MECHANICAL ANALYSIS AND SEISMIC PROFILE OF THE GEOMETRY OF FAULT-RELATED FOLDS

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References

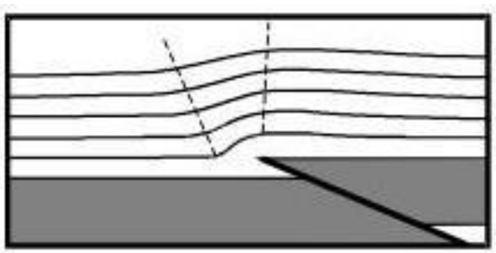
- Kaj M. Johnson and Arvid M. Johnson, 2002. **Mechanical analysis of the geometry of fault-related folds.** Journal of Structural Geology Volume 24, Issue 3, March 2002, Pages 401-410
- Taija Torvela , Clare E. Bond, 2011. **Do experts use idealized structural models? Insights from a deepwater fold-thrust belt.** Journal of Structural Geology 33 51-58.

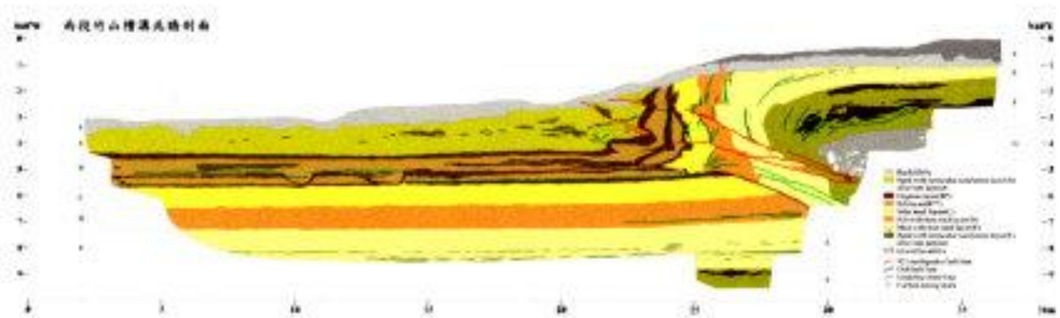
Outline

- Introduction
- Mechanical model of fault-related fold
- Influence of anisotropy on fold form
- Interpretation of the seismic profile
- Discussion and conclusions

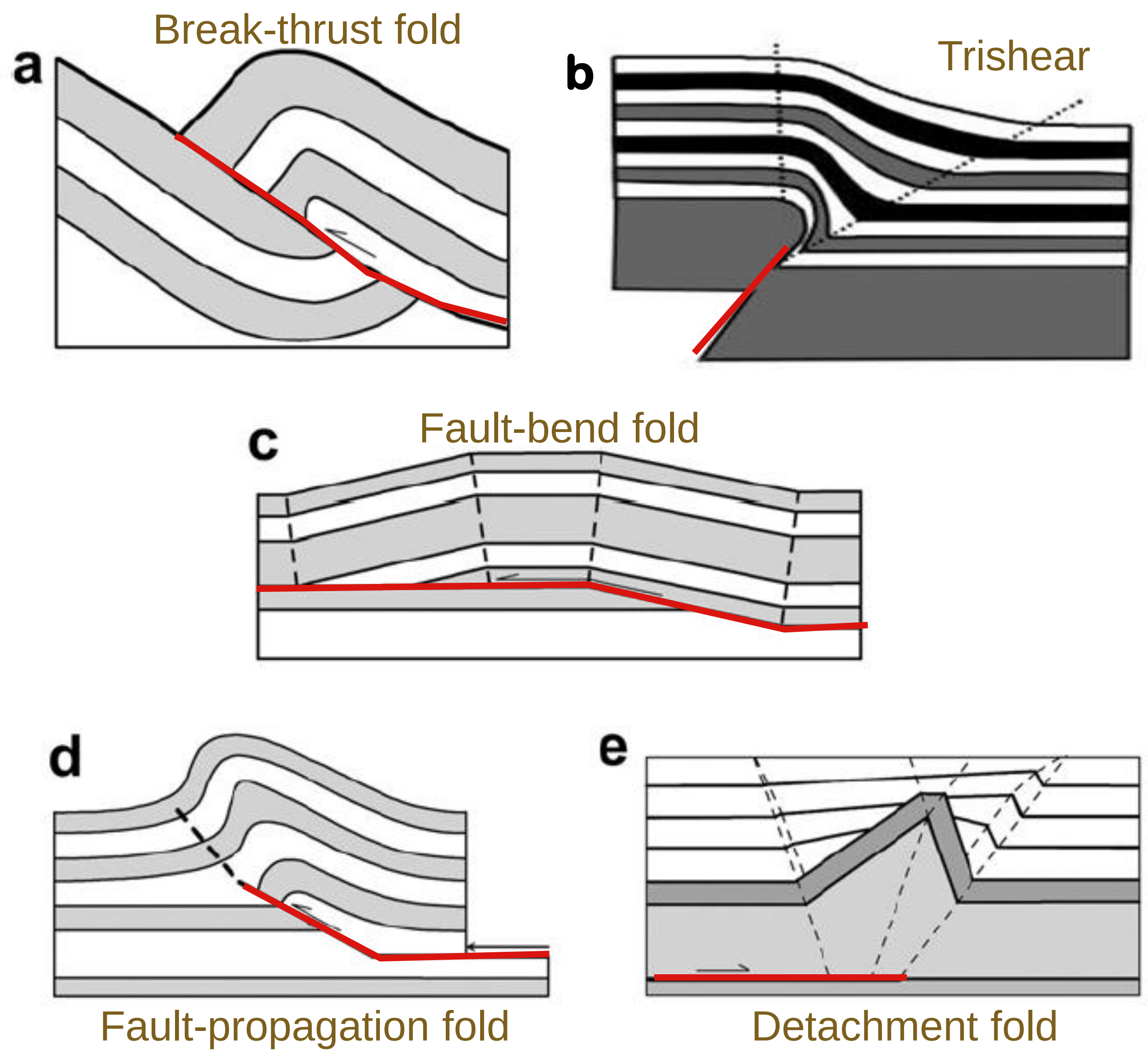
Introduction

- Typical structures are fault-related folds that form over basement faults. Outcrops and seismic profiles show that the folds are typically asymmetric monoclines.





圖四

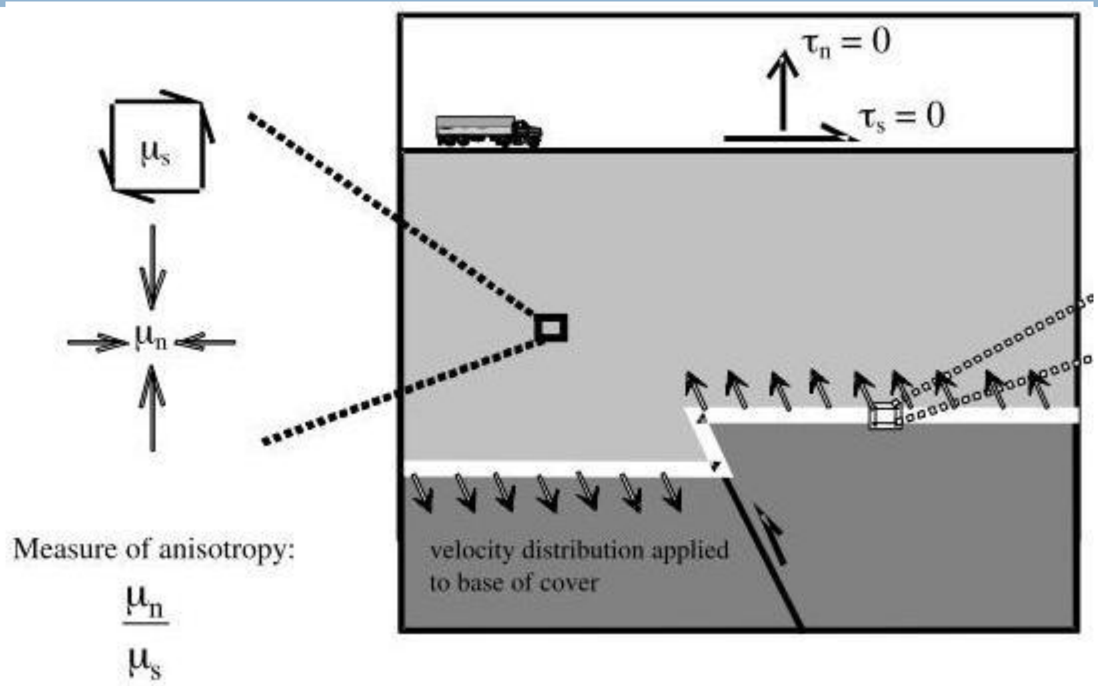

Break-thrust fold
a
b
Trishear
c
Fault-bend fold
d
e
Fault-propagation fold
Detachment fold

