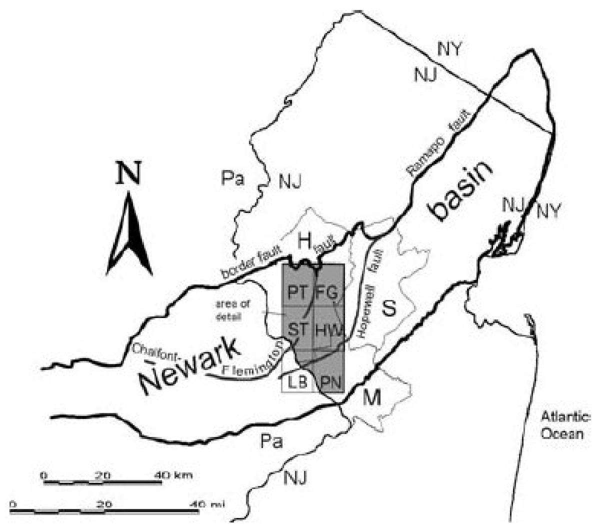
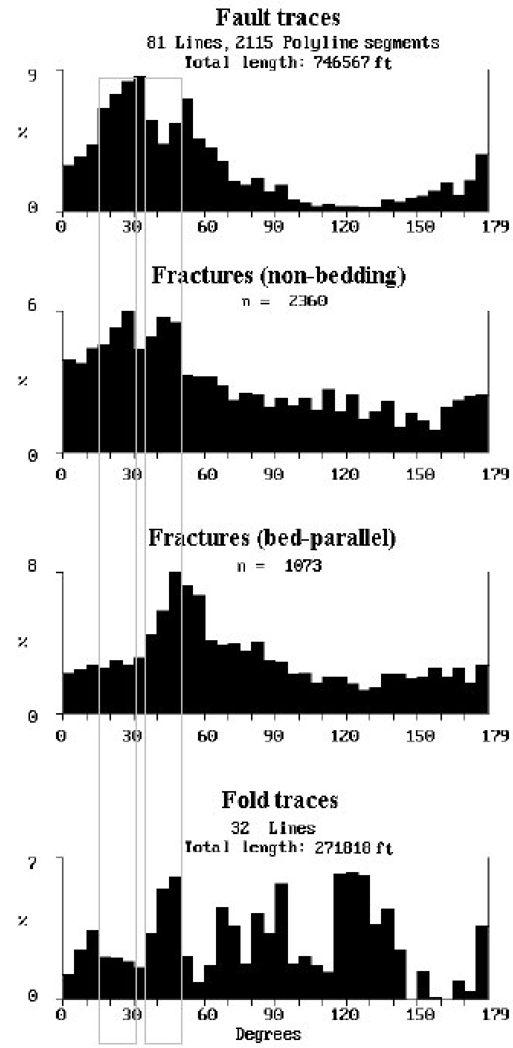
Structural Geology

Wikipedia - **Structural geology** is the study of the three-dimensional distribution of rock units with respect to their deformational histories. The primary goal of structural geology is to use measurements of present-day rock geometries to uncover information about the history of deformation (strain) in the rocks, and ultimately, to understand the stress field that resulted in the observed strain and geometries. This understanding of the dynamics of the stress field can be linked to important events in the regional geologic past; a common goal is to understand the structural evolution of a particular area with respect to regionally widespread patterns of rock deformation (e.g., mountain building, rifting) due to plate tectonics.

Structural Geology Laboratory.





Structural geology is used to quantify the depth, thickness, and angular relationships of geological features that contain hydrocarbon, mineral and water resources for anthropogenic uses. It is used in conjunction with stratigraphy, geophysics, and geography in order to characterize oil and gas reservoirs, precious and semi-precious mineral deposits, and aquifers.

Traditional structure degree BS-->MS-->PhD, structure, advanced structure, Masters, Dissertation.

Scope of this laboratory

•Learn core principals of traditional structural geology and modern means of communicating 2D- and 3D geological relationships.

•Introduction to advanced structural concepts grounded in material engineering and geophysics.

•Will focus on the role structural geology plays in fractured-bedrock aquifer analyses

•Will use geographic information systems (GIS), computer-aided drafting (CAD), and Google Earth (GE) to portray structural geological relationships of outcrop and subsurface (drill and well) data

1. A. Intro
   B. Flash drive contents (Rider/GCH_310_Lab.doc)
   C. Overview with Primary & Secondary rock structures (Rider/Powerpoint/Introduction.ppt)
   D. Trig, Descriptive and Analytical Geometry (Rider/Powepoint/1B. Descr_Trig_Anal_Geom.ppt)

2. A Map projections, coordinates, scales, north.
   B. Plane Dip and Strike, Lineation Plunge and Trend,
   C. Structural Measurements conventions, the Brunton Compass, and Field Book
   D. Intro to the NJGS Field data Management System (FMS)

3. Field Trip I or
   A. Geologic maps, topographic maps, and outcrop patterns.
   B. Structure contour (elevation), isopach (thickness),and isobath (depth) maps

Drawing cross-sections

4. Same as 3

5. A. Fractures and Faults
   B. Folds and Cleavage
   C. Histograms and Stereographic projections

   EXAM 1

6. A. Balanced cross-sections
   B. Measuring compressional and extensional strains

7. A. Structural analysis of fractured-bedrock aquifers.
   B. Borehole imaging techniques, and virtual fracture rendering, GIS and GE..

8. **Field Trip II:** Kittatinny Valley Field Trip: Martinsburg Rt.46 and Federal Springs RR cut
   A. Kittatinny Valley exercise 1

9. A. 2D and 3D Geological analyses in compressional fold-and-thrust belts 1
   B. Complex folds and faults
   C. Kittatinny Valley exercise 2

10. 2D and 3D Geological analyses
    Kittatinny Valley GE and GIS exercises
    3D structures and well-fields

11. A. 2D and 3D Geological analyses in extensional terraine 1
    B. Geological analysis Newark basin exercise 1.

12. **Field Trip III:** Mine Brook Park (Trl-JTRp-Jo) or Pennington RR cut (JTRp).
    Geological analysis

13. Project Presentations

Introduction to Primary and Secondary Geological Structures

Primary Geological Structures develop at the time of formation of the rocks

They commonly are found in sedimentary and igneous, and are sometimes preserved in metamorphic rocks.

Primary structures include sedimentary bedding and compositional layering in igneous and metamorphic rocks.

