

Internal Students Only

THE UNIVERSITY OF QUEENSLAND
Examination
June 2004

**ERTH2004
DEFORMATION AND STRUCTURAL GEOLOGY**

Time Allowed: **2 hours**

Perusal time: 10 minutes

Answers must be written legibly in pen using grammatically correct English.

Any calculators or drawing instruments are allowed.

Questions carry the marks shown.

This examination provides 50% of the final grade in the subject.

**Write your answers directly into the examination paper using the spaces provided.
Do not cramp your answers until they are illegible, or write in the margins.
If you are cramped for space with your answer use the opposite blank page**

**This question paper is not to be removed from the examination room
Ensure that you have put your name and student number below:**

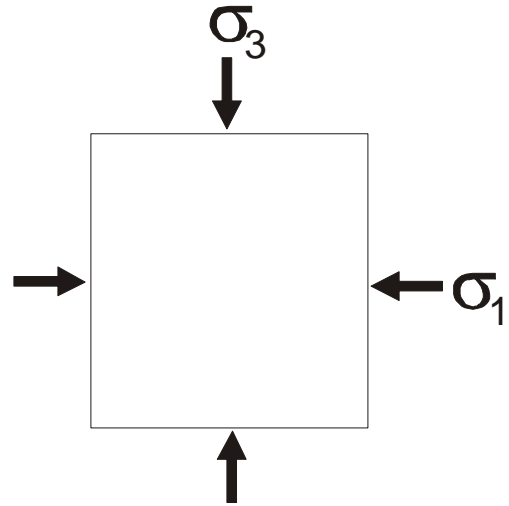
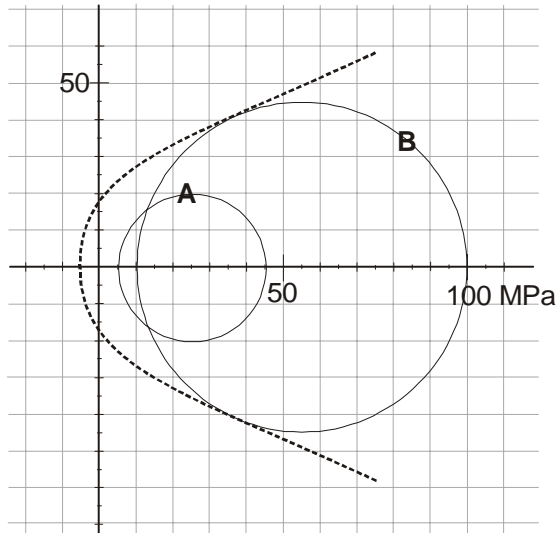
Name: _____

Student No: _____

***Guidance to students:** The paper consists of 12 questions with a total of 120 marks to be answered in 120 minutes. Therefore allow yourself about 1 minute per mark.*

QUESTION 1

The Mohr circles representing the states of stress at two points, **A** and **B**, and in the same rock type at different levels in the crust are shown in the figure below with the Mohr Failure envelope for the rock type. The principal stresses at each point are vertical and horizontal as shown. The rock at **B** is at the point of failure.



- a. Which point is deeper in the crust, **A** or **B**? (1 mark)
- b. What is the mean stress at point **A**? (1 mark)
- c. What is the differential stress at point **B**? (1 mark)
- d. What is the value of σ_3 at point **A**? (1 mark)
- e. Is σ_3 at point **A** tensile or compressive? (1 mark)
- f. What is the orientation, relative to the principal axes, of the fractures that form at point **B**? (2 marks)
- g. Are these fractures at **B** shear or tensile fractures? (1 mark)
- h. Show on the figure at top right the orientation of these fractures with the sense of movement that they would undergo under the given stress. (1 marks)

The pore fluid pressure at **A** is increased until the rock hydraulically fractures.

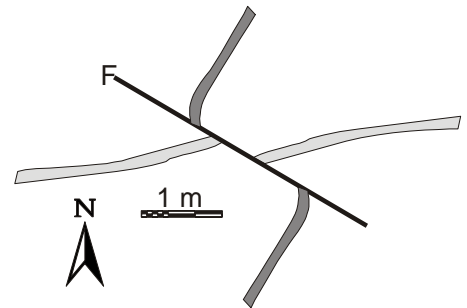
- i. What would be the pore fluid pressure at the point of fracture? (2 marks)
- j. What would be the orientation of the hydraulic fractures that form? Show the orientation of these fractures on the figure at top right. (2 marks)
- k. Are the hydraulic fractures shear or tensile fractures? Show on the figure the sense of movement that such fractures would undergo under the given conditions. (2 marks)

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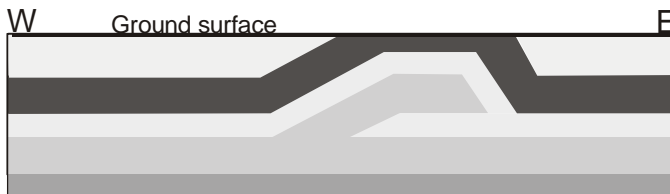
QUESTION 2

The figure shows the outcrop pattern of a fault cutting two veins. The apparent sense of offset of each vein is different.