Mechanical model of fault-related fold

$$\frac{\mu_n}{\mu_s} = 1$$ *Isotropic*

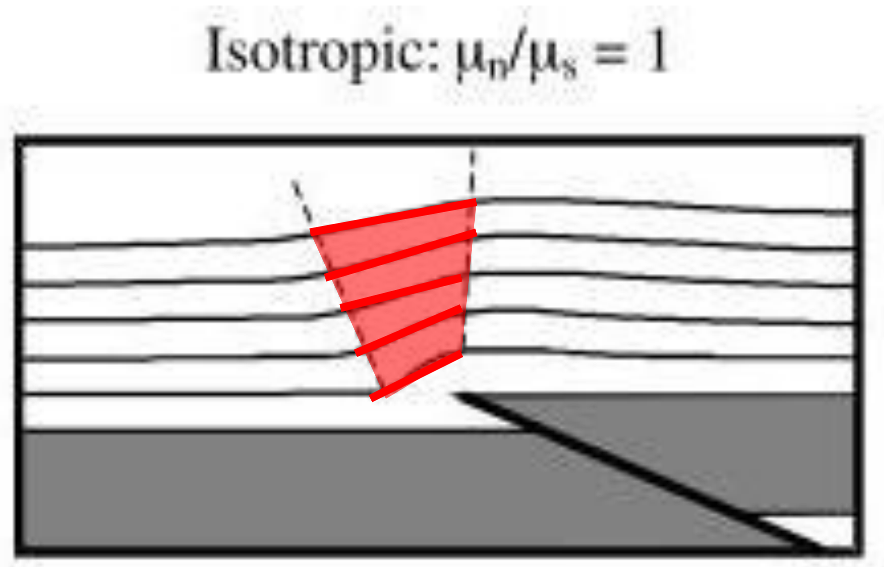
$$\frac{\mu_n}{\mu_s} < 1$$ *Anisotropic (Layer-parallel soft)*

$$\frac{\mu_n}{\mu_s} > 1$$ *Anisotropic (Layer-parallel stiff)*

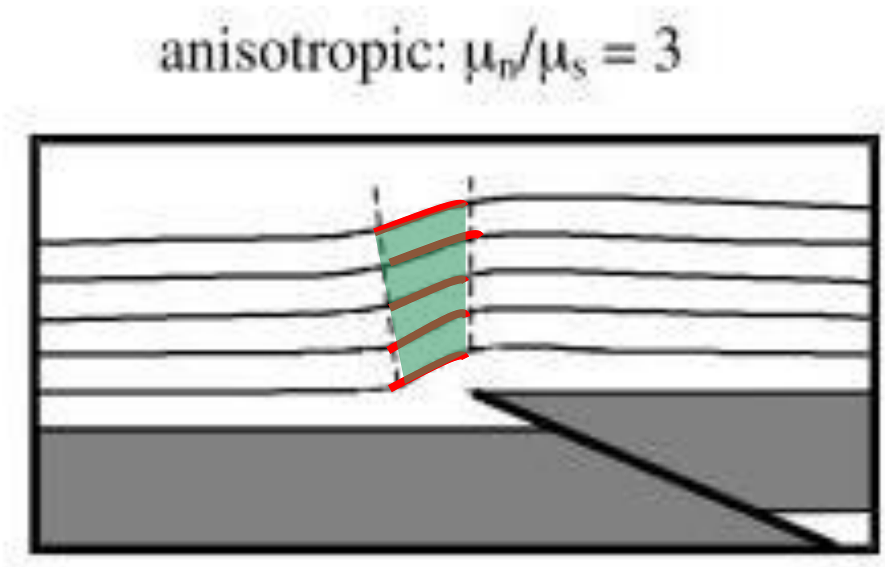


- The model does not include propagation of faults from the basement into the cover.

