Structural Analysis of Deformed rocks (GEO4-1411) - Exam 29-01-2008

Time: 14.00 – 17.00 hr.
Place: AW

Answer 4 out of the 5 questions (make your own choice)

Please read carefully!

Question 1 – On flow in rocks

a) Flow parameters for deformed rocks can be reconstructed on the basis of vein systems, rotated porphyroblasts, fibres in tension gashes etc. This can be expected to result in the recognition of one of the following flow types: Pure shear, simple shear, general shear. Explain clearly what the differences are between these flow types.

On the basis of rotated porphyroblasts in medium-grade schists from the Moundang Valley, Central Pyrenees, the following Velocity Gradient Tensor **L** has been defined:

$$\mathbf{L} = \begin{pmatrix} 3x10^{-13} & -3x10^{-13} \\ -6x10^{-13} & -2x10^{-13} \end{pmatrix} \qquad [s^{-1}]$$

b) Make a Mohr circle representation of **L**. Carefully (!) label all axes and explain what the intersections of the Mohr circle and the axes mean. Also, determine the mean instantaneous stretching rate and the kinematic vorticity number.

c) What does this **L** tensor (or its Mohr representation) tell you about volume change during deformation of the schist?

d) On the right (Fig. 1.1), a drawing is given of the bulk flow pattern belonging to **L**, according to the Pyrenean researchers. Are they right? Explain your answer.

e) Velocity gradient tensors cannot easily be used in the analysis of folds. Why not?

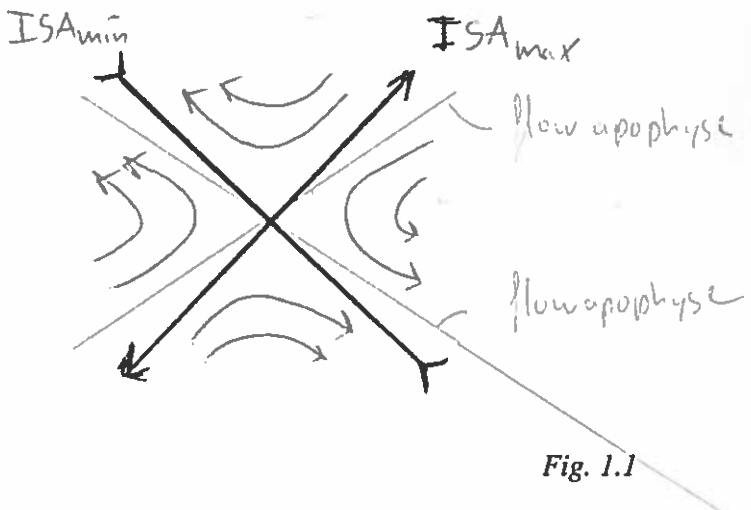


Fig. 1.1

0.3 - 0.6

Question 2 On the analysis of layered rocks and paleostress

a) Describe what is meant with "lobe and cusp structures". Also, list (and explain!) what factors determine the geometry of these structures?

b) Classical buckling theory ('Biot') predicts folding with a dominant wavelength. What factors control wavelength according to this theory, and how do they do this? You may want to use theoretical relationships (equations) to underpin your answer. Is this theory generally accepted?

c) Assume you are dealing with a sequence of calcite layers that are now exposed at the surface, but have been deformed into km-scale folds at a depth of about 14 km. Present a sensible plan that shows how you would handle to analyse the stress history of the calcite rocks. Consider questions such as: What information do I need about the calcite rocks? What elements of this rock might be useful as paleostress indicators? What techniques can I use? Is there any way that I can decipher stress history rather than just one stress event? Add anything you feel is important.

Question 3 – On mechanical instabilities and structure development 0.75 - 1.0

a) List the main factors that can lead to localized deformation, hence geological structure development, in deforming rock masses. Illustrate your answer with simple diagrams.

