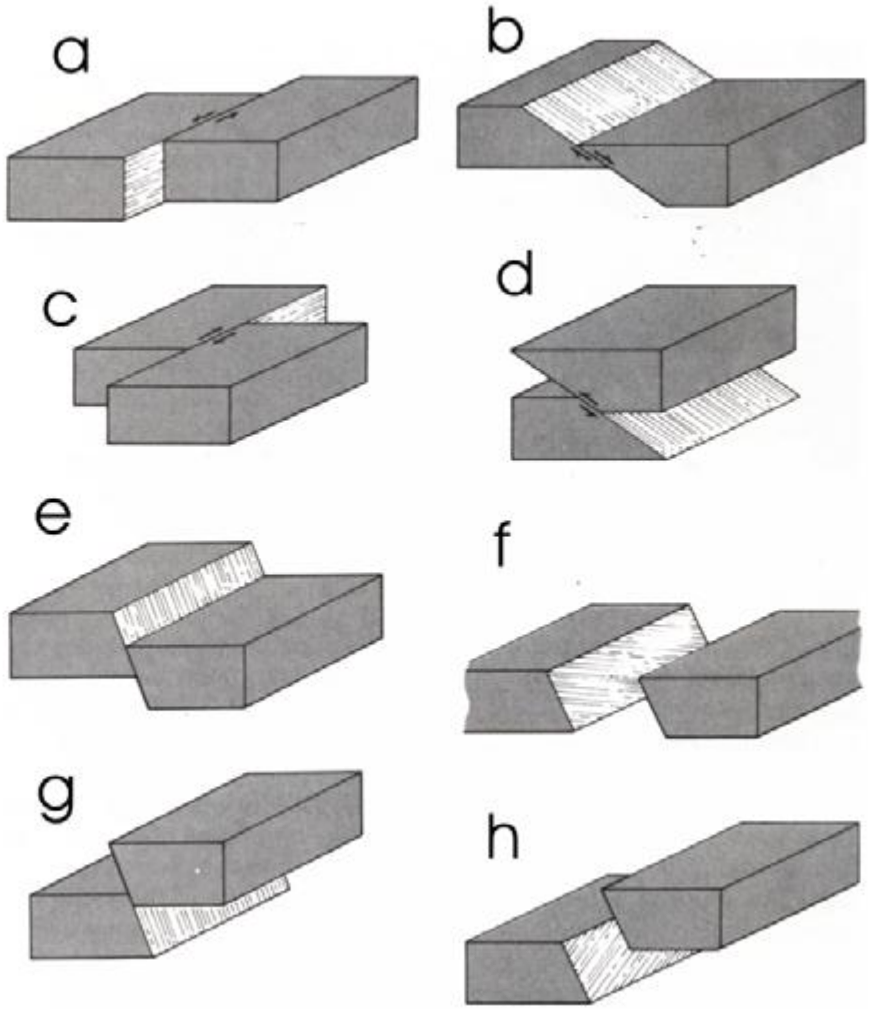
Question 1: Examine the following diagram:



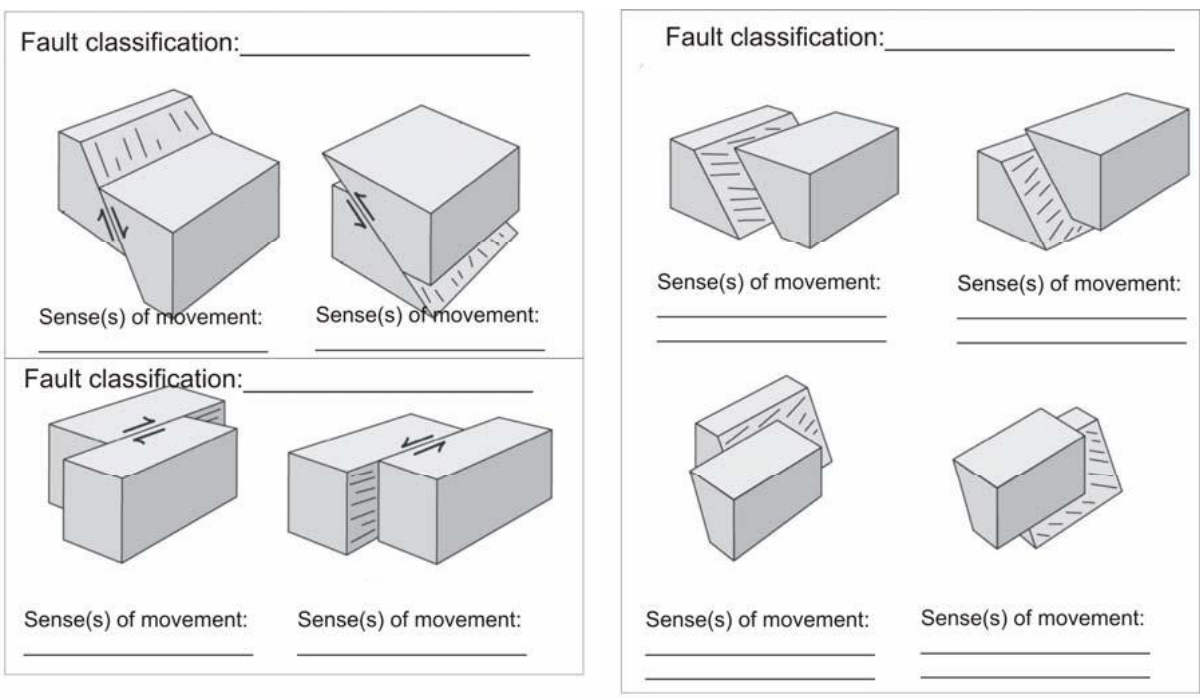
1a.) Which of the illustrated faults is a left-handed strike-slip fault? **= a**

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)

