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GLY 254 STRUCTURAL GEOLOGY  
CLASS TEST

07-30 - 08-20, Monday 16<sup>th</sup> March 2009

Answer all questions.

Time allowed: 50 minutes

This test is composed of two sections: A: multiple choice =15 marks, B: short answers = 35 marks

N.B.: Questions 1-4 require you to draw on this question paper or answer in the boxes provided. It should be handed in together with your answer sheet.

NAME: Mokoete S.P. STUDENT NUMBER: 21522771

Part A: Multiple Choice.

Question 1: Examine the following two columns of terms. Using a tie line, match each term in the left hand column with a term to which it most closely relates in the right hand column. A non-geological example is shown. Use a ruler to make neat tie lines!

Steering Wheel	Horizontal axial plane ✓
Pseudotachylite	Normal Fault ✓
Ultramylonite	Reverse Fault ✓
Cataclasite	Ductile Shear zone ✓
Recumbent fold	Motor car
Microolithon	Shear Zone ✓
Hanging wall block moves down dip	Meteorite Impact ✓
Hanging wall block moves up dip	Brittle faulting ✓
Ribs and Hackles	Strike-slip faults ✓
Riedal Shears	Joint planes ✓
SC foliation	Cleavage ✓

10

Question 2: Examine the following diagram:

(10 marks)

left-handed strike slip	a	b	Normal slip
Right handed strike-slip	c	d	
Normal dip fault	e	f	oblique
	g	h	left handed strike slip - Reverse

- 2a.) Which of the illustrated faults is a left-handed strike-slip fault?
- 2b.) Which of the illustrated faults is a normal-slip fault?
- 2c.) Which of the illustrated faults is an oblique-slip left-handed-normal fault?
- 2d.) Which of the illustrated faults is a right-handed strike-slip fault?
- 2e.) Which of the illustrated faults is a reverse-slip fault?

a	✓
b	✓
F	✓
c	✓
d	✓

(5 marks)

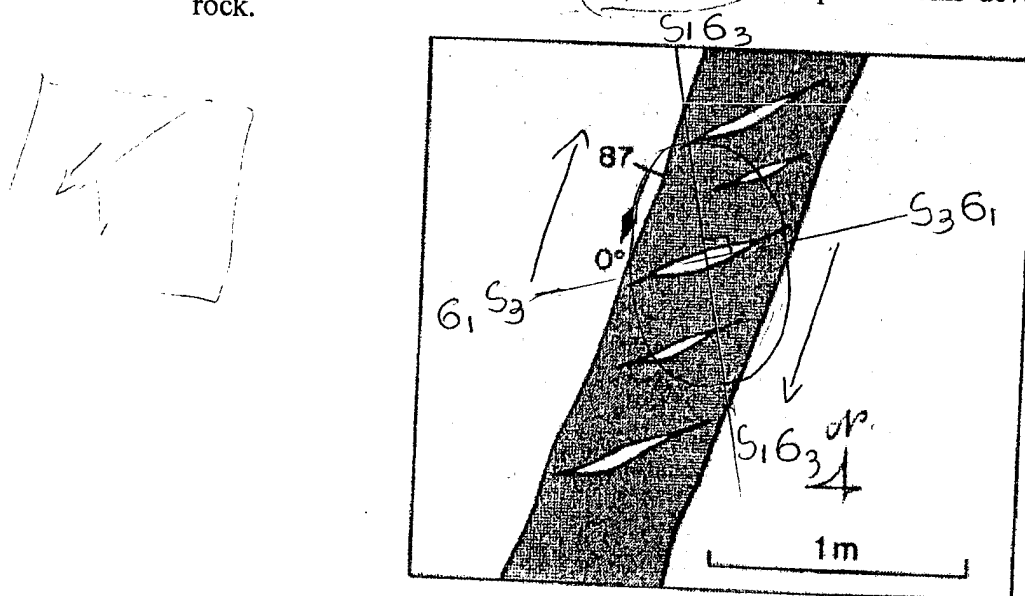
**Part B: Short Answers.**

**Question 3:** Examine the following photomicrograph, which shows a thin section of slate. Annotate the photomicrograph, labelling a cleavage plane and a microlithon zone. Show the shortening direction to which the slate has been subjected on the photomicrograph.



(4 marks)

**Question 4:** Examine the following field sketch from a geologist's notebook, which shows a large-scale map of a fault plane with quartz veins developed within the fault rock.



4a. What is the term which describes the orientation of these veins? (1 mark)

Coaxial veins

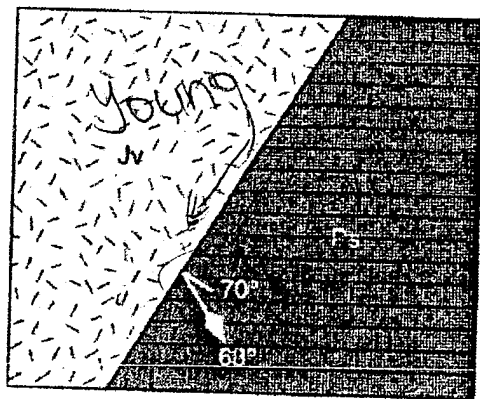
4b. Deduce the orientation of (i) the strain ellipsoid and (ii) the stress ellipsoid. Add them to the sketch above, including labelled strain and stress principle axes (5 marks)

4c. From the stress ellipse which you have drawn, deduce what type of fault is shown. What is the sense of movement? (4 marks)

Right handed ~~Fault~~ Strike slip.  
~~Fault~~ Fault.

Question 5: Examine the following map of Jurassic (Jv)- and Permian (Ps)-aged strata separated by a fault. The dip of the fault plane and trend and plunge of slickenside lineations are also indicated. What type of fault is illustrated? What components of dip- and strike-slip are present? The Permian period is older than the Jurassic period.

(10 marks)

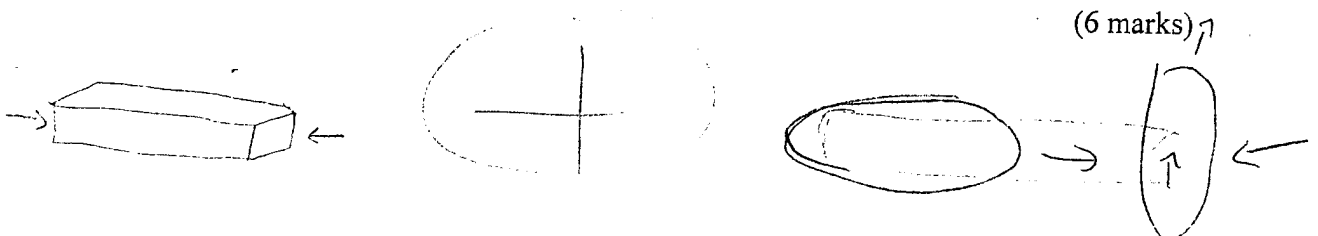


Left handed Thrust fault because dip is  $> 45^\circ$ . Direction of dip is given SE

Question 6: A stress field has the following orientation:  $\sigma_3$  horizontal in an E-W direction,  $\sigma_1$  horizontal in a N-S direction and  $\sigma_2$  vertical.

Which type of faults (according to Anderson's theory) will form in such a stress field? What are the strike(s) and dip(s) of the fault(s) that form?

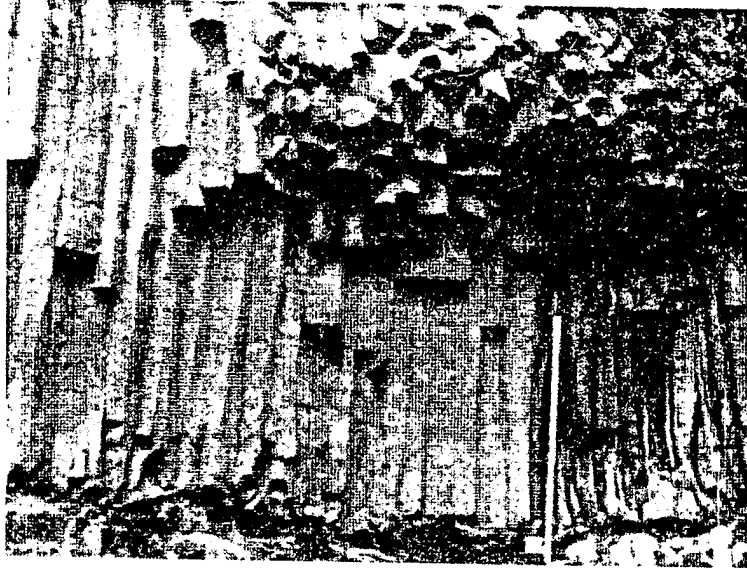
Sketch (draw stress and strain ellipses for the system) and discuss the types and orientations (strike and dip; trend and plunge) of all associated structures that can possibly form in association with the stress orientations.