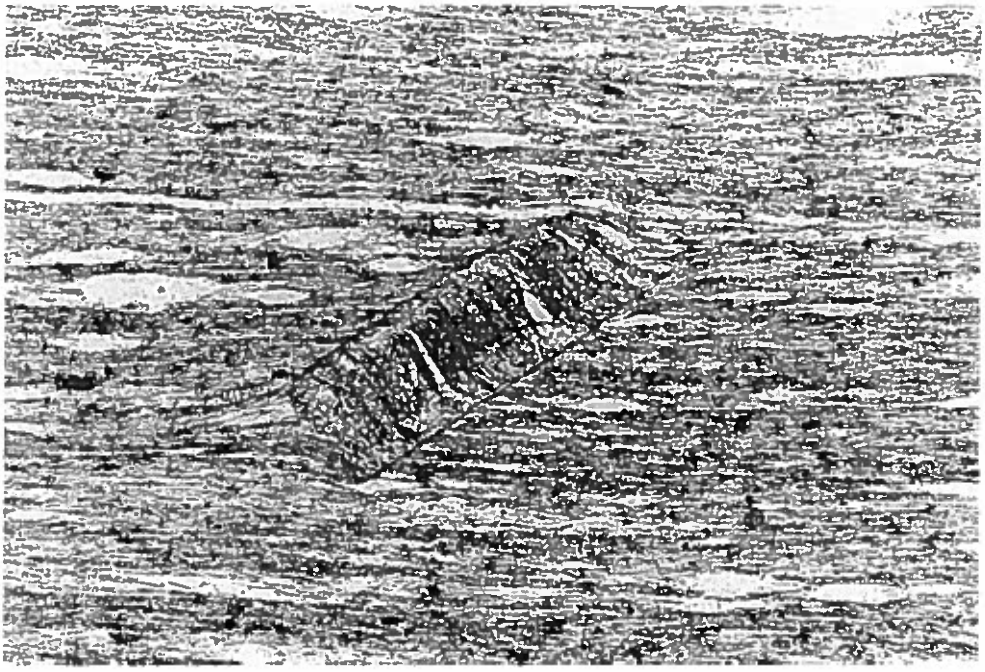
b) Explain in detail what is meant by the terms
- unstable deformation process
- stable deformation process
- geometric perturbation

c) Explain with the aid of a feedback diagram why rock materials deforming by a dislocation creep process are expected to be more prone to localized deformation than those deforming by diffusion creep.

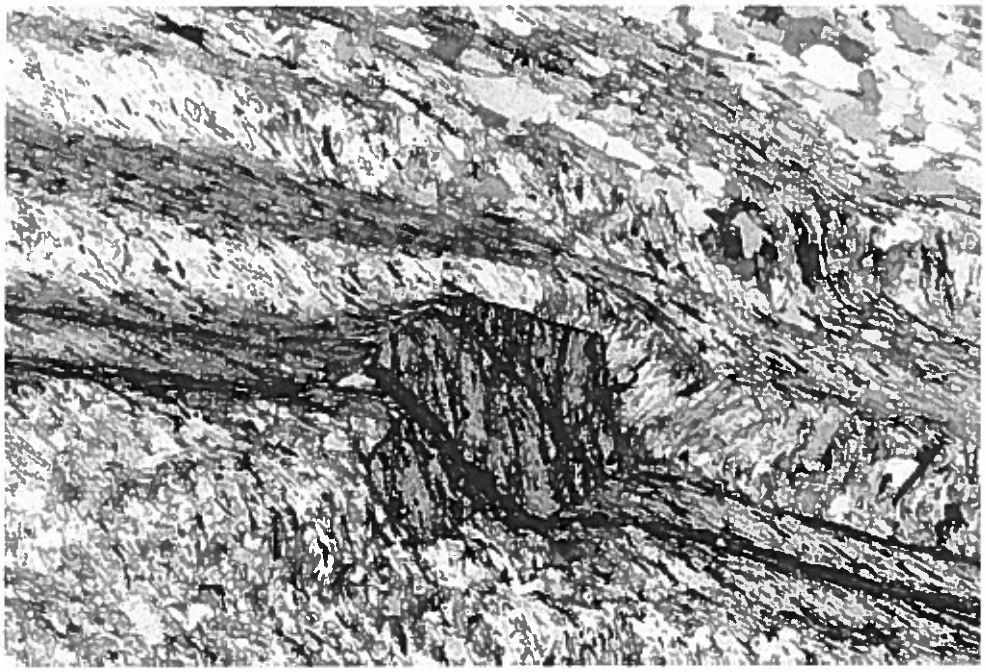
d) Define the term "ductile shear zone" from the point of view of a structural geologist working in the field.
- Go on to use the concept of "positive feedback" to outline at least two different ways in which ductile shear zones can dynamically localize in a deforming rock mass.
- What features might you look for in the field to determine how a given ductile shear zone formed (i.e.localized).