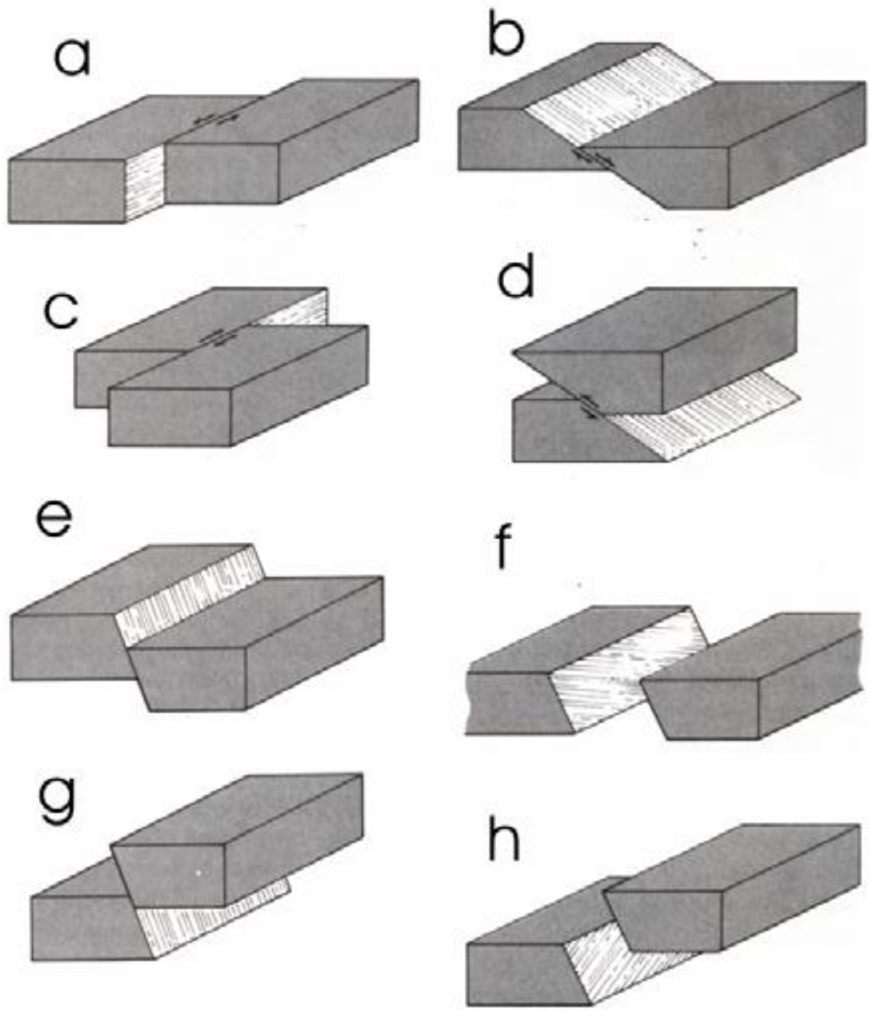
Question 1. Examine the following diagram, which shows a block diagrams with a variety of faults. The direction of fault block movement is indicated by slickenside lineations developed on the fault plane. Classify the faults according to whether it is they are dip-, strike- or oblique-slip faults, and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



(15 marks)

1. Dip slip: Normal-slip fault, Thrust-slip fault
2. Strike slip: Right-handed strike slip fault, Left-handed strike slip fault
3. Oblique slip: Normal left-slip fault, Left- handed reverse slip fault
4. : Normal right-slip fault, Right-handed reverse slip fault

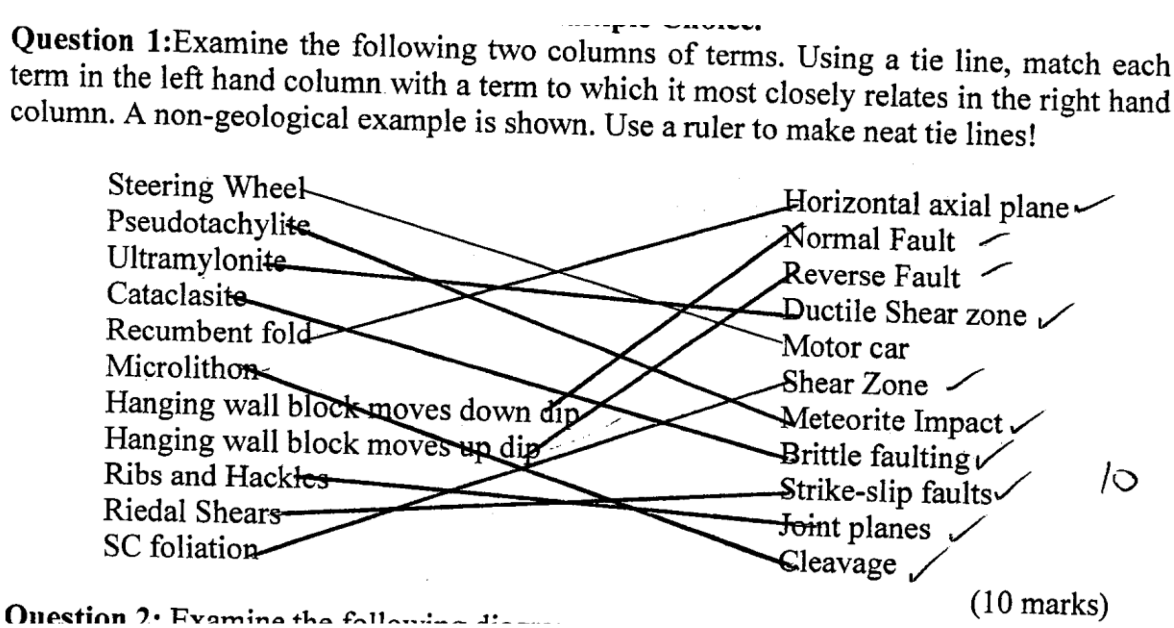
Question 1: Examine the following diagram:



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

(10 marks)

a) **Left-handed strike slip fault**
b) **Low-angled normal slip fault**
c) **Right-handed strike slip fault**
d) **Thrust slip fault**
e) **Normal slip fault**
f) **Normal left slip fault**
g) **Reverse slip fault**
h) **Left-handed reverse slip fault**



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
Microlithon	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