(6 marks)

**Question 7:**

Examine the following field photograph of basalt:



What type secondary structure is shown in the photograph? Under what circumstances did this structure form?

(5 marks)

(Total = 50 marks)

This class test is worth 35% of the semester mark

Columnar Jointing

- associated with thermal stress.
- Contrast when cooling.
- Thermal stress by intrusions and burials.

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UNIVERSITY OF PRETORIA  
Department of Geology  
STRUCTURAL GEOLOGY -GLY 254  
SEMESTER EXAM

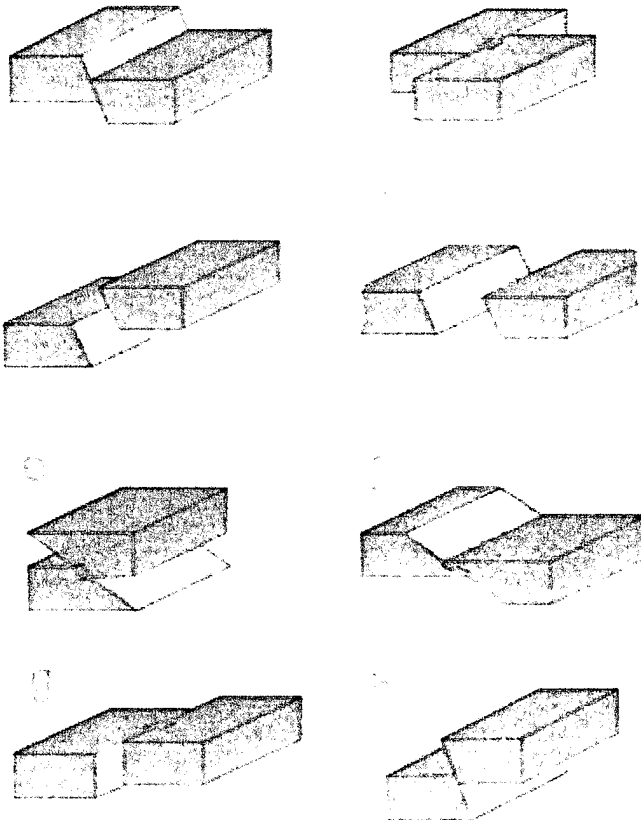
9<sup>th</sup> June 2009  
Time: 3 hours

Internal examiner: Dr A.J. Bumby  
External examiner: Prof P.G. Eriksson

Answer all questions. Use diagrams to help explain your answers.

NAME: \_\_\_\_\_ STUDENT NO: \_\_\_\_\_

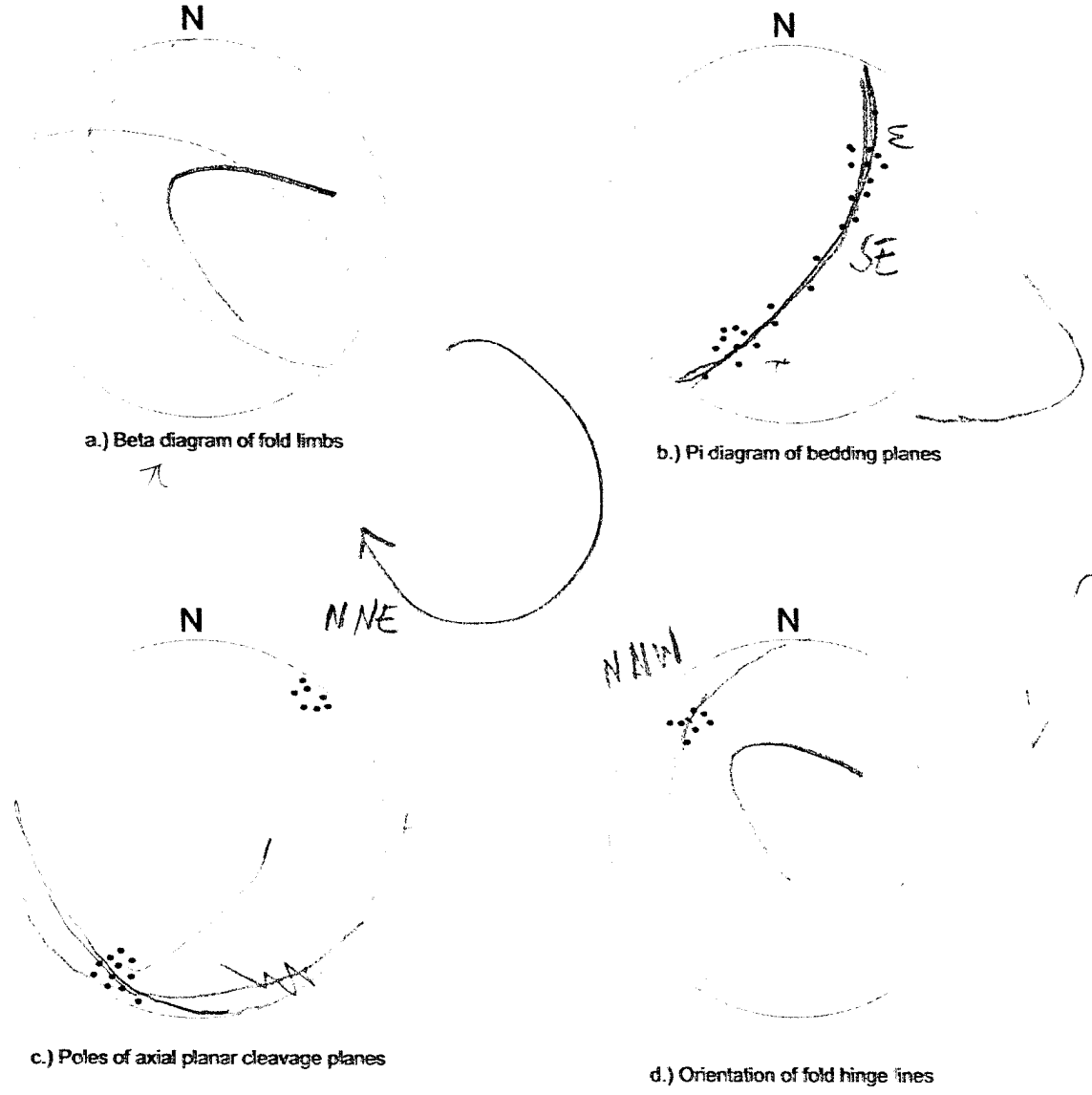
Question 1: Examine the following diagram:



Give a name to each of the faults illustrated, which accurately describes the sense of movement.

(10 marks)

**Question 6:** The following stereographic projections show orientation data of a number of different secondary structures recorded in a field area underlain by Ordovician sandstone. Write a brief report characterising the deformation in the area. Your report should give an indication of how each stereographic projection relates to the deformational history, and the number of different deformational events you think have affected the study area.



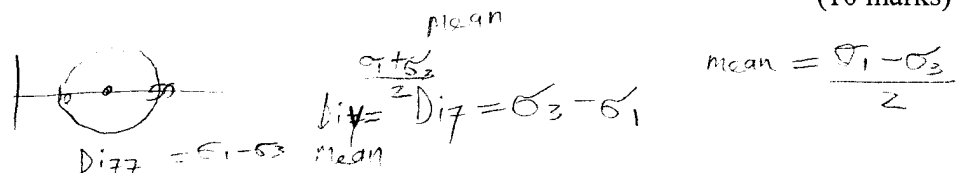
(20 marks)

**Question 7:**

a.) A point in a rock is subjected to a confining pressure of 10 MPa, and a mean (hydrostatic) stress of 30 MPa. What is the value of  $\sigma_1$  under these conditions?

b.) Failure of the rock occurs when the value of  $\sigma_1$  given in your answer to section (a.) is reached. The resultant fault plane forms an angle of 30° to  $\sigma_1$ . What is the magnitude of normal and shear stress at the point of failure?

