Notes X
Strike-slip faults

Fall 2005

1 Reading

Chapter 7 in TM is a short chapter on strike slip faults. Its particularly good at dealing with the problems of kinematic compatibility: this is the notion that informs a lot of analysis of how fault systems "work together". In particular, look at the discussion of how strike slip faults terminate; the role of tear and transfer faults; why mountain ranges and sedimentary basins are found at bends in strike slip faults; the description of the active tectonics of Southern California. Look at the maps, draw simplified cartoons that show how all the faults "work together".

2 Required jargon

You should be familiar and know the significance of the following terms. Drawing little cartoons of these is a very good strategy for keeping track of all the jargon and being able to really learn the geometry so that you can recognize the structure out in nature.

Piercing point – *en echelon* folds – flower structure – transfer fault – tear fault – transform fault – pull-apart basin – restraining bend – releasing bend – transpression – transtension.

3 Notes

3.1 Characteristics of strike-slip faults

Strike-slip faults are faults with very little vertical component of motion, i.e.: the slip vector is nearly parallel with the strike line. Strike-slip faults are typically steep or vertical and in Andersonian fault theory are associated with a stress regime where both maximum and minimum stresses are near horizontal.

3.2 Relationships between strike-slip faults and compressive or extensional structures

Often a major strike slip fault (think the San Andreas or the North Anatolian fault in Turkey) is associated with many secondary extensional or compressive structures.

Some of these are related to distributed strain around the fault zone – particularly before the fault has localized. If a wide zone is accommodating strain, we can predict the orientation and rotation of extensional structures (tension fractures, normal faults) and compressive structures (thrust faults, folds) according to our understanding of the progressive evolution of the finite strain ellipse in plane strain, simple shear. These secondary structures often form *en-echelon* arrays of folds or fractures.

Other secondary structures follow from kinematic compatibility: if a straight strike slip fault takes a bend or a jog, then either a basin (pull-apart basin at a releasing bend) or a thrust bound range (at a constraining bend) needs to begin growing to solve the space problem that results from trying to move material parallel to the strike of the range.

Many cross-sections of releasing or restraining bends shows that the normal or thrust faults associated with the restraining or releasing bend merge into the strike slip fault at depth. These are called flower structures.

Finally, in areas that are dominated by extensional or compressional structures, strike slip faults are commonly found in order to transfer deformation from one fault to another. This is especially true at the terminations of faults.

Transform faults in the oceans occur because spreading ridges are offset from one another (they do not offset the ridge, they are required by the offset of the ridge). In continental extensional terrains, the kinematically equivalent structure is known as a transfer fault. In compressive environments, abrupt changes in the amount of displacement along a thrust fault can be accommodated by tear faults.

3.3 What happens to strike-slip faults at depth?

Many strike slip faults are idealized as being vertical cuts going, presumably, all the way to the core-mantle boundary. In truth, the geometry of apparently vertical strike slip faults is quite variable with depth.

One example has been alluded to above: flower structures are associations of thrust or normal faults that merge into a master strike slip fault at depth. They are often associated with restraining or releasing bend.

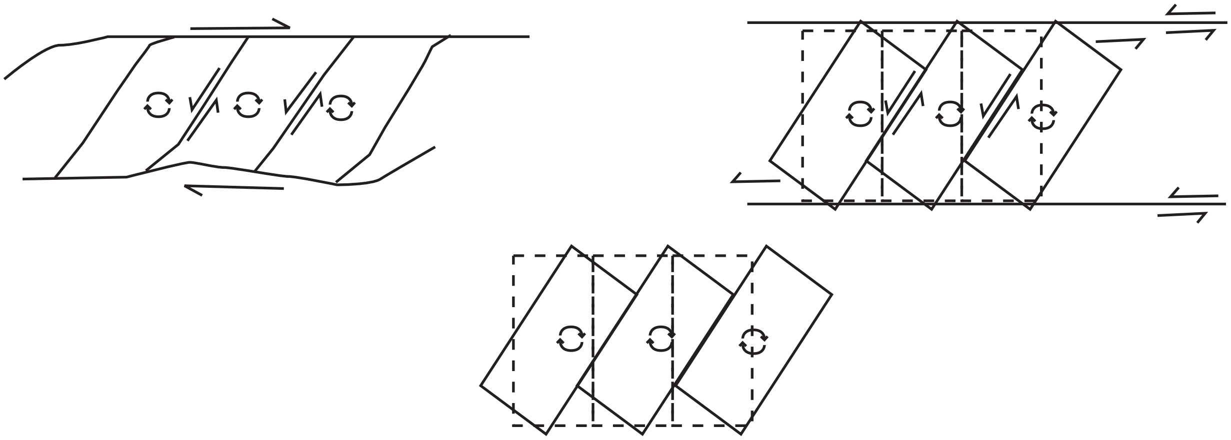
A strike slip fault that bounds a fold and thrust belt (thus accommodating the differential motion of the thrust belt from an undeformed region) need not penetrate deeper than the decollement of the thrust belt. (See figures 7.10a and 7.14 for examples).

