

# Lab 7: Fold and Thrust Belts

Fall 2005

## 1 Anatomy of thin skinned fold and thrust belts

It is quite possible that the literature dealing with thin skinned fold and thrust belts is the most jargon laden in all of geology – which is saying a huge deal. For the following terms, provide a clear, concise definition and illustrate with a cross-section, map or block diagram.

1. Backthrust.
2. Foreland and hinterland.
3. Thrust nappe.
4. Duplex.
5. Out-of-sequence thrust.
6. Blind thrust.

## 2 Thrust related folds

### 2.1

Construct a cross-section from the data provided in the geological map of figure 2.2. Be sure to extrapolate the geological units above the present erosion surface.

Other data: The Cretaceous rocks are 800 ft. thick. At the location of the letters A and B are two wells. Well A logged a thrust plane at 1500 ft. depth. The logs for well B are as follows:

Depth to the top of unit	Unit encountered
300	Jurassic rocks below an interval of gouge
900	Triassic rocks
1680	Permian rocks
2550	Proterozoic crystalline rocks

Determine (1) the type of folding; (2) the amount of shortening.

### 2.2

Construct a cross-section from the map and incomplete section provided in figure ???. Again, extrapolate units above the erosion surface. The well trace shows the position of lithologic contacts, but not their attitude. The thick line indicates a major fault surface.

Determine (1) the type of folding; (2) the amount of shortening.

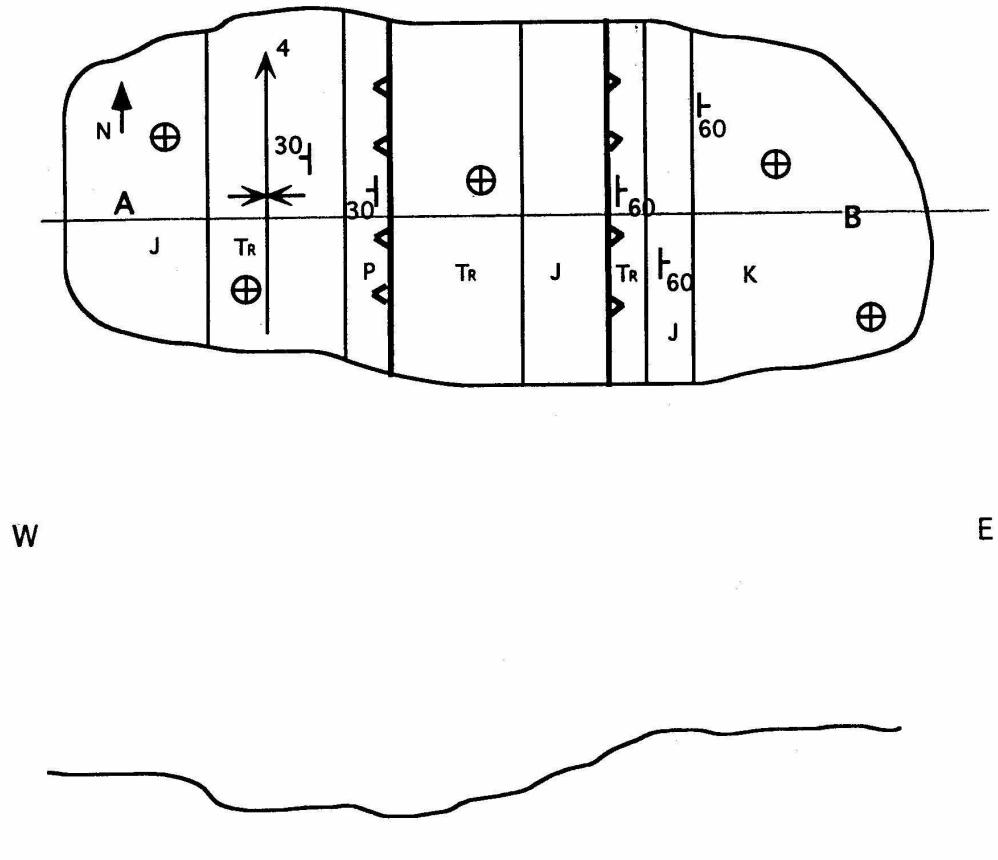


Figure 1:

### 3 Sandboxes and critical taper theory

Describe the sandbox experiment, with particular emphasis on the development of stable geometries, the locus of deformation, the response of the wedge to simulated erosion and sedimentation.