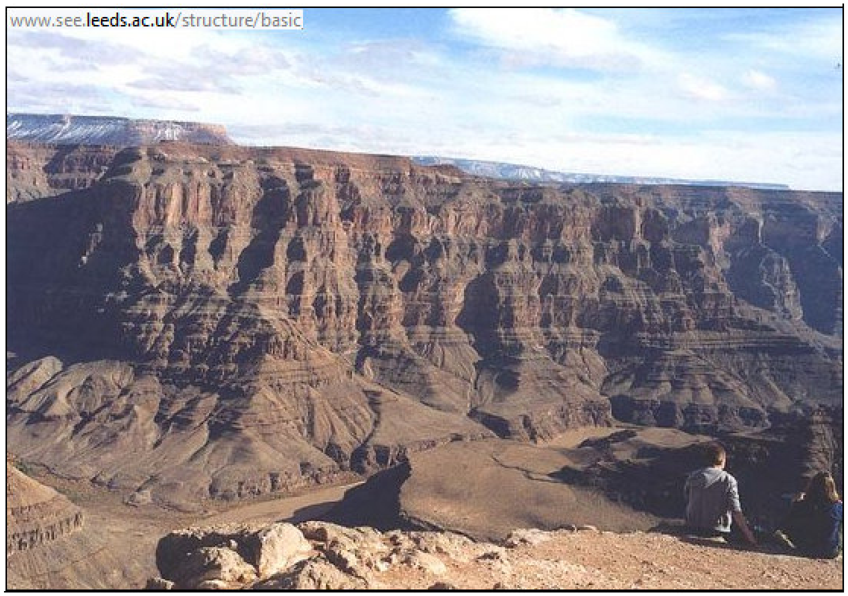
Secondary Geological Structures develop in rocks after their formation from being subjected to external forces including heat and pressure.

Compound structures form by a combination of events some of which may be contemporaneous with the formation of a group of rocks

Primary Geological Structures - Sedimentary bedding

A primary consideration is their orientation, flat-lying, tilted (dipping), upright or overturned?

Sedimentary and stratigraphic features that help identify primary layers and their orientation include mud cracks, grading bedding, ripple marks, fossil burrows, and load casts.



Sandstone sedimentary layers and low grade coal formed in swampy landscapes in the ancient past.

Primary Geological Structures -

Igneous layering within intrusions (sills and dikes) and extrusions (pyroclastic and lava flows)

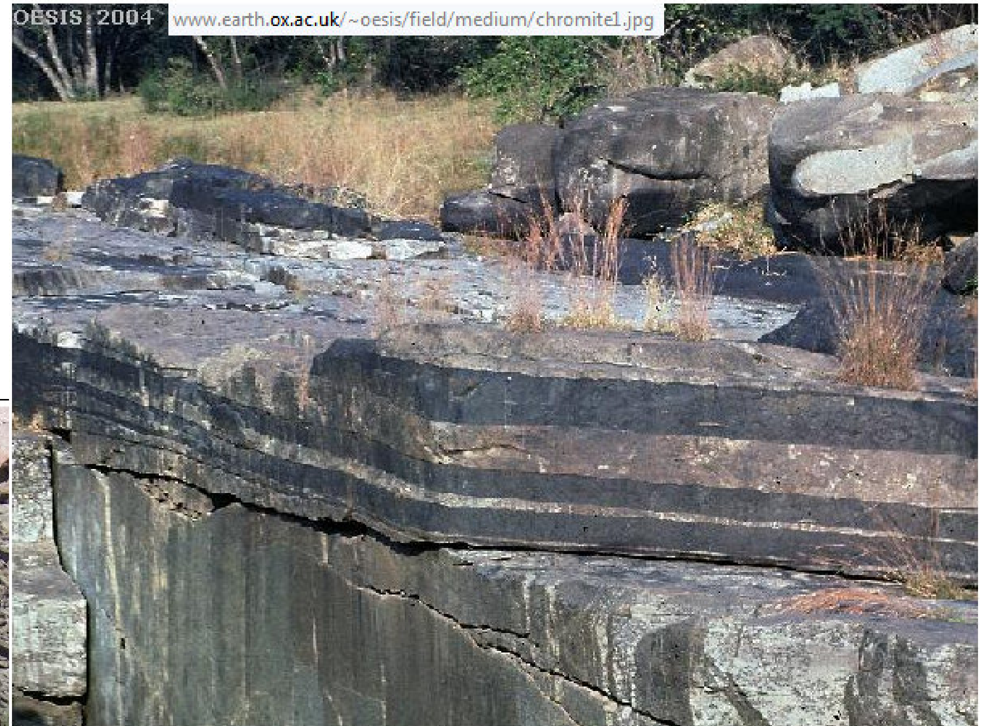


Figure 4. West view of diabase layering and columnar jointing in the western rock face, 3rd quarry level at station 77916 (fig. 5). Layering is about 2 to 15 m thick and dips steeply from the upper right to the lower left (~N094E/80S) with polygonal cooling joints (below) formed in each set of layers and generally oriented at high-angles to layered contacts. The density of fracturing varies among and within layers. Most fracture surfaces are slickensided shear planes that locally form sigmoid structures (S - white dotted line), suggesting that cooling and slip may have been contemporaneous. No compositional differences were seen between the more massive and finely fractured intervals within the same layer, but different layers locally vary in both composition and texture.

www.geologyclass.org/Igneous Concepts.htm © Larry Fellows.

Basaltic sill near Logan Pass in Montana's Glacier National Park.