(10 marks)



**GLY 254 STRUCUTRAL GEOLOGY  
PRACTICAL TEST  
STEREOGRAPHIC PROJECTIONS  
8-30 – 9-20, Tuesday 13<sup>th</sup> March 2009**

**Answer all questions.  
Time allowed: 50 minutes**

**YOU will need: Schmidt Stereonet, Drawing Pin, Pencils and coloured pencils.  
PROVIDED: Tracing Paper**

You have been asked by a mining company to compile a report on the geometry of a saddle reef ore deposit. A saddle reef ore deposit typically forms along the hinge line of a fold, where tension fractures allow ores to be precipitated from mineralised hydrothermal fluids (see Figure 1). As head of the project, you despatched your staff to prepare a geological map of the project area, including a record the orientations of bedding planes. The map shows that dominant lithologies in the area are Ordovician limestone, which host the ore bodies, overlain by Cretaceous sandstone.

**The compiled map is shown below in Figure 2:**

**A. Plot the poles to bedding for the *Ordovician* strata, construct a  $\pi$ -circle and determine the fold axis of the fold using the available bedding data.**

(40 marks)

**B. Answer the following questions:**

1. Is the fold a cylindrical fold? What factor determines your answer? ✓

(5 marks)

2. If the reefs exposed at the surface are to be mined, at what orientation should a tunnel be dug to follow the line of the reefs at depth? ✓

(10 marks)

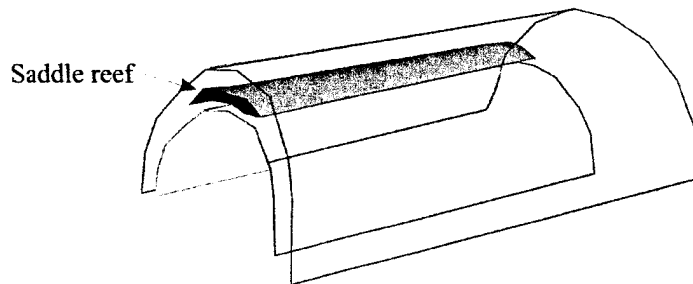
3. Label the poles of the East and West limbs on your stereonet. What is the approximate inter-limb angle?

(10 marks)

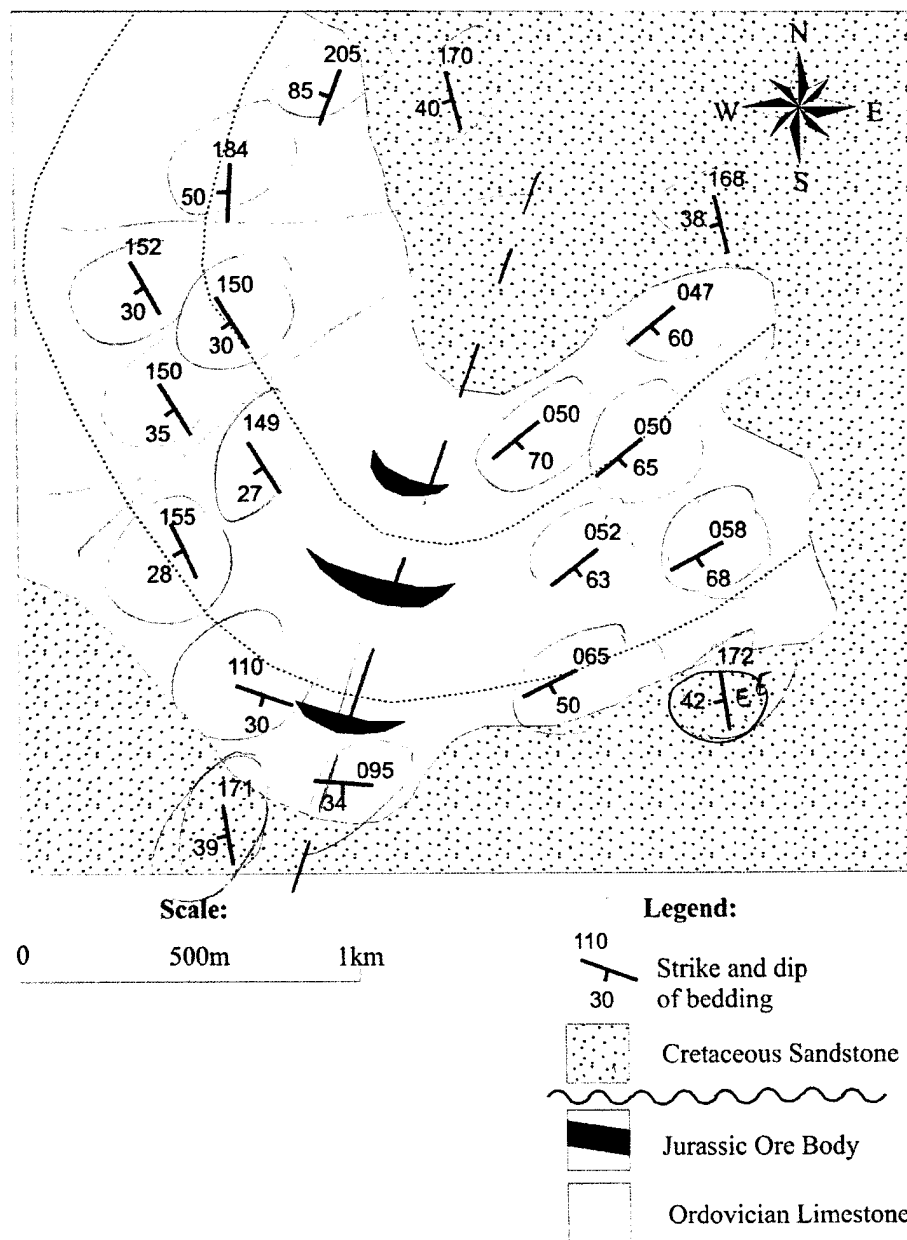
✓ 4. Use the stereonet to give an approximate orientation of the axial plane of the fold.

(10 marks)

**Figure 1: Diagram showing the form of Saddle Reef deposits**



**Figure 2: Geological Map of the Target area**





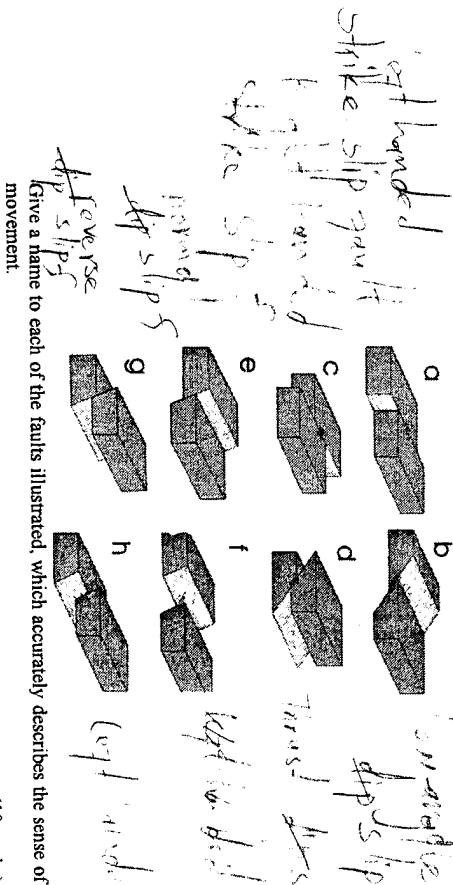
This test is composed of two sections: A: Short answers = 80 marks, B: Long answer = 20 marks

Answer all questions in section A and one question from section B.  
Note that questions 6, 7, 8 and 9 require you to write in this question booklet. It should be handed in together with your answer book.