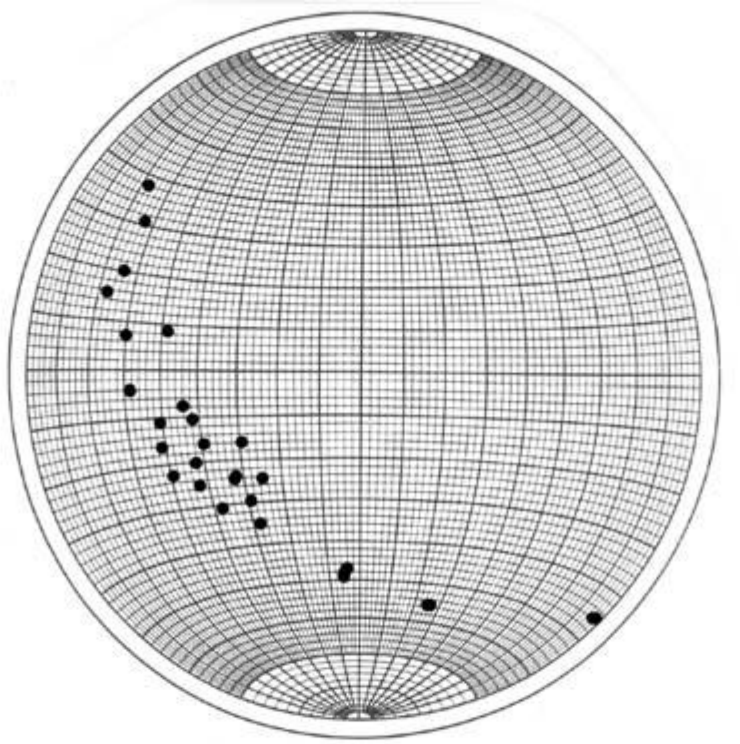
10

(10 marks)

Question 2: Examine the following diag...

1. Steering Wheel- Motor car
2. Pseudotachylite- Meteorite Impact
3. Ultramylonite- Ductile shear zone
4. Cataclasite- Brittle faulting
5. Recumbent fold- Horizontal axial plane
6. Microlithon- Cleavage
7. Hanging wall lock moves down dip- Normal fault
8. Hanging wall moves up dip- Reverse fault
9. Ribs and Hackles- Joint planes
10. Riedal shears- Strike-slip fault
11. SC foliation- Shear zone

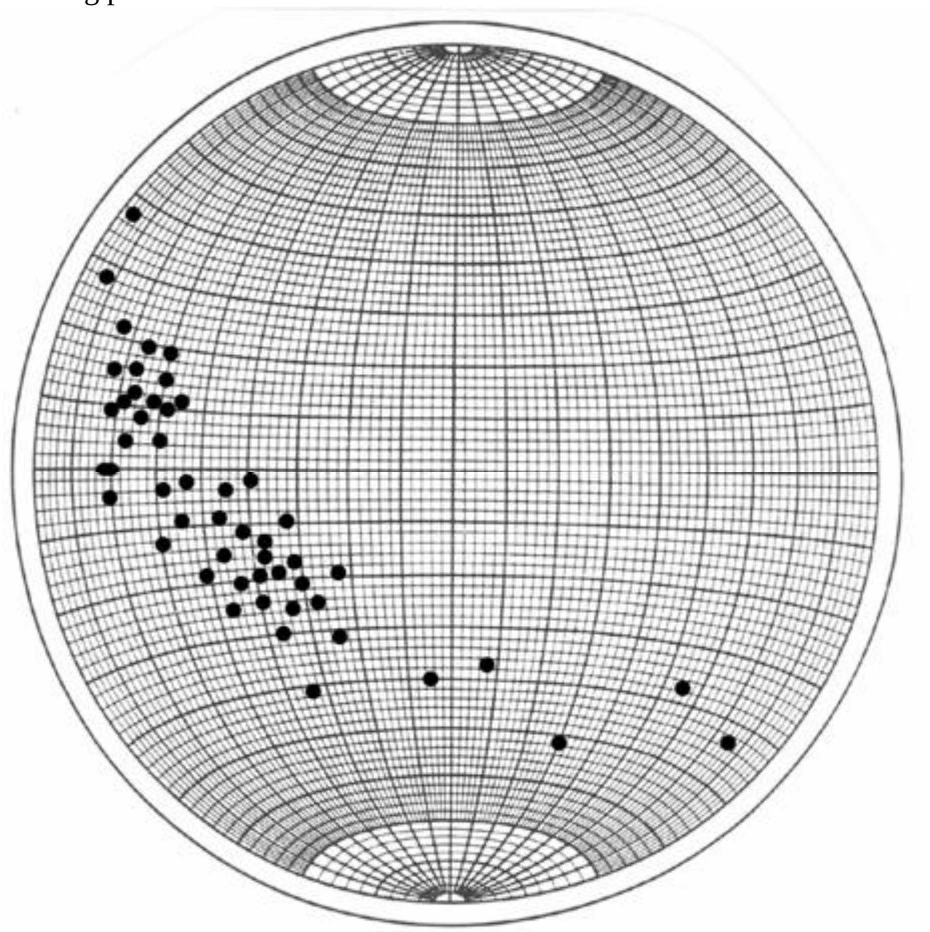
Question 2: Examine the following stereographic projection, which shows the orientation of poles to bedding planes in an area of folded strata:



2a,) The approximate orientation of the π-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 σ_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 σ_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 σ_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 2: Examine the following stereographic projection, which shows the orientation of poles to bedding planes in an area of folded strata:



a.) Estimate what the orientation of the π-circle is **= $135^0/45^0$ SW**

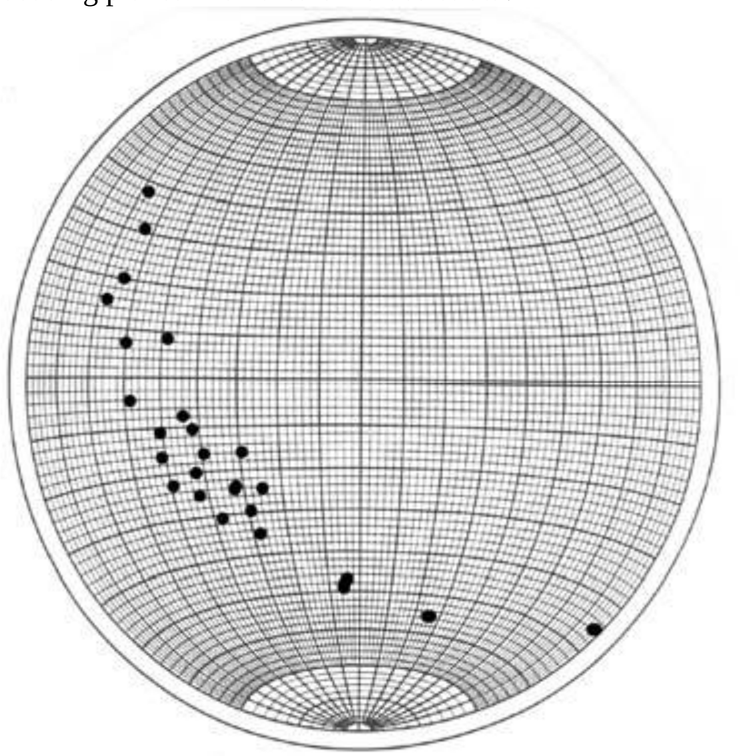
b.) In relation to your answer in (a.) above, what is the orientation of the fold axis? =

c.) What is the orientation of the σ_1 axis, the σ_2 axis and the σ_3 axis?