Primary Geological Structures - Metamorphic compositional layering

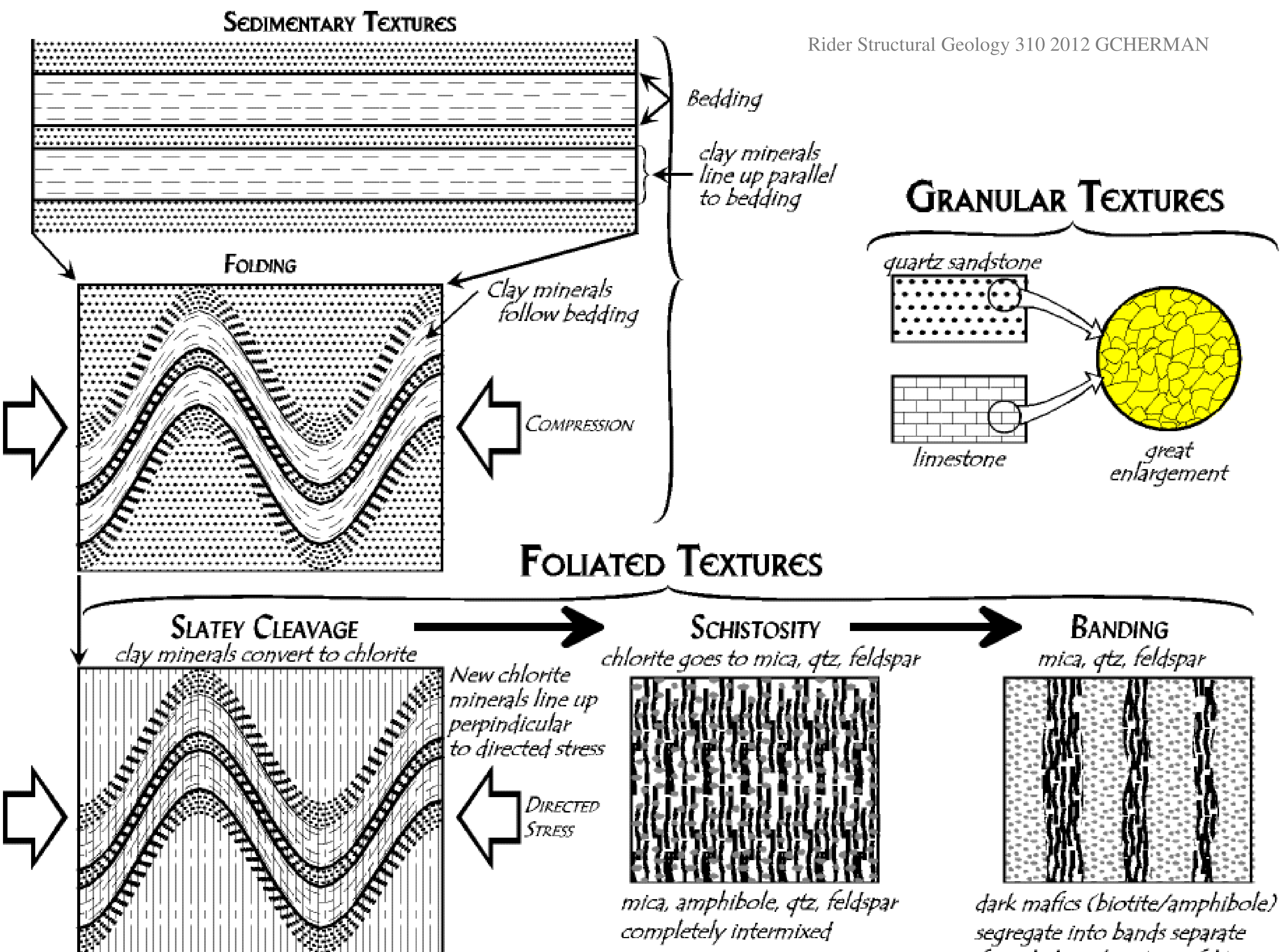
Figure 10. Light brown quartzite beds and dark gray phyllite beds of the Kittery Formation at Two Lights. This nearly vertical exposure shows beds that are about 10 centimeters thick and gently inclined.

Sedimentary beds of varying composition and texture are commonly seen in low-grade (greenschist-facies) metamorphic rocks

Figure 13. Coarse-grained metamorphic sandstone beds separated by a metamorphic siltstone that is spanned by the mechanical pencil. The interior of the siltstone bed adjacent to the pencil appears to have fain undulatory bedding. Tracking the bed toward the upper right corner, the siltstone is eroded in its core and shows what may be the trace of undulatory bedding. The undulatory surface could represent ripple marks, or possibly deformation by syndepositional slump folds. If so it would suggest the top of the beds is to the upper left corner of the photo. Kingfield Elementary School, Kingfield, Maine.

Compositional layering seen at greenschist through amphibolite to granulite facies, but definition becomes more obscure and questionable increasing metamorphic grades

Texture Development in Metamorphic Rocks



csmres.jmu.edu/geollab/fichter/MetaRx/Textdevel.html

Metamorphic Textures -

Schistosity

www.earth.ox.ac.uk/~oesis/field/medium/schist3.jpg

en.wikipedia.org/wiki/File:Cresheim_Creek,_Wissahickon.jpg

Metamorphic Textures -
Gneissic layering

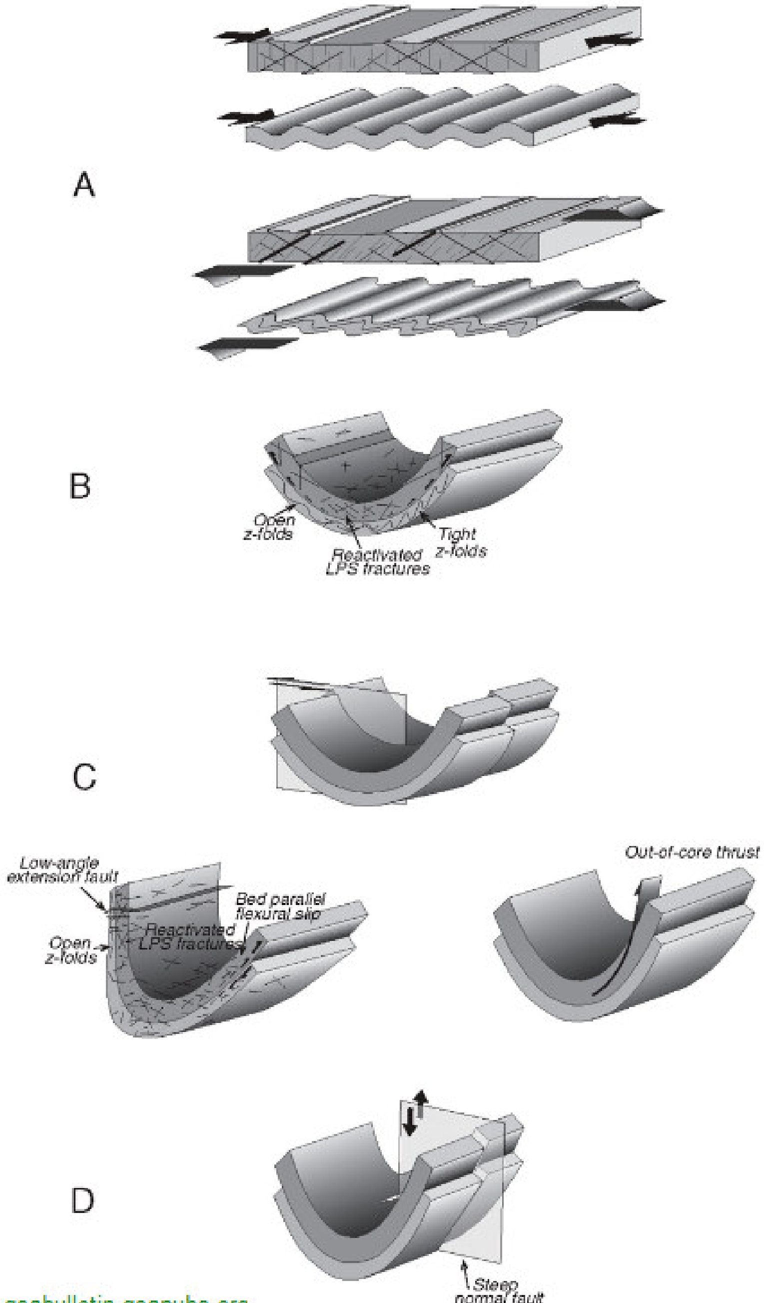
www.discovergrandteton.org/teton-geology/teton-rocks/

Gneiss
Site: Mt. Moran, Teewinot

Gneiss forms at high temperature and pressure deep underground. Layered gneiss has distinct layers alternating dark gray and white. These layers form during metamorphism and are not the original rock layers.