Question 4 **On the analysis of Deformation Histories.**

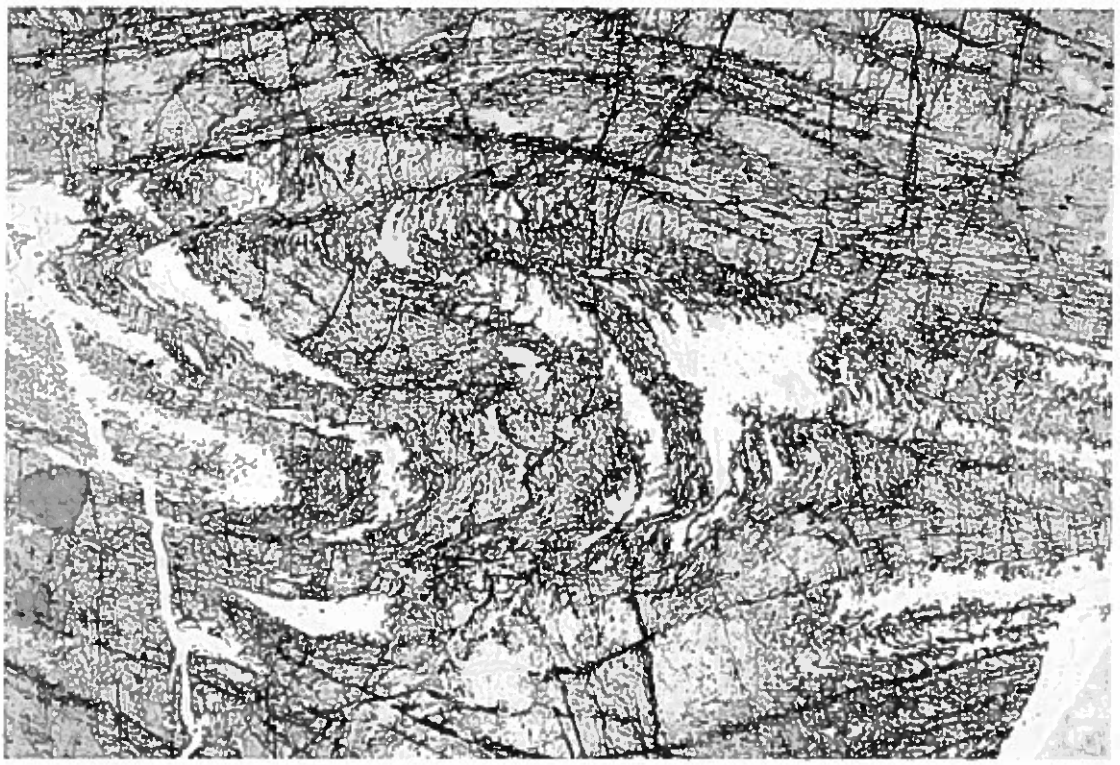
a) The micrograph shows a chloritoid porphyroblast from Curaglia, Switzerland. Describe the development of the microstructure and the timing of chloritoid growth and deformation.

