National Exams December 2019

18-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 a CLOSED BOOK EXAM.
   A Casio or Sharp approved calculator is permitted.
   A protractor, drawing compass and ruler are also permitted.

3. All questions constitute the complete exam paper. (100 marks)

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.

QUESTION A. (30 Marks)

True or False.
Answer T (True) or F (False) next to the number. ***[1 mark per correct answer]***

A1. Stress traction refers to the state of stress at a point.

A2. Mode 1 cracks formed in extension form perpendicular to σ_1.

A3. Layer thickness is the primary factor that dictates fold wavelength.

A4. In theory, flexural flow folding produces only Class 1b folds.

A5. Coaxial strain does not involve shear.

A6. Nonrigid deformation involves dilation and/or distortion.

A7. Mode 2 fractures have displacement perpendicular to the fracture front.

A8. The axial surface trace connects points of maximum curvature of a folded surface.

A9. Lines that represent the principal strain axes were perpendicular before the strain.

A10. Differential stress is the non-hydrostatic stress that tends to produce distortion.

A11. For ideally plastic material strain is linearly related to stress.

A12. Griffith's Law refers to failure by frictional sliding on a pre-existing plane of weakness in a rock.

A13. Nabarro-Herring creep involves the intra-crystalline movement of point defects.

A14. The same bedding contact can intersect the axial planar cleavage of a fold only once.

A15. An intersection lineation between bedding and cleavage provides the orientation of the axial surface.

A16. An edge dislocation is oriented parallel to the Burgers vector.

A17. A reclined fold has a hinge line that plunges perpendicular to the strike of a fold's axial surface.

A18. The stress tensor can be fully defined by 6 different components of stress.

A19. A sheath fold is a cylindrical fold formed in zones of high shear strain.

A20. Poisson's ratio expresses the ratio between the normal stress and the related elastic extension or shortening in the same direction.

Fill in the blanks ***[Each correctly filled in blank is worth 1 mark]***

A21. Name two mechanisms by which buckle folds form: _____ and _____.

A22. _____ is the apparent relative displacement related to a fault.

A23. _____ is the term for diffusion of material along grain boundaries.

A24. _____ connect points of equal inclination on the outer and inner bounding surfaces of a folded layer.

A25. _____ is a fault melt that freezes to glass.

A26. With regard to failure by frictional sliding, what does ϕ_f represent?_____.

A27. Please give the equation for the Coulomb Law of Failure: _____.

A28. Name two types of point defects: _____ and _____.

QUESTION B. (20 marks) ANSWER ONLY 5

Briefly explain the fundamental difference between the terms in each of the following groups. In many cases a well-labeled sketch will save many words. It is important to demonstrate the meaning of the terms in the answer:

(B1) Stress versus Strain */4*

(B2) Traction versus Stress Tensor */4*

(B3) Fold Axis versus Fold Hinge */4*

(B4) Fault Slip versus Fault Separation /4

(B5) Coaxial Strain versus Non-coaxial Strain /4

(B6) Point Defect versus Line Defect /4

(B7) Homogeneous Strain versus Heterogeneous Strain /4

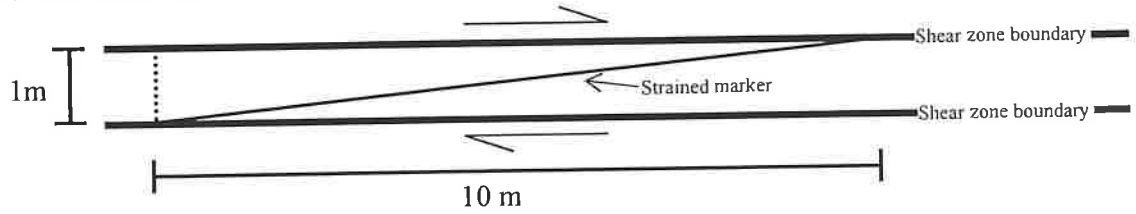
(B8) Joint versus Shear Fracture /4

(B9) Finite Strain versus Incremental Strain /4

(B10) Trend versus Rake /4

QUESTION C. (40 marks)

(C1) The shear zone below is 1m wide and has had approximately 10m of dextral slip.