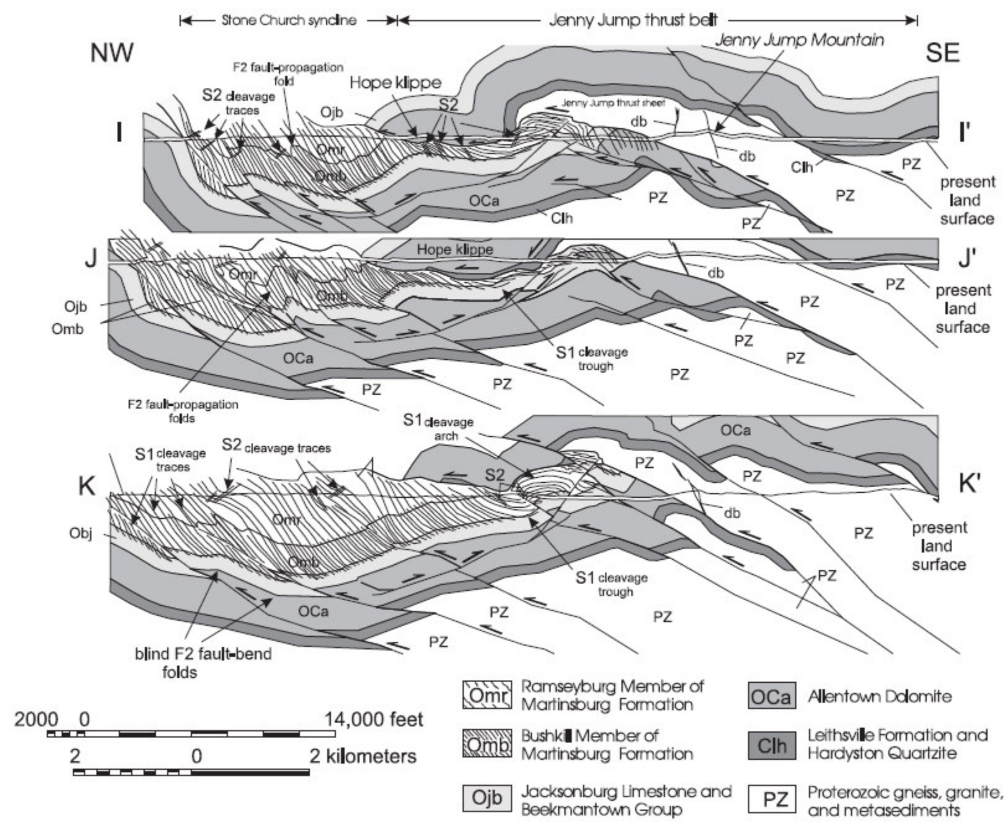
geol.ucsb.edu

Secondary Geological Structures - Fractures, Cleavage, Folds, and Faults



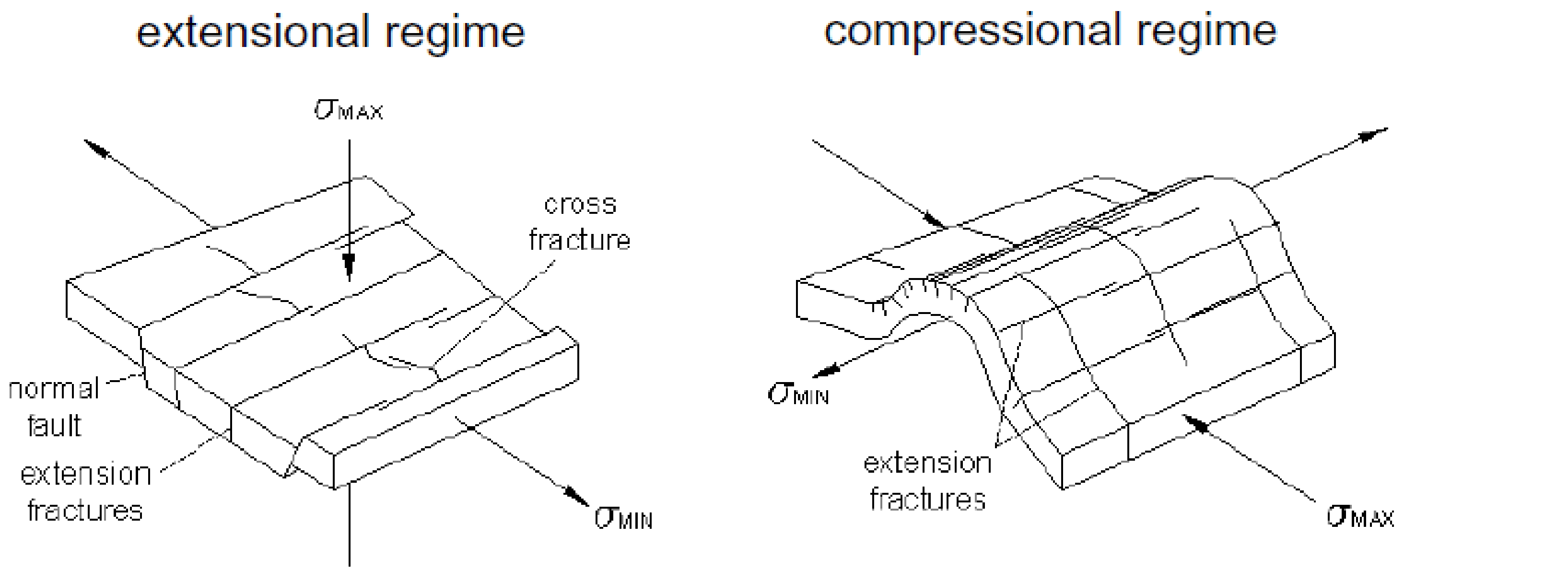
gsabulletin.gsapubs.org

HERMAN ET AL. Geological Society of America Bulletin, August 1997



Kittatinny Valley and Jenny Jump Mt. Overthrust, Warren and Sussex Counties, New Jersey

