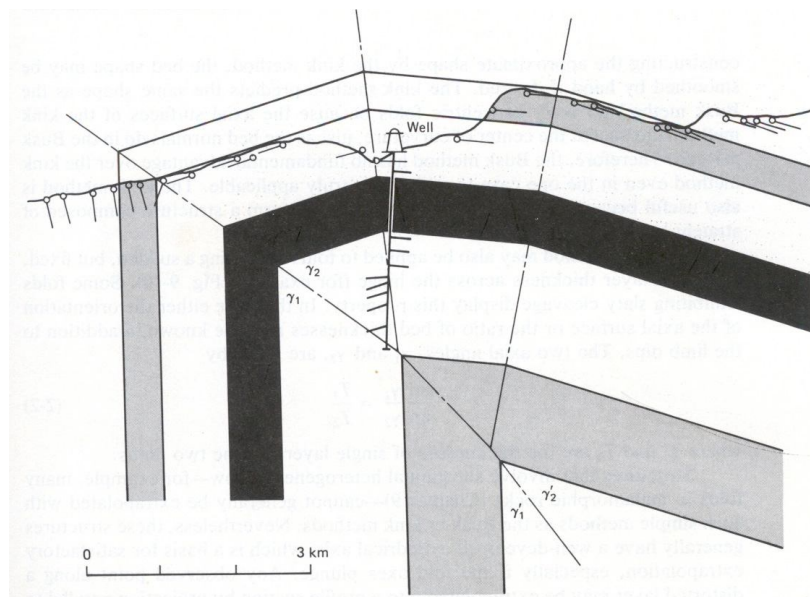
shddin © 2012



Multiple kink surfaces are constructed in the same way

## Kink Band Method

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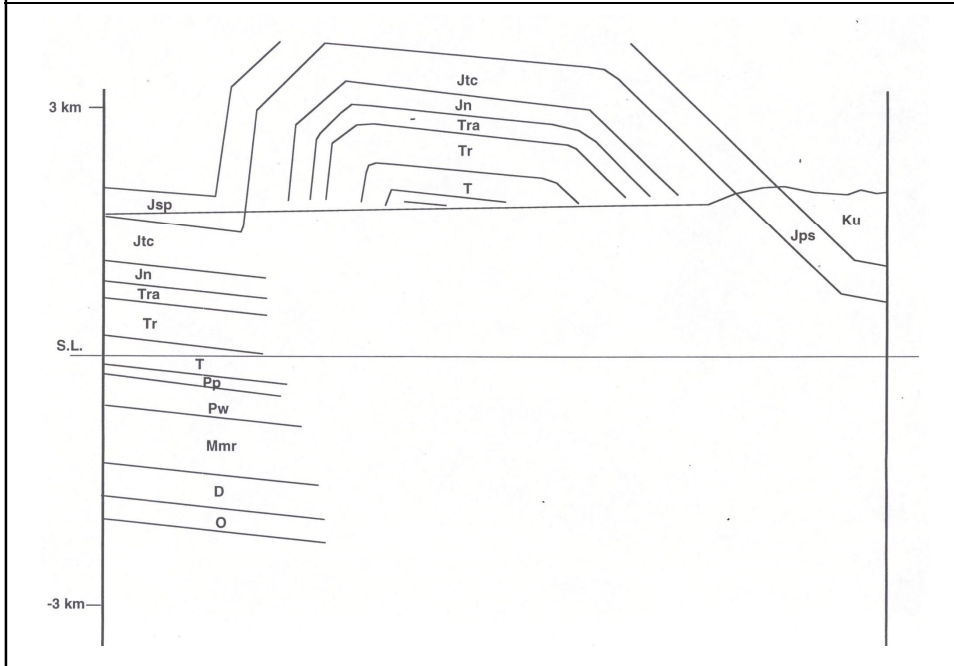


Kink band reconstruction of a fold in Taiwan

(Suppe, 1988)