Influence of anisotropy on fold form



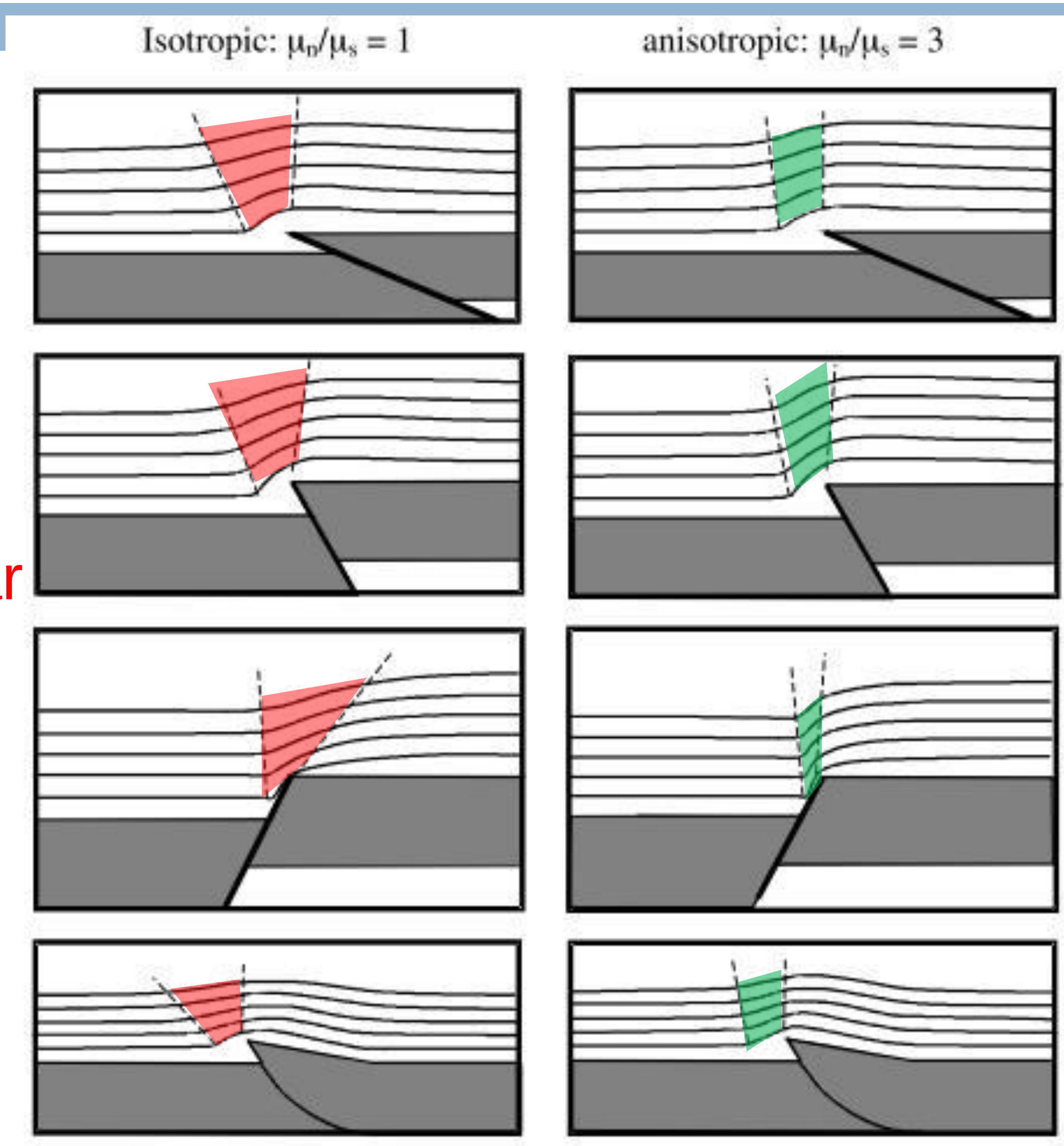
Triangular



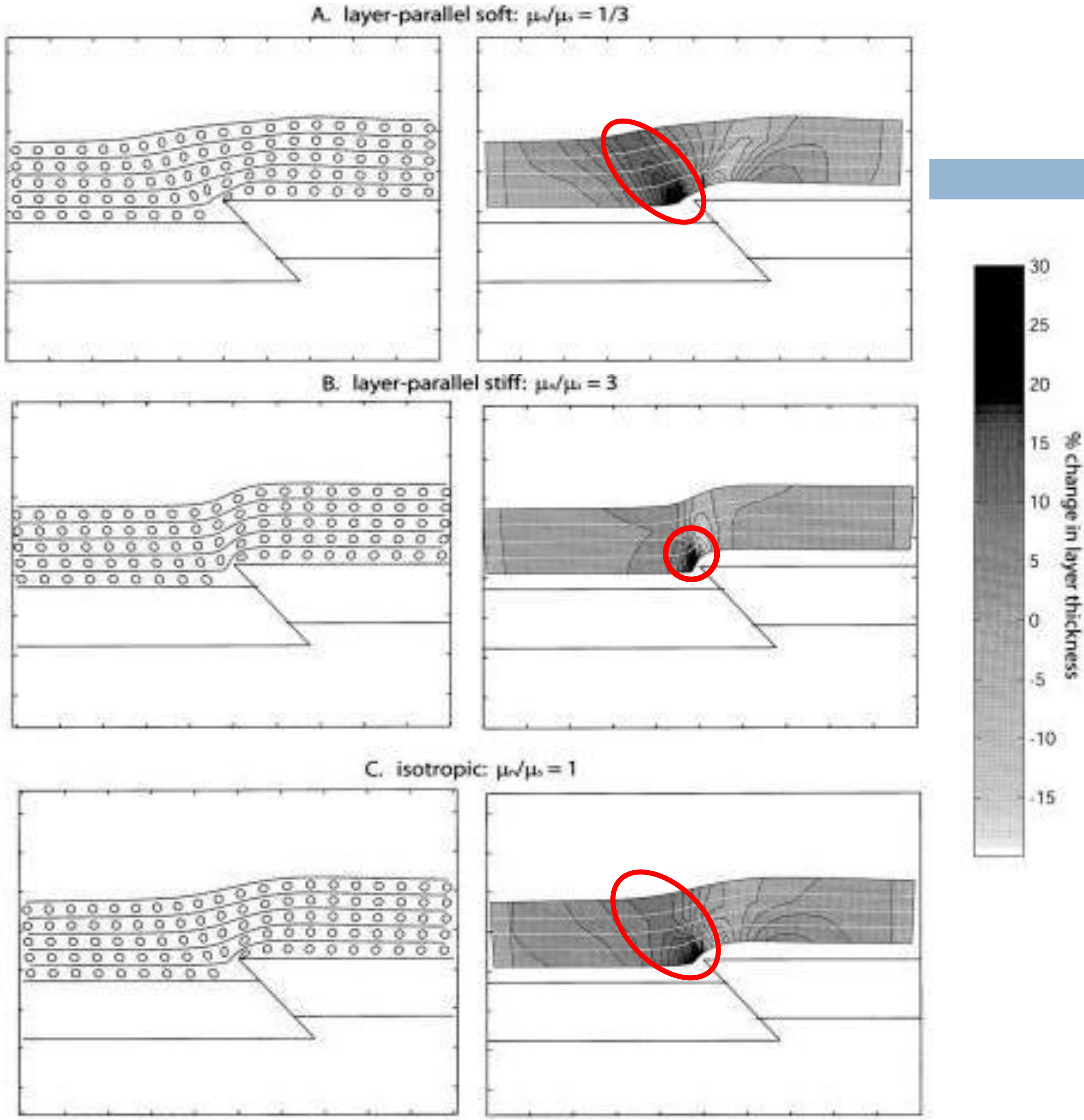
Rectangular

Influence of anisotropy on fold form

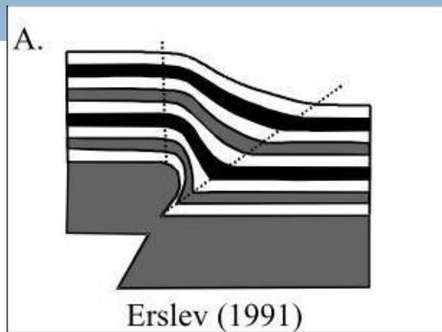
Triangular



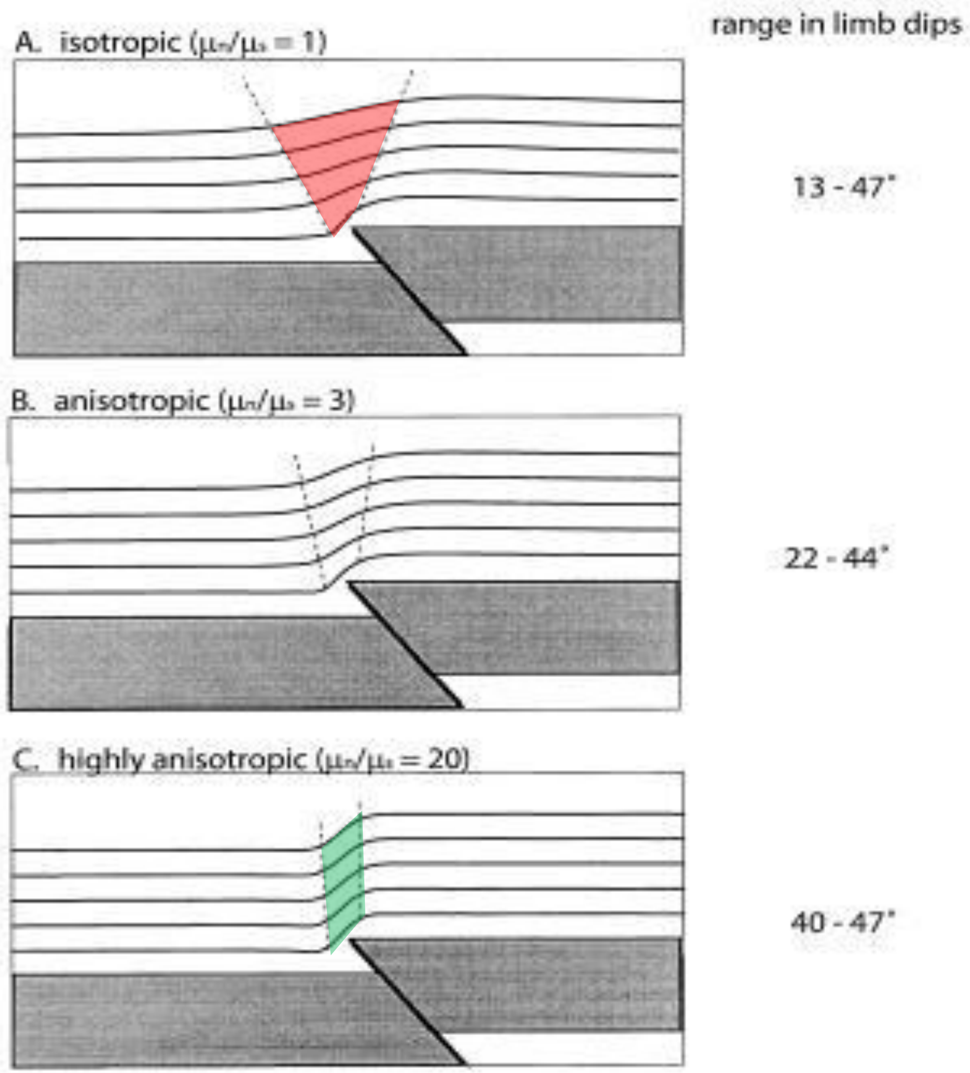
Rectangular


A. layer-parallel soft: $\mu_n/\mu_s = 1/3$
B. layer-parallel stiff: $\mu_n/\mu_s = 3$
C. isotropic: $\mu_n/\mu_s = 1$
30
25
20
15
10
5
0
-5
-10
-15
% change in layer thickness