d.) 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 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 π-circle is:
a.) 330° 45° 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.) 055° 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 2: Write short, illustrated notes describing the differences between each of the following terms:
a.) Angular unconformity b.) Non-conformity c.) Disconformity
(10 marks)

- **Unconformity- is a buried erosion surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous.**

  - ✓ **Unconformity are produced by nondeposition or erosion (or both)**
  - ✓ **And results in a loss of strata for a part of geologic record**

a) Angular unconformity

- ✓ **Angular relationship that exists in rocks where a sequence has been deposited and later tilted, followed by erosion (or nondeposition), then renewed deposition.**
- ✓ **The whole sequence may later be deformed and tilted by further orogenic activity.**
- ✓ **Are produced where a sequence has been deposited and later tilted as a result of the tectonic processes of faulting and folding.**
- ✓ **Erosion commonly accompanies the episode of faulting or folding.**
- ✓ **When the area subsides, or sea level rises, and deposition is renewed, an angular relationship exists between rocks below the unconformity and those above it.**

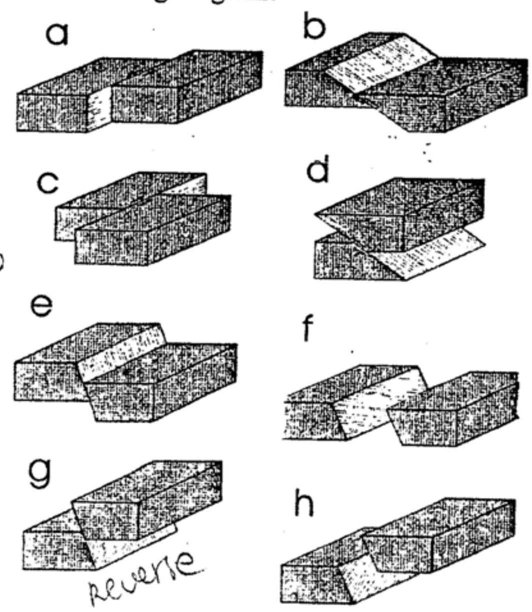
b) Non-conformity

- ✓ **Unconformity in which igneous or metamorphic rocks or both occur below the erosion surface and sedimentary rocks occur above.**
- ✓ **If the rock below the break is Igneous or has lost its bedding by metamorphism the plane of juncture is nonconformity.**
- ✓ **No distinction made between an angular relationship and topographic relief on the surface.**

c) Disconformity

- ✓ **Is an unconformity between parallel layers of sedimentary rocks which represents a period of erosion or non-deposition**
- ✓ **Are produced by deposition of a sequence of rock units, followed up by uplift or a drop in sea level**
- ✓ **Erosion occurs without tilting or deformation of the sequence; then comes subsidence and renewed deposition.**
- ✓ **Bedding in the rocks above and below the unconformity remains parallel.**
- ✓ **They are recognised where rock units are missing either by erosion or because they were never deposited.**

Question 2: Examine the following diagram: (10 marks)



2a.) Which of the illustrated faults is a left-handed strike-slip fault? a ✓

2b.) Which of the illustrated faults is a normal-slip fault? b ✓

2c.) Which of the illustrated faults is an oblique-slip left-handed-normal fault? f ✓

2d.) Which of the illustrated faults is a right-handed strike-slip fault? c ✓

2e.) Which of the illustrated faults is a reverse-slip fault? d ✓

(5 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.) Pseudotachylite 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? **= a**
3e.) Which would you expect to find associated with ductile shearing? **= d**
(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.) Pseudotachylite 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? **= a**
3e.) Which would you expect to find associated with ductile shearing? **= d**
(10 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? **= 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? **= 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)

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

(10 marks)

a) Microlithon

- ✓ **Uncleavage zones between cleavage surface are microlithons**
- ✓ **Microlithon: preserved slices of the original rock.**
- ✓ **Usually no preferred orientation.**
- ✓ **They provide evidence of an earlier foliation in a deformed and metamorphosed rock mass**

| Microlithon | | cleavage |

b) Axial planar cleavage

- ✓ **Plane or surface that results by connecting fold axes on successive folded surface of the same fold.**

- ✓ **Fold axes may be horizontal, but more often inclined to the horizontal and are called plunge**
- ✓ **Folds with nonhorizontal axes are called plunging folds**
- ✓ **The distance from the crest to crest of adjacent anticline or trough to trough of adjacent synclines is the wavelength**
- ✓ **Half the distance from the crest of an anticline to the trough to the trough of an adjacent syncline, measured parallel to the axial plane, is the amplitude of the fold.**
- ✓ **It passes through successive hinge lines in a stacks of folded surface**

c.) Crenulation cleavage

- ✓ **Cleavage that overprints an existing cleavage or foliation by crinkling and crenulating the earlier structure**
- ✓ **Cleavage marked by small-scale crinkling or crenulation is called crenulation cleavage**
- ✓ **Occurs in zones of mineral differentiation coincident with the limbs of the microfolds in a crenulated rock fabrics**
- ✓ **They can be symmetric or asymmetric; symmetric crenulation occur in the hinge zone of the fold whereas asymmetric crenulation occurs on the limb of a fold**
- ✓ **Forms under conditions that are amenable to the occurrence of pressure solution**
- ✓ **Form in rock with pre-existing cleavage**
- ✓ **They are formed by buckling and fluid-induced mobility**
- ✓ **They are formed by pure shear or simple shear**
- ✓ **They forms on microshears developed by heterogeneous strain parallel to the shear planes in the strain ellipsoid**
- ✓ **Is a type of disjunctive cleavage**
- ✓ **Most crinkles are spaced and symmetric, and the short limb is usually a plane of breakage.**
- ✓ **It usually formed by deformation of an earlier cleavage or bedding**
- ✓ **Microlithons between the crenulation cleavage planes preserve the earlier crenulated cleavage or foliation.**
- ✓ **It cuts a pre-existing cleavage = microfolds**
- ✓ **There are two types of Crenulation cleavage, namely: Discrete Crenulation cleavage**
  - **Cleavage domains truncate earlier Microlithon**

