Structural Geology and Tectonics AW3-3107

Date: Wednesday April 7th 2004
Time: 09.00-12.00 hr.

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

Question 1: Deformation processes in the elastic/brittle and ductile fields

a) Draw a labelled diagram illustrating a realistic brittle failure envelope for a well-cemented siltstone with a porosity of say 10%. Now add labelled sketches of the structures that characterize the different portions of the envelope that you have drawn.

b) Define what the following structures seen in sedimentary rock sequences are, and explain their origin:
   i) Compaction bands in porous sandstones
   ii) Stylolites

c) Explain with the aid of diagrams how you would recognize from a microstructural study (i.e. a thin section study) if the following mechanisms of deformation had operated in a given rock material:
   i) dislocation creep
   ii) grain size sensitive flow (dominated by diffusion and/or grain boundary sliding)

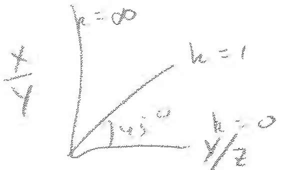
d) You are conducting a field mapping study and discover a mylonitic shear zone cutting right through your area. The zone is poorly exposed and the sense of shear is not apparent in the field. Write a brief account of how you could use microstructural studies of quartz mylonites from the zone to gain insight into the shear sense and differential stress associated with its formation.

Question 2: Quantification of strain

In a valley near St. Lary-Soulan in the French Pyrenees, a shear zone has been studied consisting of a multilayer of microconglomerate and limestone – see section in Fig. 1. Shape and orientation of small pebbles in the microconglomerate have been measured using the R_f-ϕ' method (Fig. 1a). The limestone contains deformed fossils (Fig. 1b) that originally had symmetrical shapes. There is no evidence for any volume change during deformation. You can assume that deformation was of 'plane strain' character.

a) Explain briefly what the principle is behind the Breddin graph of Fig. 1c

b) Determine what the strain ratio R_1 is of the small pebbles (Fig. 1a) and R_2 of the deformed fossils in the limestone (Fig. 1b). Why are R_1 and R_2 different in the same shear zone?



c) Quantify the strain of the limestone in 3 dimensions by giving values for the principal strains. Show the result in a suitable and well-labelled Flinn diagram. Plane strain => Y=1
XYZ = 1 = XZ

d) Previous investigations of the same shear zone have resulted in a forward position gradient tensor that is believed to describe the deformation of the fossils in the limestone layer. Analyse the tensor in order to check if your results of c) are consistent with the predictions of the tensor. Consider strain magnitude as well as orientation.

$$F_{ij} = \begin{pmatrix} 1.0 & 0.7 \\ 0.15 & 1.1 \end{pmatrix}$$

Note: parts a)-c) are worth 0.5 points each, d) alone is worth *1* point.

Question 3: Structural styles

Fig. 2 shows sections through the Rheden structure in the Saxony basin, Germany. The top figure (c) shows the present-day geometry, the other two sections are reconstructions for late-Jurassic time (b) and early-Triassic time (a). The letter-coding in the sections refers to the different stratigraphic units, their exact meaning is irrelevant for this exam question.

a) Analyse the three individual sections and describe the structure, keeping the idea of 'Structural Styles' in the back of your mind. Focus on clarity!

b) Assume you are given the task to model the development of structures of Fig.2 in the laboratory, for example by making use of sand-sillipputty multilayers. Present a short plan in which you i) define a meaningful problem in relation to Fig. 2, ii) outline how the model should look like, and iii) define a few essential steps in running the model.

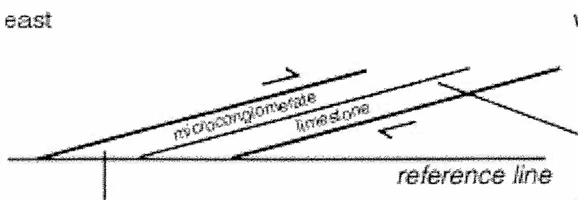
Question 4: Anatomy of orogenic belts

Fig. 3 gives the text of one of the conclusions in a paper on the structure and evolution of the Variscan (central) Pyrenees (Vissers 1992, *Tectonics*, Vol.11). The text suggests that the early Pyrenees had the anatomy of a 'core complex'.

a) Compare the conclusion in Fig. 3 with you knowledge of core complexes. Which elements need, in your opinion, to be described in the paper in order to become convinced by the author?

b) Design a diagram in which relative timing of porphyroblast-grow and deformation is indicated for this Pyrenean example. Many answers are possible, of course, but make sure that your diagram is at least consistent with core complex model

c) It has been suggested that a length-throw analysis of the faults of the tilted half-grabens can help substantiate the ideas for the development of the Variscan Pyrenees. Explain what exactly is meant with such an analysis and discuss why indeed this might be a useful approach.



