Steeply dipping axial plane cleavage. These folded sedimentary layers exposed near Sullivan River in southeastern British Columbia dramatically illustrate the awesome forces constantly at work reshaping the features of the earth. Photo by R.A. Price.

Quiz 7 Due Today
4 April

See
**Strike & Dip Symbols**

- N
- 30° = Dip Angle in Degrees

**Stress vs. Strain**

- Force vs. Response

**Low Temperature, Pressure**
- Brittle Rocks - Faulting

**High Temperature, Pressure**
- Ductile Rocks - Folding

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**Stress**

- Unstressed cube of rock
- A: Tensile stress
- B: Compressional stress
- C: Shear stress
FOLDS

Compression

FOLDS

Compression

Rails Compressed During 1964 Earthquake Alaska

National Earthquake Information Center
neic.usgs.gov/neis/eqlists/USA/1964 03 28 pics 1.html
Types of Folds
- Anticline
- Syncline
- Monocline

Eroded (or Breached) Folds
- Anticline
- Syncline
- Monocline
- Erosion Surface
  - Younger Rx
  - Older Rx

Other Types of Folds
- Anticlinorium
- Synclinorium
- Geanticline
- Geosyncline
- Dome
- Basin
- large folds
- larger folds
- closed folds
**Strike & Dip Symbols**

- **Symbols**: Symbols used to represent strike and dip in geology.
- **N**: North.
- **30° = Dip Angle in Degrees**: The angle at which a rock layer is inclined from the horizontal.

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**A. Inclined plane**

- **Horizontal plane**: A plane that is parallel to the Earth's surface.
- **Line of intersection**: The line where the inclined plane intersects the horizontal plane.
- **30° angle of dip**: The angle at which the inclined plane is tilted from the horizontal.
- **All horizontal lines on the inclined plane are parallel**: Lines that are horizontal on the inclined plane maintain a constant horizontal orientation.

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**B. Geological Cross Section**

- **Shale**: A type of sedimentary rock.
- **Sandstone**: Another type of sedimentary rock.
- **Limestone**: A sedimentary rock composed of the mineral calcite.
- **Kilometer**: Unit of length equal to 1000 meters.

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**C. Hinge lines**

- **Hinge line of syncline**: The line along which a fold in the rock is axisymmetrically curved to one side of the fold.
- **Hinge line of anticline**: The line along which a fold in the rock is axisymmetrically curved in the opposite direction of the syncline.
- **Youngest rock exposed on surface**: The youngest rock layer is exposed on the surface.
- **Oldest rock unit exposed on surface**: The oldest rock unit is exposed on the surface.
Parts of a Fold

Limb

Axis = Line of Symmetry

Plural = Axes

Axial Plane
Plunging Fold

Axial plane

mb

Horizontal Plane

Plunge

Age of Rocks. Superposition: Youngest on Top

Where are older rocks exposed at the surface? Younger Rocks
Where are Older Rocks, Younger Rocks? Remember "Superposition"
Progression of Folding
Symmetrical
Asymmetrical
Overturned
Recumbant
Thrust Fault

Overturned Fold
Up-Side-Down (Overturned) Limb

Recumbant Fold
Recumbant Limb
Thrust-Faulted Fold

Earthquakes & Faults

- **Stress**: Force Applied
- **Strain**: Response to Force

Stress vs. Strain
Fault

- Plane of Weakness Along Which Movement Has Occurred

Joint

- Break Without Significant Movement

Go to this site to see animations of different fault types:
http://www.iris.edu/gifs/animations/faults.htm

Check Out Fig 15.21 in Plummer Text Book, 10th Ed.

Dip-Slip Motion

Mostly Up and Down
Fault Parts

Normal Fault

Before

Stress

Tension = Pull-Apart

After

Normal Fault

Tension
Reverse Fault

Thrust Fault
- Low-Angle (<30°) Reverse Fault
- May Have Great Displacement
Thrust Fault, Eastern Pennsylvania

Strike-Slip Motion

Right-Lateral Fault
- Map View - Before
Right-Lateral Fault
- Map View - After

Stream Offset on San Andreas Fault Lineament

Left-Lateral Fault
- Before
- After
Types of Faults

<table>
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<tr>
<th>Block diagram</th>
<th>Name</th>
<th>Definition</th>
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<tr>
<td></td>
<td>Strike-slip fault</td>
<td>Movement horizontal</td>
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<tr>
<td></td>
<td>Oblique-slip fault</td>
<td>Combined horizontal and vertical movement</td>
</tr>
<tr>
<td></td>
<td>Hinge fault</td>
<td>Combined horizontal and vertical movement</td>
</tr>
</tbody>
</table>

