04-Geol-A4, Structural Geology

EXAM

INSTRUCTIONS: This Exam is THREE HOURS in length. 100 MARKS in total.

There are 3 Sections to this Exam:

This is a closed book exam however one textbook of the candidates' choice is permitted to be brought into the exam room and a Casio or Sharp calculator. Drawing instruments and two sheets onion paper need to be brought into the exam.

FOR PART 1 – Answer on this exam paper
FOR PARTS 2 and 3 Answer ALL questions in the ANSWER BOOKLETS provided

Be sure to clearly label the question number for each solution on every page including loose pages of tracing paper (onion skin).

BE SURE TO HAND IN COMPLETE EXAM QUESTION PAPER – PLACE INSIDE OF ANSWER BOOKLET

AIDS PERMITTED: ruler, scale bar, protractor, compass, thumbtack, calculator

AIDS PERMITTED: 2 pages of onion skin (tracing paper).

ALL PAGES must be handed in

PLEASE NOTE: If doubt exists as to the interpretation of any question, then, for any question requiring a written answer the candidate is urged to submit with the answer paper a clear statement of any assumptions made.

STUDENT NAME:
PART 1: (30 marks) Answer ALL questions on this question paper

1.1 (10 marks)
Answer all of the following T (True) or F (False):

____ Coaxial refolding can be the result of a single deformational event
____ A higher fracture frequency results in an decreased RQD
____ Normal and reverse faults dip approximately parallel to the syntectonic σ2
____ Transpressional deformation is associated with hydrothermal ore emplacement.
____ Bedding thickness must be preserved in a balanced section
____ In an ideal plastic material the strength is dependant of the magnitude of strain
____ Softer rock units within a sequence will have fewer joints than stiff rock units
____ Porphyroclasts preserve the pre-shear foliation
____ Coaxial strain does not involve shear
____ Paleotectonic strain directions are consistent with in situ stress measurements.

1.2 (10 marks)
Put the number of the structure or measurement on the left in the blank next to the most relevant kinematic or dynamic relationship on the right:

| Veins Parallel To M-Plane | 1 |
| Cleavage-Cleavage Intersection | 2 | \( 45 - \phi / 2 \) |
| Planar Sliding Failure | 3 | \( \frac{1}{2} (\sigma_1 + \sigma_3) - \frac{1}{2} (\sigma_1 - \sigma_3) \ll 0 \) |
| Andersonian Mechanics | 4 | \( S_1 / S_2 = S_2 / S_3 \) |
| Llistric Normal Faulting | 5 | \( \Delta \sigma_{hoi} = \{\mu / (1-\mu)\} \rho g \Delta h \) |
| Extension Joints | 6 | Dip > \phi |
| Tunnel Support Design | 7 | \( F_2 \) axis |
| Project from Map to Profile View | 8 | \( e_3 < 0, e_1 = e_2 > 0 \) |
| Plane Strain | 9 | \( x \ sin(\text{plunge}) \) |
| Fluid Pressure Increase | 10 | \( S_1 = 1 / S_3 ; S_2 = 1.3 \) |
| Erosional Stress Relief | 11 | \( Q = \text{RQD} / \text{Jn} x \text{Jr} / \text{Ja} x \text{Jw} / \text{SRF} \) |
| Chocolate Tablet Boudinage | 12 | |

Student Name:
1.3 (10 marks)

INCO's new Victor mine is being proposed to initiate mining at a minimum depth of 1700m in Grenville Metamorphics. The horizontal EW normal stress in the rock immediately below the ground surface have been measured to be 10 MPa. The NS horizontal stress at any depth is estimated to be 2/3 of the EW stress. It has been observed that the NS lithostatic stresses increase with depth (MPa/m) at a rate of 2x the rate of vertical stress increase.

a) What is the vertical stress at the top of the proposed Victor Mine.

b) Calculate the two principal horizontal stresses at this point and specify their direction.

c) What is the maximum stress difference at this depth and give the orientation of the plane in which it acts.

d) On a Mohr plot below, construct a Mohr circle for this plane. Label axes and this circle.

e) Plot the Mohr circle for the stresses acting in the horizontal plane.

f) What are the normal and shear stresses acting on a vertical plane striking NE.

g) Construction of the shaft has revealed a fault with a strike of 020 and a dip of 60 degrees. This fault shows signs of recent dip slip reverse movement. Is this currently an Andersonian fault? Explain.
PART II: (50 Marks)

Answer ALL questions in the answer booklet(s). If you start an answer and then decide to choose a different question, clearly cross out the unfinished answer. Otherwise answers will be marked in order from the first up to the maximum (i.e. first 7 answers for 2.1 and so on).

