Structural Geology and Tectonics GEO3-1307

Date: Wednesday April 20th 2011
Time: 13.30-15.30 hr.
Place: BBL 169

Please read the complete exam before starting. Ask any language related questions. Then, answer all 4 questions (they are worth 2.5 points each). Always explain how you came to your answer. Be creative and good luck!

Question 1: Quantification of strain

In an outcrop along the Meuse valley, Belgian Ardennes, a folded Carboniferous limestone has been found (Fig. 1). The limestone contains deformed grains as well as deformed fossils. The shape and orientation of the grains have been measured using the R_f-ϕ' method, the deformation of the fossils has been quantified using the Breddin graph method.
Stylolitic planes are present in the outcrop, dipping steeply SSE. There is no evidence for any strain parallel to the fold axis. Thin sections of the limestone taken perpendicular to the fold axis show a lot of grains with socalled indentation structures. A total volume change of 20% has been estimated on the basis of these indentation structures. The fossils do not show any evidence of volume change.

a) What does the presence of stylolites and indented grains tell you? Do you expect the volume change to be the same in all directions? If yes, why? If no, what will be the difference(s)?

b) Determine the strain ratios of the grains *and* the deformed fossils for *both* the SSE and NNW limb of the fold.

c) A small difference should have appeared between the strain ratios for grains and fossils (question 1b). Give two possible reasons for this difference (read the introduction again).

d) On the basis of observations further south along the Meuse, the fold has been classified as a "buckling fold". What does this mean? Was the folding mechanism buckling by orthogonal flexure or by flexural shear? Explain.

e) Quantify the strain of the limestone in 3 dimensions by giving values for the three principal strains. Are you going to use the grains or the fossils (why?)? Illustrate the type of strain that you obtain in a suitable Flinn diagram.

Question 2: Structural styles

a) When analyzing deformed parts of the crust, it is useful to think in terms of structural styles. What are the characteristic elements of the structural style of Strike Slip Tectonics?

b) Fig. 2 shows an interpreted cross-section through the Kubor complex, Papua New Guinea (from Rob Butler, UK). Make a clear and complete list of *observations*.

c) Give an *interpretation* of the geological history of the structure, consistent with your observations (part b). Present this interpretation in a framework of 'structural styles'.

Question 3: Deformation processes in the elastic/brittle and ductile fields

Fig. 3 shows a throw profile for a normal fault from the Tambaredjo oil Field, Surinam (from Wessels 2010). The profile is made for top-Cretaceous. The fault dips 52° (i.e. the angle between the horizontal and the fault plane is 52°). The top Cretaceous sediment has been tested in the laboratory, resulting in a value for the "cohesion" of the sediment of 5 MPa, and a coefficient of internal friction (μ) of 0.25.

a) Analyse the diagram of Fig. 3 in terms of length-throw relations. Then give an interpretation of the character of the length-throw profile.

b) Given that the top-Cretaceous sediment has a density of 1900 kg/m^3 and lies at a depth of 700 m, what was the differential stress (σ_1- σ_3) that caused the fault to develop?

Looking deeper into the earth now:

c) Write a brief account of what is meant with "dislocation creep". Include in your account i) the basic mechanism of dislocation creep, ii) a rough indication of the conditions under which this mechanism operates, and iii) the diagnostic microstructures.

d) Dream up one exam question that nicely fits this course (GEO3-1307) and deals with recrystallization during deformation. (take this question serious)

Question 4: Anatomy of orogenic belts

Fig. 4 shows the Glarus thrust in the Alps of eastern Switzerland. It is a major thrust zone that locally has a width of only 2 m, but with the overlying rocks being thrusted up to 100 km. Local geologists have analysed the shape of the grains in the thrust zone and came up with a forward position gradient tensor that may describe the deformation. The thrust plane has been used as the X-axis of the reference frame.

$$F_{ij} = \begin{pmatrix} 1.3 & 5.0 \\ 0 & 0.7 \end{pmatrix}$$

a) Determine the strain ratio and orientations of the principal strain axis for the tensor that is given.

b) Even without doing the detailed calculations required at a), the information given about the Glarus thrust zone immediately tells you that the tensor cannot give the full story. Demonstrate this (be quantitative if possible). What reasons can you think of that cause that the locally measured strain differs from the large scale deformation?

c) Describe the evolution of a metamorphic "core complex" Design a relative timing diagram of porphyroblast growth (Mineral A, B C...) versus deformation phase (D1-D2-D3...) that fits the general evolution of a core complex. Explain how you came to the diagram.