- a. Explain how different markers can show opposite senses of offset in this way in a single episode of fault slip. Use the terms **separation** and **true slip** in your answer. **(4 marks)**

**QUESTION 3**

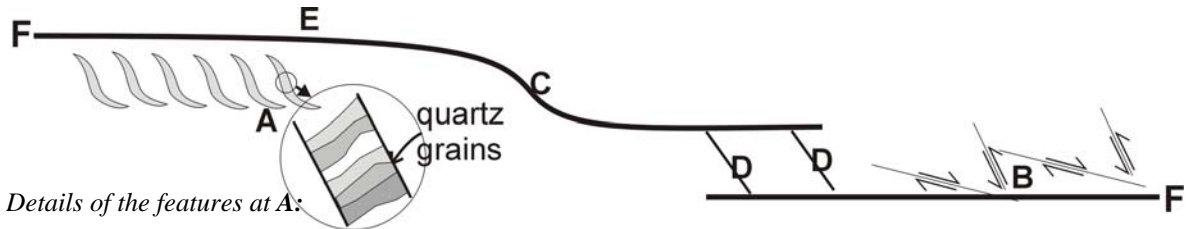
The following structural cross-section has been inferred from dips of beds at the surface. The folds are related to faulting at depth below the area of this cross-section.



- a. What type of fault would cause such folding: a staircase thrust ramp, a blind imbricate thrust, a listric normal fault ramp, or a tear fault? **(1 mark)**
- b. What is the name given to this type of fault-related fold? **(1 marks)**
- c. Show on the figure the possible orientation, position and shape of the fault surface throughout the section. **(3 marks)**
- d. Show on the diagram the position of: (i) a hangingwall ramp, and (ii) a décollement fault. **(2 marks)**
- e. What is approximate value of the cut-off angle? **(1 mark)**

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QUESTION 4



The figure shows several types of structure that occur in a zone of distributed shear adjacent to a small strike slip fault (F). At D, relay structures connect two segments of the strike-slip fault.

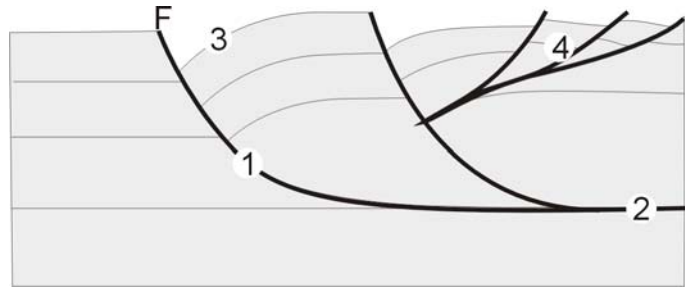
- a. Show on the figure the sense of shear on the fault **(2 mark)**
- b. What are the features at A called? **(2 mark)**
- c. Why are the features at A sigmoidally curved? That is, how did they evolve and why are they curved? **(4 marks)**
- d. What are the sets of shears at B called? **(2 mark)**
- e. When would the set of shears at B, most likely have formed: prior to fault rupture; during fault displacement; or after faulting? **(1 mark)**
- f. What is the bend in the fault at C called? **(1 mark)**
- g. What type of faults are the small connecting faults at D most likely to be: strike-slip, normal, or reverse? **(2 mark)**
- h. Show on the diagram the likely axial plane trace of an array of small fault-related folds that form at E. **(1 mark)**

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QUESTION 5

The figure shows a cross-section of a faulted area.



- a. What is the name of the curved fault at the point marked 1? **(2 marks)**
- b. What is the name of the type of fault marked 2? **(2 marks)**
- c. What is the name of the antiformal structure at 3? **(1 marks)**
- d. Is the structure at 4 best described as: a duplex, a counter fan, an imbricate thrust stack, a domino fault, a synthetic fault array, or a positive flower structure? **(1 mark)**
- e. What type of deformation is accommodated by such a fault system: wrench, extension, or contraction **(2 mark)**

QUESTION 6

Describe, using a sketch where necessary, the critical features by which each of the following primary structures can be used to determine stratigraphic younging:

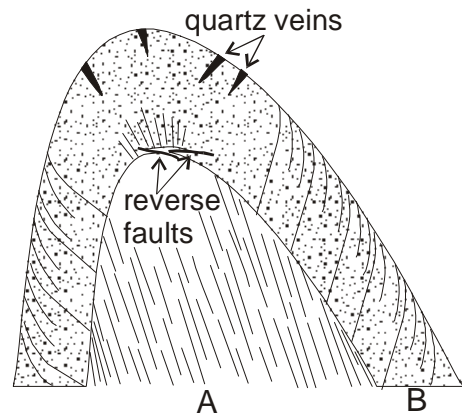
- a. Ripple cross-lamination **(3 marks)**
- b. Graded bedding with load casts **(3 marks)**

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QUESTION 7

The figure shows a folded sandstone layer (B) in phyllite (A) with a strong slaty cleavage in the phyllite and a spaced stylolitic cleavage in the sandstone. The cleavage in the phyllite is planar and strongly developed. The cleavage in the sandstone is poorly developed on the inner part of the sandstone bed and curves and becomes much more strongly developed on the outer margin.

Explain how or why the following features formed, and **in each case** indicate whether the feature formed during the buckling phase of folding or during the subsequent homogeneous flattening phase:

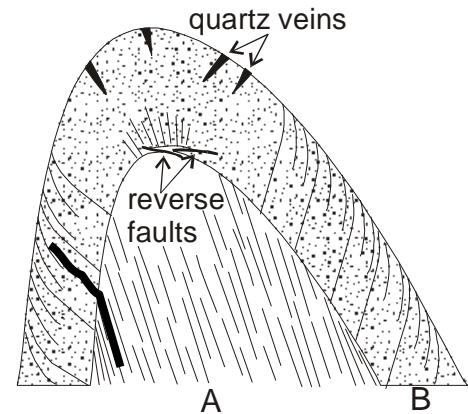


- a. the quartz veins; **(3 marks)**
- b. the small reverse faults and local cleavage development in the core of the fold hinge in the sandstone unit; **(3 marks)**
- c. the variable layer shape with a thickened fold hinge; **(3 marks)**
- d. the well-developed cleavage in the phyllite; **(3 marks)**

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QUESTION 8

With reference to the same outcrop as shown in the previous question, answer the following:

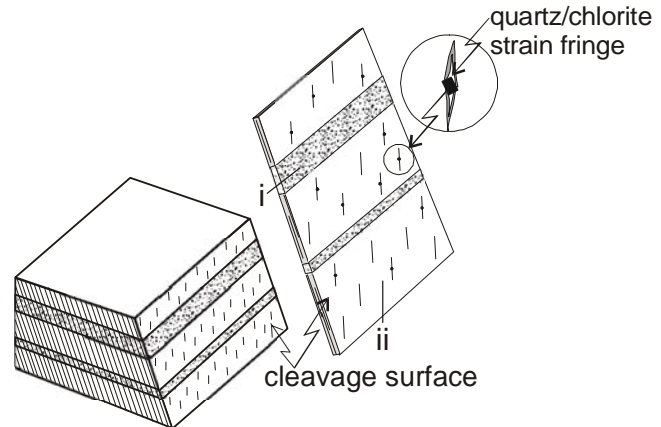


- a. The cleavage in the sandstone unit fans around the fold. What is the name for the abrupt change in cleavage orientation between the phyllite and the sandstone unit (shown by the heavy line) and why is the cleavage pattern in the sandstone layer curved? **(2 mark)**
- b. The cleavage in the sandstone is a spaced stylolitic cleavage. Cleavage (foliation) is a grain-scale fabric reflecting processes that induce contraction normal to the cleavage plane. Name and describe the process that formed this spaced stylolitic cleavage in the sandstone and explain how its formation induces contraction in the rock. **(4 marks).**

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QUESTION 9

A sample of the phyllite shows two prominent lineations on the cleavage planes (labelled **i** and **ii** in the figure at right). Lination **i** is defined by the trace of bedding on the cleavage surface. Lination **ii** is a faint alignment of fine mineral grains and elongate strain shadows around small magnetite crystals. Both lineations are interpreted to have formed during the deformation that produced the folds in the area.



- a. Using a **genetic** classification, what type of lineation is the one marked (**i**)? **(1 mark)**

- b. What type of structural information would lineation (**i**) yield? **(2 marks)**

- c. Using a **genetic** classification, what type of lineation is (**ii**)? **(1 mark)**

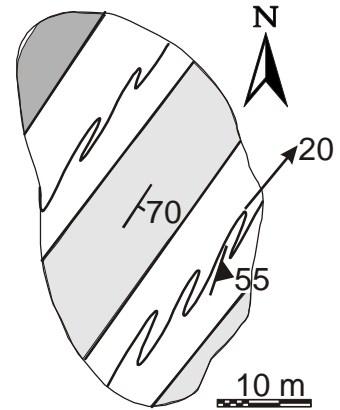
- d. What type of structural information would lineation (**ii**) yield? **(2 marks)**

- e. What type of structural information would the cleavage yield? **(2 marks)**

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QUESTION 10

Examine the sketch of a small outcrop shown in the figure. Strike and dip symbols show the orientation of bedding and of the axial plane of small folds in the outcrop. The arrow symbol shows the plunge of the small-scale folds. Larger folds are known to exist in the region.