2.1 (3 marks each = 18 marks)

For ANY and ONLY 6 of the following, in one or two sentences and clear figures where appropriate distinguish clearly and completely between:

a) Porphyroblast and porphyroclast
b) Strike slip and strike separation
c) Listric and imbricate faulting
d) Flexural slip folding and passive similar folding
e) Growth twinning and mechanical twinning
f) Transpressional and simple shear deformation
g) Boudins and mullions
h) Prolate vs oblate deformation
i) Stiffness and ductility
j) Toppling and planar slip failure

2.2 (3 marks each = 12 marks)

Answer ANY and ONLY 4 of the following questions:

a) Where would you prospect for gold concentrations in a region of “active” folding of competent bedded strata. Explain with a sketch.
b) Explain two mechanisms by which tensioned rockbolts can increase the stability of sliding joint-bounded blocks and wedges
c) Explain how to resolve the fold axis for an F2 fold. Show on a sketched stereonet a general example of refolded L1 lineation.
d) What are the requirements for a Balanced Cross Section?
e) On a Ramsey diagram show a strain path for plastic shear strain accompanied by vein formation.
f) Illustrate with a Mohr sketch, plumose, hackled joint surface formation.
g) Describe two types of structural traps key to the formation of oil reserves.
h) Explain how dome and basin interference patterns form.
i) How does cleavage form?
2.3  (5 marks each 20 marks)

Answer ANY and ONLY 4 of the following questions in reasonable detail (2 -3 paragraphs). In addition, use Sketches where appropriate. (5 marks each)

a)  Describe and illustrate with a diagram at least 5 types of brittle structures associated with simple active folding of competent strata

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

c)  What are the typical elements of a rockmass classification scheme? How does each element impact on rock strength or excavation support requirements.

d)  Describe four different primary structures which can be used for determining the younging direction. Explain with a figure how this is determined in each case.

e)  Explain with text and figures the formation of undulose extinction, subgrain boundaries and mechanical twinning.

f)  Describe how confining pressure (depth), temperature, strain rate, chemistry and the presence of fluids affects the strength and ductility of geomaterials.

g)  Describe two typical interference patterns for polyphase folding. Illustrate the relationship between the two component folds in each case.
PART III: (20 marks)

**Do ONLY 1 of the following Questions (III.A.B.C)**

Place Answers in Answer Booklet AND/OR on Exam Paper as indicated. Clearly label the question # (including onion skins)

III.A (20 marks)

A typical marble (S.G. = 2.5) has a Mohr-Coulomb strength envelope corresponding to

\[ \tau_{\text{max}} = 40 \text{MPa} + \sigma_n \tan 35^\circ \]

Tensile strength is tested to be 5 Mpa

Rough pre-existing fracture surfaces in this limestone have been tested in direct shear to have the following strength:

\[ \tau_{\text{max}} = 10 \text{MPa} + \sigma_n \tan 30^\circ \]

a) Draw these two complete envelopes on a Mohr diagram. Fully label the diagram.

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The stresses at depth are isotropic (k=1). Due to stress concentration, the circumferential stress parallel to the wall of a circular tunnel in these conditions is known to be double the initial rock pressure.

b) If this is a horizontal hydro-tunnel connecting a reservoir with a power station and the tunnel is situated inside a mountain at a depth of 400m, what height of water (above the tunnel) in the reservoir will result in the formation of radial extension fractures in the tunnel wall?

c) What is the depth at which new fractures will form near the wall of a horizontal circular tunnel? Plot the Mohr circle (at the wall location) for the states before and after the tunnel excavation.

d) At what depth would the existing fractures be remobilized in shear adjacent to the wall?

e) Using the diagram from a), explain why the creation of new fractures near the excavation would result in a sudden release of stress (and strain). This is called a rockburst.
III.B (20 marks)

The fault shown below has slickenlines and striations measured with a pitch of 50 degrees. The sense of shear is not detectable from these features.

Using a graphical technique answer the following questions:

a) Plot all of the relevant features on a stereonet.
b) Give the pitch, in the fault plane, of the contact and of the vein.
a) Describe fully the kinematics of this fault.
b) What are the dips slip and strike slip components of movement?
c) A large ore bearing vein is located as shown in footwall. Find the continuation of this vein in hangingwall and locate it on the map.
d) What is the orientation of the M-plane in this case?
e) Were the fault and the vein formed by the same stress field? Explain your answer.

Scale = 1:1000
III.C 20 Marks

Three joints sets are mapped in a mining tunnel. The average strike/dip of each is:
1) 040/45 2) 270/50 3) 170/70

The tunnel has a flat back and a span of 10m

a) What would be the worst orientation (trend) for a tunnel in this rockmass (orientation leading to the largest demand for support)?

b) For a tunnel trending North-South, calculate the maximum height and weight of an unstable wedge that might form in this tunnel.

c) For the NS tunnel: If a standard grouted steel cable-bolt has a capacity of 500kN, how many bolts per square metre are required to achieve a factor of safety of 1.5 (capacity = 1.5 times the distributed weight)?

d) A survey is performed of tunnel roof structure along 2000m of preexisting tunnel. The trace length of Joint 2 in the roof is never observed to exceed 5m (it is not a persistent joint). As an geological engineer charged with risk analysis and optimizing support, how would this survey change your answer to question b) with respect to the maximum anticipated wedge.
APPENDIX (includes 2 sheets of onion skin)

Equal Angle Net