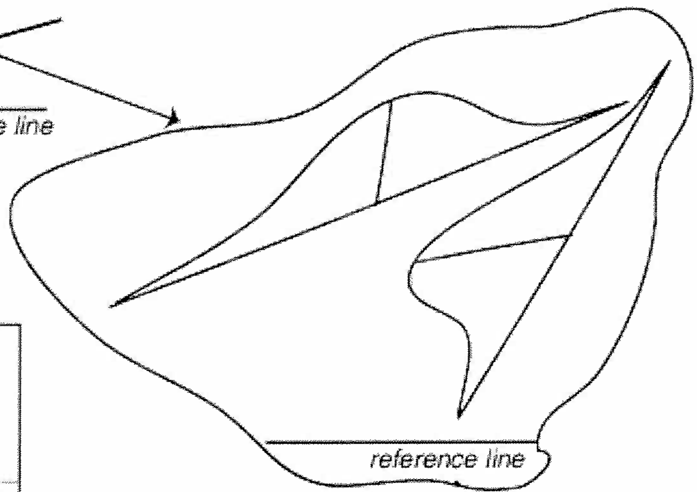


Fig 1b - deformed fossils in limestone layer

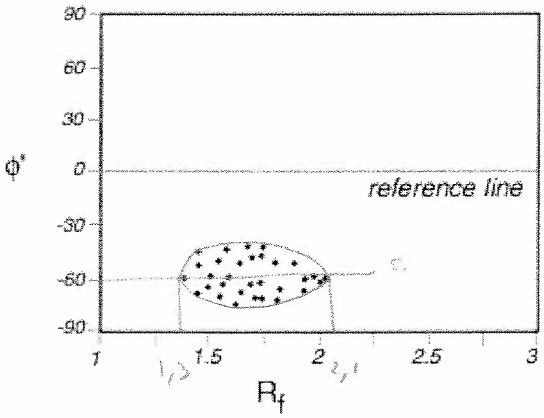


Fig 1a - positive angles φ' measured clockwise from reference line

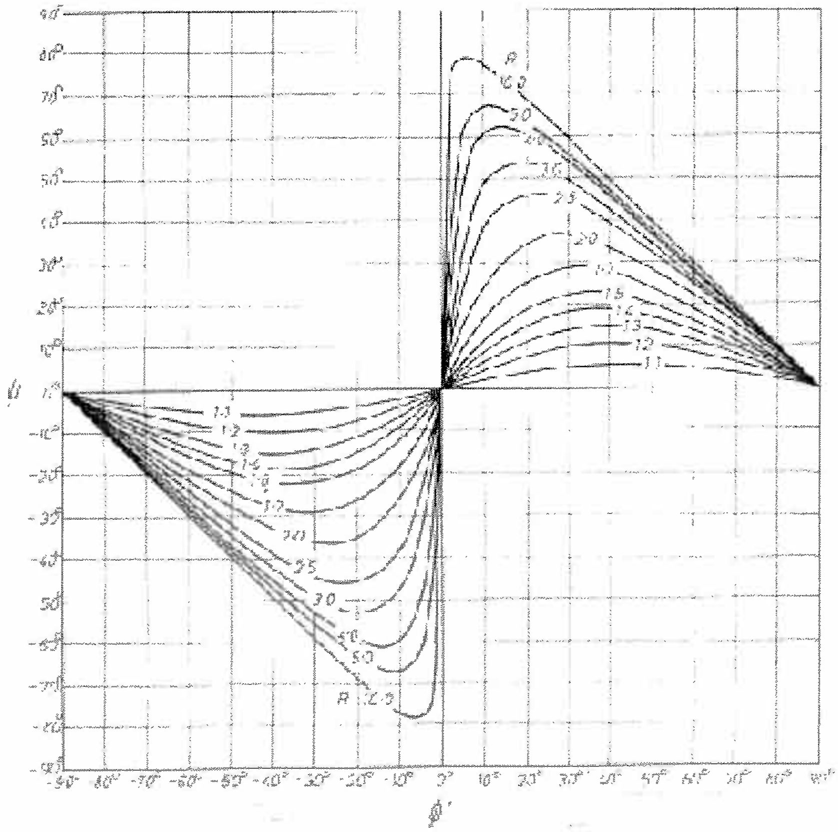


Fig 1c - Breddin Graph

Fig. 2
(with question 3)

