GG611
Structural Geology Section

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Lecture 3

Folds, and grain-scale fabrics

Folds

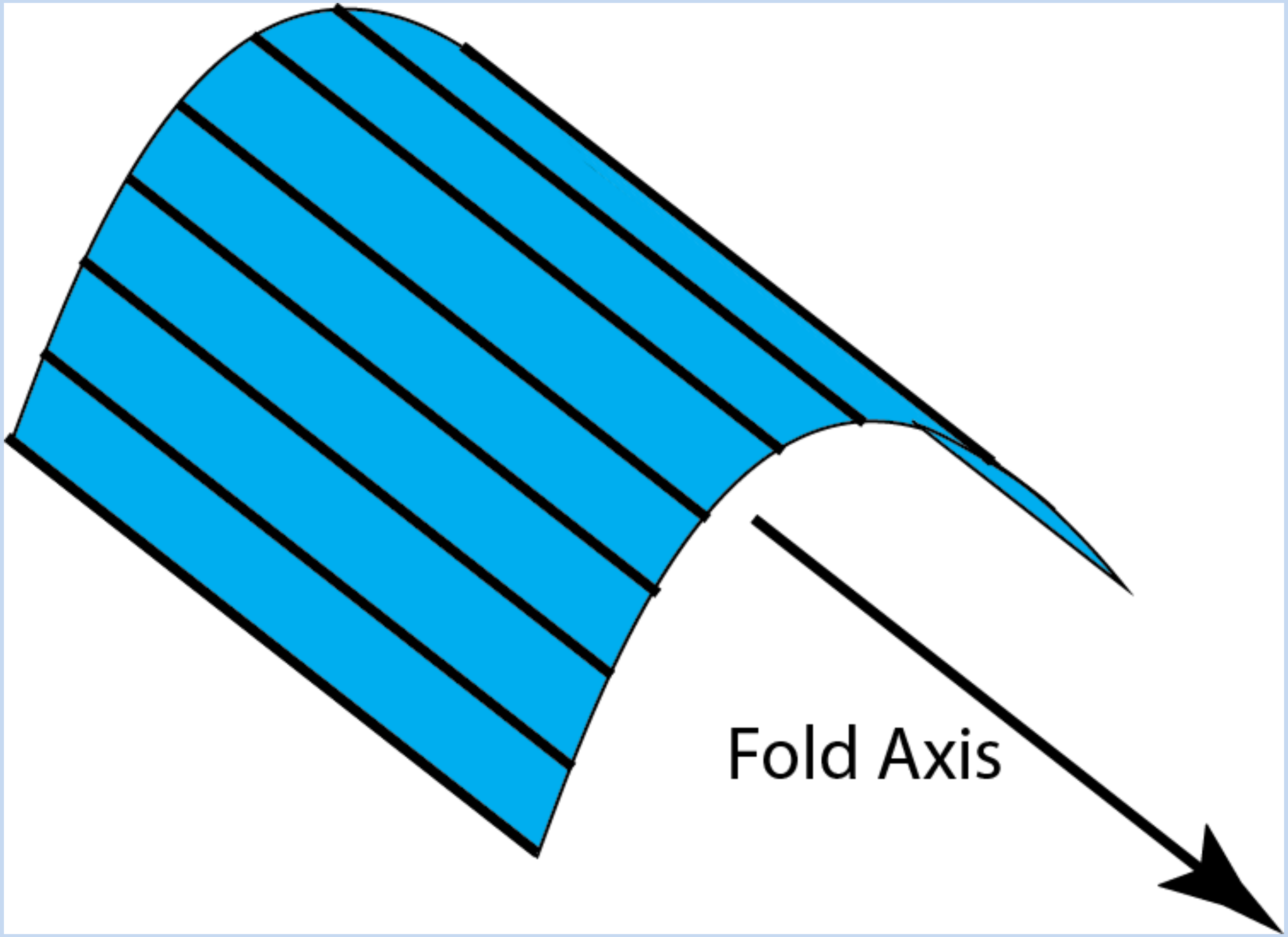
http://jupiter.ethz.ch/~kausb/Crete_folds.jpg

- Surfaces which have experienced, at least locally, a change in their normal curvature (rate at which a unit tangent or a unit normal to a surface) changes with respect to distance along a surface

Folds

- Most readily identified in rocks that are layered or bound by parallel discontinuities; folds occur in all rocks, *including plutonic rocks*!
- Folding commonly causes bedding planes to slip
- Historical 2-D conceptualization of folds

Cylindrical Fold (2D)



