National Exams December 2017

04-Geol-A4, Structural Geology

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.

3. All questions constitute the complete exam paper. (100 marks)
   There are choices in each main question (read instruction line)

4. Some questions require an answer in short answer or short essay format with figures as appropriate. Clarity and organization of the answer are important.

5. The exam is a total of 11 pages with pages 6, 9 and 11 being blank for your use.

QUESTION A. 20 Marks

(1 mark per correct answer -0.5 marks for an incorrect answer blanks = 0)

Answer all of the following T (True) or F (False) <u>in the answer booklet</u> next to the number.

1. Thrust faults propagate down section, towards the hinterland.
2. Axial surfaces of upright folds dip more steeply than bedding.
3. Folding of rock is generally associated with brittle loss of cohesion, while fracturing is related to ductile transformation.
4. Measurement of an axial surface completely describes the orientation of a fold.
5. If stress conditions of σ_s and σ_n lie outside of the Mohr Envelope, the rock mass will generally be stable, and not undergo brittle rupture.
6. Mode 1 cracks formed in extension form perpendicular to σ_1
7. A lineation orientation is recorded by a strike and a dip.
8. A Mode I fracture may form from either positive or negative normal stresses.
9. For a viscous material strain is linearly related to stress.
10. Coaxial strain does not involve shear.
11. Slickensides are reliable shear sense indicators.
12. Bedding is steeper than cleavage in overturned folds.
13. An intersection lineation between bedding and cleavage provides the orientation of the axial surface.
14. Increasing the strain rate of deformation results in decreasing the strength of rocks.
15. Axial planar cleavage forms in the $S_1 - S_2$ plane of the strain ellipse.
16. To fully describe the stress tensor, 9 independent variables are required.
17. Shear fractures form at 45° to σ_1, the angle of highest resolved shear stress.
18. The yield point in a rock deformation experiment is the onset of inelastic deformation.
19. Stretching lineations always form parallel to the long axis of the strain ellipse.
20. Shear zones form under non-coaxial strain.

QUESTION B. (6 marks each for style and clarity: 30 marks)

Answer **ANY and ONLY 5** of the following questions in reasonable detail (1/3 of a page in the answer booklet)

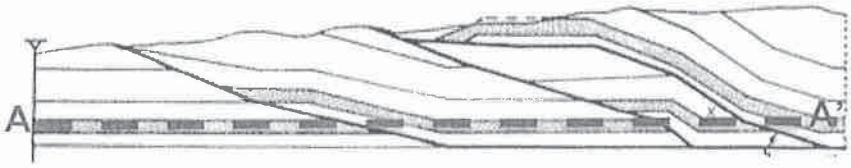
In addition, use sketches where appropriate.

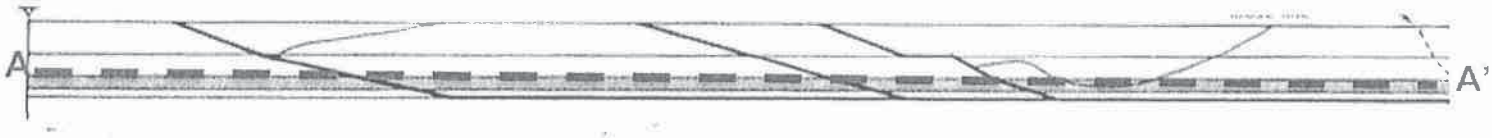
1. Explain (with the *aid* of diagrams) how a vein or a dyke can undergo both compression and extension under a progressive simple shear. Use the concepts of progressive strain and strain ellipses
2. Draw and explain the significance of the main features that define a Plumose Structure on Mode I fracture surfaces. On your diagram illustrate the direction of crack propagation
3. Describe and illustrate with a diagram a thrust *duplex* and an *imbricate fan*. Indicate the thrust propagation direction on each diagram.
4. With the aid of a stress-strain curve, describe the phenomenom of strain hardening in materials. Give a practical example.
5. Draw stress – strain curves to illustrate the effects of increasing temperature, confining pressure, pore fluid pressure and strain rate have on rocks. There should be 4 independent stress-strain curves; one for each variable.
6. Using the concept of the "brittle-plastic transition" in the crust, explain what extrinsic (physical conditions of deformation) variables are most important in a) the brittle part of the crust, and b) the ductile part of the crust.
7. Describe the relationship between mylonitic foliation, stretching lineation and the plane of observation for shear sense indicators in ductile shear zones.
8. Describe the differences between active and passive folding. Indicate in which structural setting you would expect to find each type of fold.
9. Describe both the mechanical and chemical effect of fluids on rocks during deformation.
10. Define "strain partitioning". Apply the concept to the formation of shear zones.