NAME: \_\_\_\_\_ STUDENT NO: \_\_\_\_\_

Section A: Short Answers

Question 1: Examine the following diagram:



(10 marks)

Question 2: Write short, illustrated notes describing the differences between each of the following terms:  
a) Angular unconformity b) Non-conformity c) Disconformity

(10 marks)

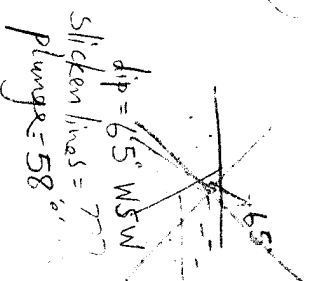
Question 3: Write brief illustrated notes on any five of the following terms, all of which apply to various types of fabric:  
a) Microfolding b) Axial planar cleavage c) Crementation cleavage  
d) Boudin e) Sigmoidal foliation f) Pressure solution g) Augen gneiss

(10 marks)

Question 4: Write a paragraph describing the differences between slaty cleavage, schistosity and gneissic banding. How do these fabrics form in relationship to the stress field? Use diagrams to help explain your answer.

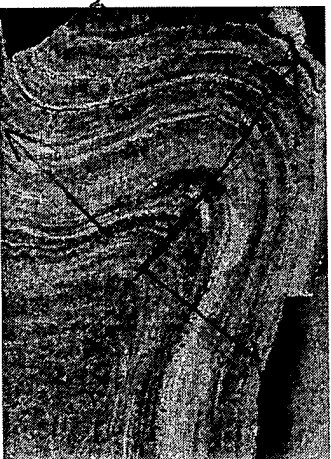
(10 marks)

Question 5: Examine the following sketch map, which shows the orientation of a fault plane and slickenside lineations. Give a descriptive name to the fault in order to describe the direction(s) of movement along the fault plane. Note that the Carboniferous predates the Jurassic.



(6 marks)

Question 6: Examine the following fold. Draw in about 10 dip isogons on the fold. Based upon these dip isogons, how would you categorise this fold?



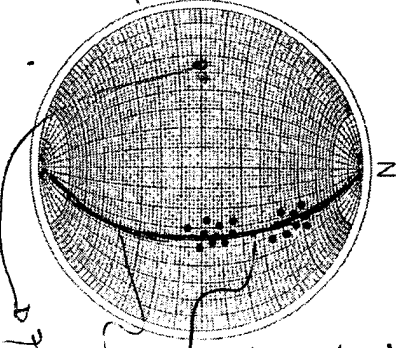
(4 marks)



Thickness of layers are not =

not sure of layer thickness  
asymmetric, elliptical, similar to...  
concentric, isoclinal

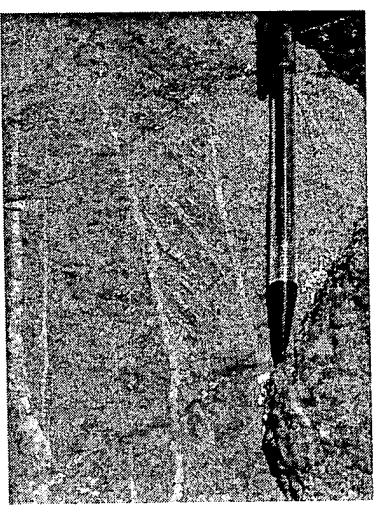
Question 7: A geologist working in the field was sent out to measure the orientation of bedding planes on the limbs of a large-scale fold in Cambrian strata. The geologist plotted the data in the following stereographic projection. Write a short paragraph giving as much detail as you can about the geometry of the fold, based upon what the stereographic projection shows.



- It is cylindrical  
- orientation of fold axis  
- The 2 limbs  
- symmetry  
- interlimb  
-  $\pi$  diagram =  $55^\circ$

(10 marks)

Question 9: Examine the following field photograph.

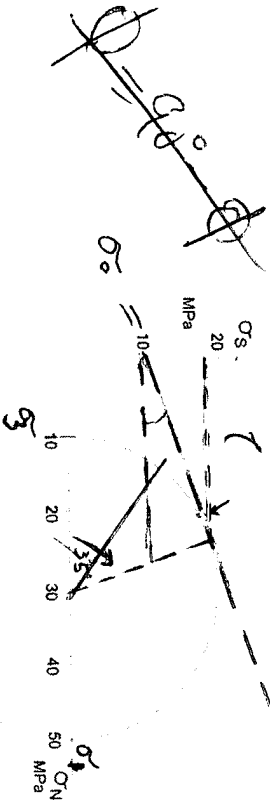


What type secondary structure is shown in the photograph? Under what circumstances did this structure form? What kinematic information can you deduce from this exposure? Use sketches with strain ellipses to help illustrate your answer. (10 marks)

Section B: Long Answers.

N.B. Write an essay on only ONE of the following questions:

Question 8: N.B. you will need a protractor to fully answer this question. Examine the following Mohr stress diagram, which shows the result of a triaxial compressive strength test on a piece of limestone. What was the confining pressure? What value of  $\sigma_1$  led to failure? What was the differential stress? Assuming that the cohesive strength ( $\sigma_0$ ) of the rock is 10MPa, and that sinistral faulting of the rock took place at an angle of  $35^\circ$  to the  $\sigma_1$  direction, what values of normal and shear stress at the fault surface led to failure? What is the angle of internal friction ( $\phi$ ) of the rock?



Conf. Pres. = 10MPa =  $\sigma_3$   
 $\sigma_1 = 50MPa$   
Differ.  $\sigma = \sigma_1 - \sigma_3$   
= 50 - 10 = 40MPa

Mean  $\sigma = \frac{\sigma_1 + \sigma_3}{2} = 30$   
Differential  $\sigma = \frac{\sigma_1 - \sigma_3}{2} = 20$

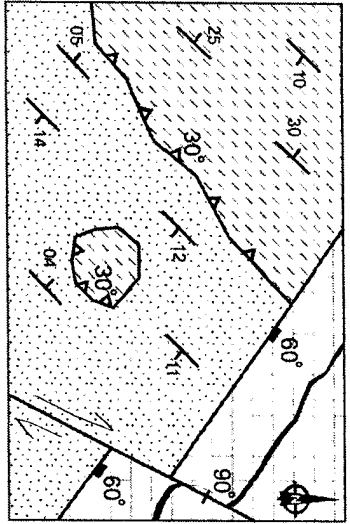
Question 11: Write a paragraph describing the differences between brittle and ductile deformation. What are the different variables that can govern whether rock behaves in a brittle or ductile manner? (20 marks)

Question 12: Examine the following geological map. Write a short report to describe the geological history of the area. In your report, make use of Anderson's theory of faulting to account for the history of faulting in the area shown on the map. How might other structures and the sedimentary record indicated on the map relate to the faulting? (20 marks)







Internal friction =  $(\phi) \neq$   
 $\sigma_c = \sigma_0 - \sigma_N \tan \phi$   
 $\tan \phi = \frac{\sigma_c}{\sigma_N - \sigma_0} =$

(10 marks)

$\sigma_N = \frac{(\sigma_1 + \sigma_3)}{2} - (\frac{\sigma_1 - \sigma_3}{2}) \cos 2\theta = (30 - 20 \cos 70^\circ)$   
 $\sigma_c = (\sigma_1 - \sigma_3) (\sin 2\theta) = 20 \sin 70^\circ$



Right hand side

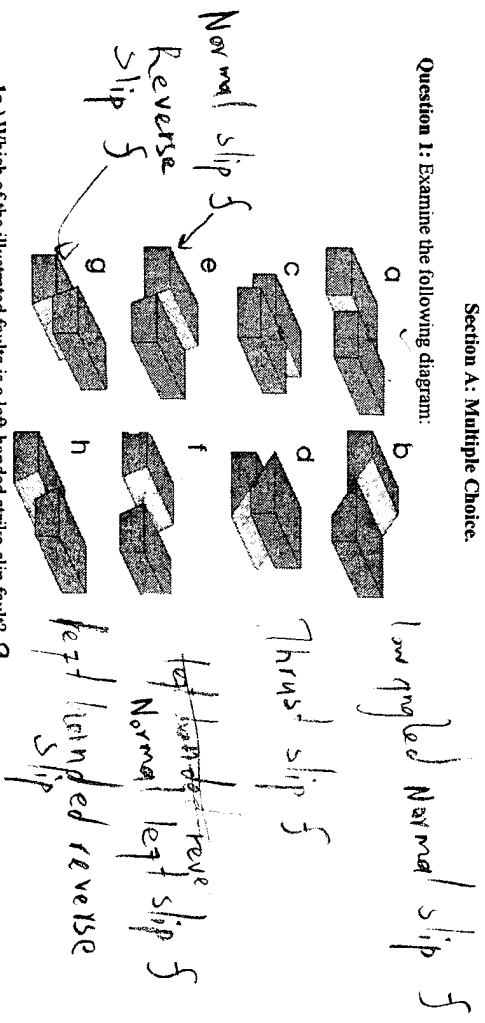
-  Dolerite dyke
-  Limestone
-  Sandstone
-  Shale
-  Strike and dip of bedding
-  Strike and dip of fault planes

Internal examiner: Dr A.J. Bumbay  
 External examiner: Dr R. van der Merwe

This test is composed of three sections: A: multiple choice =30 marks, B: short answers = 40 marks, C: Long Answers = 20 marks  
 Answer all questions in sections A and B, and one question from section C.