2D Fold Classification Factors

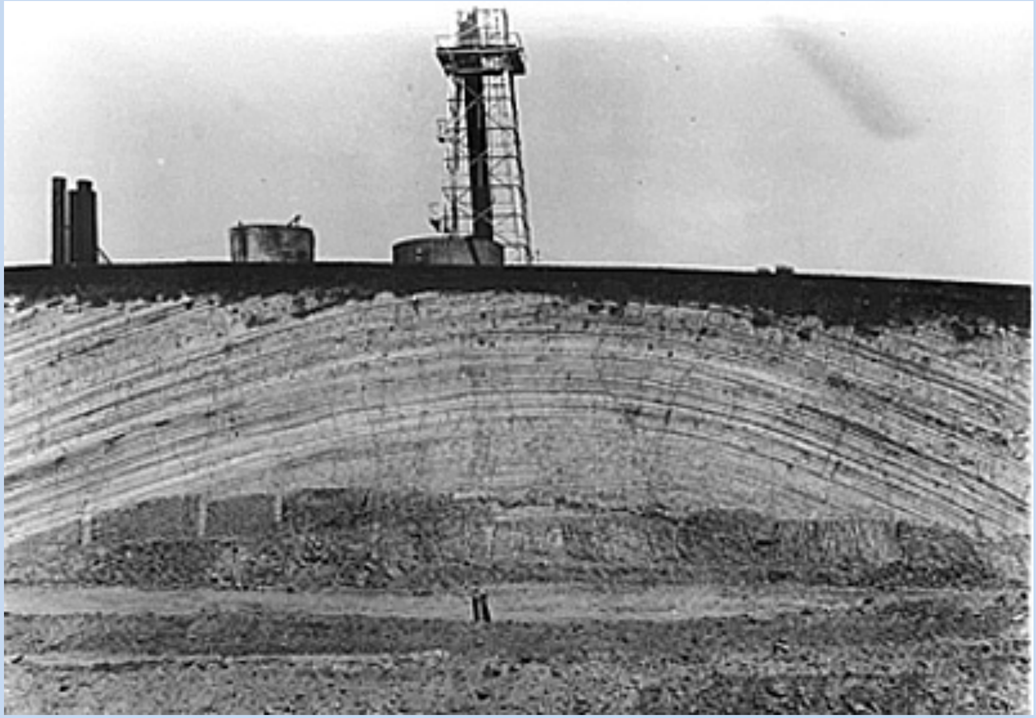
- Direction of opening of a fold (i.e., direction of curvature vector)
- Relative curvature of inner and outer surfaces of a fold
- Axial surface orientation (axial surface connects points of tightest curvature)
- Fold axis orientation (fold can be "generated" by fold axis)

Common Fold: Syncline

http://www.grossmont.edu/judd.curran/images/synclinePhoto.jpg

- Youngest rocks in center of fold
- Usually "U-shaped" (i.e., they open down)

Common Fold: Anticline



http://rst.gsfc.nasa.gov/Sect5/OilAnticline.jpg

Oldest rocks in center of fold

Usually "A-shaped" (i.e., they open down)

Common Fold: Recumbent Fold

http://en.wikipedia.org/wiki/File:Caledonian_orogeny_fold_in_King_Oscar_Fjord.jpg

Fold opens horizontally

2D Fold Classification Factors

- Direction of opening of a fold (i.e., direction of curvature vector)
- Relative curvature of inner and outer surfaces of a fold
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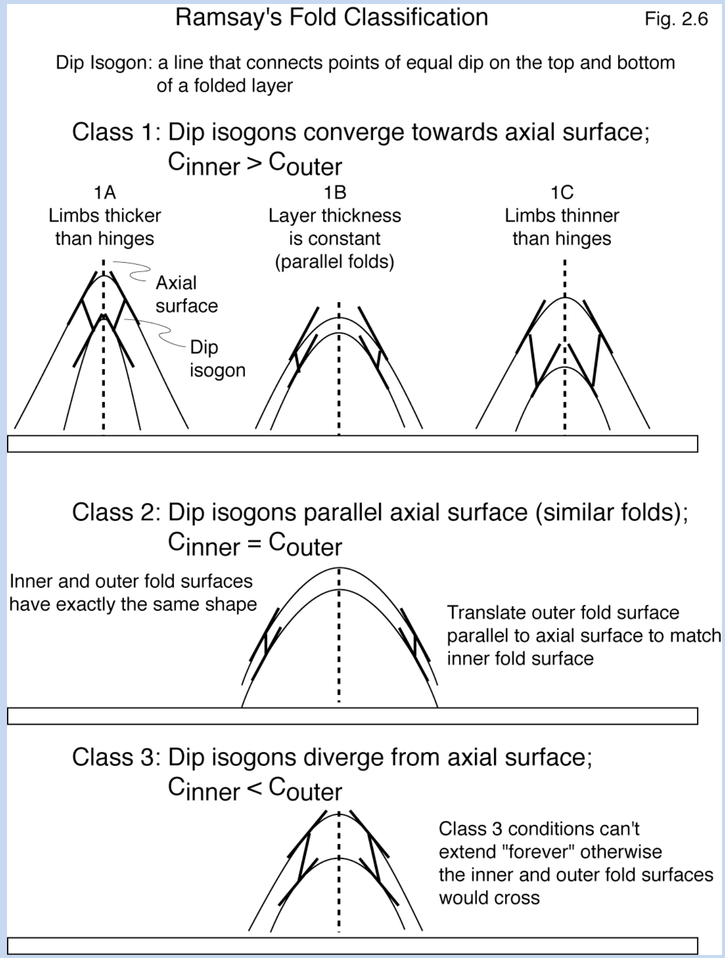
- Fold axis orientation (fold can be "generated" by fold axis)