For other strike slip faults, the change in geometry with depth is not abundantly clear. For one thing, at greater depths, the mechanisms of deformation will be ones that accommodate ductile flow (why?), and so we can expect some changes in fault geometry. Perhaps a narrow brittle fault zone at the surface is linked to a wide zone of mylonitic rocks at depth. But if the middle and lower crust is very weak, it is conceivable that the fault dies out into the lower, fluid like layer. Along these lines, there are two end-members of description of strike slip faults in the continental crust. The first is a "plate boundary" model, where the strike slip fault is a lithosphere-penetrating structure (but dies out in the ductile, flowing asthenosphere). Alternatively, some faults do not penetrate past the upper or middle crust, and the upper crust becomes essentially decoupled from the flowing lower crust.

Transpressive plate boundaries Transpression refers to a combination of strike slip ("**trans**lational") and com**press**ional motion. A transpressive plate boundary is one where the relative plate convergence vector is neither parallel nor perpendicular to the plate margin. Transpressive plate boundaries are rather common, and include the Sumatra plate boundary. In these zones, the relative plate motion is commonly partitioned into separate structures – this is exactly analogous to breaking a vector into separate components. In Sumatra, much of the strike-slip (plate boundary parallel) component of the relative plate motion vector is taken up by a prominent strike slip fault located near the volcanic arc (the localization of the strike slip fault where the crust is weakest is no accident). The question that arises, then, is what happens to the faults (i.e. the subduction zone megathrust and the strike slip fault along the arc) at depth. Does the strike slip fault cut the megathrust or vice-versa?

3.4 Systems of strike-slip faults

In many areas, many strike slip faults together form a complex pattern that is not immediately obvious how to interpret. In these places, strike slip faults define the boundaries of crustal fragments or blocks whose deformation can be characterized by vertical axis rotation. The overall effect of a system consisting of a mosaic of rotating crustal fragments may be to accommodate a broad zone of diffuse shear. Alternatively, block rotation may be a response to being caught between two independent strike-slip faults. Two examples are shown below. The first – where a broad zone of diffuse shear is accommodated – can be thought of as toppling dominoes or books on a shelf and parts of the complex deformation of southern California (particularly the Mojave block) can be understood in this way. In this example, the strike slip faults are **antithetic** to the overall sense of shear of the zone.



Alternatively, rotating blocks may owe their rotation to their being caught between two independent strike slip faults. In this case (right side of the figure), faults bounding the rotating blocks will be **synthetic** with respect to the bounding faults. Distinguishing between these two models of block rotation has certain implications for what drives block rotation.

4 Review questions

1. Draw the associated *en-echelon* folds and tension fractures you would expect to be associated with a left-lateral (sinistral) strike slip fault.

2. Using Google Maps, satellite view, find Death Valley. Death Valley is the type-example (meaning it is the example that motivated the definition) of a pull-apart basin. What is the sense of shear on the Death Valley fault?

3. To the south of Death Valley is the E-W striking Garlock fault. The Garlock fault is the type example of a transfer fault: in this case it accommodates differential extension of the crust to its north and south. What is the sense of shear on the Garlock fault? Follow the fault until its junction with the San Andreas. What is the sense of shear on the San Andreas? How do those two faults interact (i.e. does one cut the other, do they mutually deform one another)?

4. Follow the San Andreas down to Los Angeles. Find the Big Bend of the San Andreas (going south, it takes a big jog to the east to join up with the Salton Sea and the Gulf of California). Is the Big Bend a releasing bend or a restraining bend?

5. Explain the concept of kinematic compatibility.