Section A: Multiple Choice.

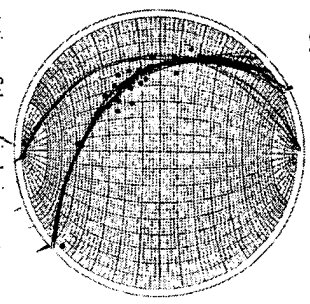
Question 1: Examine the following diagram:



- 1a.) Which of the illustrated faults is a left-handed strike-slip fault? **g**  
 1b.) Which of the illustrated faults is a normal-slip fault? **e**  
 1c.) Which of the illustrated faults is an oblique-slip left-handed-normal fault? **F**  
 1d.) Which of the illustrated faults is a right-handed strike-slip fault? **C**  
 1e.) Which of the illustrated faults is a reverse-slip fault? **g**

(10 marks)

Question 2: Examine the following stereographic projection, which shows the orientation of poles to bedding planes in an area of folded strata.



- 2a.) The approximate orientation of the fold circle is:  
 a.) 330° 75° NE b.) 125° 20° SW c.) 220° 60° SE d.) 145° 30° SW  
 e.) horizontal
- 2b.) The approximate orientation of the fold axis is:  
 a.) 310° 30° b.) 210° 10° c.) 05° 60° d.) 180° 75° e.) vertical
- 2c.) The approximate shortening direction for the folding is:  
 a.) 040°-220° b.) 145°-325° c.) 360°-180° d.) 090°-270° e.) 080°-260°
- 2d.) The largest amount of data was collected from  
 a.) NE-dipping bedding planes b.) SW-dipping bedding planes c.) Vertical bedding  
 d.) horizontal bedding e.) NW-dipping bedding planes

(8 marks)

Question 3: Examine the following list of features associated with secondary structures, and choose which answer is the best fit:

- a.) Flexural-slip folding b.) Passive folding c.) Plumose structure  
 d.) Ultramylonite e.) Pseudotachylite f.) Slickenside lineations g.) Horizontal axial plane
- 3a.) Which would you expect to find associated with a meteorite impact? **c**  
 3b.) Which would you expect to find associated with a brittle fault? **f**  
 3c.) Which would you expect to find associated with a joint surface? **c**  
 3d.) Which would you expect to find associated with shallow-level folding? **A**  
 3e.) Which would you expect to find associated with ductile shearing? **d**  
 3f.) Which would you expect to find associated with recumbent folds? **g**

(12 marks)

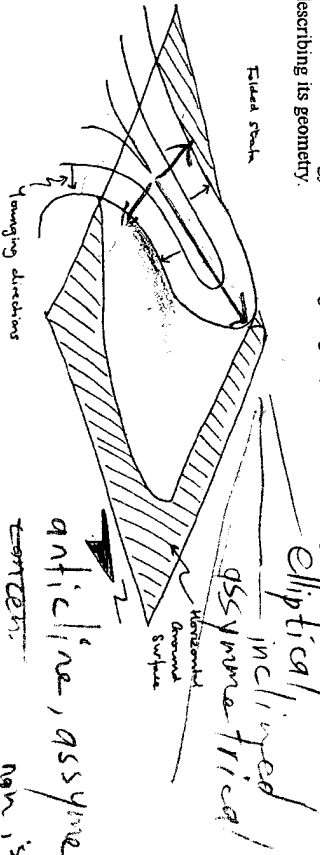
**Section B: Short Answers.**

**Question 4:** Write brief illustrated notes on any *four* of the following terms, all of which apply to shear zones:

- a) SC foliation - *shear zone*
- b) Porphyroclasts as indicators of sense of shear - *relics of porphyroclasts occur under*
- c) Sheath folds - *formed by strain*
- d) Plane strain - *formation of shear zones*
- e) Sigmoidal foliation - *crystallize*
- f) Progressive deformation - *form porphyroclasts*

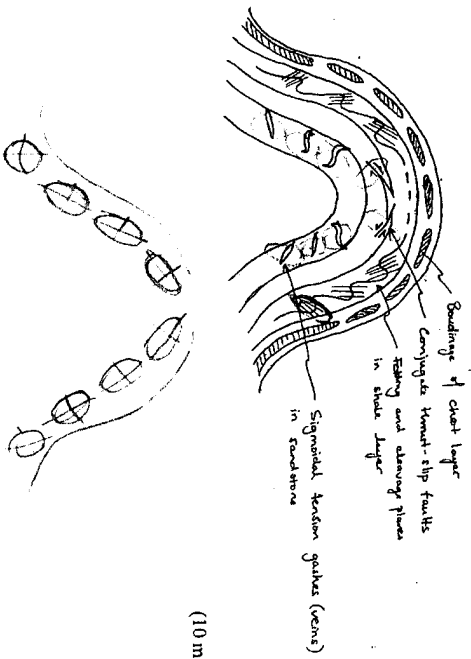
(12 marks)

**Question 5:** Examine the following field sketch of a folded sequence of strata. Using the established terminology of structural geologists, write a short description of the fold describing its geometry:



(4 marks)

**Question 6:** Examine the following field sketch, which shows a concentric fold, composed of layers of strata with contrasting physical properties. A variety of labelled structures appear on the limbs of the fold. Sketch the fold in your answer book, and annotate it with a series of strain ellipses to show how the strain field varied around the fold. Explain how each of the listed structures formed in relation to the local strain field.



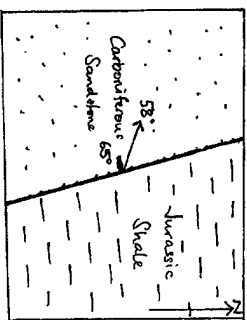
(10 marks)

**Question 7:** Use diagrams to show the orientation of the strain ellipsoid in each of the following cases:

- a) Axial planar cleavage
- b) Sigmoidal foliation in a shear zone
- c) Left-handed displacement across a brittle fault
- d) Normal fault

(8 marks)

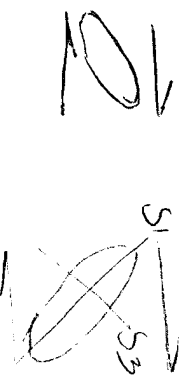
**Question 8:** Examine the following sketch map, which shows the orientation of a fault plane and slickenside lineations. Give a descriptive name to the fault in order to describe the direction(s) of movement along the fault plane. Note that the Carboniferous predates the Jurassic.