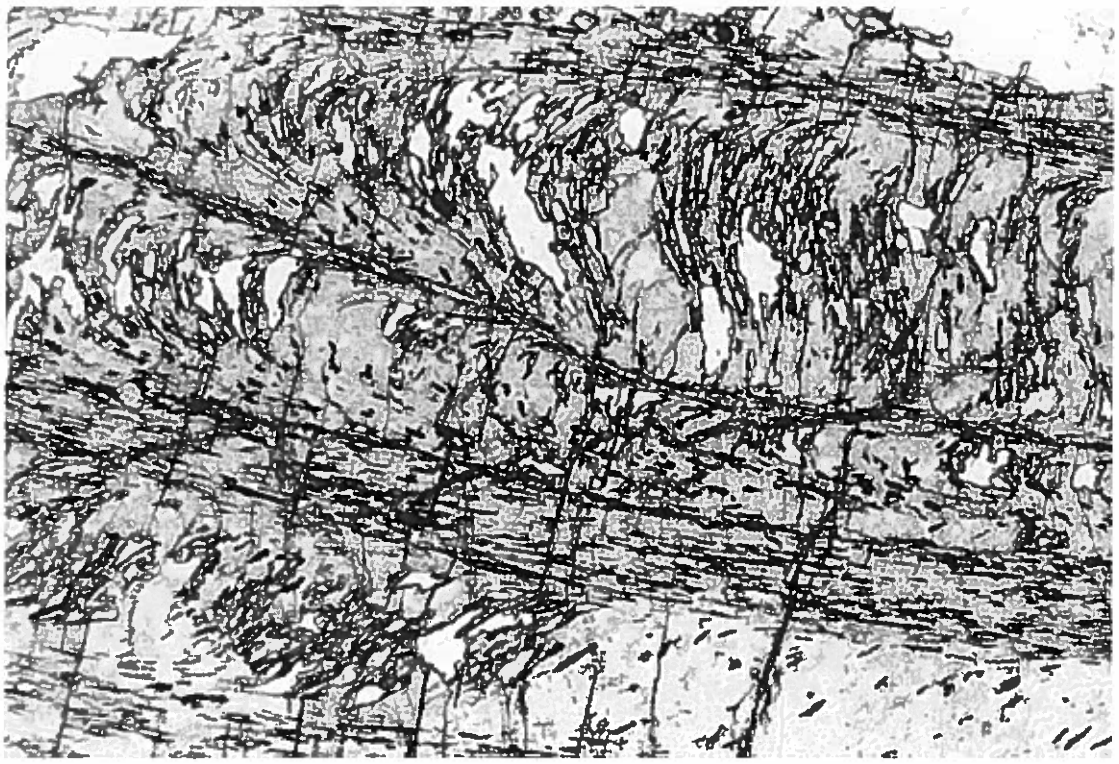


b) The micrograph shows garnet mica schist from Brazil. Describe the sequence of garnet growth and deformation.



c) The micrographs show a) part of a large garnet porphyroblast from Vermont, USA, and b) a detail of the same porphyroblast. Explain the inclusion pattern.





0.4 -1.0

Question 5 - On Structural Analysis of Crustal terranes

a) How can exhumed crustal scale fault zones be recognized in the field? What sequence of fault rocks is expected along exhumed thrust zones and exhumed extensional detachments?

b) How can structures produced by fault zone re-activation in different orogenic events be distinguished from overprinting structures that formed during progressive deformation and exhumation in a major crustal fault zone?

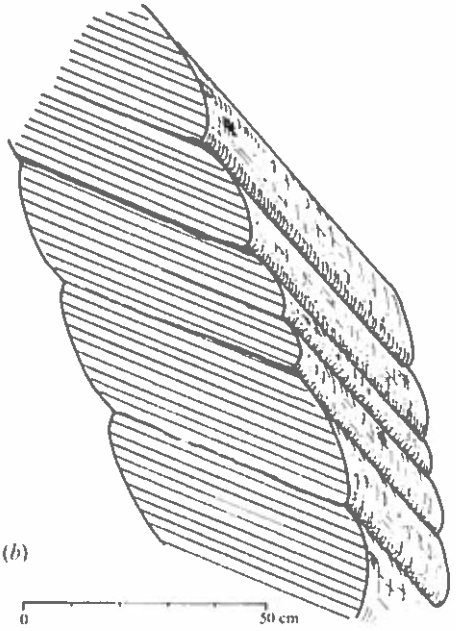
c) The diagram shows a page from the field note book of a young geologist mapping the Moine mylonite zone and Moine schists in NW Scotland. The structure is a fold of the mylonitic foliation Sm, with all fold axes sub-parallel to the mylonitic lineation Lm. Is our young geologist correct if they interpret this fold interference structure as evidence for two distinct deformation events in the mylonite zone?

