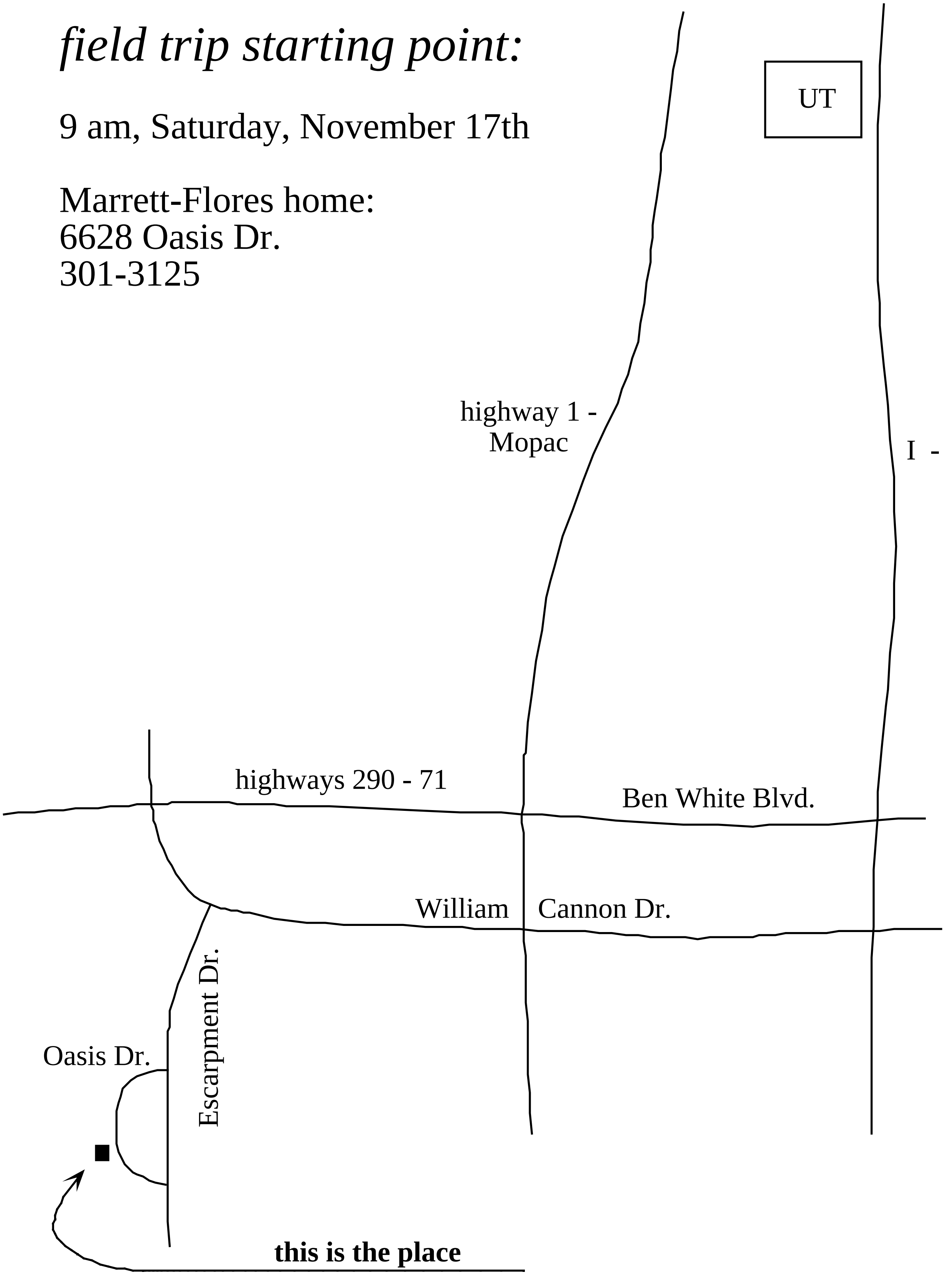
field trip starting point:

9 am, Saturday, November 17th

Marrett-Flores home:
6628 Oasis Dr.
301-3125



Geo380C problem set 7

FAULT KINEMATICS

A series of road cuts along Hwy 281 near Bulverde expose the Cretaceous Glen Rose Limestone. The road cuts provide both cross-sectional and fault-plane exposures (Collins, 1993). Numerous faults of the Balcones fault zone are exposed here. Most of the faults have displacements under 20 cm, however two faults have displacements estimated to be between 6 and 35 m. The larger faults are arranged en echelon but are not directly connected at the surface, and both dip to the southeast. Consequently the strata between the faults are gently folded into a relay ramp, where fractures are more intensely developed than in adjacent areas. Particularly intense fracturing developed in halos around the large faults. These are examples of fracture intensity variation according to structural position.