2D Fold Classification Scheme



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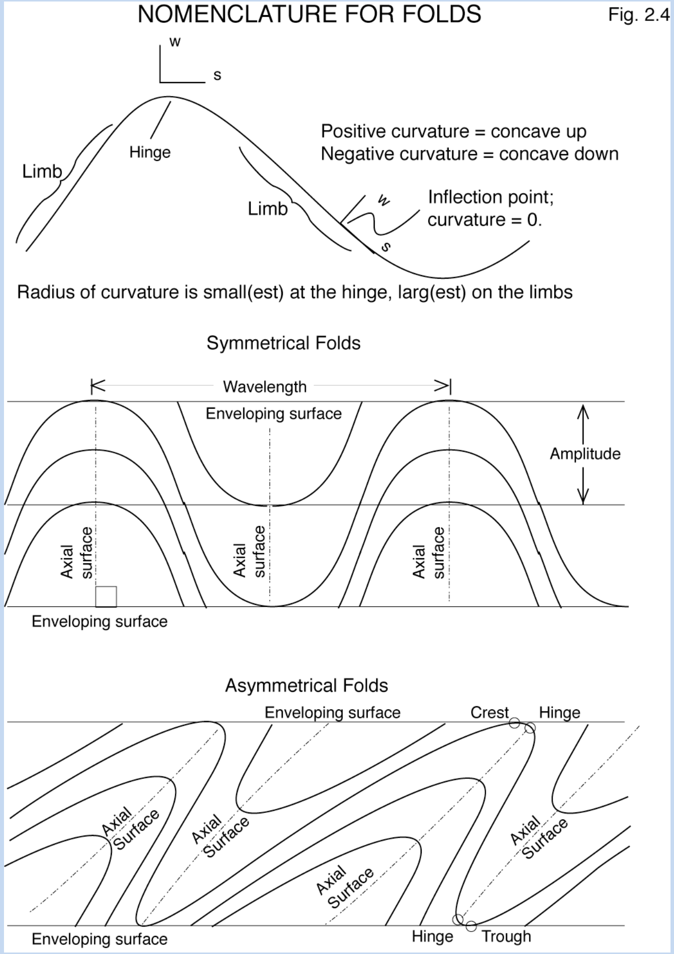
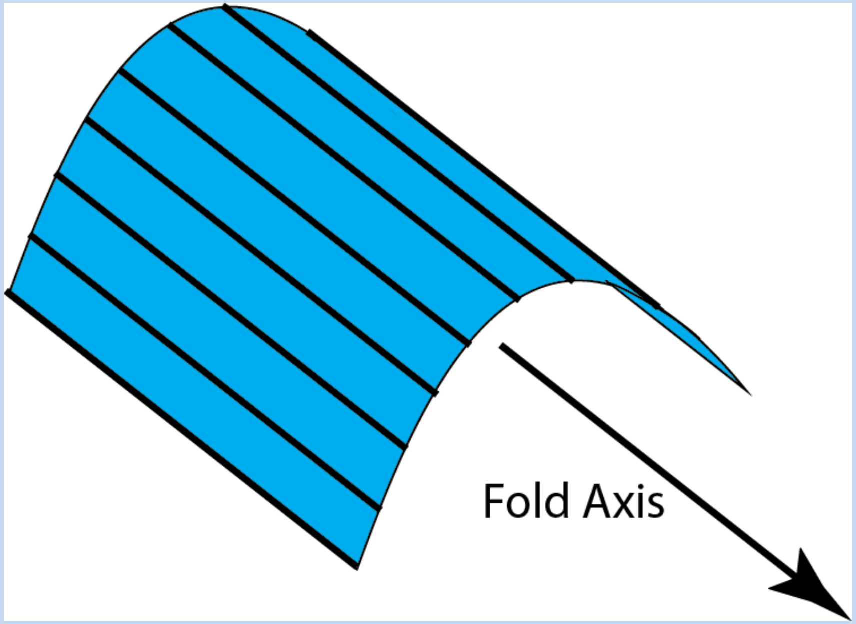
Fold Terminology