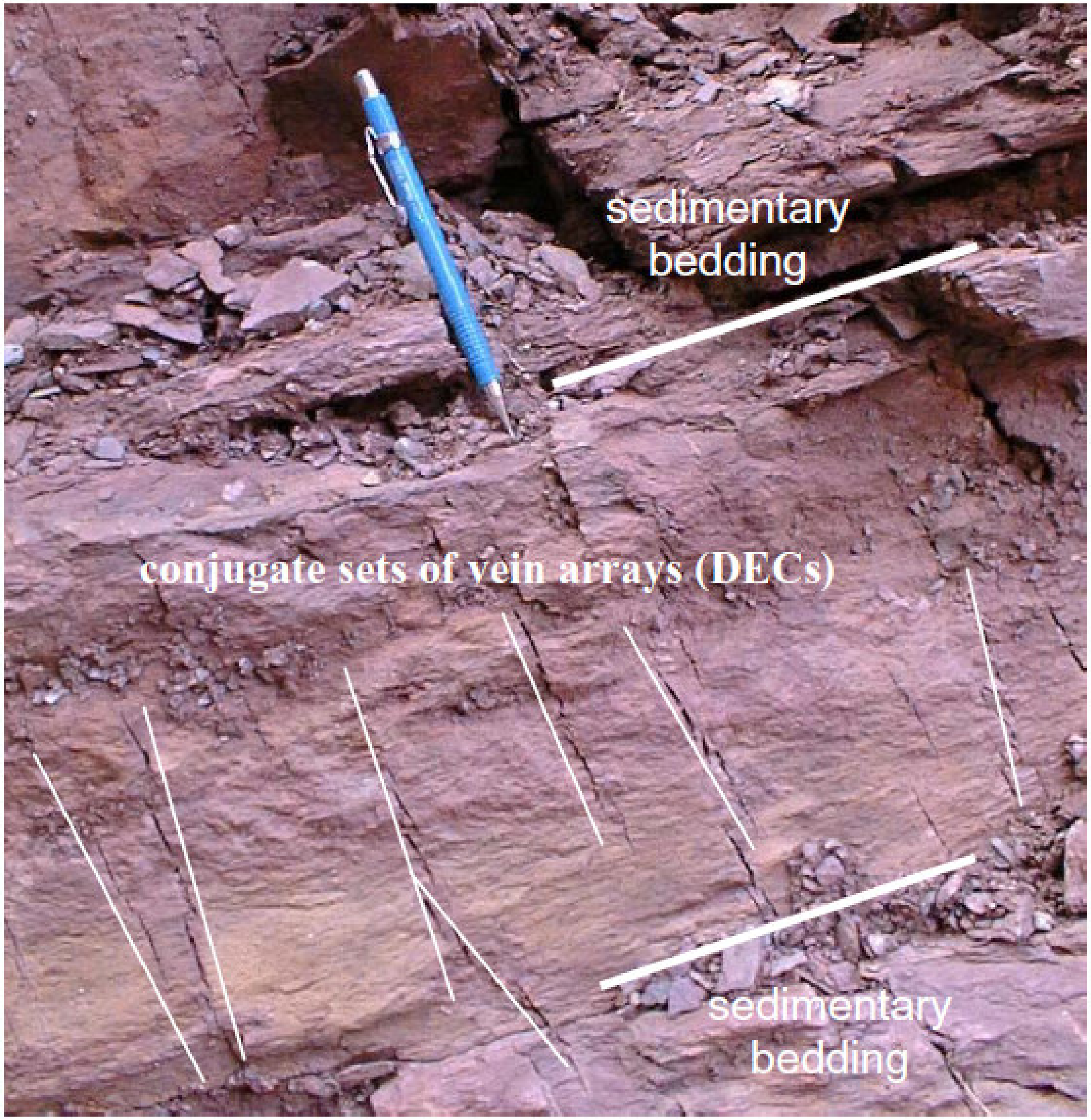
Secondary Geological Structures - Fractures, Folds, and Faults



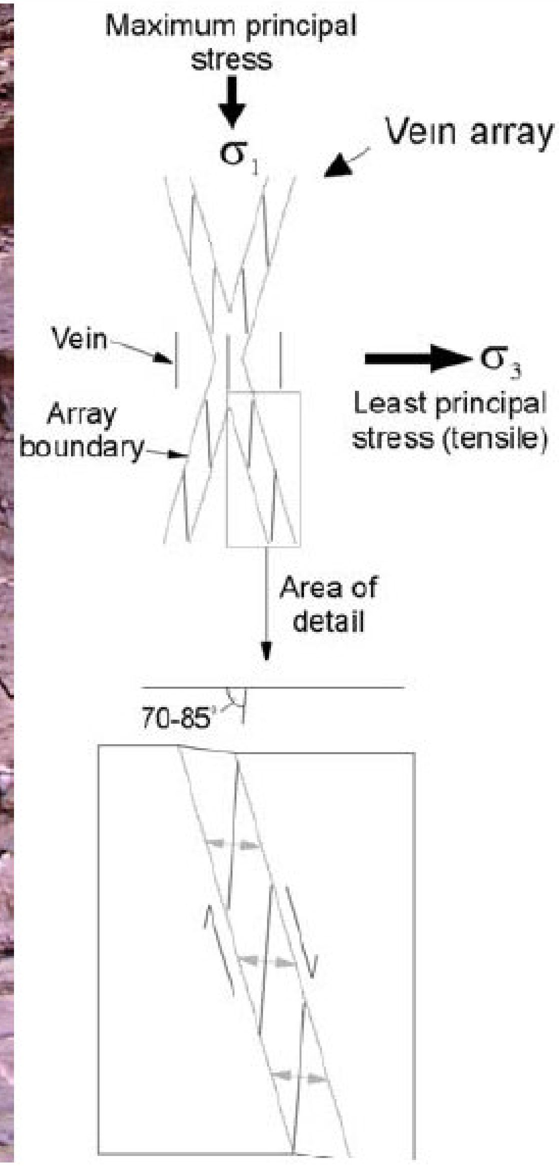
www.ganj.org/2005/NB_joints_veins.pdf

Figure 2. Block diagrams illustrating extension and cross fractures and normal faults in an extensional tectonic regime, and extension fractures in folded strata in a compressive tectonic regime; with respect to the maximum (σ_{MAX}) and minimum (σ_{MIN}) principal stress directions. Intermediate principal stress direction is not shown but is oriented orthogonal to the other principal stresses. σ_{MAX} in the extensional regime is oriented subvertical and stems from sedimentary loading. Extension fractures in the extensional regime strike parallel to normal faults. Extension fractures in the compressional regime strike both perpendicular to and parallel to fold axes, allowing strata to be stretched both along the fold axes and in the outer arc of the fold. Note that cross fractures in the extensional regime strike subparallel to extension fractures in the compressional regime if the orientation of the principal axes remains unchanged and σ_{MIN} is inverted to σ_{MAX}.