QUESTION C. (6 marks each: 24 marks)

For **ANY and ONLY 4** of the following.

1. After a long field season you have resolved the structural geology of part of the fold and thrust belt in the Rocky Mountains (Canada), see cross-section in first figure. You spent the subsequent fall reconstructing the original position of the different thrust sheets, and come up with the second cross-section.





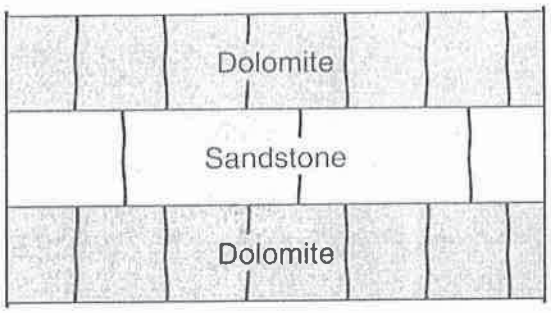
It turns out the area has been shortened significantly as a result of the development of thrust faults. The line between A-A' in the first figure is 3km, whereas in the undeformed scenario the line between A-A' is 7.5 km long.

Calculate the **elongation** and **stretch** this area has undergone as a result of the deformation. Show your work

Elongation: _____

Stretch: _____

2. Using your understanding of joint (Mode 1 crack) formation, explain why there are more joints in the dolomite layers than in the sandstone layer.



3. Sketch all structures associated with:

1. A dextral strike-slip, left step-over.

2. A dextral strike-slip, right step-over.

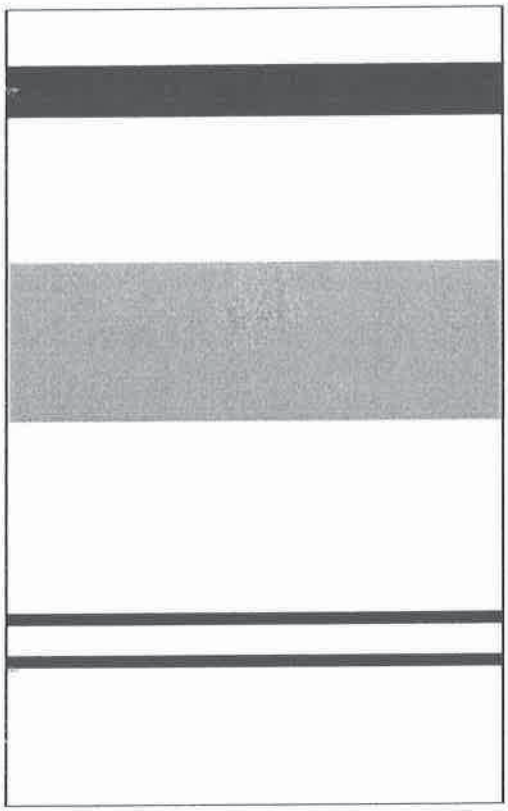
If you are working in an area with known gold bearing quartz veins, for each sketch, indicate and explain where you might anticipate to find quartz vein mineralization.