- Axial surface orientation (axial surface connects points of tightest curvature)

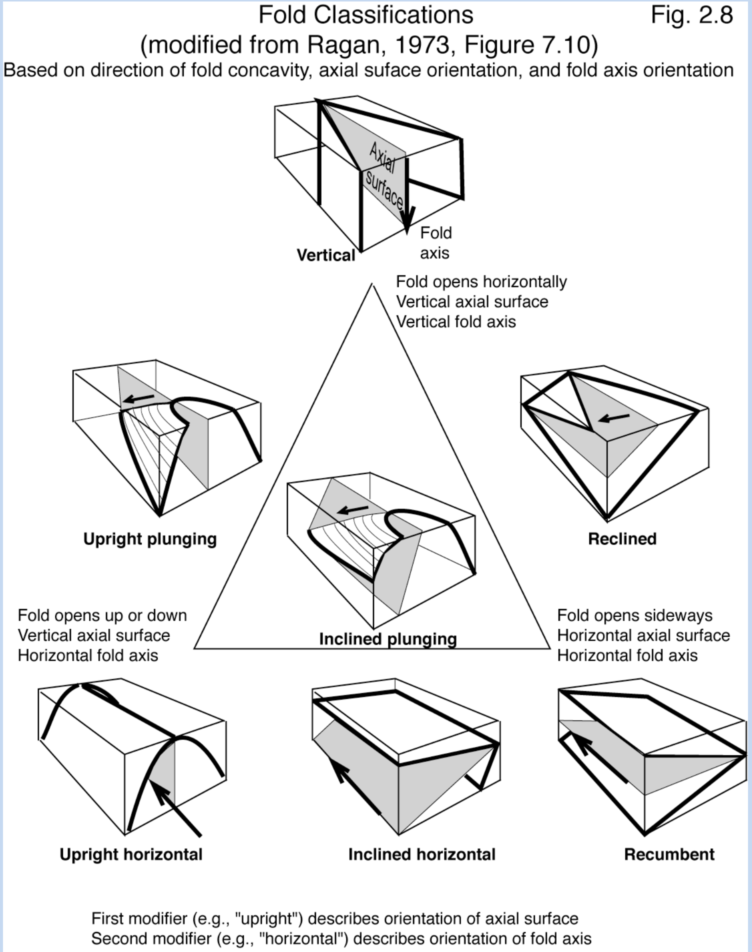


Cylindrical Fold (2D)

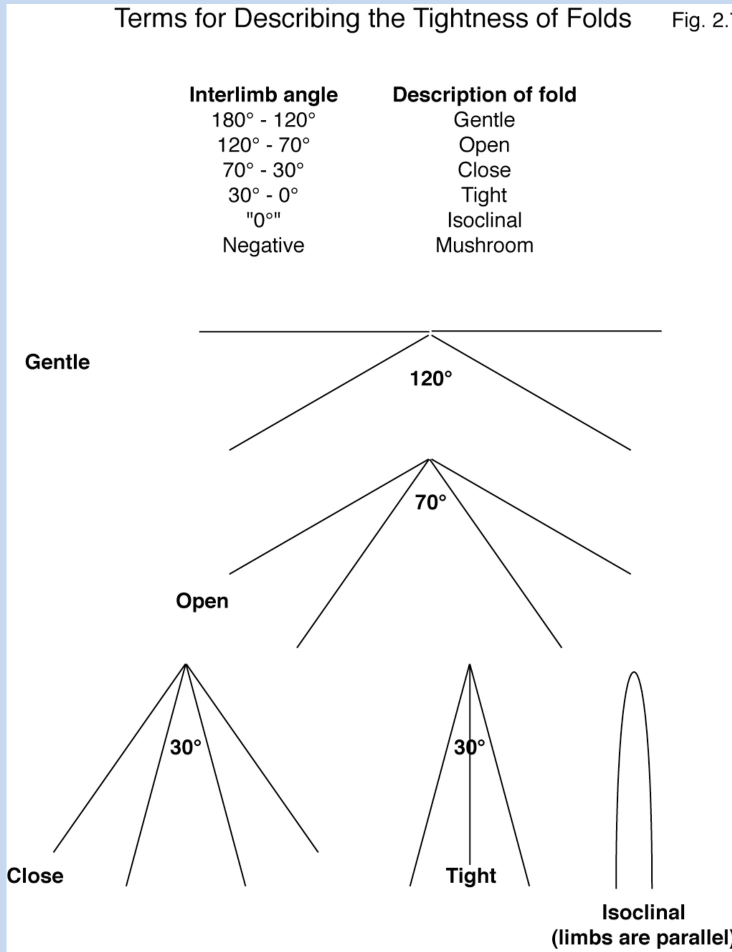
- Fold axis: Line parallel to the surface of a cylindrical fold