Secondary Geological Structures - Fractures, Folds, and Faults



14a



14b

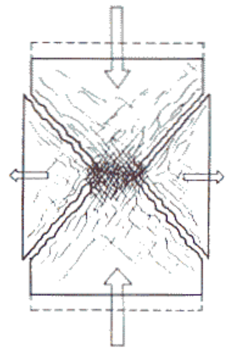
Secondary Geological Structures - Fractures

Brittle fracture

LABORATORY TESTING OF ROCK

TRIAXIAL COMPRESSION TEST

Shear Strength and Deformation Properties www.cast.com.sg/s_soil.html



B Conjugate shear fractures in 'brittle' rock (after L. Müller, 1963;reprinted by permission of Ferdinand Enke Verlag). Angle between rupture surfaces remains preserved during shortening; accommodation of shortening by brecciation and dilatation.

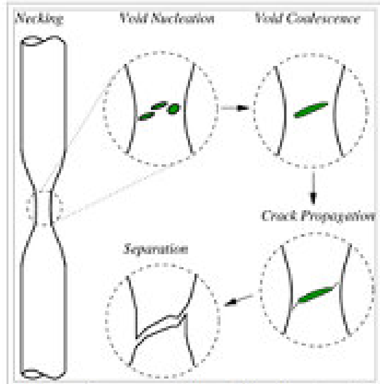
Mechanics of tectonic faulting, G. Mandl, 1988, Elsevier

SAMPLE AFTER TEST

Ductile fracture

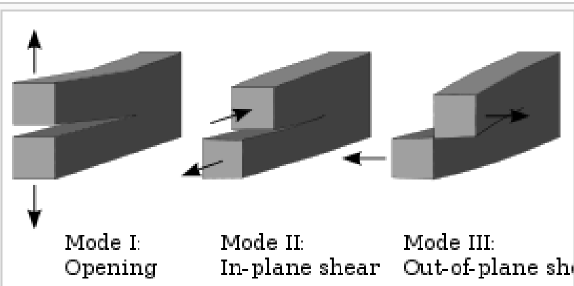
Ductile failure of a specimen strained axially.

en.wikipedia.org/wiki/Fracture



Schematic representation of the steps in ductile fracture (in pure tension).

Crack separation modes



The three fracture modes.

There are three ways of applying a force to enable a crack to propagate:

- **Mode I crack** – Opening mode (a tensile stress normal to the plane of the crack)
- **Mode II crack** – Sliding mode (a shear stress acting parallel to the plane of the crack and perpendicular to the crack front)
- **Mode III crack** – Tearing mode (a shear stress acting parallel to the plane of the crack and parallel to the crack front)

For more information, see fracture mechanics.