A good example of concentrated deformation between two faults can be seen near the northern end of the road cuts. The two faults are about 30 m apart along the road cut, but separated by only about 10 m across the strike of the faults. The block bounded by the faults has been significantly tilted relative to strata on either side, and has been intensely fractured. The distinct color of the fault-bounded block suggests that it was a focus of groundwater flow, presumably due to the concentration of fractures there. Some of the fractures are calcite-filled extension fractures, while others probably are small faults.

Several characteristics of fault surfaces are well displayed in these outcrops. In a couple of places, large areas of fault surface are exposed. We can see that fault surfaces are irregular, not only at small scales but also at metric scales. In fact faults are irregular at all scales, and the degree of irregularity varies consistently with observation scale (another fractal aspect of fractures). Geometric irregularity is present both in the dip and strike directions along faults. The fault surfaces also show slickolites, fibrous calcite mineralization, and locally travertine fill indicating that some portions of the faults were still open after the rocks were exhumed above the water table. Another feature present on some fault surfaces are slickolites, hybrids between faults and stylolites. Slickolites form where opposing sides of a fault impinge on one another without breaking, and both sides are partly dissolved as along a stylolite.

1. Collect and tabulate the following data for *at least* ten faults: fault plane orientation, slip lineation orientation, sense of slip, amount of displacement, and bedding orientation at the fault. You probably will need to measure the orientation of bedding at additional locations in order to best constrain the fold axis. Measurable faults in the roadcut range in displacement from under a centimeter to over a meter. To the extent possible, you should measure multiple

Collins, 1993

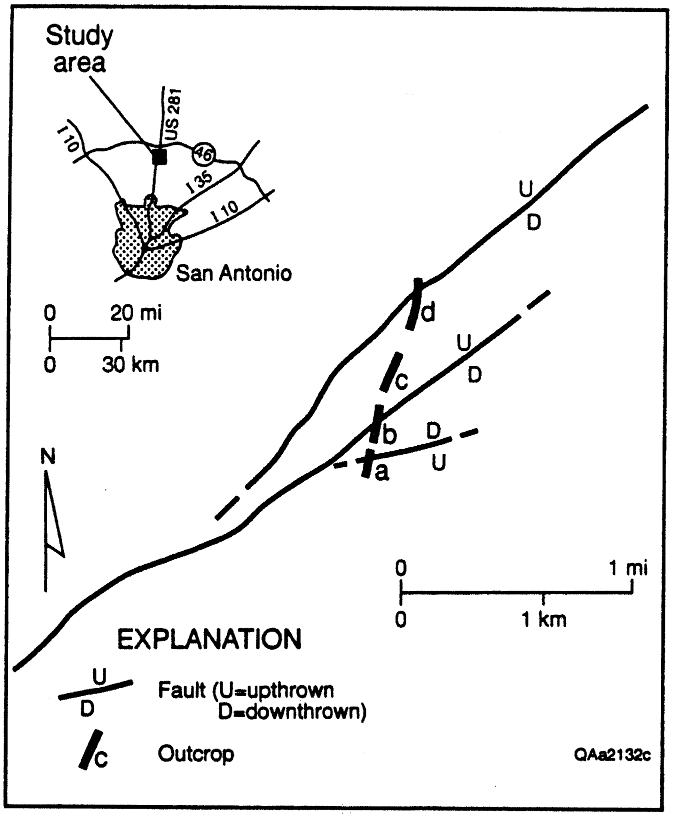


Figure 3. Location of outcrops within overlapping en echelon faults in western Comal County. Outcrops a–d correspond to cross sections a–d in Figure 4.