What sets the angle of a critically tapered wedge?

Suppose that the foreland belt of some mountain belt were a critically tapered wedge whose tip was at sea level, with a wedge angle of  $5^\circ$  and peak elevations of 3 kilometers above sea level. As material is incorporated into the wedge, it will grow self-similarly, increasing the width of the deformed belt and the elevations of the peaks to maintain the critical angle. Suppose that enough material is incorporated into the wedge to increase its width to 180 kilometers. Can you determine a reasonable value for the peak elevations in this case? What other geodynamics processes need to be taken into account?

What is the geological equivalent to the “backstop” in the sandbox experiment?

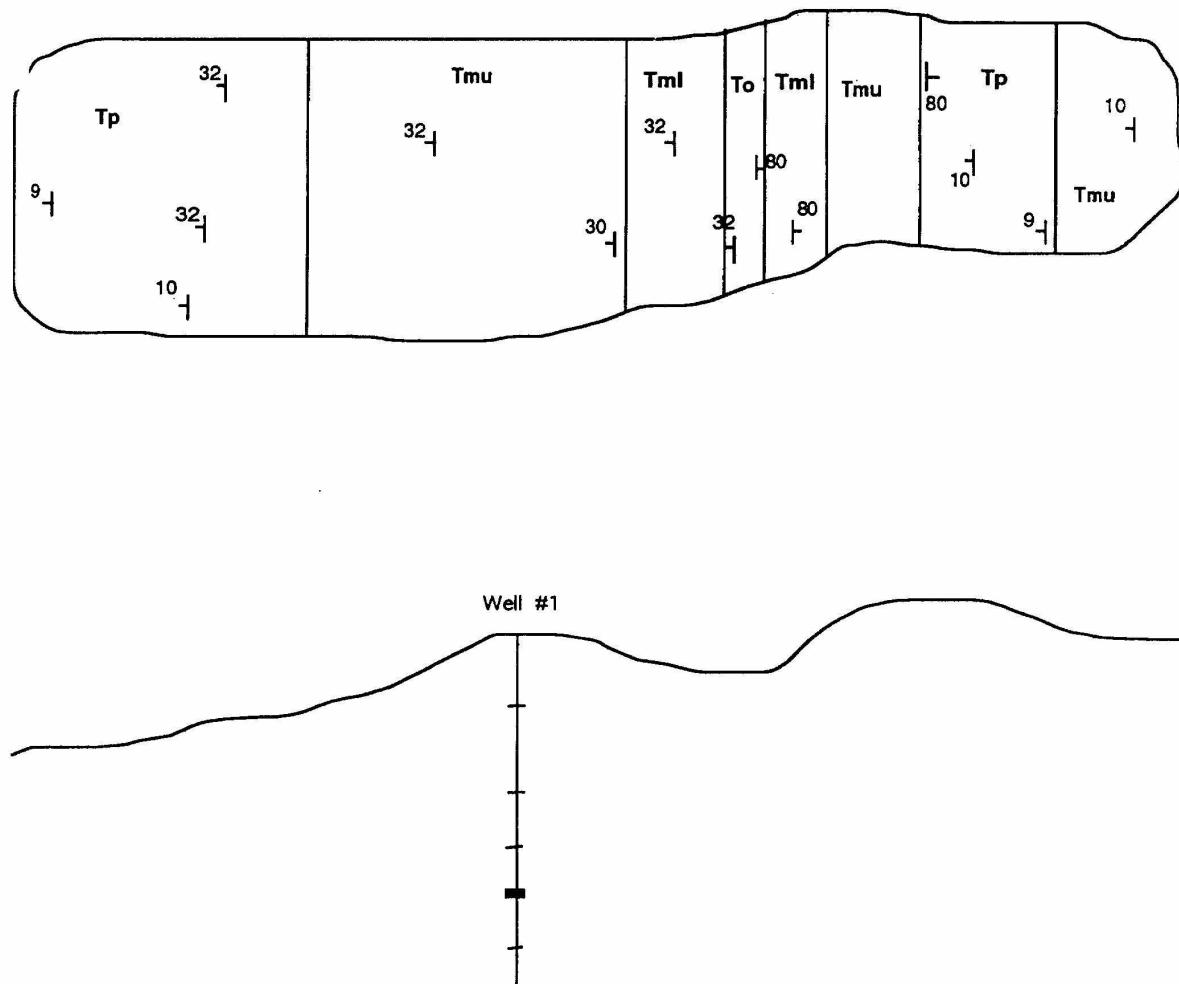


Figure 2:

#### 4 The Mechanical Paradox of large overthrusts

Thin skinned fold and thrust belts are generally characterized by the shingle-like stacking of sheets of rock whereby rocks are commonly translated large horizontal distances and older, deeper parts of the stratigraphy are placed on younger, shallower units. Some basic, common observations include:

1. Faults can be very low angle, commonly  $< 10^\circ$ .
2. Overthrust sheets of rock are relatively thin, 5 – 10 km.
3. The map trace of these faults can be very long, with individual faults traceable over hundreds of kilometers.
4. The hangingwall blocks have been displaced large distances, 10s to even 100s of kilometers.

This problem was classically treated in a series of papers by M. King Hubbert (the same dude who analyzed oil production curves, the origin of the term "Hubbert's Peak") and W. Rubey. What's the problem? Basically, the process of emplacing these kinds of thrust sheets has been compared to trying to push a wet napkin along a table. There's just no way that the napkin will move as a rigid unit without breaking or suffering considerable internal deformation. In this lab, we will do a simple "first pass" at the problem. To keep things simple, we will consider a horizontal thrust fault.

1. Draw the relevant diagram. A block of thickness  $h$  is pushed from behind by a tectonic force per unit width of the sheet  $F_T$ . Write an expression for the horizontal stress  $\sigma_{xx}$  in terms of  $h$  and  $F_T$ .