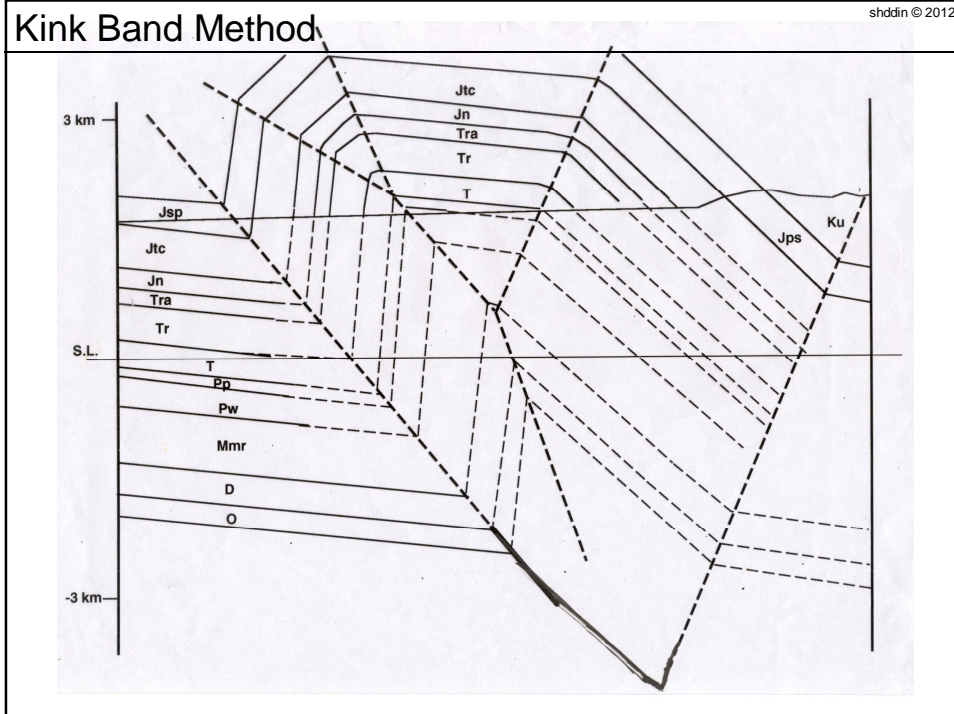
# Kink Band Method

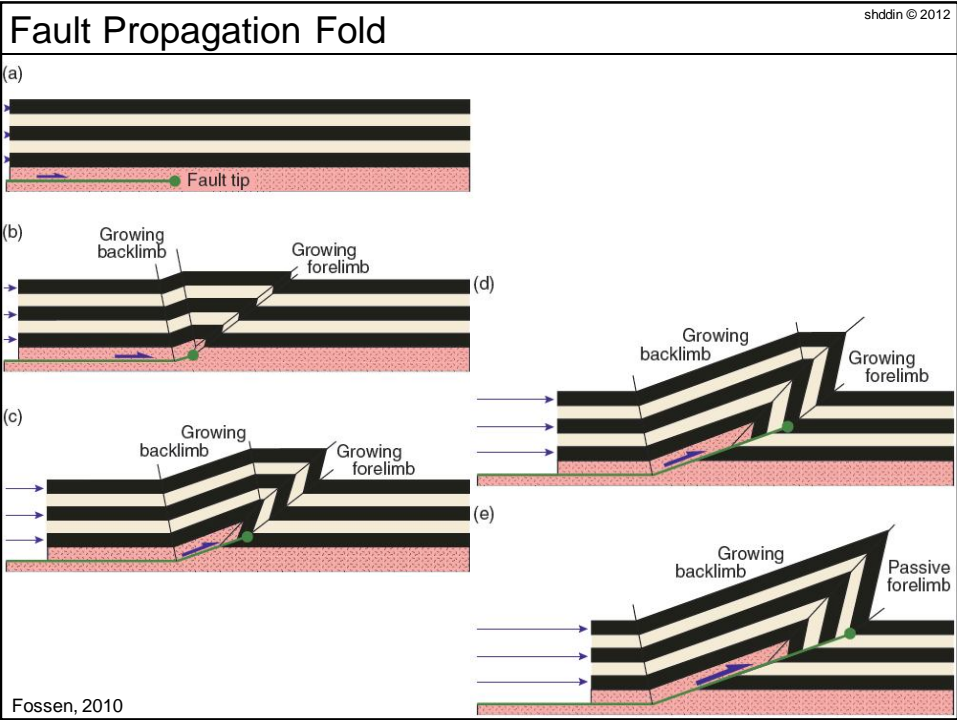