2D Fold Classification Scheme



2D Fold Classification Scheme



3-D Characterization of Folds

http://www.le.ac.uk/geology/wdc2/calcsilicate%203d%20folds.jpg

3-D Characterization of Folds

http://upload.wikimedia.org/wikipedia/commons/4/45/Shar_pei_welpen.jpg

3-D Characterization of Folds

http://image.shutterstock.com/display_pic_with_logo/9916/9916,1122427430,2/stock-photo-wrinkled-cloth-450464.jpg

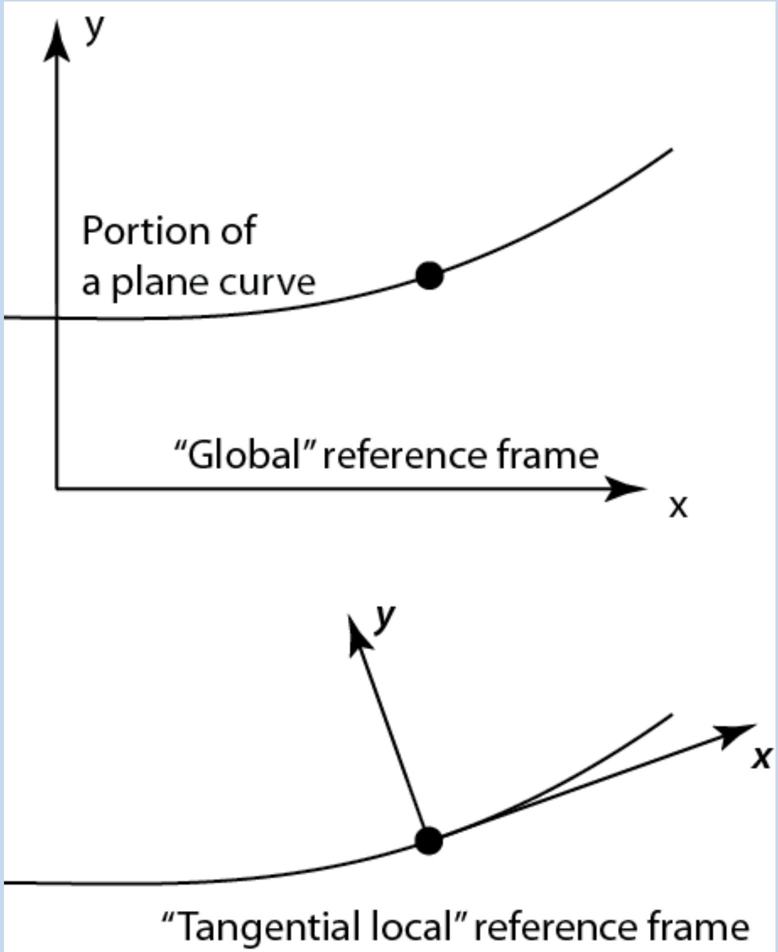
Curvature of a Plane Curve

- In global reference frame

$$k = \frac{\frac{d^2y}{dx^2}}{\left(1+\left(\frac{dy}{dx}\right)^2\right)^{3/2}}$$