(6 marks)

*oblique right reverse slip f*

**Question 9:** Examine the following field sketch.



What type secondary structure is shown in the photograph? Under what circumstances did this structure form? Use sketches with strain ellipses to help illustrate your answer. (5 marks)

enclaves, v. sigmoidal quartz  
vertical shear zone

**Section C: Long Answers.**

**N.B. Write an essay on only ONE of the following questions:**

**Question 10:** The San Andreas Fault and 'Basin and Range' province of Southeastern USA are characterised by strike-slip and normal faulting respectively. Write an essay briefly discussing how the configuration of the North American, Farallon and Pacific plates since the Eocene has resulted in faulting in these areas (10 marks). Using Anderson's theory of faulting, relate the stress conditions in these areas to the type of faulting observed (10 marks). (20 marks)

**Question 11:** What is a Mohr diagram? Discuss the construction of the Mohr diagram and then show how this diagram is used to illustrate the behaviour of rocks in tensile, compressive-tensile, and compressive strength tests. (20 marks)

**Question 12:** Write an illustrated essay describing how you might make use of Rampelli's rule in mapping an area of complex deformation with poor outcrop (10 marks). If the area exhibits complex folding, what types of data will you collect to describe the folds, and to determine their geometry? What technique(s) will you use in your structural analysis of these folds? Describe the techniques (10 marks). (20 marks)

**(Total = 90 marks)**

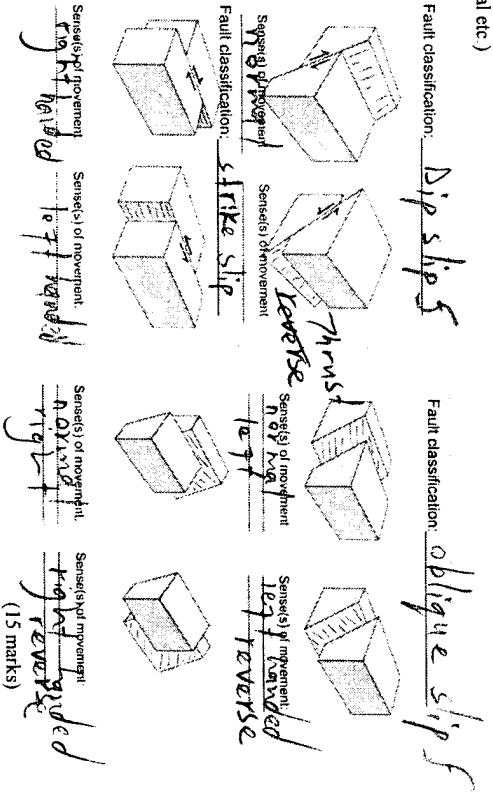
Internal examiner: Dr A.J. Bunby  
External examiner: Prof P.G. Eriksson

This test is composed of two sections: A: Short Answers = 40 marks, B: Long Answers = 30 marks  
Answer all questions in sections A, and two questions from section B.

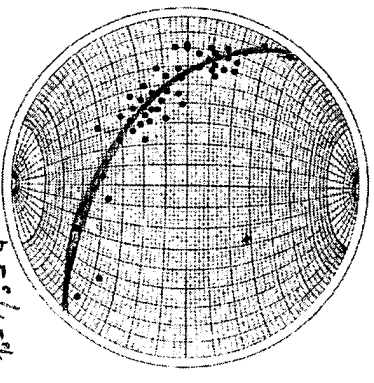
NAME: \_\_\_\_\_ STUDENT NO: \_\_\_\_\_

Section A: Short Answers.

**Question 1.** Examine the following diagram, which shows a block diagrams with a variety of faults. The direction of fault block movement is indicated by slanted lines developed on the fault plane. Classify the faults according to whether it is they are dip-, strike- or oblique-slip faults, and give the sense of movement (e.g. normal, left-lateral etc.)



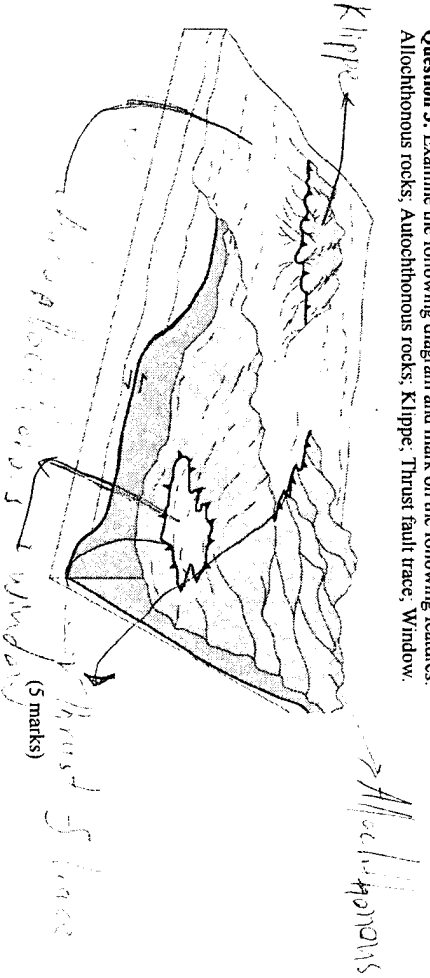
**Question 2:** Examine the following stereographic projection, which shows the orientation of poles to bedding planes in an area of folded strata:



- Estimate what the orientation of the  $\pi$ -circle is
- In relation to your answer in (a.) above, what is the orientation of the fold axis?
- What is the orientation of the  $\sigma_1$  axis, the  $\sigma_2$  axis and the  $\sigma_3$  axis? 135°/45°SW
- Based on the information given in the stereographic projection, what could you conclude about the geometry of the fold(s)? Your answer should include a description of the plunge and the symmetry of the fold(s), and the whether the fold is likely to be upright or overturned. Draw an orientated 3D sketch to illustrate these geometrical characteristics

(10 marks)

**Question 3:** Examine the following diagram and mark on the following features: Allochthonous rocks, Autochthonous rocks, Klippe, Thrust fault trace, Window.

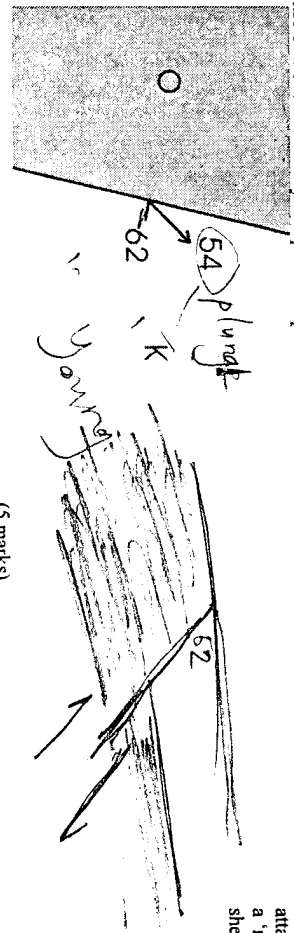


**Question 4:** Examine the following page from a geologist's field notebook, which shows a sketch map of a small outcrop of granitic with approximately spherical xenoliths of mafic rock.



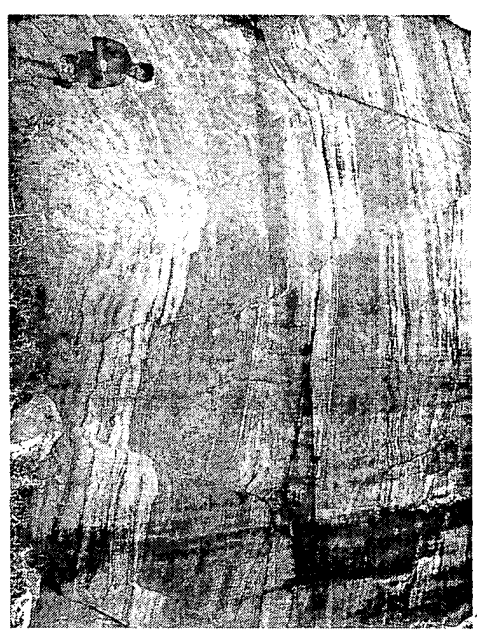
What deformation do you think the geologist has sketched? Annotate the field sketch by adding at least four orientated strain ellipses in the box on the left to show how strain varies from south to north through the area

**Question 5:** Examine the following map, which shows Ordovician strata (O) and Cretaceous strata (K) in contact along a fault. The strike, dip and dip-direction of the fault plane are indicated. What type of fault is shown? Ensure that in your answer you give an indication of the sense of movement of any component slip directions.



(5 marks)

**Question 6:** Examine the following photograph, which shows a cliff section of sandstone. What secondary structures do you see in the photograph. In what sort of plate tectonic environment do you think these structures might have formed?