2. The tectonic driving force is resisted by a shear stress  $\sigma_{yx}$  acting on the base of the thrust sheet. Write an expression for the total resisting shear force per unit width  $F_R$  in terms of  $\sigma_{yx}$  and  $L$ , the length of the thrust sheet.
3. Typically, the base of the thrust sheet is characterized as a frictional rheology. The resisting stress is proportional to the normal force pressing down on the surface. That is,  $\sigma_{yx} = \mu\sigma_{yy}$ , where  $\mu$  is a coefficient of friction (this can be cast in terms of the angle of internal friction:  $\mu = \tan\phi$ ). Assuming that  $\sigma_{yy}$  has the lithostatic value, and equating the driving force to the resisting force you should be able to write an equation for  $\sigma_{xx}$  in terms of the coefficient of friction, the density of the rocks in the thrust sheet, the acceleration due to gravity and the length of the block.
4. A typical value for the tectonic stress might be 100 MPa. What value of  $\mu$  would you require to move a thrust sheet ( $L = 100\text{km}$ ,  $h = 10\text{km}$ )? What angle of internal friction does this correspond to? How does this compare to normal ranges of values (you might have to dig around for this)?
5. Suppose that you assumed that a reasonable value for  $\mu$  was 0.6. What sorts of tectonic stresses are required to move the block? How does this compare to the kinds of stresses needed to initiate new fractures?

This is the mechanical paradox of large overthrusts. How did Hubbert and Rubey try and solve the paradox? In lecture, Clark noted several observations in and around the Keystone thrust that suggested that this could not be the whole story. What sorts of observations are these?

Read Price, R. (1988) The mechanical paradox of large overthrusts, *Geological Society of America Bulletin*, v. 100, p. 1898–1908. and the comment and reply following the paper. What are the problems that Price sees with Hubbert and Rubey's solution? What is his hypothesis? Following the paper, Washington and Price get their knickers tied up in knots talking about wedges. Price claims that "Washington's model adds nothing to this picture but confusion". Briefly summarize and critically evaluate their exchange.