30. Folds (III)

I  Main Topics
   A  Mechanics of folds near faults (e.g., monoclines)
   B  Buckling mechanics (fold trains)
   C  Structural traps

Monocline in limestone, Australia
Folds near reverse fault, Himalaya (from Grasemann et al., 2005)

30. Folds (III)
Radar Image, Folds in Pennsylvania

http://rst.gsfc.nasa.gov/Sect6/AppFolds.jpg

30. Folds (III)
Geologic Map and Cross Section

From Willis, 1894
30. Folds (III)

Mechanics of folds near faults (e.g., monoclines)
Fractured Monoclines, Koae Fault System

View along fold axis
View across fold axis
30. Folds (III)

II Mechanics of folds near faults (cont.)

Monocline in limestone, Australia

Folds near reverse fault, Himalaya (from Grasemann et al., 2005)

Displacements arising from slip on mode-II crack, 2D elastic model (from Pollard and Segall, 1987)

\[
\begin{align*}
    u_x &= \frac{-\Delta \sigma_{II}}{2G} r \left\{ \left( 1 - 2v \right) \left( \frac{R}{r} \cos \Theta - \cos \theta \right) + \sin \theta \left[ \frac{r}{R} \sin(\Theta - \theta) \right] \right\} \\
    u_y &= \frac{\Delta \sigma_{II}}{2G} r \left\{ 2 \left( 1 - v \right) \left( \frac{R}{r} \sin \Theta - \sin \theta \right) + \sin \theta \left[ \frac{r}{R} \cos(\Theta - \theta) - 1 \right] \right\}
\end{align*}
\]

Shear stress reduction on fault

Shear modulus of host rock
30. Folds (III)

Normal Fault Model Displacement Field

Normal Fault Model Displaced Layers

Monocline

Thrust Fault Model Displacement Field

Thrust Fault Model Displaced Layers

Monocline
30. Folds (III)

Folding Around a Reverse Fault
From Grasemann et al., 2005

Elastic model of originally horizontal layers with fault-parallel displacement

From Willis, 1894
30. Folds (III)

III Buckling mechanics (fold trains)

From Willis, 1894

30. Folds (III)

III Buckling mechanics

Dimensional analysis of terms in governing equation for buckling of an elastic layer (from Johnson, 1970)

\[
\frac{d^2 v}{dx^2} + \frac{12 P v}{B b H^3} = 0
\]

\(v\) = vertical deflection of mid-plane (Length)
\(x\) = horizontal distance (Length)
\(L\) = length of flexed part of layer (Length)
\(P\) = axial force (Force)
\(B\) = stiffness (Force/area)
\(b\) = width of beam (Length)
\(H\) = thickness of layer (Length)

*Dimensions check*
30. Folds (III)

III Buckling mechanics

Form of solution

\[
\frac{d^2 v}{dx^2} = \frac{-12 P v}{B b H^3}
\]

For sinusoidal (or cosinusoidal) functions the second derivative is proportional to the negative of the original function.

Let \( v = A_i \cos \left( \frac{2\pi k x}{L} \right) \)

\[
\frac{d v}{d x} = \left( \frac{2\pi k}{L} \right) A_i \sin \left( \frac{2\pi x}{L} \right)
\]

\[
\frac{d^2 v}{d x^2} = \left( \frac{2\pi k}{L} \right)^2 A_i \left[ -\cos \left( \frac{2\pi x}{L} \right) \right] = \frac{-12 P v}{B b H^3} = \frac{-12 P}{B b H^3} \left[ A_i \cos \left( \frac{2\pi x}{L} \right) \right]
\]

Eliminating common terms

\[
\left( \frac{2\pi k}{L} \right)^2 = \frac{12 P}{B b H^3} \Rightarrow \left( \frac{2\pi k}{L} \right) = \left( \frac{12 P}{B b H^3} \right)^{1/2} \Rightarrow k = \left( \frac{L}{2\pi} \right) \left( \frac{12 P}{B b H^3} \right)^{1/2}
\]

\[
v = A_i \cos \left( \frac{12 P}{B b H^3} \right)^{1/2} x
\]
30. Folds (III)

III Buckling mechanics

Form of solution
A sinusoidal term would also satisfy the governing equation, so the general solution should include both a cosinusoidal term and a sinusoidal term.

\[
v = A_1 \cos \left( \frac{12P}{BbH^3} \right)^{1/2} x + A_2 \sin \left( \frac{12P}{BbH^3} \right)^{1/2} x
\]

Note that the amplitudes \( A_1 \) and \( A_2 \) need not be equal.

A truly sinusoidal fold form suggests a buckling origin.

30. Folds (III)

IV Folds as Structural Traps

http://www.wou.edu/las/physci/Energy/graphics/OilAnticline.jpg
30. Folds (III)

IV Folds as Structural Traps

Saddles are unstable traps

(e.g., low permeability shale)
(e.g., hydrocarbons)
(e.g., water)
(e.g., high permeability ss)

http://www.wou.edu/ias/physci/Energy/graphics/OilAnticline.jpg