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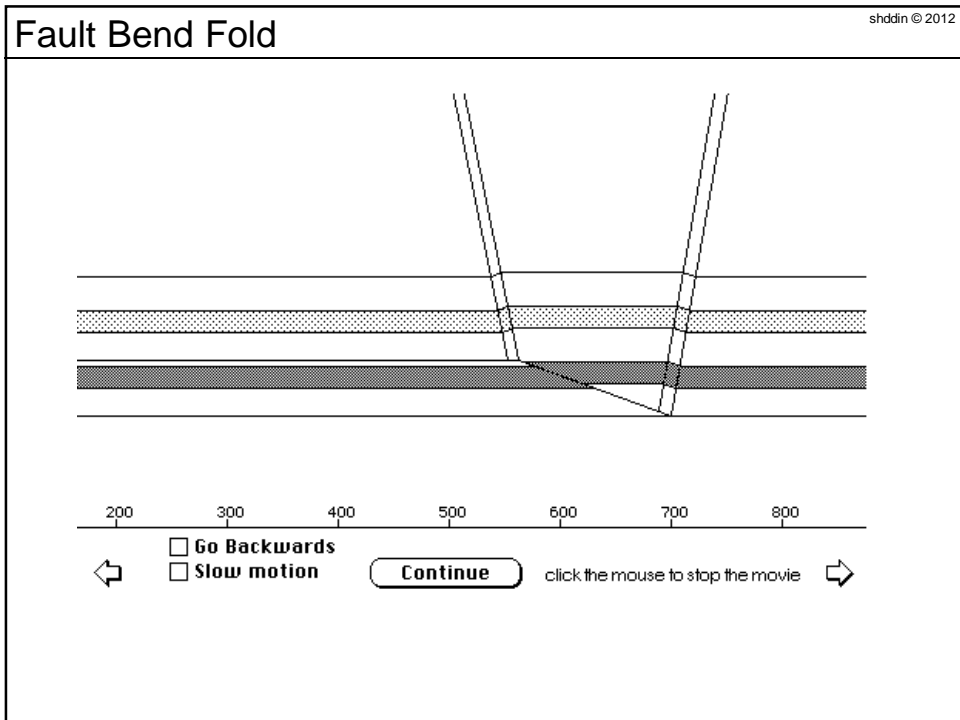
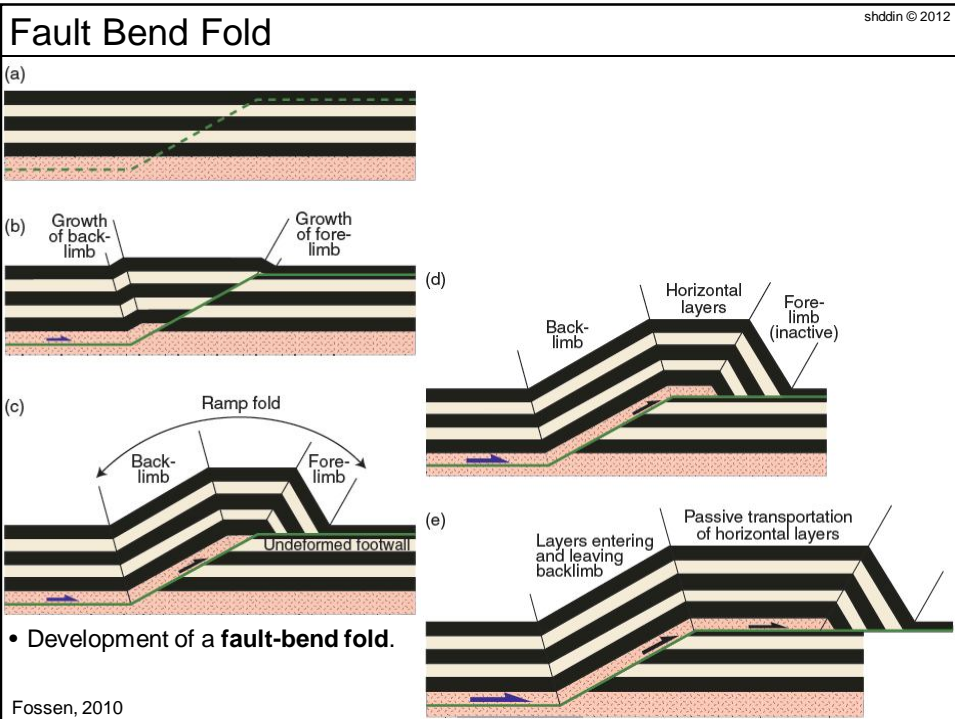