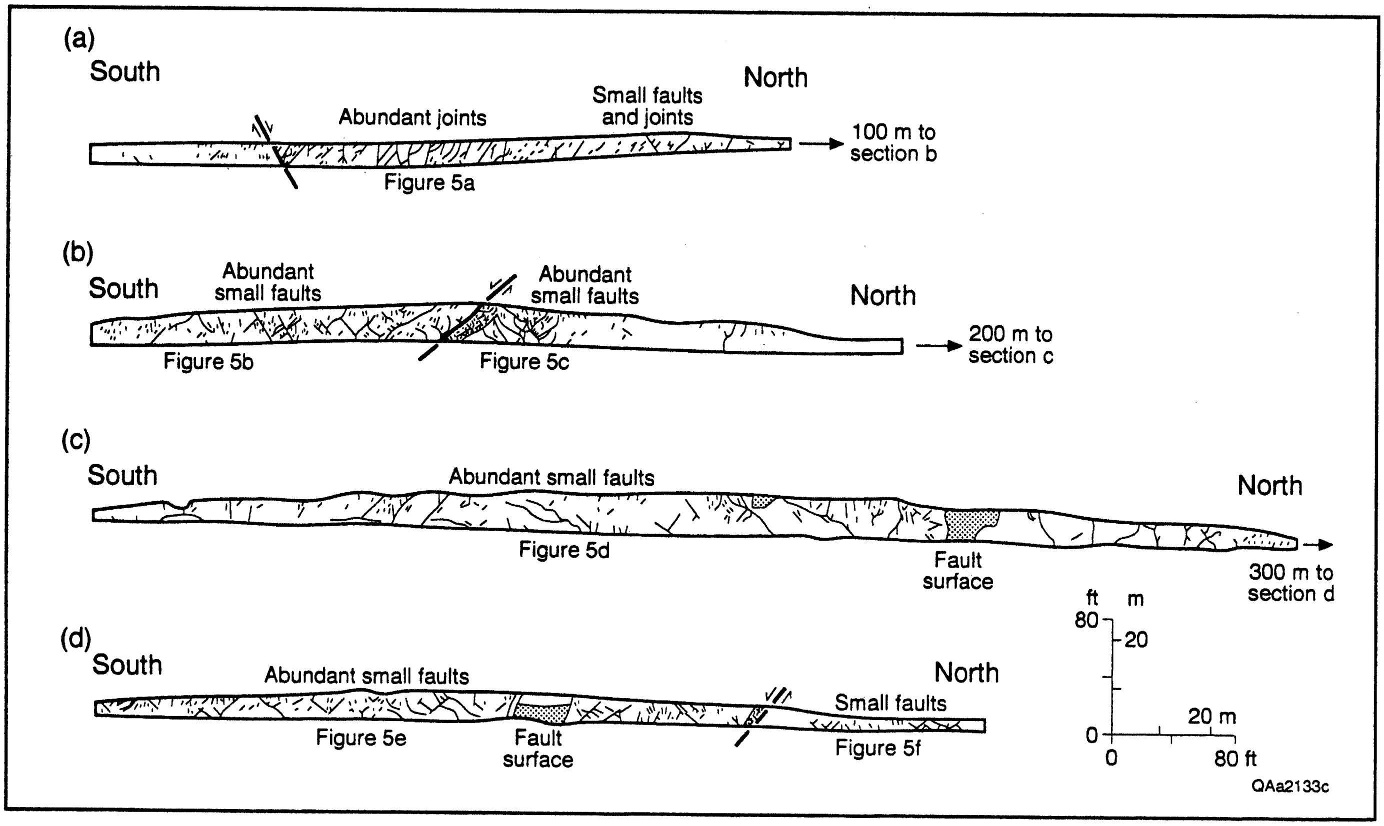


Figure 4. Cross sections of fractured Cretaceous Glen Rose Limestone showing fracture intensity within overlapping en echelon faults. Cross sections a–d correspond to outcrop locations a–d in Figure 3. Locations for collection of fracture data that are presented in equal-area net plots of Figure 5 are indicated as 5a–5f.