  : Zonal Crenulation cleavage

- **Wider cleavage domains coincident with limbs of microfolds in earlier microlithons.**

✓ **Crenulation cleavage = S_2**

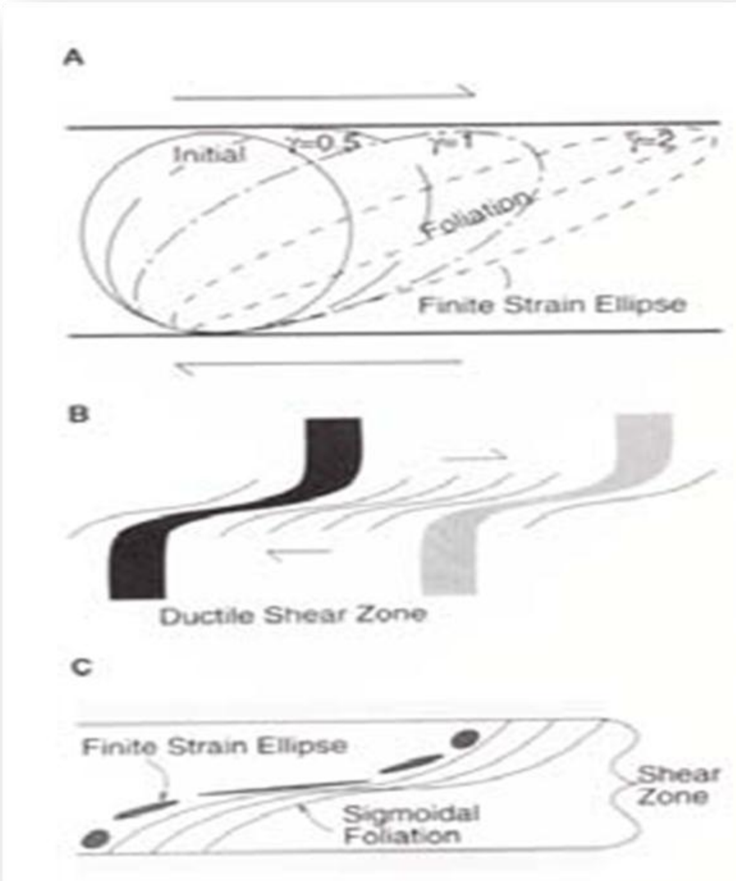
d.) Boudin

- ✓ **Are tablet-shaped lenses of a relativity rigid lithology, embedded in a weaker matrix, that have collectively undergone layer-parallel stretching.**
- ✓ **Sausage-shaped segments of a layer that has been pulled apart**
- ✓ **Boudins can develop under conditions either ductile or brittle**
- ✓ **Shapes of boudins range from angular (brittle layer segmented) to round (ductile layer segmented)**
- ✓ **Boudinage is mostly seen in the limbs of folds, where most flattening and layer-parallel extension occurs.**
- ✓ **Layers parallel extension (layer perpendicular flattening) of stiff and soft layers**
- ✓ **Shape of boudins controlled by ductility contrast between layers and magnitude of stretches (S_1,S_2,S_3)**
- ✓ **Boudins are 'chocolate tablet' in 2D. In 3D are separated by narrow boudin necks that are linear objects.**

e.) Sigmoidal foliation

✓ **Foliation patterns: - Inclined to shear zone for any noncoaxial deformation.**

- Sigmoidal shape of foliation gives sense of shear


A
Initial
γ=0.5
γ=1
γ=2
Foliation
Finite Strain Ellipse
B
Ductile Shear Zone
C
Finite Strain Ellipse
Sigmoidal
Foliation
Shear
Zone

- ✓ **Orientation of veins tells us orientation of maximum extension of instantaneous strain ellipse, and rotation to Sigmoidal shape progressively**

f.) Pressure solution

- ✓ **Deformation mechanism that involves dissolution at grain boundaries under stress of soluble constituents such as calcite or quartz**
- ✓ **Generally active at low to moderate temperature in the presence of water**
- ✓ **Produces space cleavage by dissolving the most soluble parts of a rock mass, leaving behind discrete residues in planar zones that define the cleavage.**
- ✓ **Spacing of pressure solution surfaces may range from less than a mm to more than a cm**
- ✓ **They may be irregular where rock mass is more severely deformed**
- ✓ **Passive folding forms by pressure solution**

g.) Augen gneiss

- ✓ **Augen gneisses and mylonitic gneisses deformed ductilely by a strongly asymmetric simple-shear component commonly develop tails on porphyroclasts**
- ✓ **The tails are symmetric in the direction of ductile flow**
- ✓ **Contains relatively large feldspar clasts floating in a finer-grained matrix**

h.) Slately cleavage

- ✓ **Penetrative planar tectonic structure consisting of parallel grain of thin layer silicates (clays)or thin anastomosing subparallel zones of insoluble residues in a fine-grained low metamorphic grade rock**
- ✓ **May be defined by layer-silicate minerals that are aligned and separated by microlithons containing layer of silicates that are not aligned**
- ✓ **Spacing of slately cleavage planes may range from a fraction of a mm to mms.**
- ✓ **Rocks that mostly develop slately cleavage are shales, mudstones, siltstone, and tuff**
- ✓ **Cleavages appear to form as a result of crustal shortening associated with folded rock**
- ✓ **Slately cleavage forms perpendicular to the direction of greatest shortening (S_3)**
- ✓ **The mineralogy of slate resembles that of shale.**