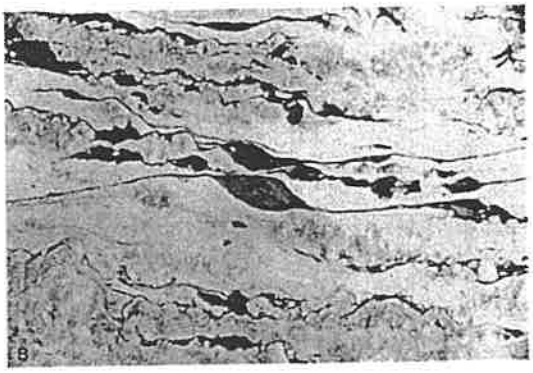


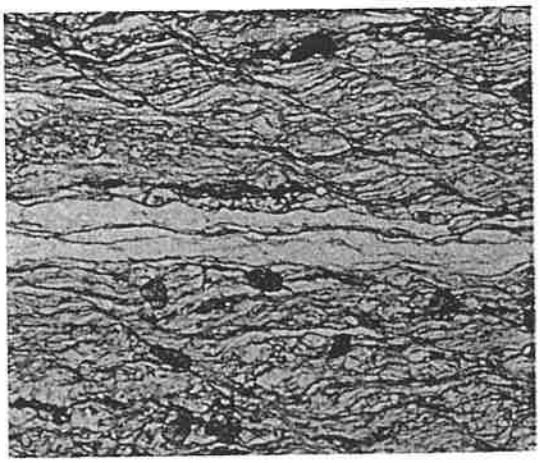
(a) What is the angular shear (ψ) and shear strain (γ) of the shear zone? {assume an initially perpendicular marker across the shear zone (i.e. dotted line) has had one end displaced 10m relative to the other} /2

(b) What is the elongation (e) of the offset marker? /2

(C2) Ductile faulting is recognized to be very common in the middle and deep crust.
Draw a ductile fault zone with an offset marker (e.g., a dike).
In the drawing, show a possible fabric trajectory across the zone with associated strain ellipses if the shearing is most intense in the centre and weakens outward from the centre of the shear zone. /4

(C3) For each of the images below, identify at least 1 shear sense indicator and name the sense of shear. /4





(C4) Anderson's theory of faulting provides a generally successful relationship between stress and strain for faulting. Anderson's theory predicts three basic fault types with specific orientations.

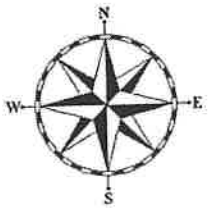
(a) Name three assumptions that Anderson's theory uses to restrict faults to three basic types? /3

(b) Show with labeled sketches the three basic fault configurations predicted by Anderson's theory. Show the angle they make with respect to the earth's surface, the orientation of the principal stress axes, and the relative sense of shear across the faults. /9

(C5) For questions **a**, **b**, **c** & **d** you have been given the following information:

Vertical max. principal stress ($\sigma 1$) = 100 MPa;
Horizontal min. principal stress ($\sigma 3$) = 20 MPa;
$\phi_f = 35°$;
Pre-existing plane of weakness dips 30° to the east

(a) Using an accurate line drawing, show the real-world configuration of the pre-existing plane of weakness and the orientation of the principal stresses, normal stress and shear stress acting upon this plane. Also indicate in your drawing the sense of shear that would develop along this plane if it failed. Would it be dextral or sinistral? */6*



For (b) and (c), use the fundamental stress equation to determine:

(b) the normal stress */2*

(c) the shear stress */2*

For (d) and (e) use the Coulomb Failure Law of Failure to answer the questions.