Oblique Fault

Stress

Before

Tension + Shear

After

Active vs. Inactive Faults

- **Active Faults:** Moved at Least Once in Last 10,000 years OR
- **Twice or More in Last 250,000 years**
Expected Earthquake Intensity

3 New Madrid Quakes 1811-1812

Modified Richter (Total Energy) Magnitude Scale

Mercalli (Surface Intensity) Scale
Focus: Point of Faulting
Epicenter: Point on Surface Above Focus

What Causes Damage?
No Opening of Earth & Gobbling up Cities
Little Damage From Fault Offset
Most Damage Caused by Seismic Waves (Including Tsunamis) & Landslides

Elastic Rebound theory
- Developed after 1906 SF Quake
At Great Depths, Rock Does Not Fully Snap Back...

Elastic Rebound
Earthquakes & Faults

Elastic Rebound

Earthquake

Elastic Rebound
Good Friday 1964 Alaska Earthquake, Magnitude 9.2

This side rose 5 m (16 ft)
Dip-slip motion

Fault Scarp

Earthquake Damage: Landslides
Anchorage Elementary School Destroyed
Earthquake Damage: Landslides

Earthquake Damage: Tsunami
= Seismic Sea Wave
(A.K.A. "Tidal Wave")

Logging Truck Wrapped Around Tree by Tsunami
18 April 1906 Quake Damage
San Francisco City Hall

http://neic.usgs.gov/neis/eqlists/USA/1906_04_18_pics_2.html

Stanford University
1906

http://neic.usgs.gov/neis/eqlists/USA/1906_04_18_pics_2.html

USGS California Seismic Risk Map
Largest Earthquake in West Virginia: 1969 November 20, Magnitude 4.5

Historic Earthquakes
Southern West Virginia
1969 11 20 01:00:09.3 UTC (Local 11/19)
Magnitude 4.53
Intensity VI

Largest Earthquake in West Virginia
Minor damage occurred in Giles County, Virginia, at Glen Lyn and Rich Creek, and at three towns in southern West Virginia. At Glen Lyn, a few bricks were knocked from a chimney, windows were broken, and plaster was broken from most of the walls in an old house. At Rich Creek, plaster cracked and fell and windows were broken. A cornice reportedly was shaken from one building in Henry County, at Collinsville, Virginia. Windows also were broken in southern Mercer County, West Virginia, at Lerona, Oakvale, and Elwood. Felt over all or parts of nine States: Georgia, Kentucky, Maryland, North Carolina, Ohio, South Carolina, Tennessee, Virginia, and West Virginia.


At Some Point (T, P) Earthquakes Are Impossible Because Rock Is Not Elastic
Roll of Fluids as Lubricants

- Water
- Nuclear Wastes in Colorado

Quiz 8 Due in Class on 6 April

http://www.geo.wvu.edu/%7Ekite/2006GEOL101Quz8Structures.htm

Quiz 9 Due in Class on 18 April (Test III)

Quiz 9 Due on 18 April - Plate Tectonics - Admission Ticket for 10:35 Time Slot on Test III
What Develops in Rock Under Compression?

Brittle Rocks: Reverse Faults

Ductile Rocks: Folds

Reverse Fault

Compression of Ductile Rocks: Folds
What Develops in Rock Under Tension?

Brittle Rocks: Normal Faults

Normal Faults

Ductile Rocks: Boudinage

Boudinage
**Boudinage**

<table>
<thead>
<tr>
<th>Force</th>
<th>Nature of Rock</th>
<th>Brittle</th>
<th>Ductile</th>
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<tr>
<td>Tension</td>
<td>Normal Faults</td>
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<td>Boudinage</td>
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<tr>
<td>Compression</td>
<td>Reverse Faults</td>
<td></td>
<td>Folds *</td>
</tr>
</tbody>
</table>

* Why Are Normal Faults & Folds Most Common?

**Slaty Cleavage in Rocks**

First Step in Metamorphic Foliation
Slaty Cleavage in Rocks

Sandstone (Joints) & Shale (Slaty Cleavage)