i.) Schistosity

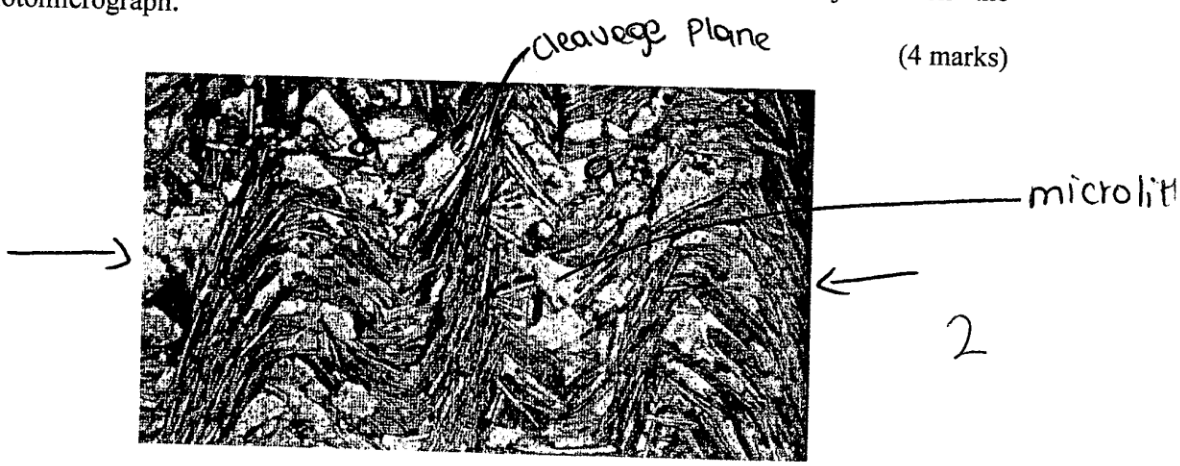
- ✓ **Foliation in schist and some gneisses**
- ✓ **Medium grained rocks (1-10mm) with micas that are visible in hand specimen**

j.) Gneissic banding

- ✓ **Foliation in gneissic rocks; commonly alternating layers of different texture, composition and colour**
- ✓ **There are three types of gneissic structure, namely Mylonitic, Banded and Migmatitic gneiss**
- ✓ **It may occur by inheritance from original compositional contrasts.**
- ✓ **It may result from transposition via folding of an earlier layering**
- ✓ **Transposition is a common process during deformation under high-temperature**
- ✓ **May be formed by metamorphic differentiation**

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.

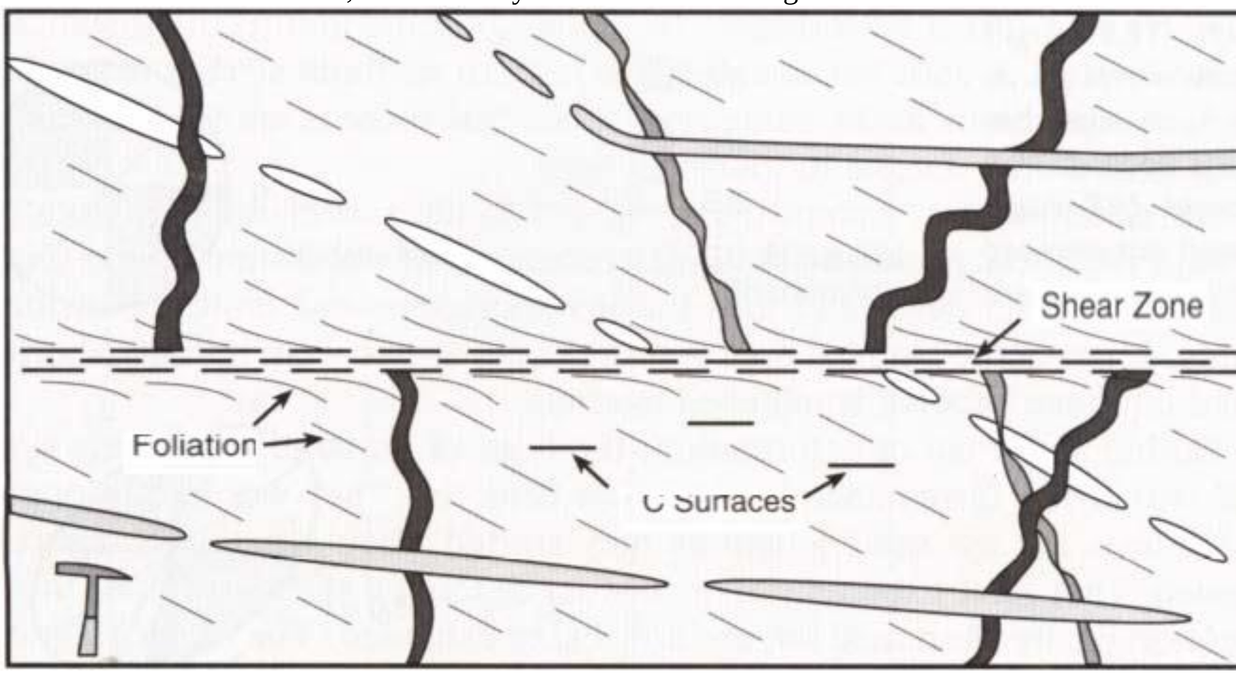
(4 marks)



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

(5 marks)

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.

(7 marks)

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

(5marks)

- **Passive folding**

- ✓ **Is the amplification of natural irregularities in the layers, or is a consequence of differential flow in volume of rock. For example, Sheath folds.**
- ✓ **The layering of material has no mechanical significance**
- ✓ **Occur in glaciers that deform close to their melting temperature.**
- ✓ **Associated with full range of cleavages (slately, phyllitic, schistosity and spaced)**
- ✓ **Occurs in highly ductile rocks, with little range in ductility contrast e.g. salt, gypsum, water-rich sediments, elevated temperature, confining pressure**
- ✓ **Forms after some initial flexural slip folding and buckling**
- ✓ **It forms by pressure solution and changes shape of fold**
- ✓ **And cleavages are usually present**
- ▪ **Sheath folds**
- ✓

- **Active or flexural folding**

- ✓ **The layering of material has mechanical significance**
- ✓ **Layers bend, fold slip and flexural flow**
- ✓ **Direction of the slip is perpendicular to the fold axis**
- ✓ **Slip along the layer can be determined using the formula: $S=t\alpha$, where S= slip, t= thickness of the folded layer and α= inclination in radians (1^0= 0.0175radians)**
- ✓ **Shear strain due to flexural slip is greatest at the inflection points, and least (zero) at the hinge**
- ✓ **Flexural slip is most readily accommodated in rocks that have low cohesive strength**
- ✓ **Two dynamic conditions that we distinguish for active folding is buckling and bending.**

- **Flexural slip/Flow Folding**

- ✓ **Fold that form from slip between the layers are called flexural slip fold**
- ✓ **The amount of slip between the layers increases away from the hinge zone and reaches a maximum at the inflection point.**
- ✓ **Slip increases with increasing in dip**
- ✓ **A geometric consequence of the flexural slip model is that the fold is cylindrical and parallel**
- ✓ **Chevron folds and kink folds are examples of flexural slip folds**