# Kink Band Method

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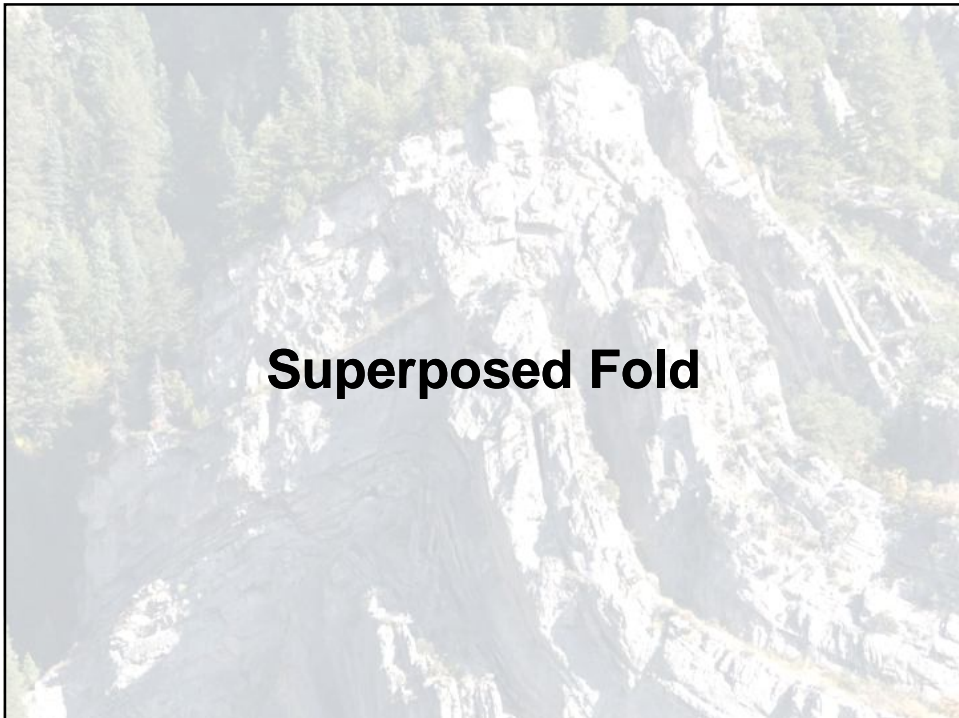
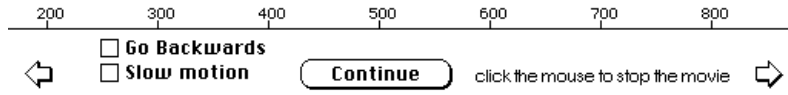
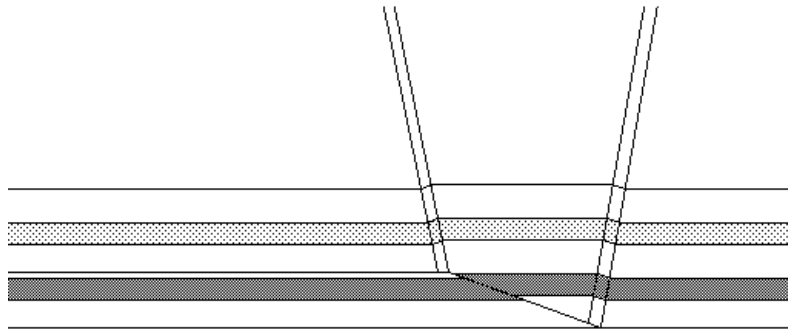