Comparison with trishear and kink band descriptions



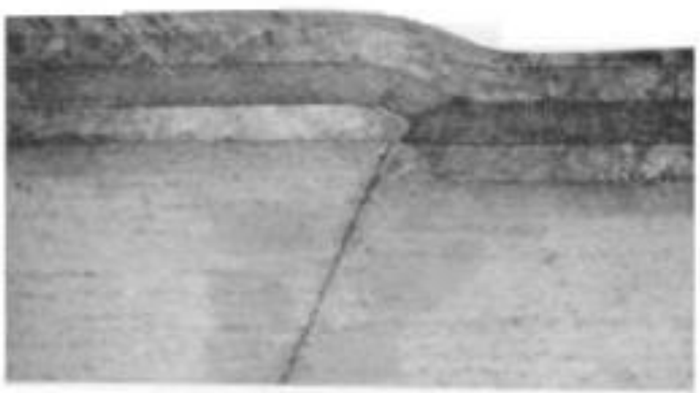
Trishear

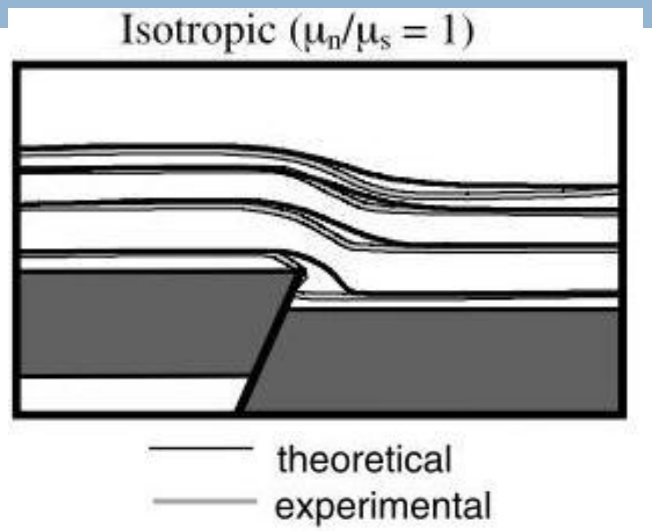


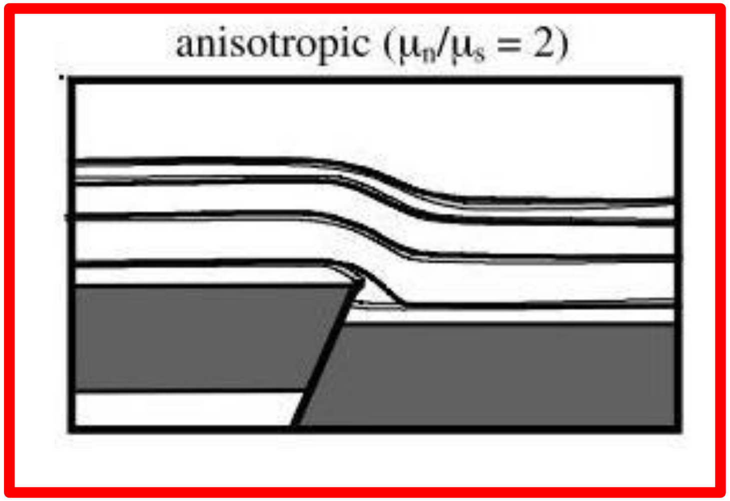
Kink band

Comparison with experiments

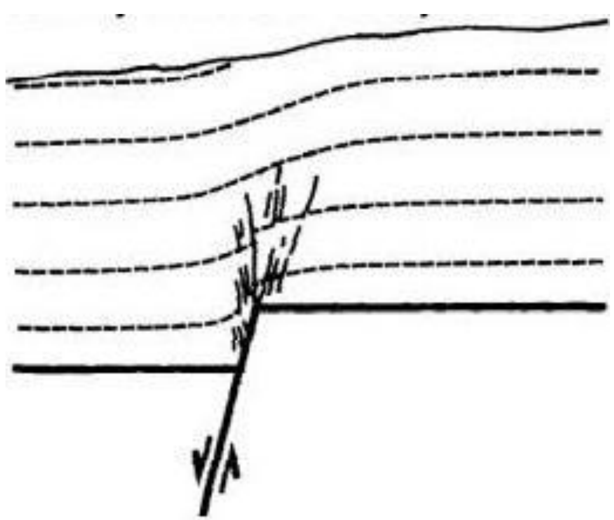
- Friedman et al.(1980) conducted experiments using lubricated layers of limestone and sandstone.

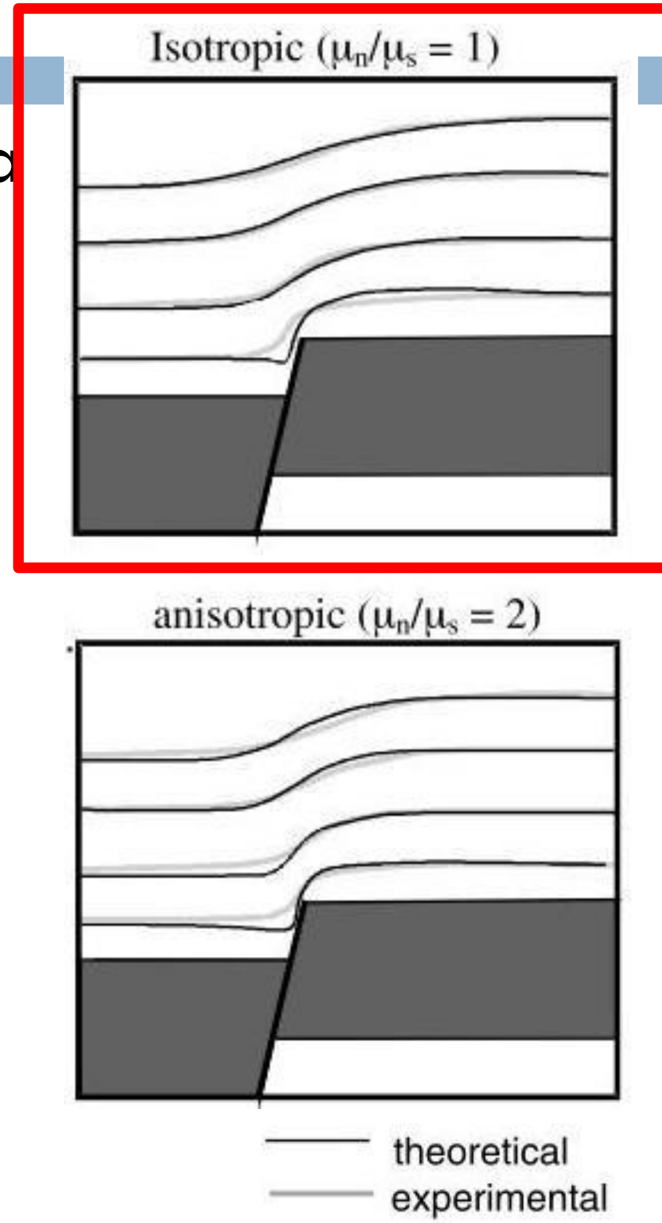




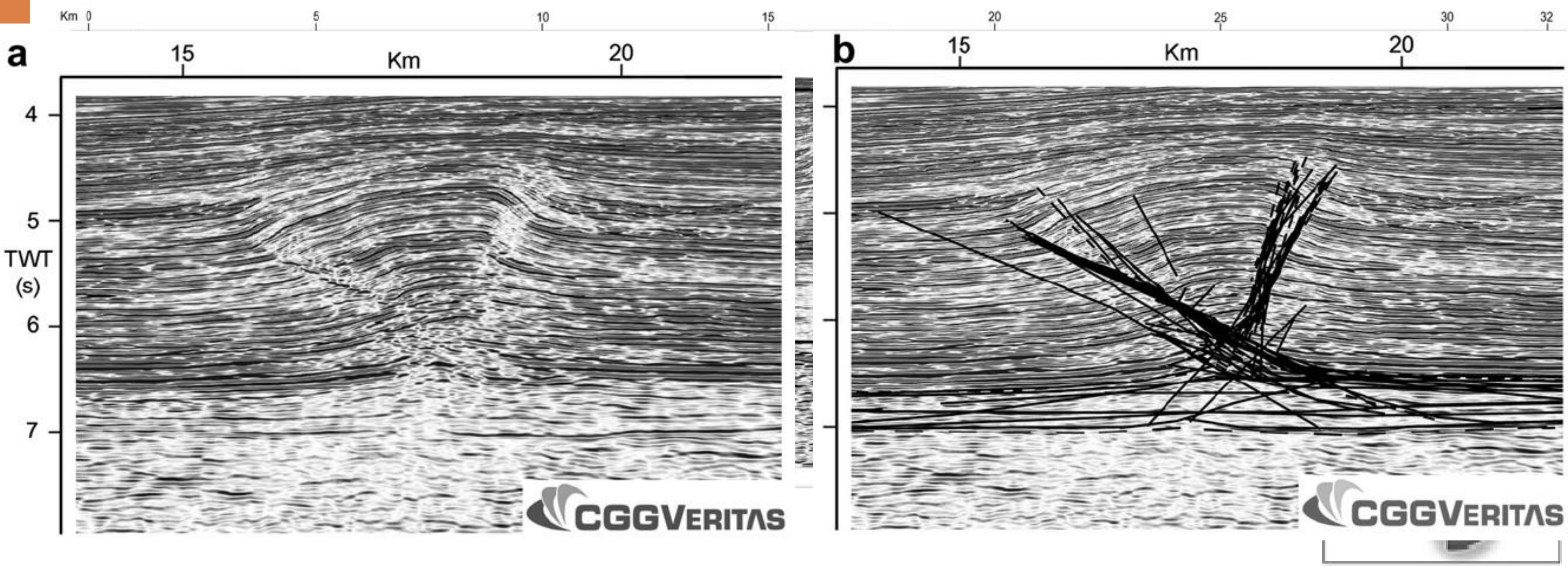


- A fold in clay material overlying a basement normal fault in an experiment by Withjack et al.(1990).