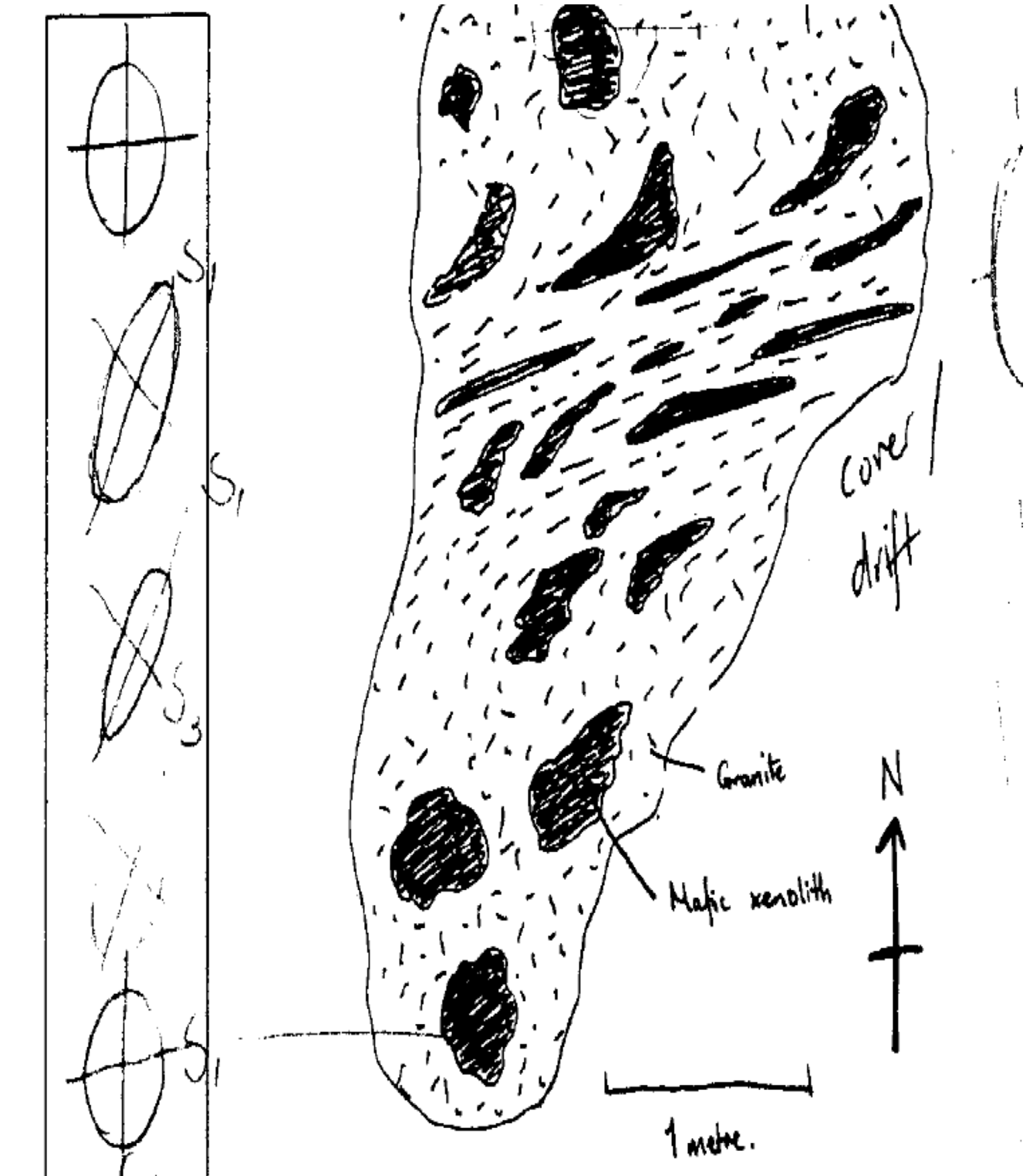
- **Kink folds**

- ✓ **Are small folds that are characterised by straight limbs and sharp hinges**
- ✓ **They occur in finely laminated rocks such as shales and slates.**
- ✓ **Formed by displacements between individual laminae**

- **Chevron folds**

- ✓ **Are large-scale equivalent of kink folds**

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



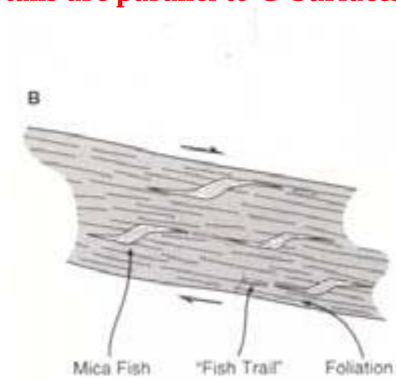
What deformation do you think the geologist has sketched? Annotate the field sketch by adding at lest four orientated strain ellipses in the box on the left to show how strain varies from south to north through the area

(10 marks)

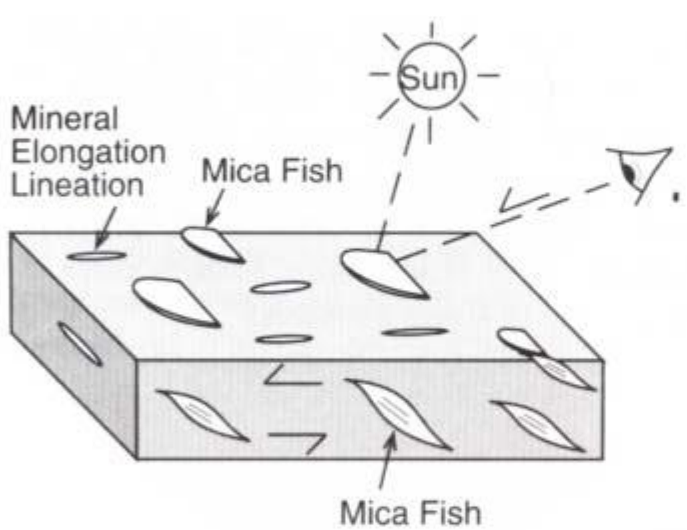
Question 4: Write brief illustrated notes on any ***four*** of the following terms, all of which apply to shear zones:

a.) **SC foliation**

- ✓ **They are composite foliation (S- and C-Surfaces)**
- ✓ **S-Surface is a penetrative planar tectonic structure (including curved surfaces) in a rock.**
- ✓ **Bedding is commonly included and designed S_o despite having a nontectonic origin**
- ✓ **C-Surface is a foliation in shear zones that develops parallel to shear-zone boundaries**
- ✓ **As shearing continues, the C-Surface may be rotated to an angle of 18^0-25^0**
- ✓ **S-Surfaces may form and rotate in the shear zones**
- ✓ **S-Surface lean in the direction of shear between each C-Surface**
- ✓ **Mica fish: Fish are aligned parallel with S-Surfaces, so lean in direction of shear and tails are parallel to C-Surfaces**