- In local reference frame

$$k = \frac{d^2y}{dx^2}$$



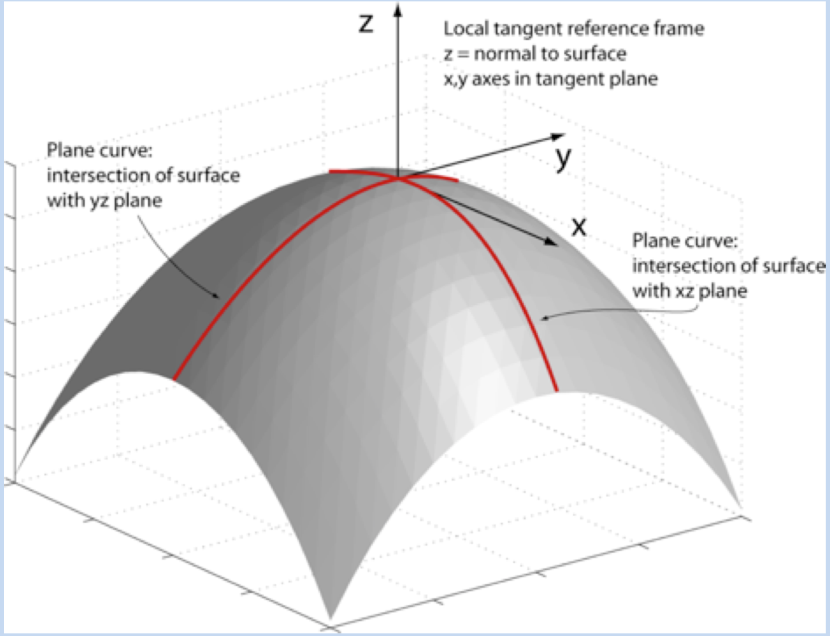
Principal Curvatures of a Surface

- Matrix of 2nd partial derivatives of surface z in local reference frame

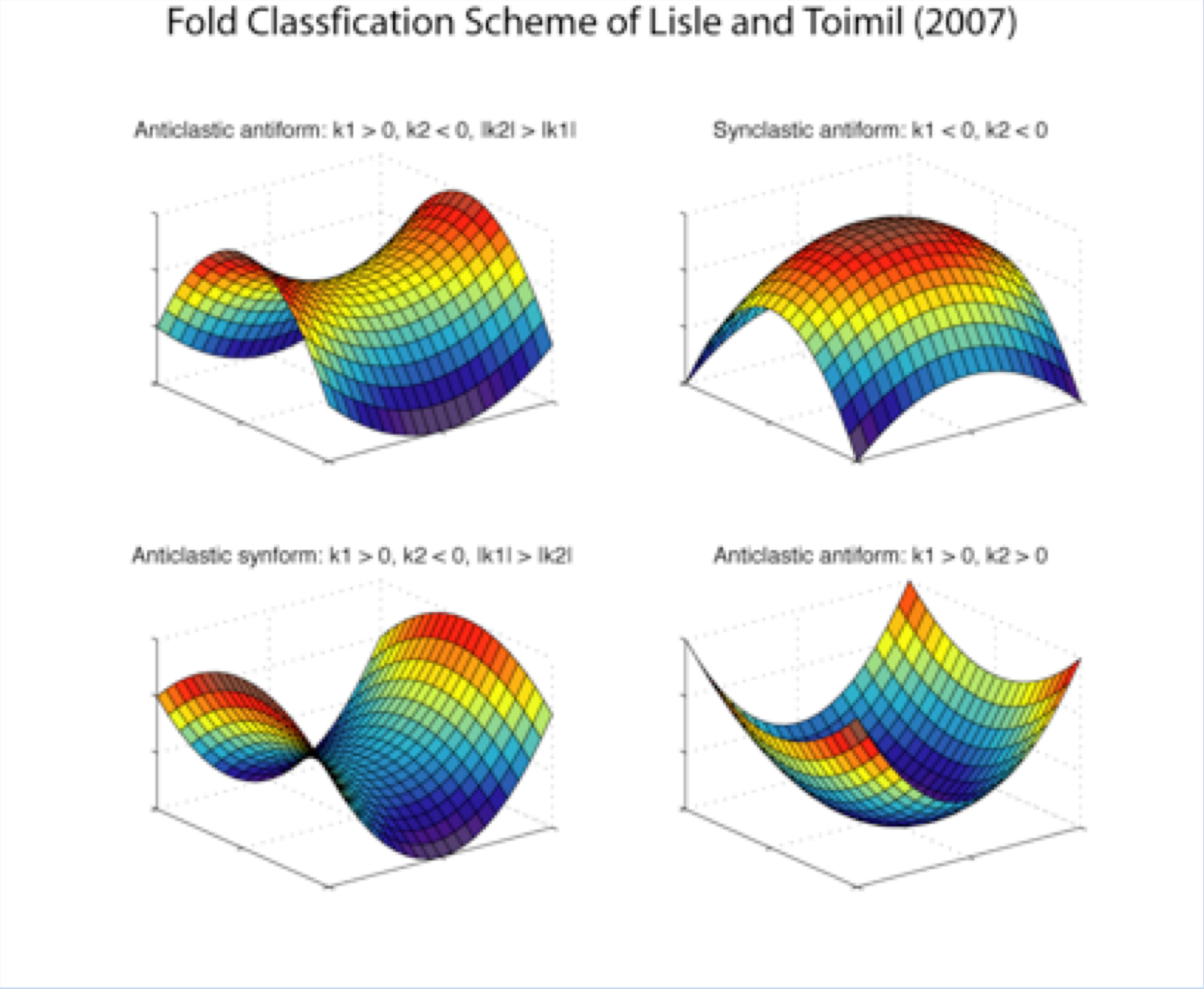
$$k = \begin{bmatrix} \frac{\partial^2 z}{\partial x^2} & \frac{\partial^2 z}{\partial x \partial y} \\ \frac{\partial^2 z}{\partial y \partial x} & \frac{\partial^2 z}{\partial y^2} \end{bmatrix}$$