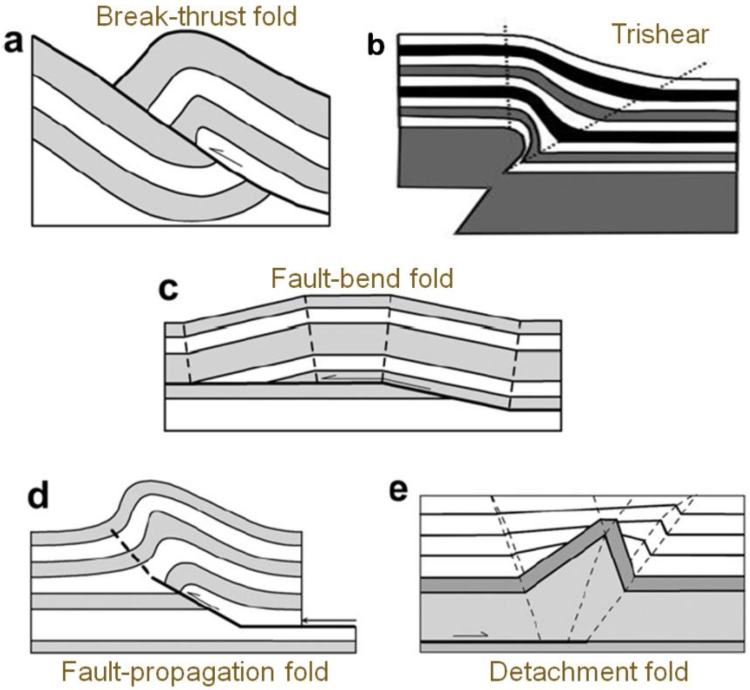


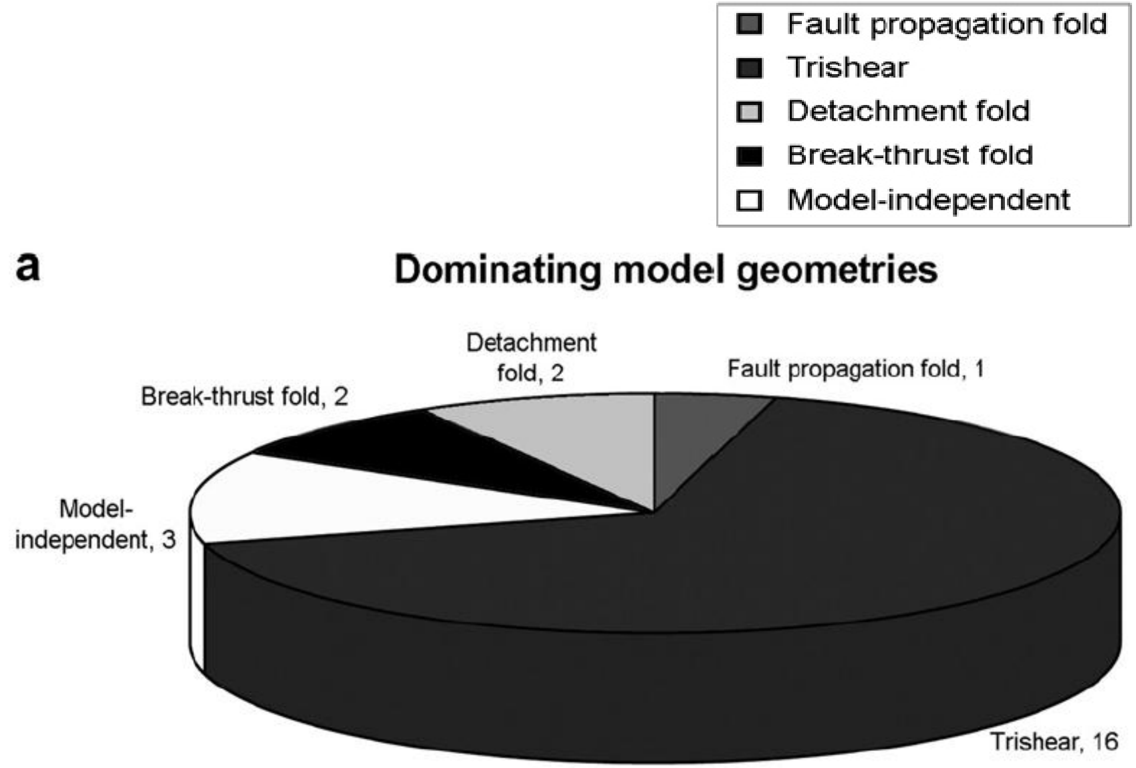


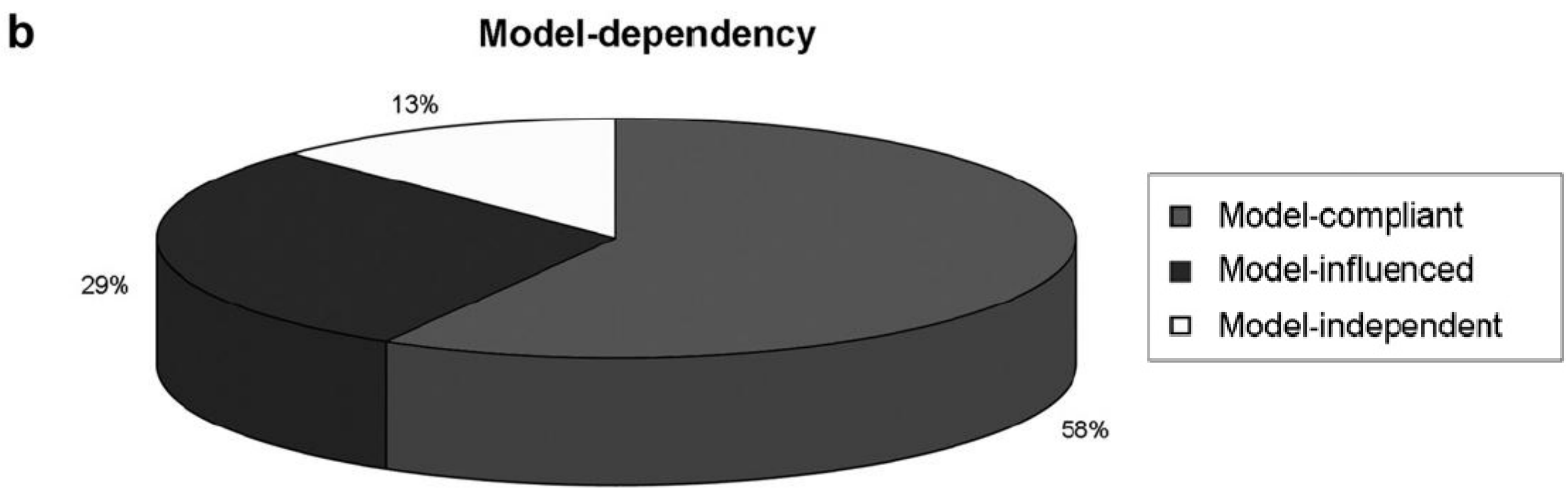
Interpretation of the seismic profile

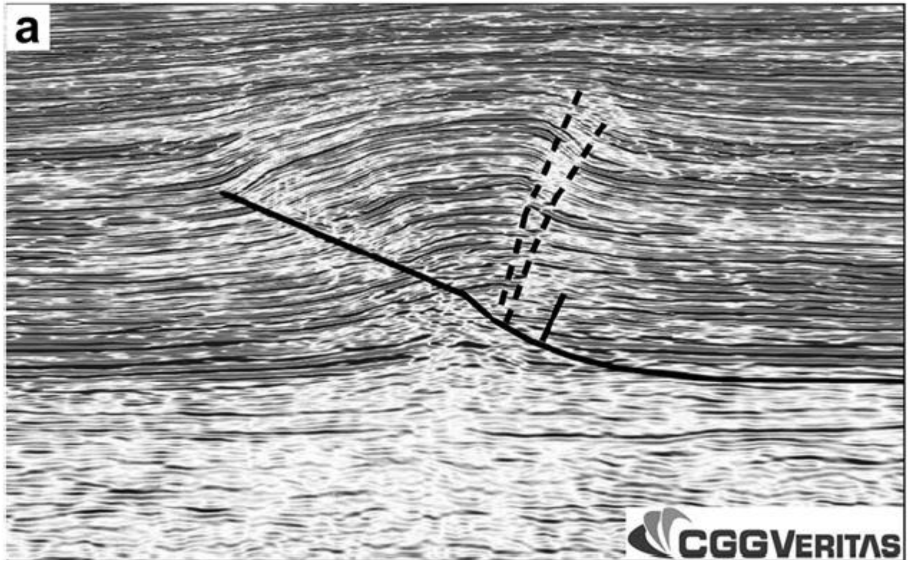


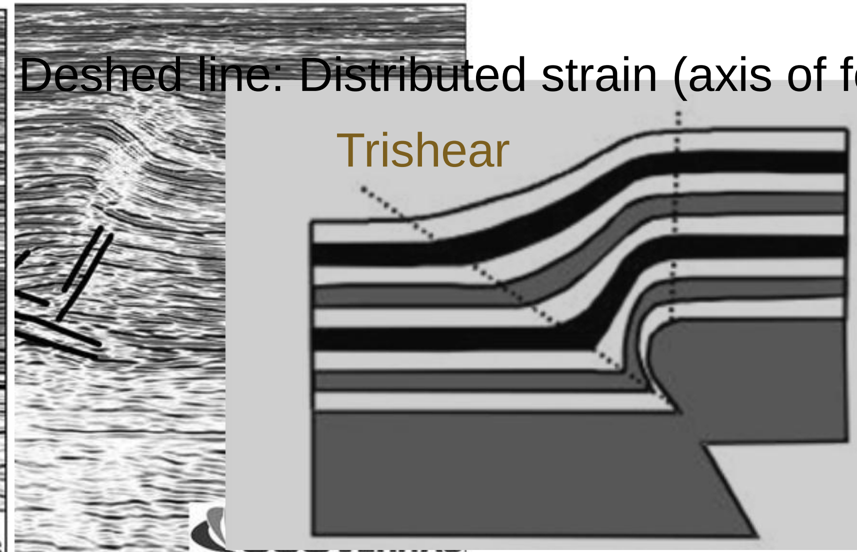
- 24 people indicated that they were specialists or had a good working knowledge in structural geology and/or seismic interpretation, respectively.


a
Break-thrust fold
b
Trishear
c
Fault-bend fold
d
Fault-propagation fold
e
Detachment fold


Fault propagation fold
Trishear
Detachment fold
Break-thrust fold
Model-independent
a
Dominating model geometries
Detachment fold, 2
Fault propagation fold, 1
Break-thrust fold, 2
Model-independent, 3
Trishear, 16

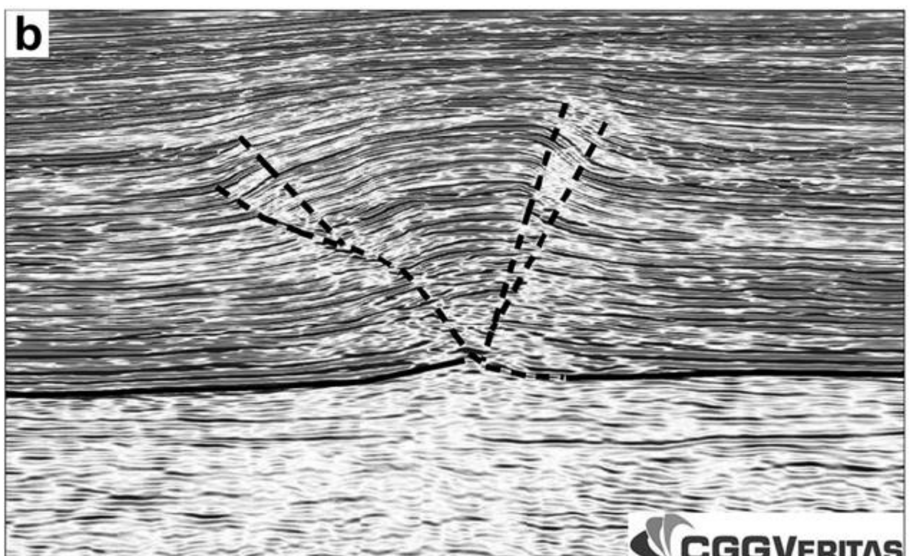

b
Model-dependency
13%
29%
58%
Model-compliant
Model-influenced
Model-independent