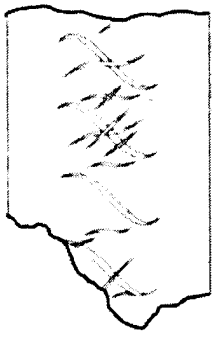


(5 marks)

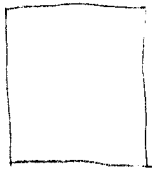
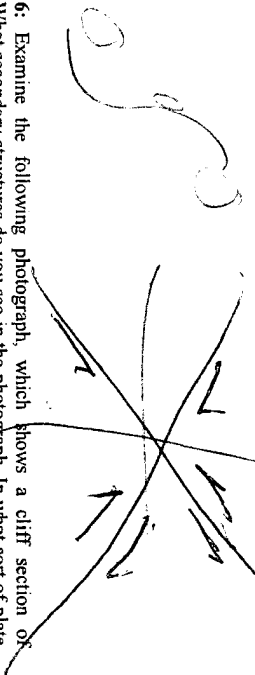
**Question 7:** A stress field has the following orientation:  $\sigma_1$  horizontal in an E-W direction,  $\sigma_2$  horizontal in a N-S direction and  $\sigma_3$  vertical. Which type of faults (according to Anderson's theory) will form in such a stress field? What are the strike(s) and dip(s) of the fault(s) that form? In what sort of plate tectonic environment might you expect this type of fault? Explain your answer.

(10 marks)

**Question 8:** Examine the following field sketch, which shows sets of veins outcropping within a shear zone. Draw a series of sketches to help explain how these veins have attained this shape. Assuming that the outcrop drawn is horizontal (i.e. you are looking in a 'map' view. North is to the top), use the diagram to determine the sense of shear of the shear zone. Illustrate your sense of shear by drawing a suitable stress ellipse.



(10 marks)





**Section B: Long Answers.**

**N.B. Write an essay on only TWO of the following questions:**

**Question 9:** You are in the field examining outcrops of folded Cambrian sedimentary rocks. What types of data will you collect to describe the folds, and to determine their geometry? What technique(s) will you use in your structural analysis of these folds? (Describe the techniques and use sketches to illustrate your methodology). (15 marks)

**Question 10:** You are mapping in an area where sedimentary and volcanic strata have been deformed by a nearby meteorite impact. In order to correctly assess the stratigraphy, you need to establish whether or not the strata have been overturned during the impact. What criteria would you look for to help establish the younging direction of the strata? Illustrate your answer. (15 marks)

**Question 11:** You are mapping in an area which has been subjected to extreme continental extension. At an outcrop, you collect a rock, which is an S-Tectonite with horizontal foliation planes, with mineralogy that suggest granulite-grade metamorphism. The hand-specimen is cut by normal faults. Write a short essay describing a credible tectonic history of the rock. Your essay should indicate which structures formed at what depth, and in which order they formed. Use illustrations where appropriate (15 marks)

**(Total = 100 marks)**

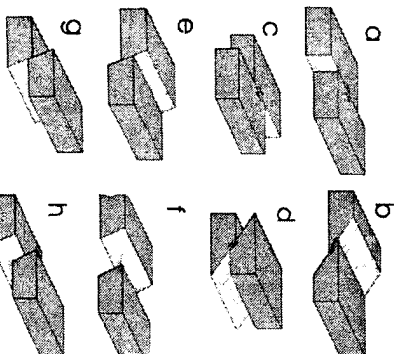
**In order to pass this module, you need to score at least 40% on this exam. The average of your score on this exam and the semester mark will be your final mark. The overall pass mark (average of this exam and semester mark) is 50%.**

Internal examiner: Dr A.J. Bunby  
 External examiner: Prof P.G. Eriksson

This test is composed of three sections: A: multiple choice =30 marks, B: short answers = 40 marks, C: Long Answers = 30 marks  
 Answer all questions in sections A and B, and two questions from section C.

Section A: Multiple Choice.

Question 1: Examine the following diagram:

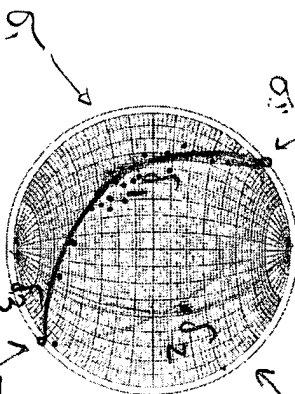


- 1a.) Which of the illustrated faults is a left-handed strike-slip fault? **a**  
 1b.) Which of the illustrated faults is a normal-slip fault? **e**  
 1c.) Which of the illustrated faults is an oblique-slip left-handed-normal fault? **f**  
 1d.) Which of the illustrated faults is a right-handed strike-slip fault? **c**  
 1e.) Which of the illustrated faults is a reverse-slip fault? **g**

(10 marks)



Question 2: Examine the following stereographic projection, which shows the orientation of poles to bedding planes in an area of folded strata.



- 2a.) The approximate orientation of the  $\pi$ -circle is:  
 a.)  $330^\circ$   ~~$45^\circ$~~  NE b.)  $175^\circ$   $20^\circ$  SW c.)  $220^\circ$   $80^\circ$  SE d.)  $145^\circ$   $30^\circ$  SW  
 e.) horizontal
- 2b.) The approximate orientation of the fold axis is:  
 a.)  $310^\circ$   $30^\circ$  b.)  $210^\circ$   $10^\circ$  c.)  $055^\circ$   $60^\circ$  d.)  $180^\circ$   $75^\circ$  e.) vertical
- 2c.) Which of the following is the most likely trend of the  $\sigma_1$  axis of the stress ellipsoid which relates to the following?  
 a.)  $040^\circ$ - $220^\circ$  b.)  $145^\circ$ - $325^\circ$  c.)  $360^\circ$ - $180^\circ$  d.)  $090^\circ$ - $270^\circ$  e.)  $080^\circ$ - $260^\circ$
- 2d.) Which of the following is the most likely orientation of the  $\sigma_2$  axis of the stress ellipsoid which relates to the folding?  
 a.)  $210^\circ$   $45^\circ$  b.)  $330^\circ$   $30^\circ$  c.)  $055^\circ$   $60^\circ$  d.)  $360^\circ$   $80^\circ$  e.)  $090^\circ$   $20^\circ$
- 2e.) Which of the following is the most likely orientation of the  $\sigma_3$  axis of the stress ellipsoid which relates to the folding?  
 a.)  $210^\circ$   $45^\circ$  b.)  $235^\circ$   $30^\circ$  c.)  $150^\circ$   $60^\circ$  d.)  $360^\circ$   $80^\circ$  e.)  $090^\circ$   $20^\circ$

(10 marks)

Question 3: Examine the following list of features associated with secondary structures:

- a.) Flexural-slip folding b.) Passive folding c.) Plumose structure  
 d.) Ultramylonite e.) Pseudotachyite f.) Slickenside lineations
- 3a.) Which would you expect to find associated with a meteorite impact?  
 3b.) Which would you expect to find associated with a brittle fault?  
 3c.) Which would you expect to find associated with a joint surface?  
 3d.) Which would you expect to find associated with shallow-level folding?  
 3e.) Which would you expect to find associated with ductile shearing?

(10 marks)

140 & 320

**Section B: Short Answers.**

**Question 4:** What criteria or observations would you use to distinguish between folds formed by flexural slip and those formed by passive folding?

(5 marks)

**Question 5:** Examine the following photomicrograph, which shows a thin section of slate. Make a sketch of the thin section, and label a cleavage plane and a microolithon zone. Write brief notes explaining what the cleavage and microolithon represent, and the significance. Show the shortening direction to which the slate has been subjected on your sketch.

(6 marks)



axial planar cleavage  
sigmoidal foliation in shear zone  
left-handed displacement across a brittle fault

**Question 6:** Use diagrams to show the orientation of the strain ellipsoid in each of the following cases:

- a) Axial planar cleavage
- b) Sigmoidal foliation in a shear zone
- c) Left-handed displacement across a brittle fault
- d) Normal fault

(8 marks)

**Question 7:** A stress field has the following orientation:  $\sigma_1$  horizontal in an E-W direction,  $\sigma_3$  horizontal in a N-S direction and  $\sigma_2$  vertical. Which type of faults (according to Anderson's theory) will form in such a stress field? What are the strike(s) and dip(s) of the fault(s) that form? Sketch (draw stress and strain ellipses for the system) and discuss the types and orientations (strike and dip, trend and plunge) of all associated structures that can possibly form in association with the stress orientations.

(6 marks)

**Question 8:** Examine the following field photograph of basalt:

roofing of basaltic magma  
columnar basalt



What type secondary structure is shown in the photograph? Under what circumstances did this structure form?