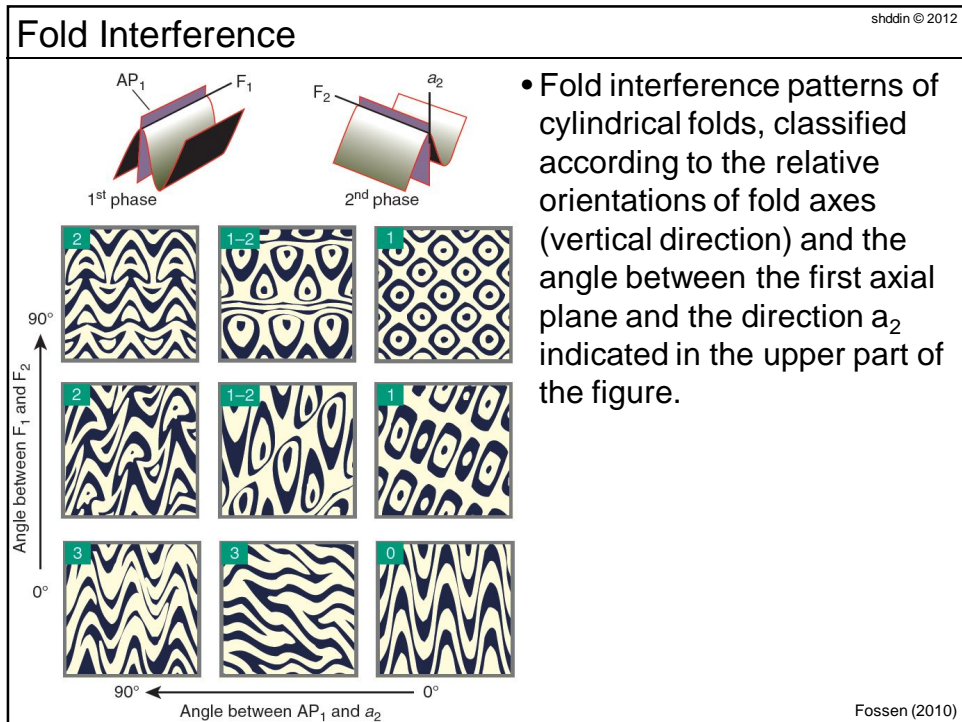
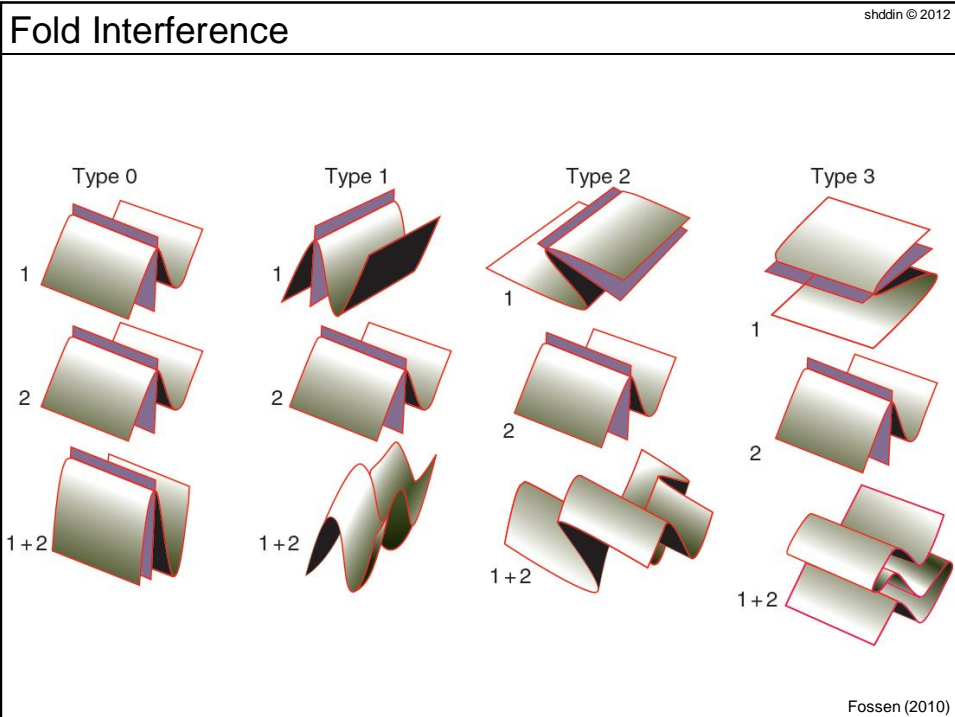




## Duplex Fault Bend Fold

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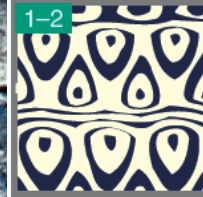


# Fold Interference

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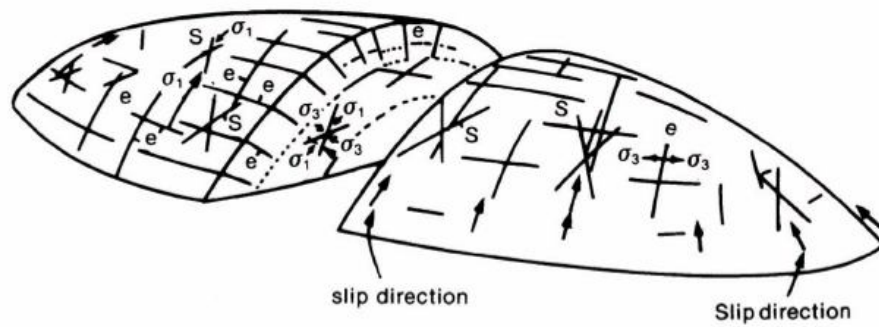
• Type 1-2 interference pattern in folded quartz schist.



Fossen (2010)

# Joint System in a Fold

shddin © 2007



S Shear joints  
e Extension joints

Adapted from Stearns (1978)