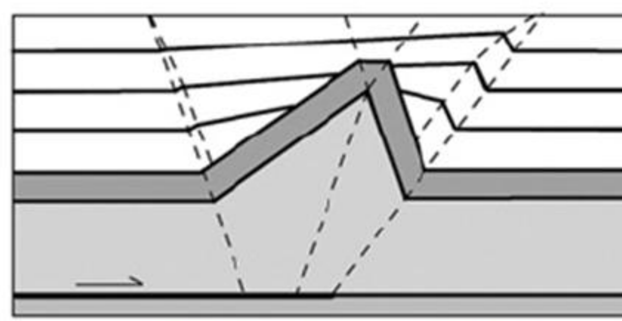


The key features of the five structural end-member models used in the analysis of the interpreted seismic images.

Model	Fault-detachment linkage	Kinematic style	Fold forelimb	Fold backlimb
Break–thrust fold	Soft- to hard-linked	Fold-first, then faulting	Faulted, major folding of FW[c]	Featureless
Trishear	Hard-linked	FP[a] from D[b] with folding	Faulted, tighter HW[d] folds toward *D*	Kink fold/minor faults
Fault–bend fold	Hard-linked	Ramped *D*	Above flat, kink folded	Kink fold
Fault propagation fold	Hard-linked	FP from D with folding	Faulted, no change in HW fold tightness	Featureless
Detachment fold	No faults above *D*	Folding above D	Kink fold	Kink fold

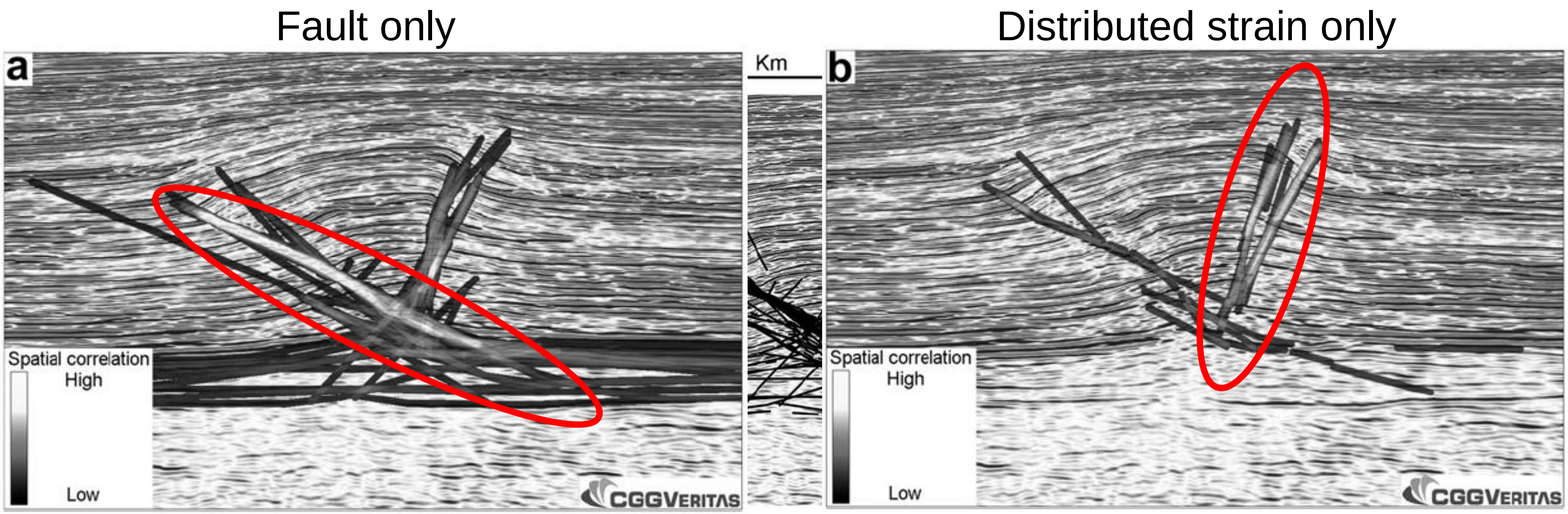


[a] FP = forward-propagating fault.
[b] D = Detachment.
[c] FW = footwall.
[d] HW = hanging wall.