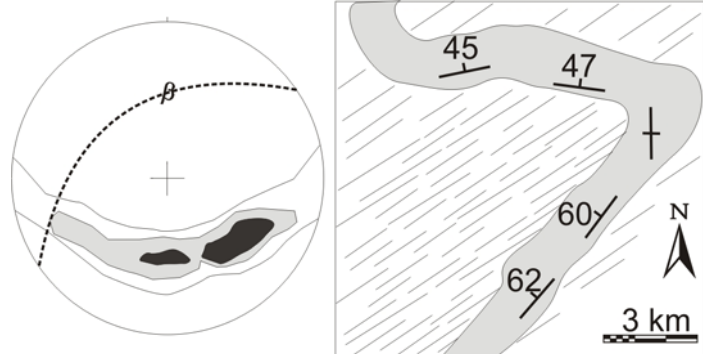


- a. What information in the outcrop indicates that you are on the limb of a larger fold rather than in the hinge? What would occur in the hinge? **(2 marks)**
- b. Is this limb structurally upright or structurally inverted? Explain your answer. **(3 marks)**
- c. If you followed the beds to the southwest, away from this outcrop, what would be the next fold closure that you met: an antiform or a synform? Explain your answer. **(2 marks)**
- d. What would be the likely orientation (approximate plunge and plunge direction) of the hinge of this next fold? **(2 mark)**
- e. What would be the likely orientation (approximate dip and dip direction) of the axial plane of this next fold? **(2 mark)**
- f. What names would you use to describe the orientation of this fold: horizontal upright; plunging upright, plunging inclined, reclined, vertical, recumbent, or can't tell from this information? **(2 marks)**

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QUESTION 11

The figure shows a map of a folded unit in an area (with representative strike and dips of the bedding shown) and a contoured stereographic projection of poles to bedding from the area. The dashed line on the projection shows the orientation of the axial plane cleavage.

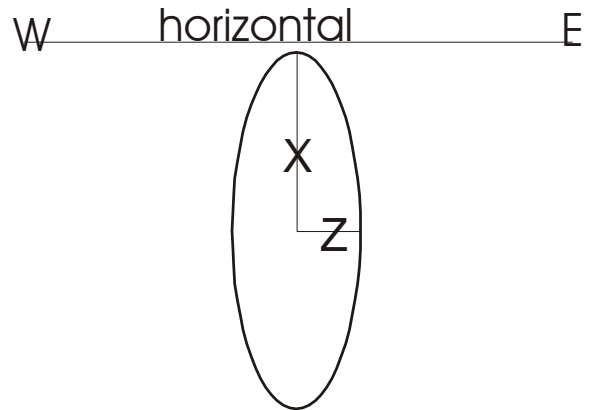


- a. What is the orientation (approximate plunge and plunge direction) of the fold hinge? **(2 marks):**
- b. Using **strike/dip/sense** notation, what is the approximate orientation of the axial plane? **(2 marks)**
- c. Is the fold cylindrical? Justify your answer. **(2 marks)**
- d. Is the fold symmetrical? Justify your answer. **(2 marks)**
- e. What names would you use to describe the orientation of this fold: horizontal upright; plunging upright; plunging inclined; reclined; vertical; recumbent; or can't tell from this information? **(2 marks)**
- f. Which **two** terms in combination most accurately describe the shape of the fold: gentle; open; tight; isoclinal; concentric; rounded; angular; chevron; kink **(2 marks)**
- g. Draw a line, marked XY, on the map showing the location of a cross-section that you would use to most accurately show the **folded** structure of the area. **(1 mark)**

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QUESTION 12

An estimation of the axial ratio (long axis/short axis) of the strain ellipse describing deformation in the Mount Isa lead-zinc mine is 2.78:1 (as shown in the figure). The long axis (X) is vertical and the short axis (Z) is horizontal (E-W).

**(4 marks)**

- a. What is the contractional Stretch in the Z direction assuming constant volume? (Show your calculation) **(4 marks)**
- b. What would have happened to a bed that is now dipping 20°E . Would it be folded or boudinaged? **(2 mark)**
- c. The estimated strain ellipse shown is approximately average for the deformation of the Mount Isa Inlier between Mount Isa and Cloncurry, 100km to the east. What was the original width of this 100km wide terrane before this deformation, based on your answer to question a, above? (Show your calculation). **(4 marks)**
- d. What is constrictional strain and what type of fabrics characterise rocks that have deformed by constrictional strain? **(4 marks)**