24. Faults (I)

Main Topics

A Why are faults important?
B Fault geometry
C Fault kinematics
D Fault classification
E Introduction to fault mechanics

Collapsed Cypress Structure, Oakland, California, after Loma Prieta Earthquake, 1989

http://upload.wikimedia.org/wikipedia/commons/1/18/Cypress_structure.jpeg
24. Faults (I)

II Why are faults important?

A Faults generate earthquakes


B Faults bound the tectonic plates of the Earth

http://geology.com/plate-tectonics.jpg
24. Faults (I)

II Why are faults important?

C Faults create mountains

http://marlimillerphoto.com/SrA-17.html

24. Faults (I)

II Why are faults important?

D Faults deform the Earth’s surface and affect sedimentation

II Why are faults important? (cont.)

E Fluid transport in the Earth’s crust
1 Water
2 Magma
3 Hydrocarbons
4 Hydrothermal fluids [ore minerals]

II Why are faults important?

F Faults are zones of weakness to account for in engineering projects
24. Faults (I)

III Fault geometry

1 Thin relative to their in-plane dimensions

2 Bounded in extent
24. Faults (I)

III Fault geometry

3 Commonly grossly planar (at least locally)

IV Fault Kinematics

A Relative (not absolute) displacement \((\text{slip})\) of originally neighboring points (or “piercing points”) is essentially parallel to the fault

B Piercing points mark intersection of a line with a fault

C The slip vector connects offset piercing points

D Slip is not the same as "movement" or "displacement"
24. Faults (I)

IV Fault Kinematics
A Relative (not absolute) displacement (slip) of originally neighboring points (or “piercing points”) is essentially parallel to the fault
B Piercing points mark intersection of a line with a fault
C The slip vector connects offset piercing points
D Slip is not the same as "movement" or "displacement"

V Classification of faults
A Geologic classification
1 Based on orientation of slip vector relative to the strike and dip of a fault
   • Strike-slip
     – Right-lateral
     – Left-lateral
   • Dip-slip
     – Normal
     – Reverse (thrust)
   • Oblique (combination of strike-slip and dip-slip)
24. Faults (I)

2 Strike-slip
   a Slip vector is predominantly horizontal (i.e., parallel or anti-parallel to the line of strike)
   b Sense of slip
      i Right lateral: in map view across a fault, a marker is offset to the right
      ii Left lateral: in map view across a fault, a marker is offset to the left

3 Dip-slip fault
   a Slip vector is parallel (or anti-parallel) to dip
   b Sense of slip
      i Normal: hanging wall moves down-dip relative to footwall
      ii Thrust fault: hanging wall moves up-dip relative to footwall
      *Deeper (older) rocks thrust over shallower (younger) rocks*
24. Faults (I)

B Slip vs. Separation

1 Slip: True relative displacement of originally neighboring points

2 Separation: Apparent relative displacement of an offset feature as seen in a map or a cross-section

24. Faults (I)

C The amount and direction of slip can change with time and/or position along a fault
24. Faults (I)

VI Introduction to fault mechanics (2D)

A Total stress field = ambient stress field + stress perturbation due to fault slip
\[ \sigma_{ij}^{\text{total}} = \sigma_{ij}^0 + \Delta \sigma_{ij} \]

B Fault slip requires faults strength (shear traction fault withstands) to decrease

24. Faults (I)

VI Introduction to fault mechanics (2D)

C General relations

1 Slip = \( \Delta u \)

2 At peak \( \Delta u \)
   a \( \frac{\partial u}{\partial x} = 0 \)
   b \( e_{xx} = 0 \)

3 \( \Delta u \rightarrow 0 \) at fault ends, but \( \frac{\partial u}{\partial x}, e_{xx} \text{ and } \sigma_{xx} \) probably high
24. Faults (I)

VI Introduction to fault mechanics (cont.)

D Long strike-slip fault
1 Model is (c)
2 \( w = b(\theta_A - \theta_B)/2\pi \)
3 \( \sigma_{xz} = \frac{-Gb}{2\pi} \frac{y}{r_A^2} - \frac{-Gb}{2\pi} \frac{y}{r_B^2} \)
4 At \( x = 0 \)
   a \( r_A = r_B \)
   b \( \sigma_{xz} = 0 \)
5 Can use displacement discontinuity in an elastic model of surface-breaking strike-slip faults

Displacement Discontinuity

\[ \sigma_{xz} = \frac{-Gb}{2\pi} \frac{y}{r_A^2} - \frac{-Gb}{2\pi} \frac{y}{r_B^2} \]