- Matrix of 2nd partial derivatives of surface z in principal local frame

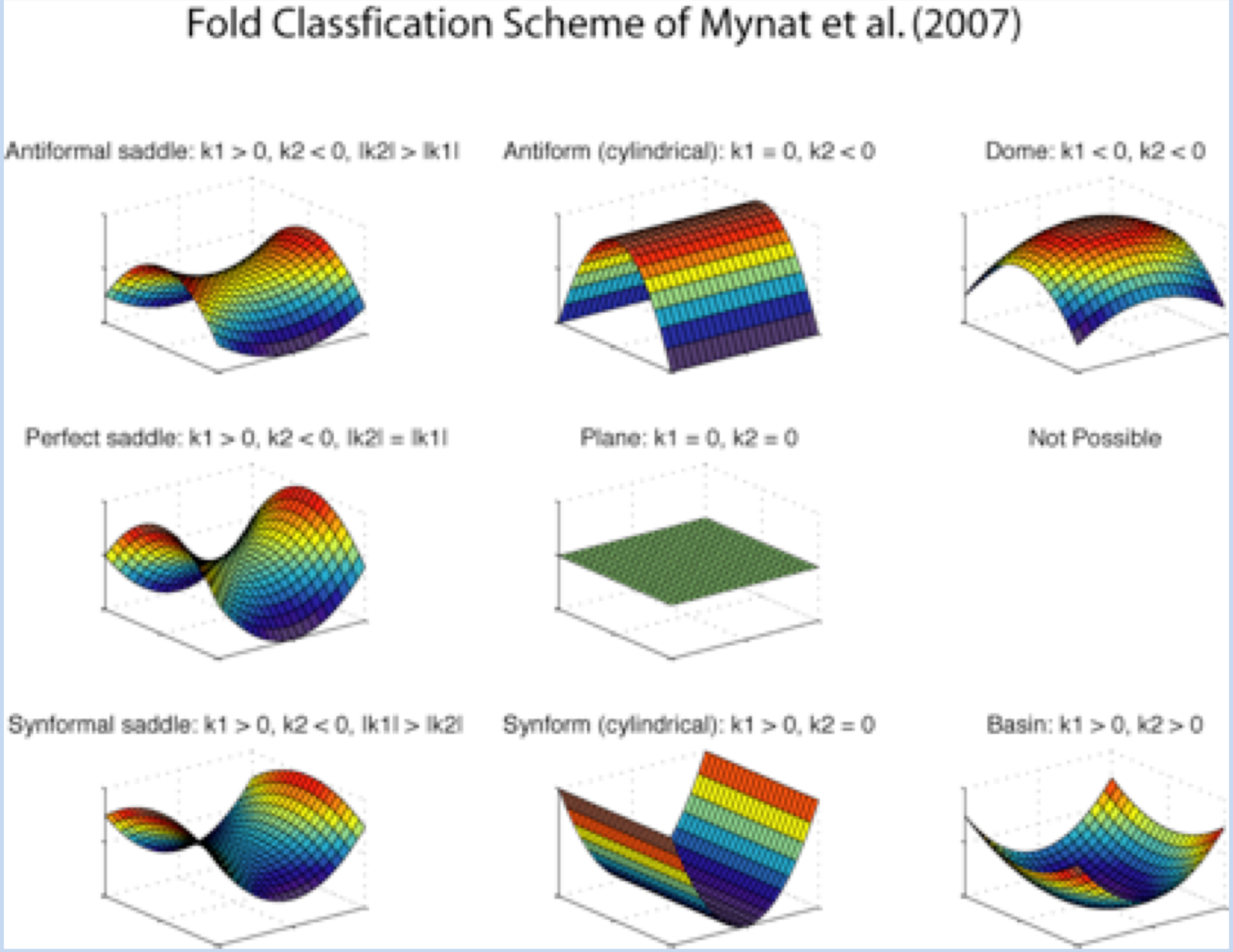
$$k = \begin{bmatrix} \frac{\partial^2 z}{\partial x^{*2}} & \frac{\partial^2 z}{\partial x^* \partial y^*} \\ \frac{\partial^2 z}{\partial y^* \partial x^*} & \frac{\partial^2 z}{\partial y^{*2}} \end{bmatrix} = \begin{bmatrix} k_1 & 0 \\ 0 & k_2 \end{bmatrix}$$