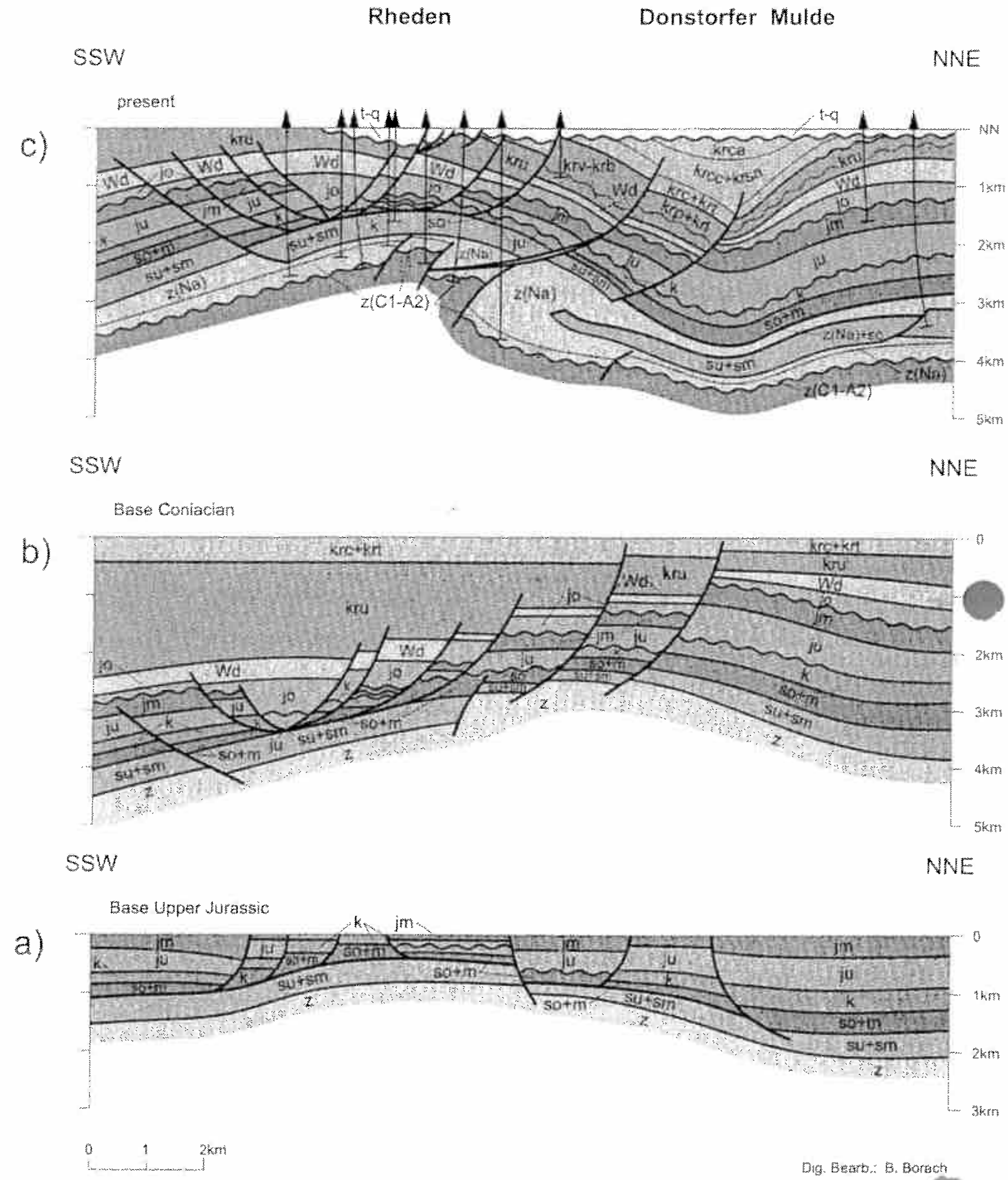


Fig. 3
(with question 4):

CONCLUSIONS

1. Structural analysis shows that the Variscan orogeny in the Pyrenees involved two stages, i.e., a Namurian-Westphalian stage of crustal shortening and thickening reflected by early thrusts and a steeply oriented low-grade suprastructure, and a Stephanian to Early Permian stage of crustal extension leading to tilted halfgrabens, flat-lying infrastructure foliations, spaced metamorphic domes, and gneissic core complexes mantled by crustal-scale shear zones. These extensional structures developed at the onset of extensive lower crustal melting and granodioritic intrusion during the Early Permian.