Secondary Geological Structures - Folds

blogs.agu.org/mountainbeltway/category/scotland/

www.flickr.com/photos/31856336@N03/galleries/72157623975198336/#photo_2040914790

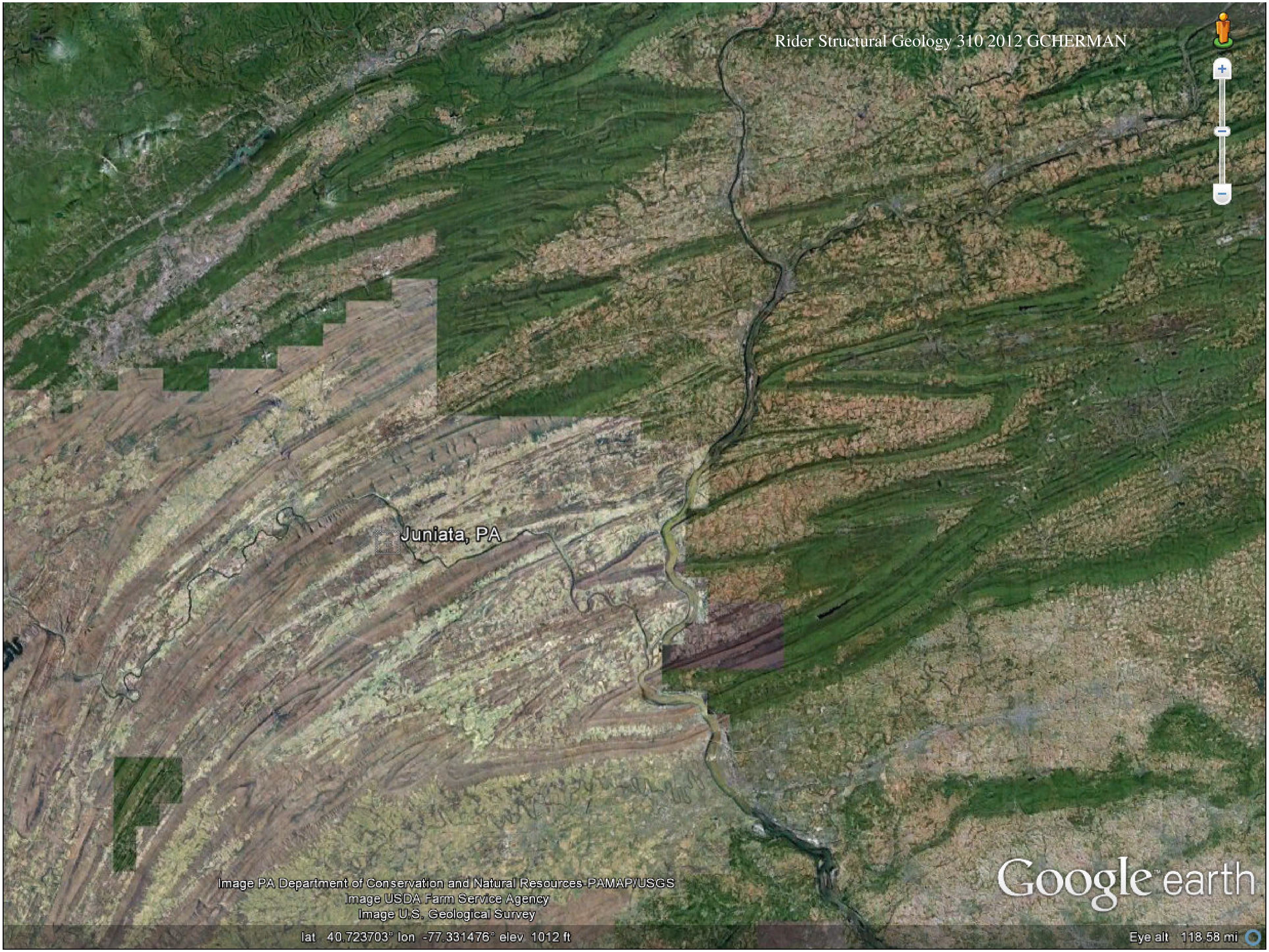
Second Valley, South Australia

www.abdn.ac.uk/geology/people/staffpages/i_alsop.php

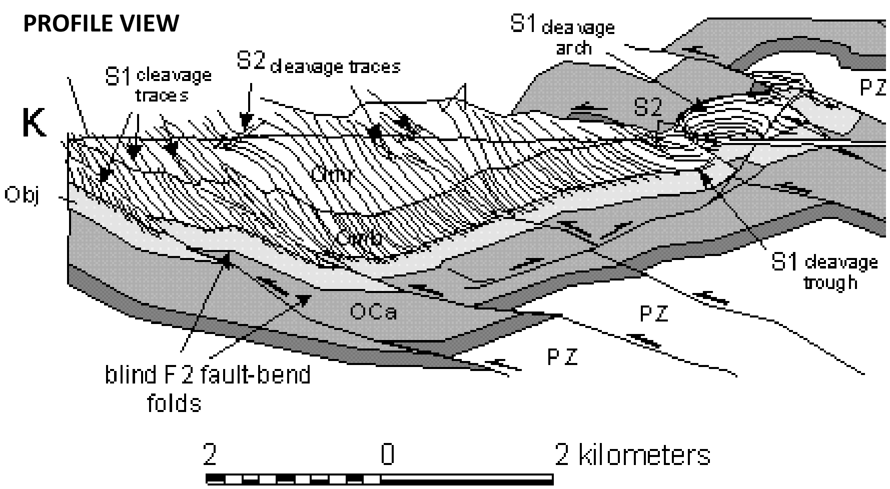
Soft-sediment folding developed in the Dead Sea (Photo © Ian Alsop).

www.dcnr.state.pa.us/topogeo/photogallery/images/eplerfold.jpg

www.nvcc.edu/home/cbentley/geoblog/labels/geology.html

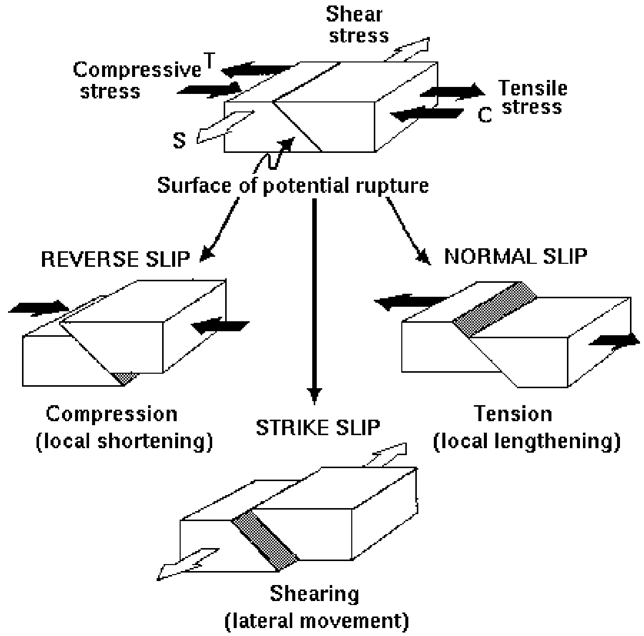

Rider Structural Geology 310 2012 GCHERMAN
Juniata, PA
Image PA Department of Conservation and Natural Resources-PAMAP/USGS
Image USDA Farm Service Agency
Image U.S. Geological Survey
lat 40.723703° lon -77.331476° elev 1012 ft
Eye alt 118.58 mi
Google earth