3D Fold Classification Scheme of Lisle and Toimil (2007)



3D Fold Classification Scheme of Mynat et al. (2007)



Fabrics

- Grain-scale structure (metamorphic rocks & igneous rocks)
- Foliation: preferred alignment of minerals (e.g., mica) parallel to a plane;
- Lineation: preferred alignment of minerals parallel to a line;

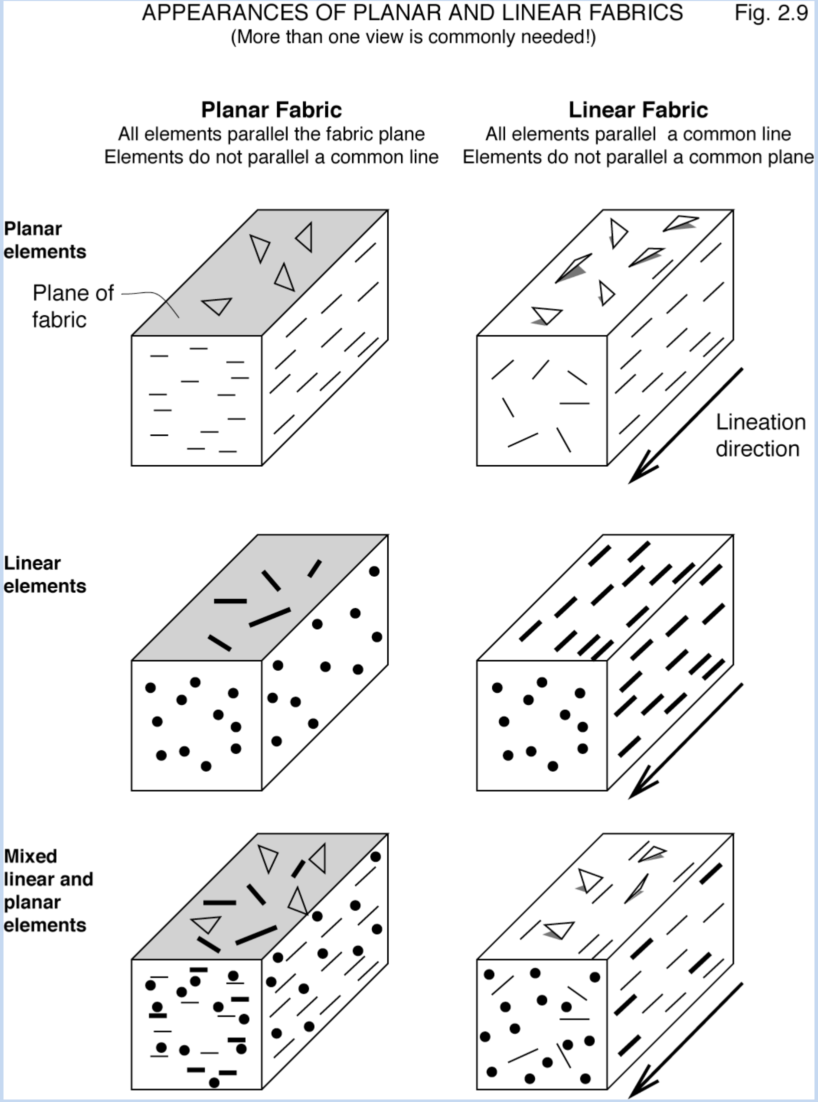
Fabrics
Grain-scale Structure

- Foliation: preferred alignment of minerals (e.g., mica) parallel to a plane
- Lineation: preferred alignment of minerals parallel to a line

http://mulch.cropsoil.uga.edu/soilsandhydrology/images/Gneiss.jpg

http://minerva.union.edu/hollochk/c_physicalgeology/images/Lineation1.jpg

Fabrics



APPEARANCES OF PLANAR AND LINEAR FABRICS
Fig. 2.9
(More than one view is commonly needed!)
Planar Fabric
All elements parallel the fabric plane
Elements do not parallel a common line
Linear Fabric
All elements parallel a common line
Elements do not parallel a common plane
Planar elements
Plane of fabric
Lineation direction
Linear elements
Mixed linear and planar elements

Kinematics of Fabric Development

- Strain
  - Flattening
  - Stretching

http://vegandwhatnot.files.wordpress.com/2009/12/flattened.jpg

- Rigid body rotation in a flow

http://vulcan.wr.usgs.gov/Imgs/Jpg/MSH/Images/MSH80_aerial_view_blowdown_06-08-80.jpg