(5 marks)

**Section C: Long Answers.**

**N.B. Write an essay on only ONE of the following questions:**

**Question 9:** Discuss Anderson's fault classification with special reference to the assumptions and the types of faults that can form under different stress conditions. (15 marks)

**Question 10:** You are in the field examining outcrops of folded Cambrian sedimentary rocks. What types of data will you collect to describe the folds, and to determine their geometry? What technique(s) will you use in your structural analysis of these folds? (Describe the techniques). (15 marks)

**Question 11:** What is a Mohr diagram? Discuss the construction of the Mohr diagram and then show how this diagram is used to illustrate the behaviour of rocks in tensile, compressive-tensile, and compressive strength tests. (15 marks)

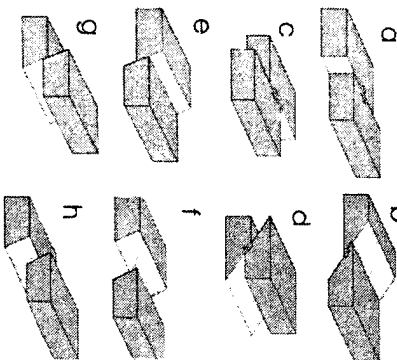
(Total = 75 marks)

Internal examiner: Dr A.J. Bumby  
 External examiner: Prof P.G. Eriksson

This test is composed of three sections: A: multiple choice =30 marks, B: short answers = 40 marks, C: Long Answers = 30 marks  
 Answer all questions in sections A and B, and two questions from section C.

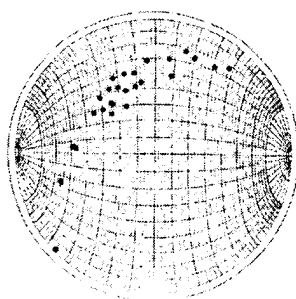
Section A: Multiple Choice.

Question 1: Examine the following diagram:



- 1a.) Which of the illustrated faults is a left-handed strike-slip fault? **a**  
 1b.) Which of the illustrated faults is a normal-slip fault? **e**  
 1c.) Which of the illustrated faults is an oblique-slip left-handed-normal fault? **f**  
 1d.) Which of the illustrated faults is a right-handed strike-slip fault? **f**  
 1e.) Which of the illustrated faults is a reverse-slip fault? **g**  
 (10 marks)

Question 2: Examine the following stereographic projection, which shows the orientation of poles to bedding planes in an area of folded strata.



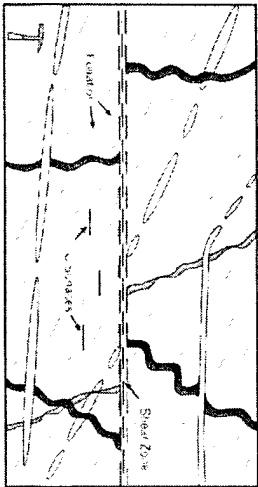
- 2a.) The approximate orientation of the  $\pi$ -circle is:  
 a.) 330° 45° NE b.) 125° 20° SW c.) 220° 60° SE d.) 140° 30° SW  
 e.) horizontal  
 2b.) The approximate orientation of the fold axis is:  
 a.) 310° 30° b.) 210° 10° c.) 050° 60° d.) 180° 75° e.) vertical  
 2c.) Which of the following is the most likely trend of the  $\sigma_1$  axis of the stress ellipsoid which relates to the folding?  
 a.) 040°-220° b.) 140°-320° c.) 360°-180° d.) 090°-270° e.) 080°-260°  
 2d.) Which of the following is the most likely orientation of the  $\sigma_2$  axis of the stress ellipsoid which relates to the folding?  
 a.) 210° 45° b.) 330° 30° c.) 050° 60° d.) 360° 80° e.) 090° 20°  
 2e.) Which of the following is the most likely orientation of the  $\sigma_3$  axis of the stress ellipsoid which relates to the folding?  
 a.) 210° 45° b.) 230° 30° c.) 150° 60° d.) 360° 80° e.) 090° 20°  
 (10 marks)

Question 3: Examine the following list of features associated with secondary structures:  
 a.) Flexural-slip folding b.) Passive folding c.) Plumose structure d.) Mylonite  
 e.) Pseudotachyite f.) Slickenside lineations

- 3a.) Which would you expect to find associated with a meteorite impact? **e**  
 3b.) Which would you expect to find associated with a brittle fault? **f**  
 3c.) Which would you expect to find associated with a joint surface? **c**  
 3d.) Which would you expect to find associated with shallow-level folding? **d**  
 3e.) Which would you expect to find associated with ductile shearing? **f**  
 (10 marks)

**Section B: Short Answers.**

**Question 4:** Examine the following diagram, which is a field-sketch of dykes of various orientations, and some other (labelled) structures exposed in a cliff face. Note that some of the dykes show folding, some have boudin structures, and others dykes show both folding and boudins:



Using the principle of progressive deformation, give an account of a single tectonic event, which might have led to the formation of all these structures. Ensure that you use diagrams to illustrate your answer:

**Question 5:** Examine the following photomicrograph, which shows a thin section of slate. Make a sketch of the thin section, and label a cleavage plane and a microfoliation zone. Write brief notes explaining what the cleavage and microfoliation represent, and the significance. Show the shortening direction to which the slate has been subjected on your sketch. (7 marks)



**Question 6:** Use diagrams to show the orientation of the strain ellipsoid in each of the following cases:

- a.) Axial planar cleavage
- b.) Sigmoidal foliation in a shear zone



- c.) Left-handed displacement across a brittle fault
- d.) S-C foliation

(8 marks)

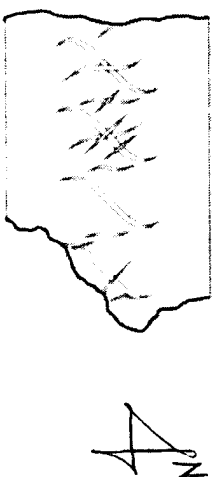
**Question 7:** Examine the following Field photograph taken from a shear zone. What is the name of the structure shown in the photograph? Draw a sketch to show how this structure might look in 3 dimensions Under what conditions might this structure have formed?



Shear fold  
high/low temp & low pressure  
(3 marks)

**Question 8:** A stress field has the following orientation:  $\sigma_1$  horizontal in an E-W direction,  $\sigma_2$  horizontal in a N-S direction and  $\sigma_3$  vertical. Which type of faults (according to Anderson's theory) will form in such a stress field? What are the strike(s) and dip(s) of the fault(s) that form? Assume that only the fault with a general E.N.E.-W.S.W. strike forms. Sketch (draw stress and strain ellipses for the system) and discuss the types and orientations (strike and dip; trend and plunge) of all associated structures that can possibly form in association with the stress conditions (6 marks)

**Question 9:** Examine the following field sketch, which shows sets of veins outcropping within a shear zone. Draw a series of sketches to help explain how these veins have attained this shape. Assuming that the outcrop drawn is horizontal (i.e. you are looking in a 'map' view: North is to the top), use the diagram to determine the sense of shear of the shear zone. Illustrate your sense of shear by drawing a suitable stress ellipse.



(7 marks)

**Section C: Long Answers.**

**N.B. Write an essay on only TWO of the following questions:**

**Question 10:** Discuss Anderson's fault classification with special reference to the assumptions and the types of faults that can form under different stress conditions. (15 marks)

**Question 11:** You are in the field examining outcrops of folded Cambrian sedimentary rocks. What types of data will you collect to describe the folds, and to determine their geometry? What technique(s) will you use in your structural analysis of these folds? (Describe the techniques). (15 marks)

**Question 12:** Which criteria can be used to determine (a) the sense of shear and (b) the amount of displacement in ductile shear zones? Discuss. (15 marks)

**Question 13:** What is a Mohr diagram? Discuss the construction of the Mohr diagram and then show how this diagram is used to illustrate the behaviour of rocks in tensile, compressive-tensile, and compressive strength tests. (15 marks)

**(Total = 100 marks)**

**In order to pass this module, you need to score at least 40% on this exam. The average of your score on this exam and the semester mark will be your final mark. The overall passmark (average of this exam and semester mark) is 50%.**