(d) For the pre-existing plane of weakness, calculate what the shear stress at failure must be. */2*

(e) i. Assuming dry conditions, will the plane fail according to your calculations above? Why? */2*

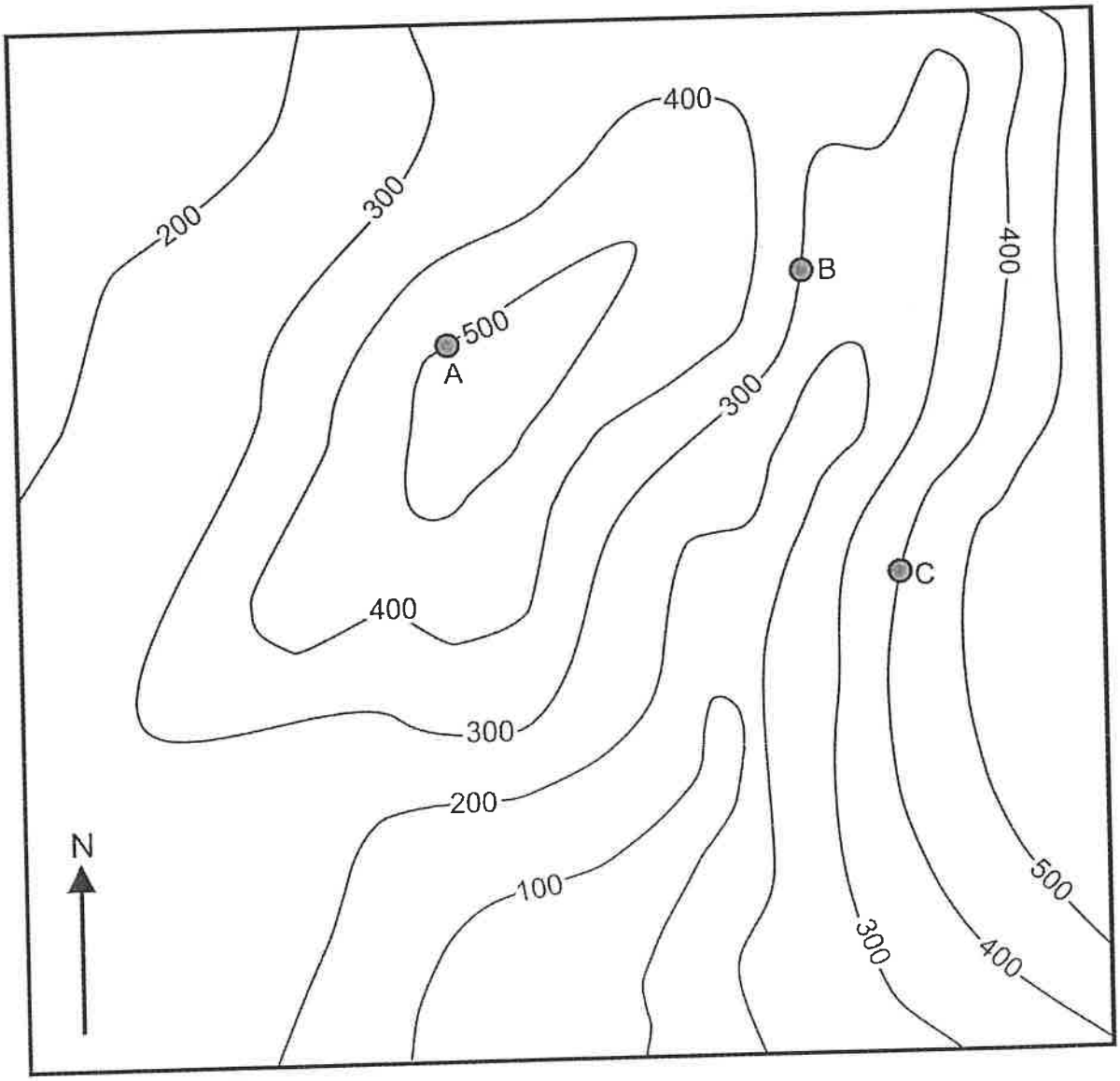
ii. If not, how much pore fluid pressure (Pp) would be required to cause failure? */2*

QUESTION D. (10 marks)

(D1) Using the map below – Points A, B and C are outcrops of a coal seam.

(a) Assuming the coal seam in perfectly planar, determine the attitude of the coal seam (i.e. strike and dip). /5

(b) Determine the outcrop pattern for the coal seam. /5



Scale 1 cm = 100 m