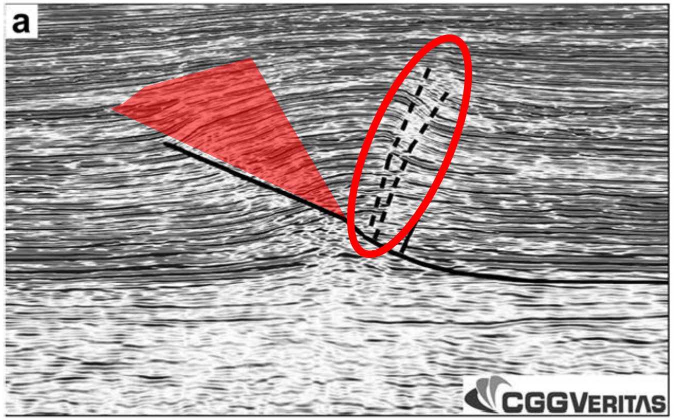
Detachment fold

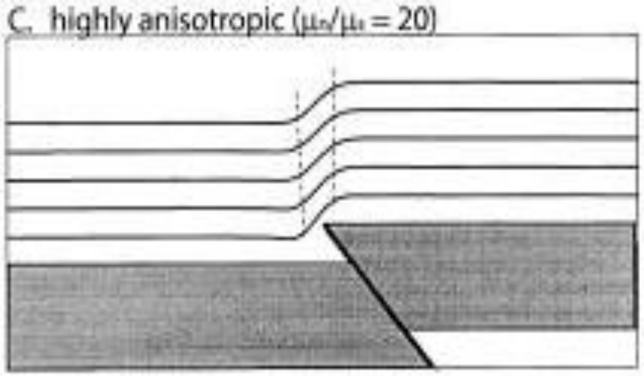
Composite spatial analysis of all interpretations



Discussion

- We realize that the model is similar to the seismic profile, but the model can't be interpreted the "kink band" of the profile.

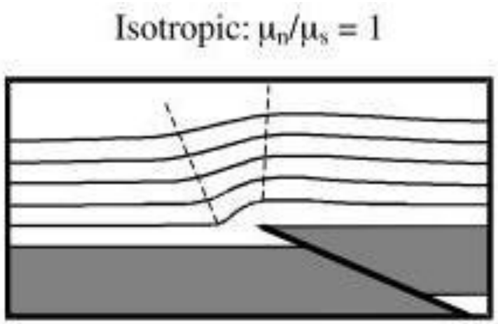


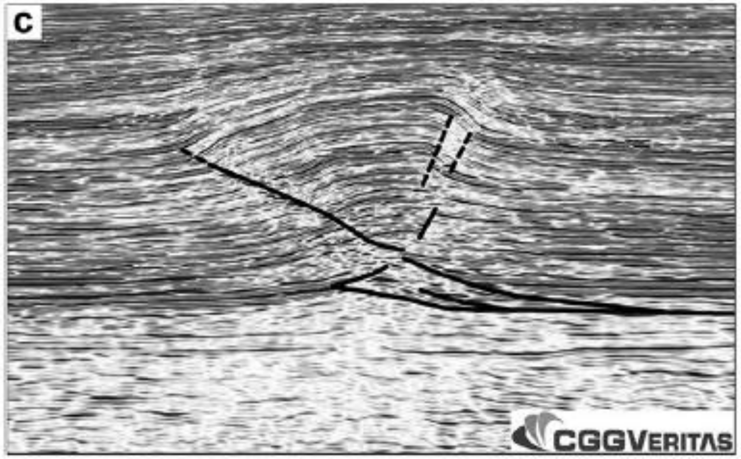


- In the forelimb of folds in anisotropic cover are nearly uniform with depth and resemble the fold forms produced by the kink band construction.

Conclusions

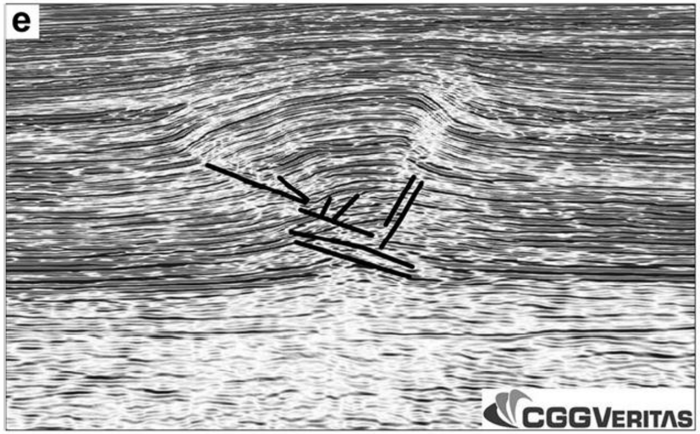
- Our model show that the geometry of the forelimb is largely influenced by the rheology of the cover and the degree of anisotropy in the cover.

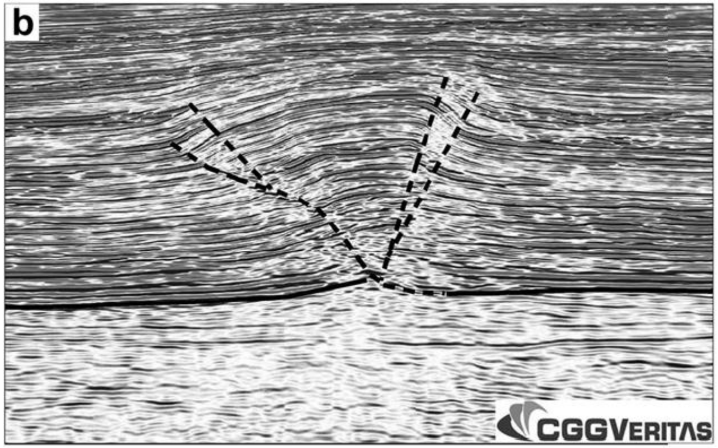




- Most of the theoretical models are characterized by propagation of a single-strand, continuous thrust fault. A significant number of participants interpreted discontinuous fault geometries.

- Discontinuous fault geometries are usually observed at outcrop analogues for deepwater fold-thrust belts, The rheology of deepwater sedimentary systems with unconsolidated sand and shale seems to inhibit brittle faulting, promoting distributed deformation.





- The model does not include propagation of faults from the basement into the cover. Thus the model can't be exactly interpreted the seismic profile.

Thank you for your attention.

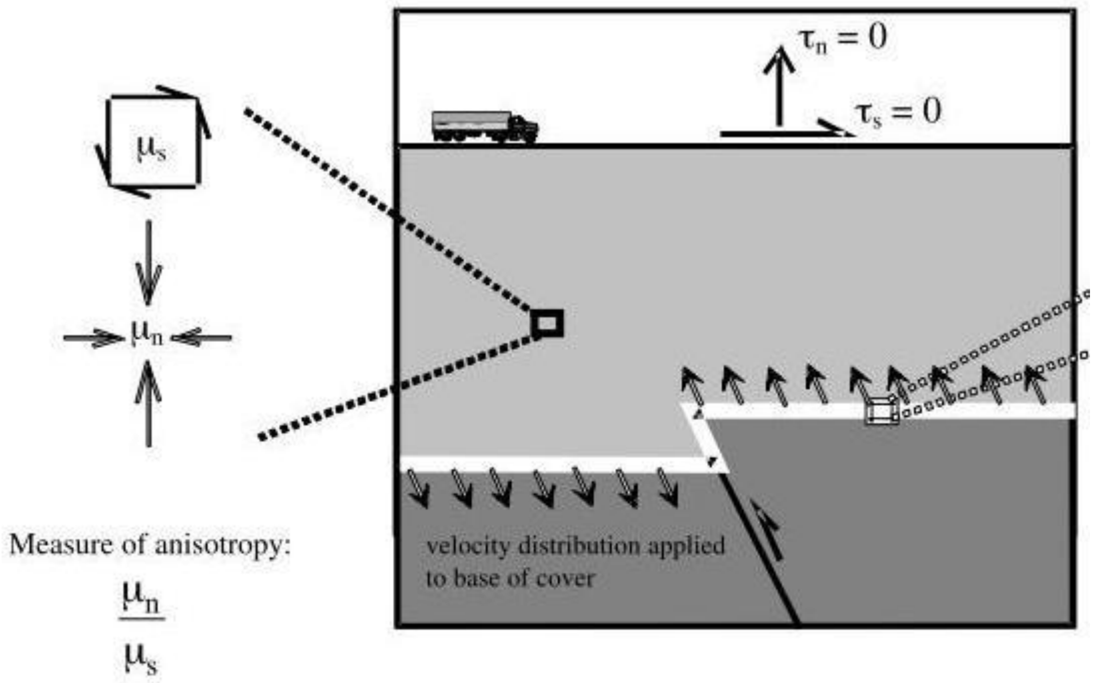
$$\sigma_n = \mu_n \varepsilon_n$$

$$\tau_s = \mu_s \gamma_s$$

$$\tau_s = \sigma_n$$

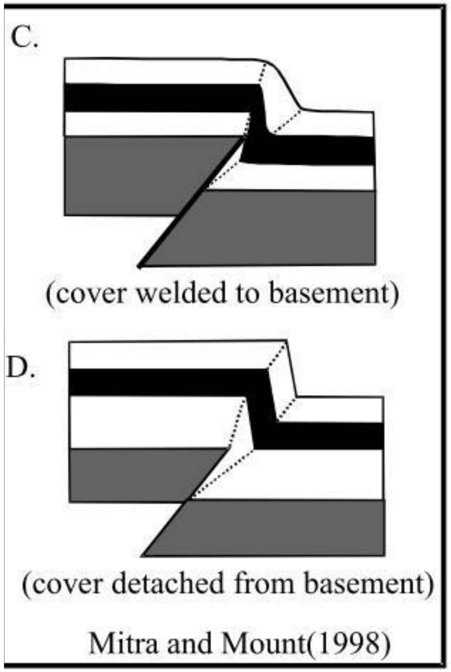
$$\frac{\mu_n}{\mu_s} > 1 \qquad \gamma_s < \varepsilon_n$$

$$\frac{\mu_n}{\mu_s} < 1 \qquad \gamma_s > \varepsilon_n$$



Influence of basement-cover contact on fold form

- Stearns(1978) deduced that whether the cover rock is thinned depends on the basement-cover contact.
- Sedimentary cover that is nearly constant in thickness through the forelimb was detached from the basement, while cover rock that is thinned in the forelimb was welded to the basement.