Secondary Geological Structures - Cleavage



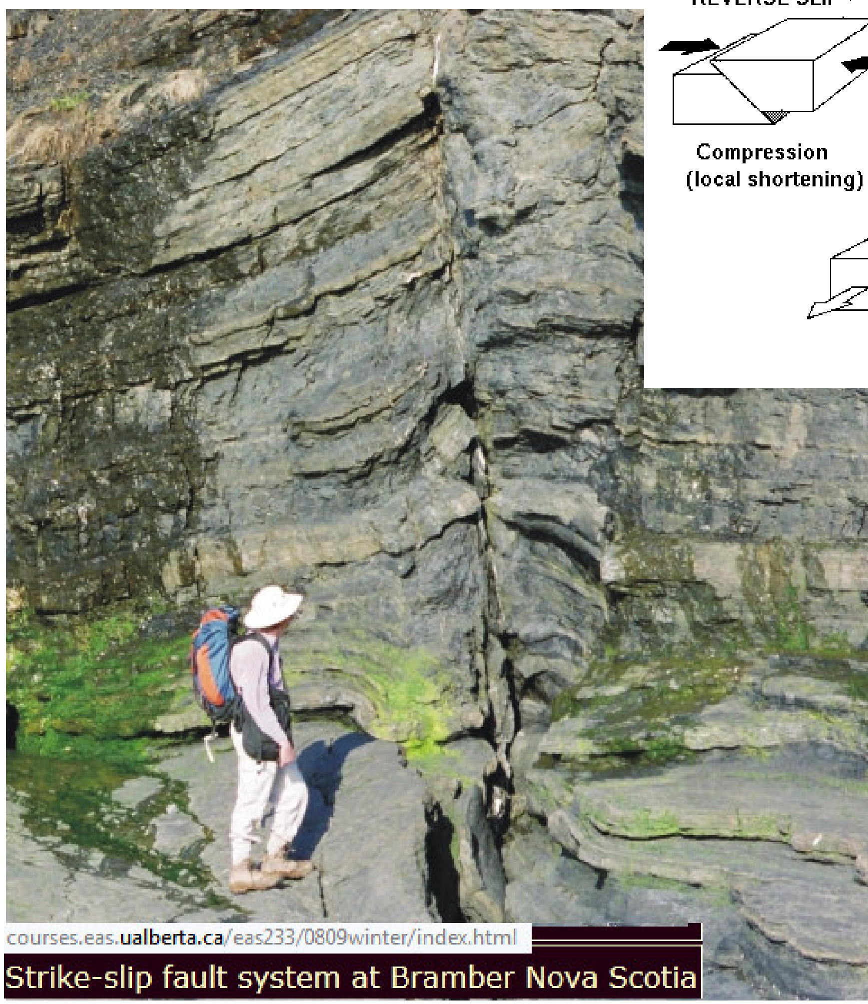
Secondary Geological Structures
Faults

Rider Structural Geology 310 2012 GCHERMAN



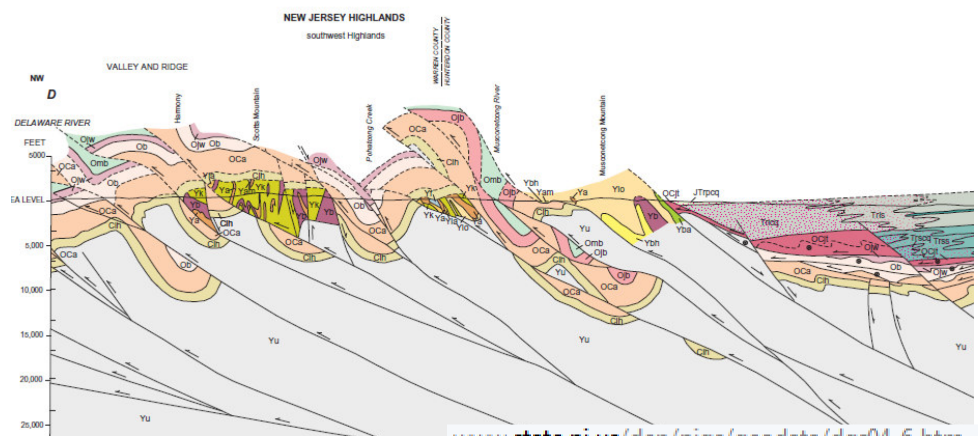
www.britannica.com/blogs/2011/02/how-fault-lines-form/

Section of the San Andreas Fault in the Carrizo Plain, western California; U.S. Geological Survey

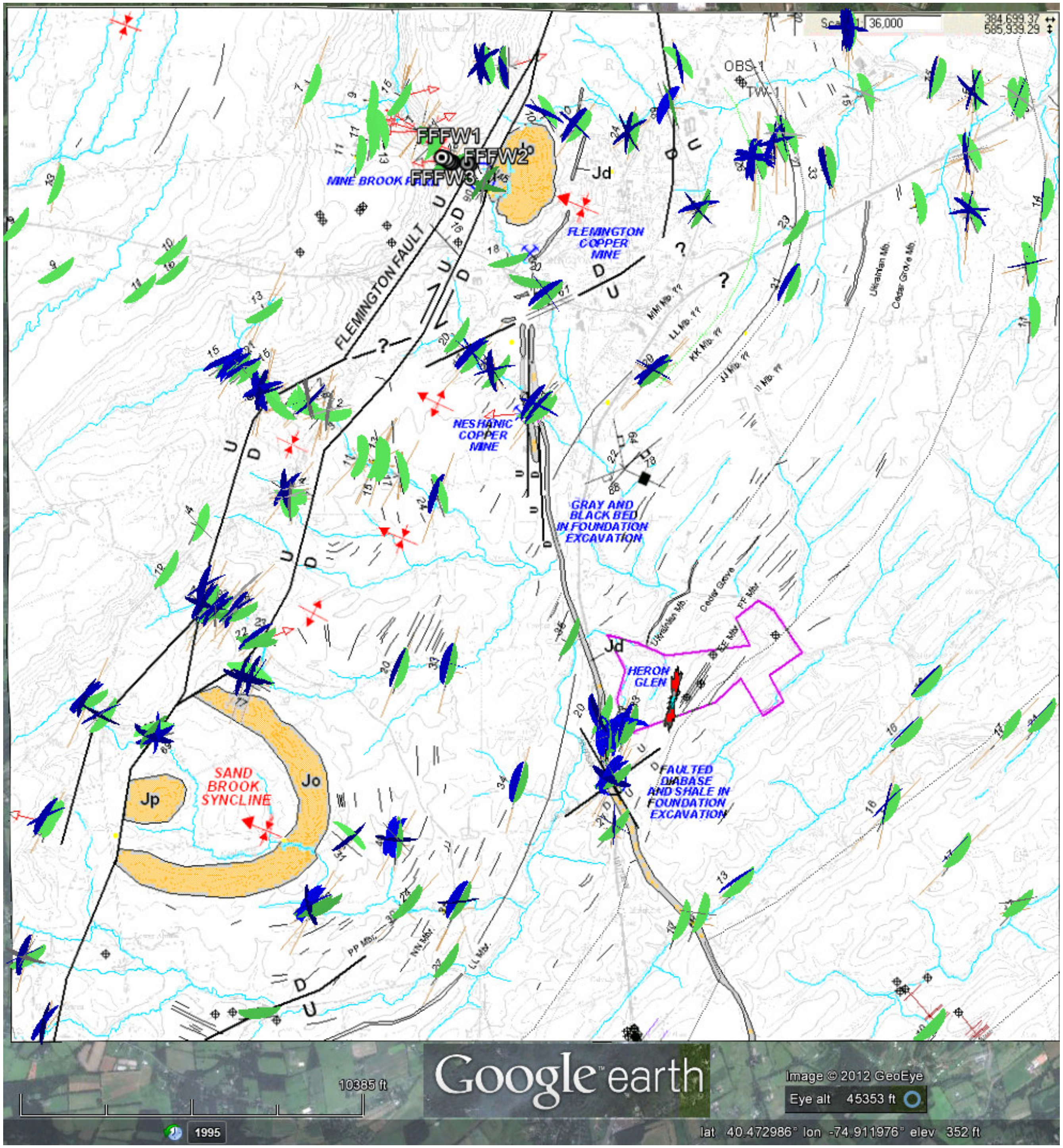


courses.eas.ualberta.ca/eas233/0809winter/index.html

Strike-slip fault system at Bramber Nova Scotia



www.state.nj.us/dep/njgs/geodata/dgs04-6.htm



Google Earth KMZ file of the bedrock geology of the Flemington, NJ area.

Flash Drive:\ Rider\GE\KMZ\Flemington2012a.kmz

Base image is from a NJGS project map showing basalt flows (orange polygons labeled Jp and Jo), bedding strike and dips, and faults (U – up thrown, and D – down thrown fault blocks).

Green (bed) and blue (fracture) ellipses are 3D Collada models that are 400 m long and 200 m wide with respect to strike and dip length (for a 2:1 aspect ratio).

Light blue lines are hydrography digital line graph shapefiles.