Fig. 2 (with question 2):

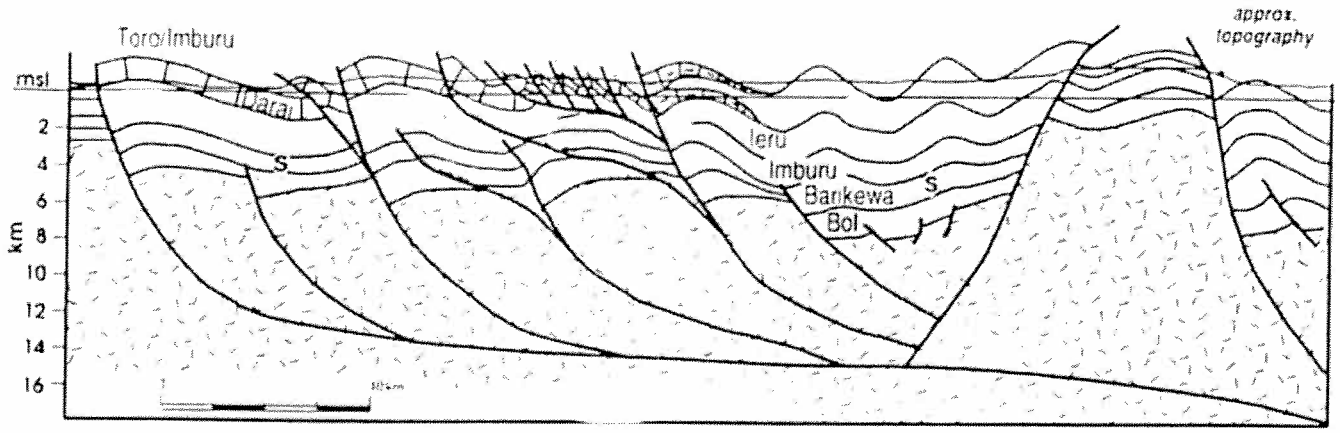

Fig. 3 (with question 3):

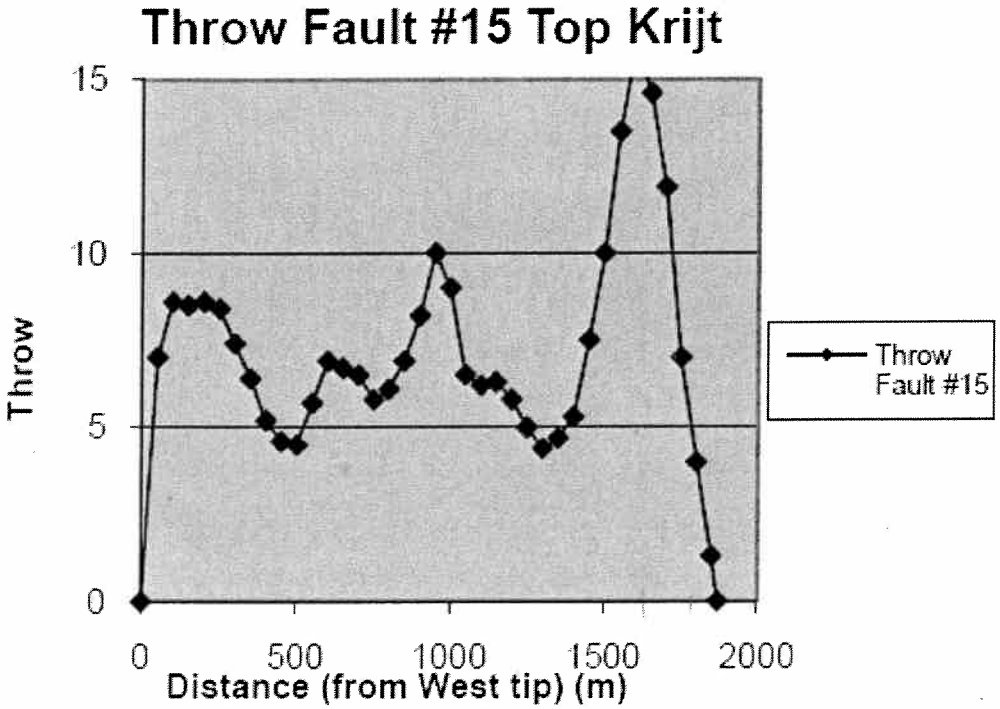

Fig. 4 (with question 4)