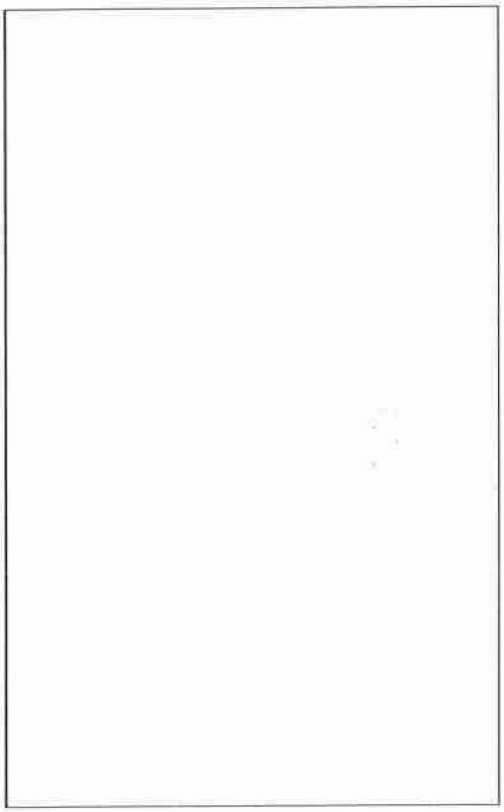
4. Describe four types of structural traps key to the formation of hydrocarbon reservoirs.

5. Describe and illustrate with a diagram, five types of brittle structures associated with simple active folding of competent strata.

6. Using a Mohr diagram and a complete Mohr-Coulomb strength envelope, illustrate the mechanics of cyclical fault-valving due to fluid pressure. Describe the nature of the resultant vein infilling.

7. Sketch (in the box provided below) the shape of the folds likely to be produced by layer parallel shortening of the layers shown below. Note that the black layers are veins, grey is sandstone, and white is shale; also $\mu_{vein} \approx \mu_{sandstone} > \mu_{shale}$.; μ is rock viscosity. Explain your answers in the context of the Biot –Ramberg equation for buckling of Newtonian viscous layers.





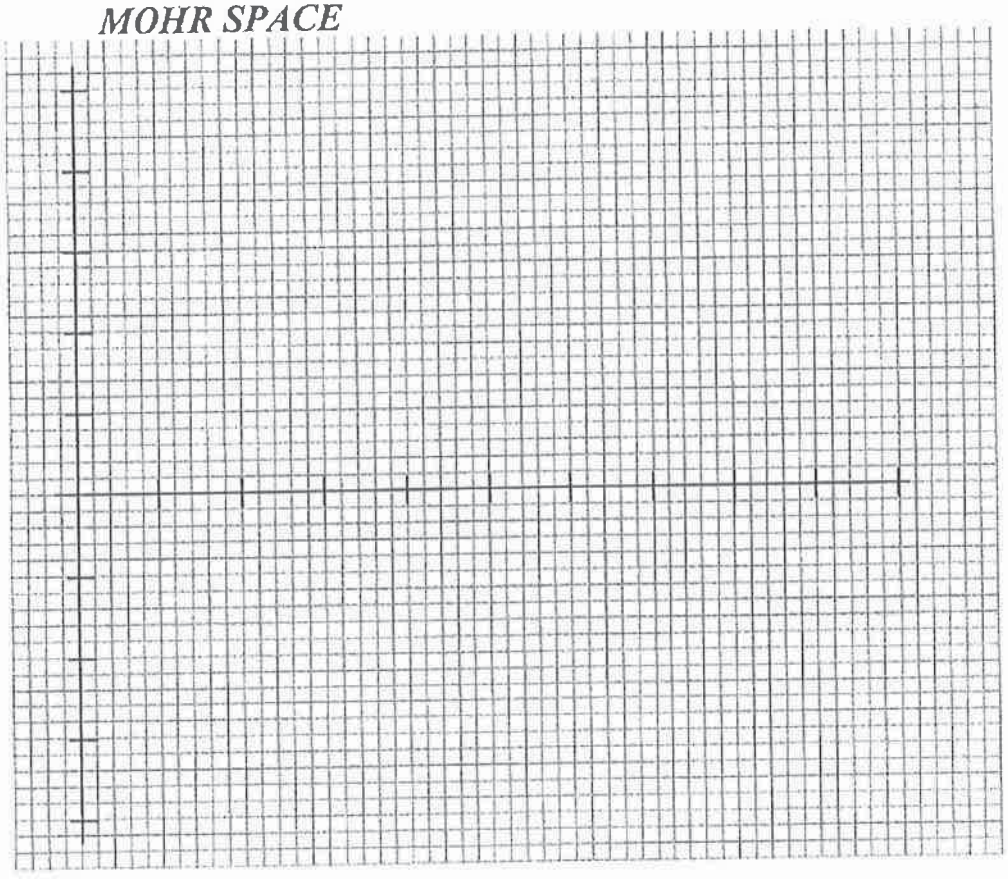
QUESTION D. (12 marks)