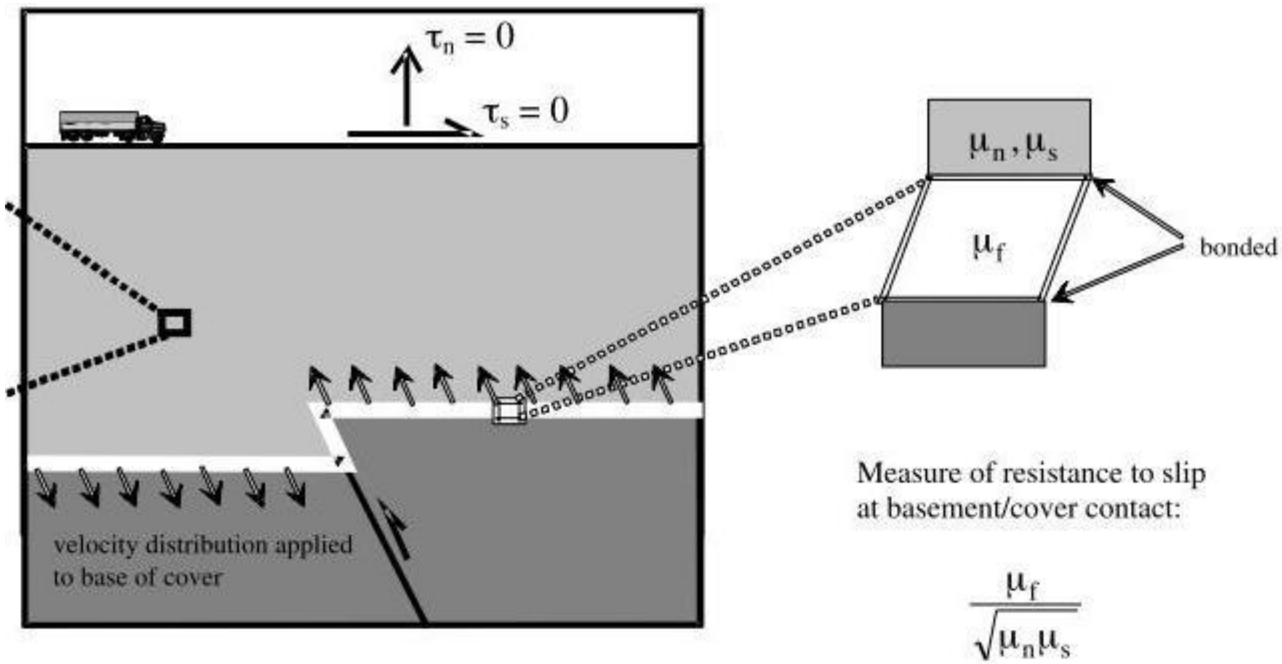
- We have added a thin film at the basement-cover contact into the mechanical model.

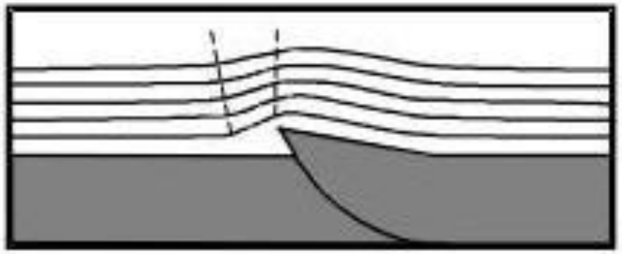
$$\frac{\mu_f}{\sqrt{\mu_n \mu_s}} = 0$$

Free slip

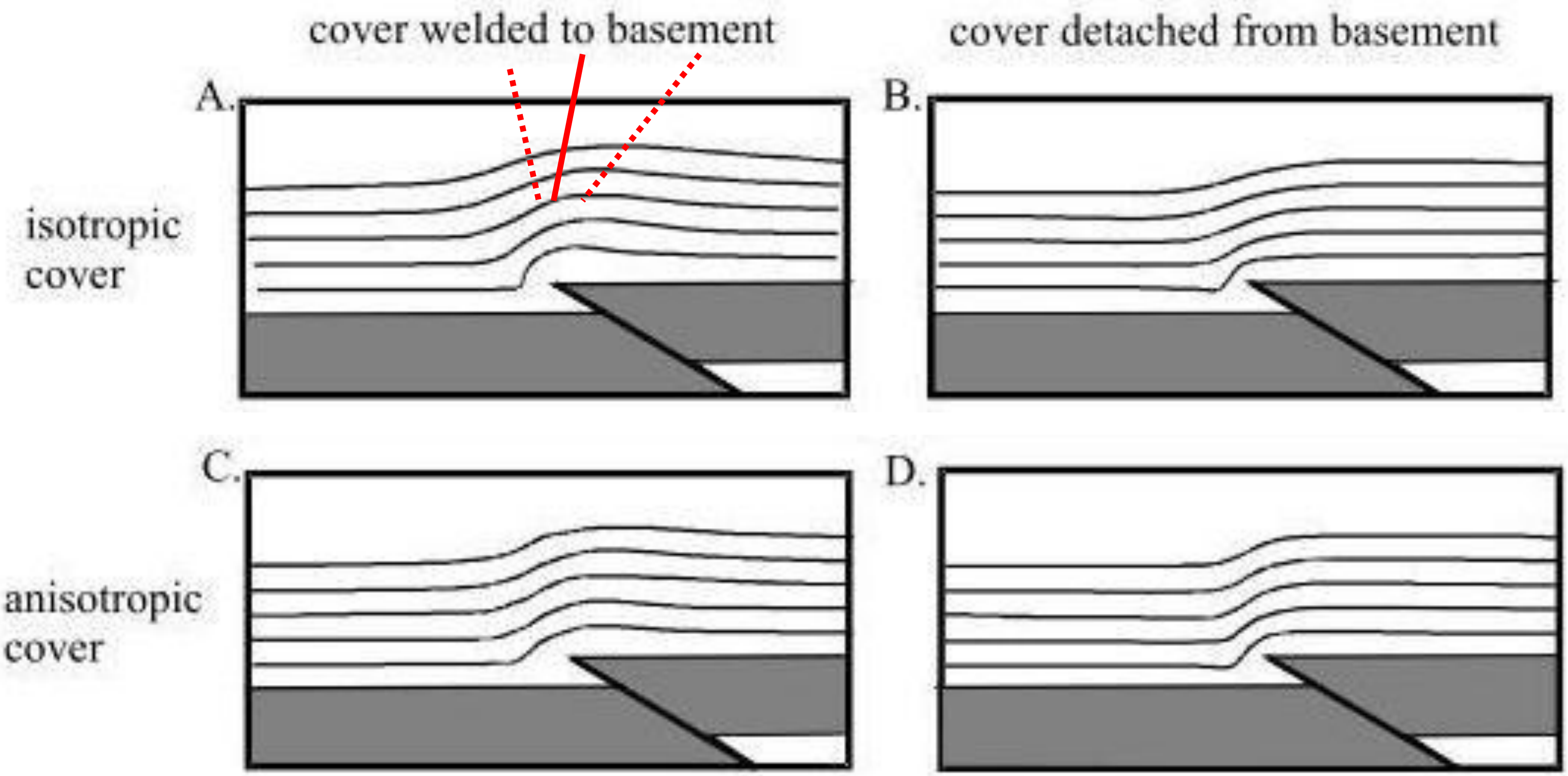
$$\frac{\mu_f}{\sqrt{\mu_n \mu_s}} >> 1$$

To welded





- The largest influence on the anticlinal hinge and backlimb geometry.



- Efforts to explain fault-related folds have followed three largely divergent paths: theoretical analysis, experimentation, and kinematic analysis.