Eye Folds: most deform Sm and So
(section // Sm, Lm. some fold So, with Sm. A.P. axes // Lm

2cm

Intrafolial, in q.f. mylonite band in Oystershell rock.

d) The diagram shows some structures developed at the interface of a folded sandstone layer, in the Ardennes. Are these structures tectonic or sedimentary flame structures?



0.6 + 0.3 + 0.75 + 0.4 = 2.05

e) The diagram below shows the foliation and lineation pattern in and around the Cauterets Intrusion in the Central Pyrenees.

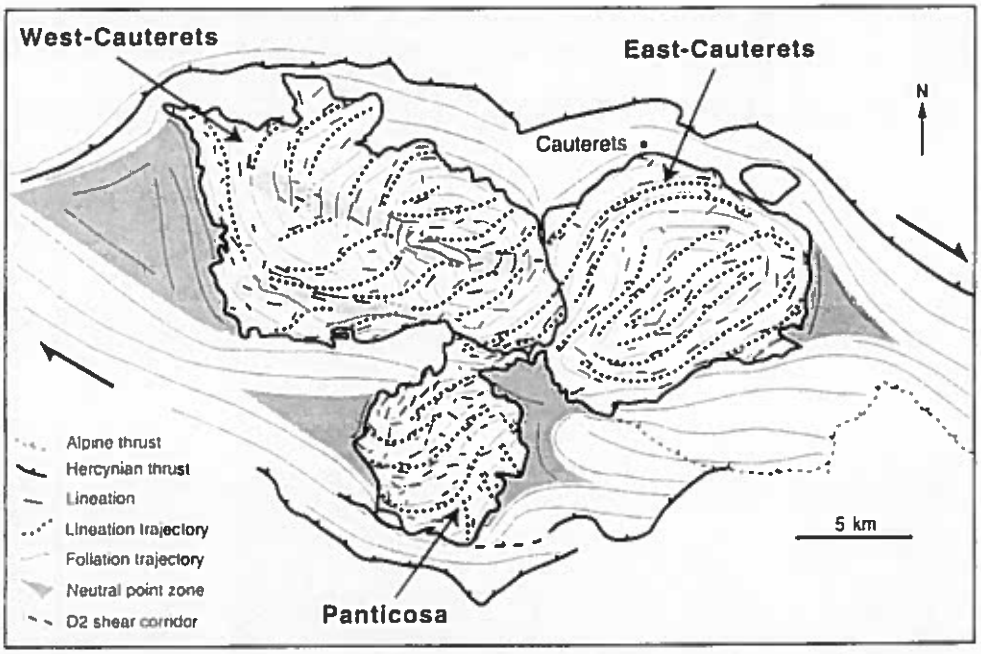


Fig. 3. Structural map of the Cauterets–Panticosa plutonic complex (AMS measurements) and its country rocks (after Santana *et al.* 1992, Leblanc *et al.* 1996*b*). The two shaded corridors in the West Cauterets body are D2 magmatic dextral shear zones.

The foliation in the granodiorite intrusion was produced by magmatic flow; the foliation in the country rocks (mainly slates, phyllites and schists) was produced by solid-state flow.

What are the typical characteristics of structures formed by magmatic flow, sub-magmatic flow and sub-solidus flow? On the basis of the foliation patterns was the Cauterets intrusion pre-tectonic, syn-tectonic or post-tectonic?