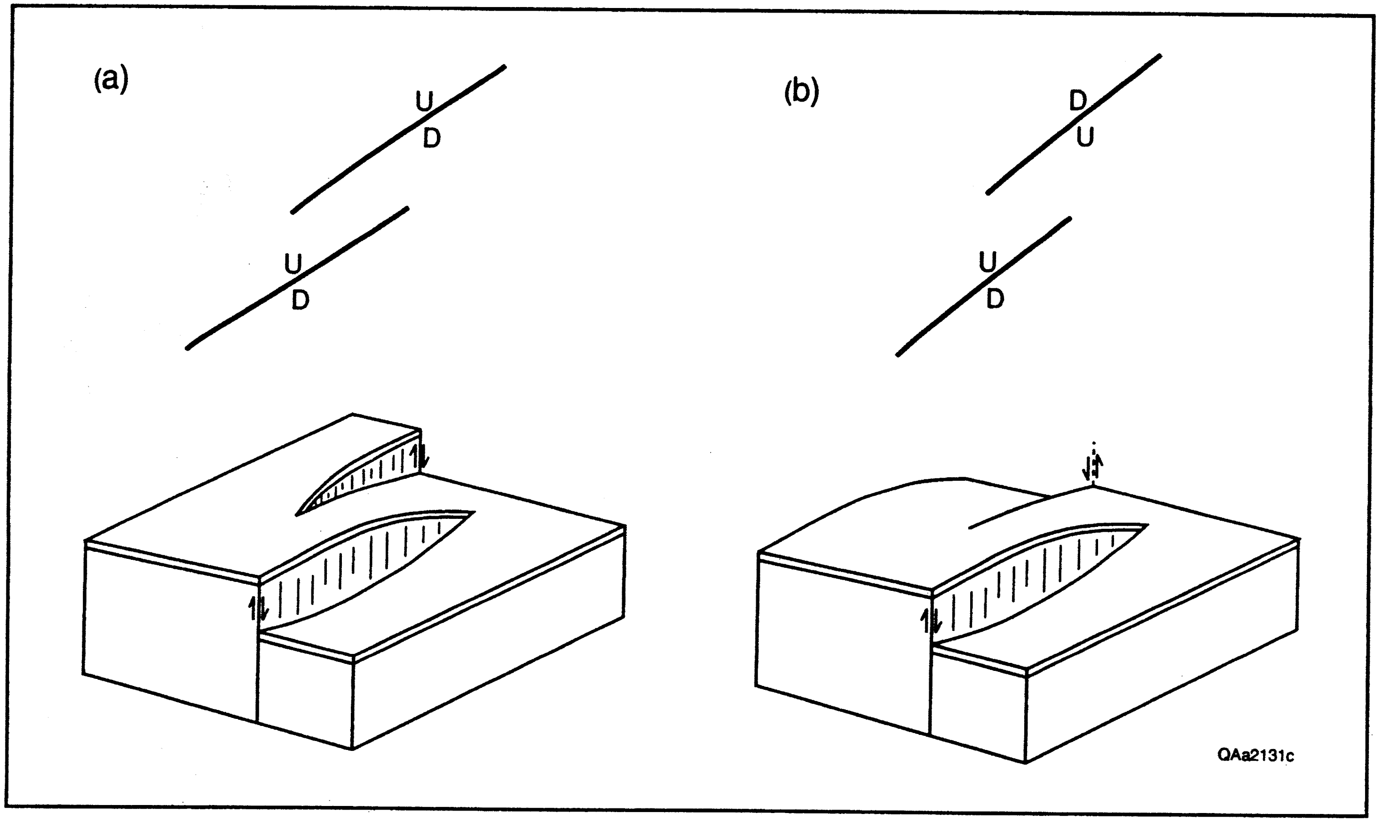


Figure 2. Plan view and block diagram of (a) relay ramp between overlapping master faults dipping in the same direction and (b) horst bridge between overlapping faults dipping in opposite directions.

Collins, 1993

faults for each order of magnitude range of displacement (i.e., < 1 cm; 1-10 cm; 10-100 cm; > 1 m). Number the faults you observe and make an outcrop sketch for each. Also, make a schematic cross section across the whole area.

2. Plot the poles to bedding, construct the π-plane, and determine a fold axis. On a separate stereogram, construct the shortening and extension axes for each of the faults you measured (number the kinematic axes and faults according to your data table, and circle the shortening and extension axes in different colors to make them easier to distinguish). Remember that to construct the kinematic axes for a fault, you need to plot the fault plane and pole to fault, mark the slip direction on the fault plane, and locate the kinematic axes in the great circle containing both the pole to fault and the slip direction. Make legends for both of the stereograms to indicate what your symbols and colors represent. What statement can you make about the predominant directions of shortening and extension? What is the geometrical relationship between the fault kinematics and the fold axis?

3. Do a fold test of the fault kinematic axes on a new stereogram. Rotate the pair of kinematic axes corresponding to each fault by the appropriate amount and direction to return local bedding to horizontal. Number and color the resulting axes as before. Are the kinematic axes more coherent in the measured configuration (previous problem) or in the ‘unfolded’ configuration (this problem)? Do the ‘measured’ or the ‘unfolded’ kinematic axes most accurately represent the deformation? What does this suggest about the relative timing of folding and faulting? Can you make a hypothesis about the relationship between folding and faulting? For example, did faulting cause folding, did folding cause faulting, or could they be unrelated? Explain your reasoning.

4. Do a weighting test of the fault kinematic axes on a new stereogram. Classify the faults into subsets representing different orders of magnitude of displacement, and draw the kinematic axes of each subset using different symbols. Number and color the axes as before, and make a legend indicating the meaning of your symbols. Do the fault kinematics vary significantly with the size of fault observed? What does this tell us about our graphical analysis of the fault kinematics, and what general conclusions can we reach about strain in the roadcuts?

Extra credit: How could we make our analysis more quantitative? Namely, what components of the deformation gradient tensor have we implicitly ignored in our graphical analysis, and what would we need to do in order to quantify the full deformation gradient tensor?

5. Along with responses to questions, turn in: (A) data table and sketches (preferably from fieldbook, but redo them if they're not legible); (B) stereogram of π-diagram; (C) stereogram of the observed fault kinematics; (D) stereogram of the fold test; (E) stereogram of weighting test.

References

Collins, E.W., 1993, Fracture zones between overlapping en echelon fault strands: outcrop analogs within the Balcones Fault Zone, central Texas: Gulf Coast Association of Geological Societies Transactions, v. 43, p. 77-85.

Marrett, R., and Allmendinger, R.W., 1990, Kinematic analysis of fault-slip data: Journal of Structural Geology, v. 12, p. 973-986.

fault plane		striae				bedding	
strike	dip	trend	plunge	sense of slip	displacement	strike	dip