Place Answers here and in Answer Booklet as appropriate.

The greatest and least principal stresses in a formation are 341 MPa and 95 MPa. A drilling company wants to hydrofracture the formation to facilitate the flow of oil. From laboratory tests, they know that the cohesion is 75 MPa and that the angle of internal friction is 28.

A) What magnitude of fluid pressure is required in the wells in order to fracture the rock?
B) What are the magnitude of the normal and shear stress on the faults that will form?
C) What magnitude of pore fluid pressure would be required to reactive the faults?

MOHR SPACE



QUESTION E. (14 marks)

Place Answers here or in the exam paper

On the following stereoplot, DRAW, IDENTIFY and SOLVE for:

a) Fold Axis: label and give approximate trend

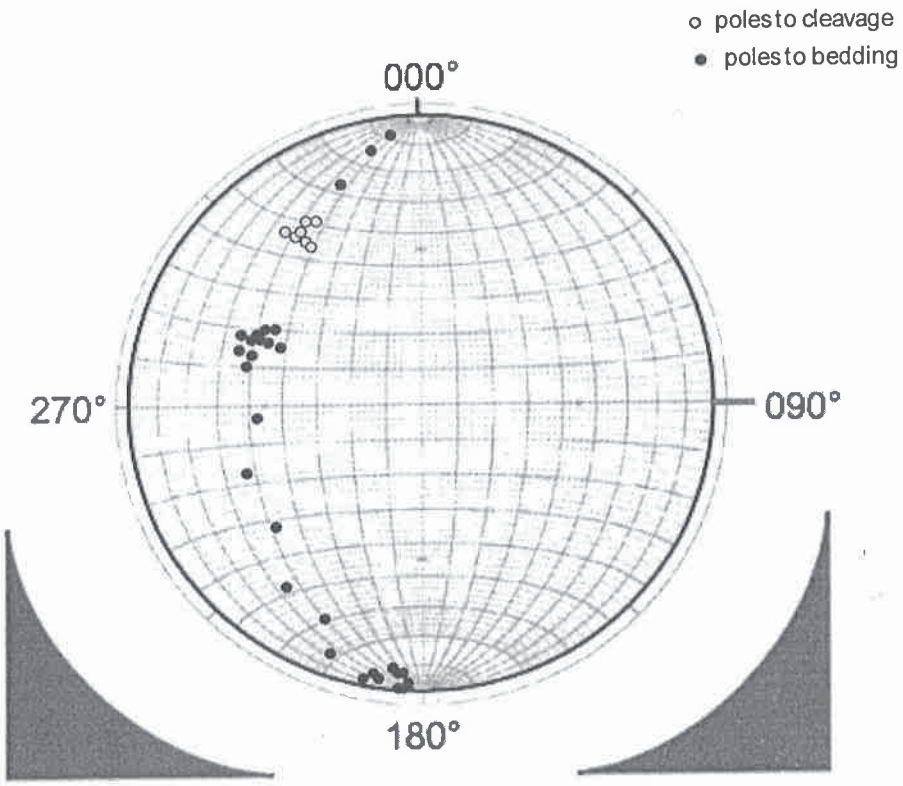
b) Profile plane: label and give approximate strike and dip (estimate)

c) Axial plane: label and give approximate strike

d) Apparent dip of the profile plane on a vertical cliff striking 100

e) Describe the fold completely (using three standard terms)

f) Draw a sketch of the fold in the profile plane


poles to cleavage
poles to bedding
000°
270°
090°
180°