- ✓ **Fish flash method of determining sense of shear**



b.) Porphyroclasts as indicators of sense of shear

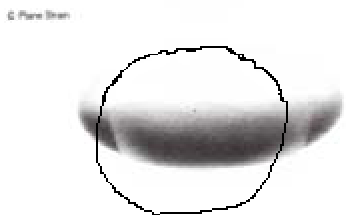
- ✓ **Relict earlier large grains of one or more minerals that remain as a rock mass is deformed**
- ✓ **Augen gneisses and mylonitic gneisses deformed ductilely by a strongly asymmetric simple-shear component commonly develop tails on porphyroclasts**
- ✓ **The tails are symmetric in the direction of ductile flow**
- ✓ **Smaller grains making up the tails may be derived both from the porphyroclasts and from the crystallized groundmass**
- ✓ **They are relict pieces of of the protolith**
- ✓ **Newly grown mantle usually weaker than monocrystalline core of porphyroclast, mantle become sheared into a wing which may be strongly asymmetric, giving sense of shear or in line.**

c.) Sheath folds

- ✓ **Noncylindrical tubular folds that are closed at one end and with fold axes tightly curved within the axial surfaces.**
- ✓ **They commonly occur in zones of ductile deformation where rocks have been deformed by a strong component of inhomogeneous simple shear**
- ✓ **They are produced if the fold axis forms initially as part of an ordinary cylindrical fold**
- ✓ **Sheath folds commonly form in ductile shear zones**
- ✓ **Sheath fold can be used as shear sense indicator**
- ✓ **Formation of sheath folds caused by lateral variation in rates of flow in shear zones**

d.) Plane strain

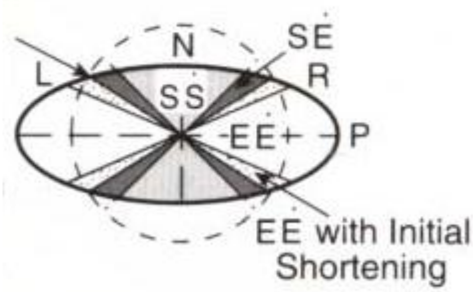
- ✓ **Strain that occurs following deformation when a series of parallel planes remains undistorted and parallel to the same set of planes in the undeformed body**
- ✓ **Strain parallel to the Ꞧ=1 line in the Flinn diagram**



- ✓ **Plane strain: LS-tectonites where $S_1 > S_2 (=1) > S_3$, Triaxial strain ellipsoid**

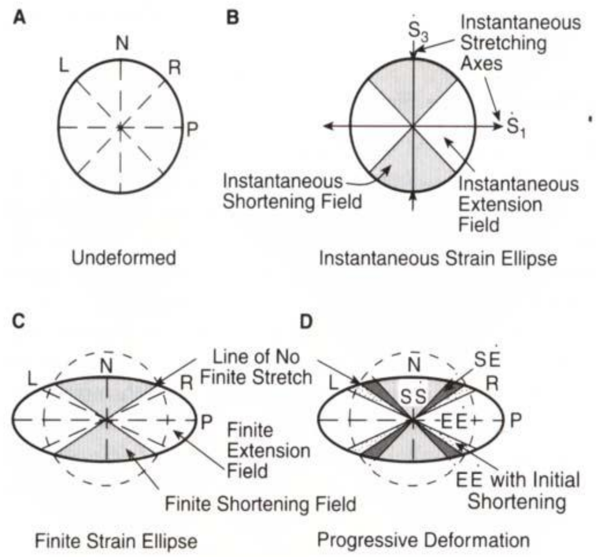
e.) Progressive deformation

- ✓ **Strain that results when a series of deformational events produces an increase in the amount of strain in a rock body through time**
- ✓ **Incremental finite strain is progressive strain**



Progressive Deformation

- ✓ **Total strain in the rock is the result of a progressive deformation**
- ✓ **Finite strain relates the instantaneous shape of a rock mass at any one time to initial undeformed shape**
- ✓ **Incremental strain involves separation steps that occur in small distortion or dilation events through progressive deformation**
- ✓ **Finite strain is the sum of incremental strains.**

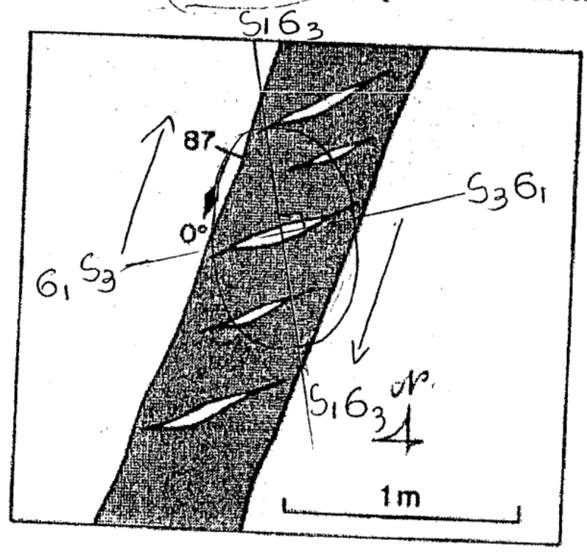

A
N
L
R
P
Undeformed
B
$\dot{S}_3$
Instantaneous Stretching Axes
$\dot{S}_1$
Instantaneous Shortening Field
Instantaneous Extension Field
Instantaneous Strain Ellipse
C
Line of No Finite Stretch
N
L
R
P
Finite Extension Field
Finite Shortening Field
Finite Strain Ellipse
D
N
SE
L
R
SS
EE
P
EE with Initial Shortening
Progressive Deformation

(12 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 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

0

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)

5

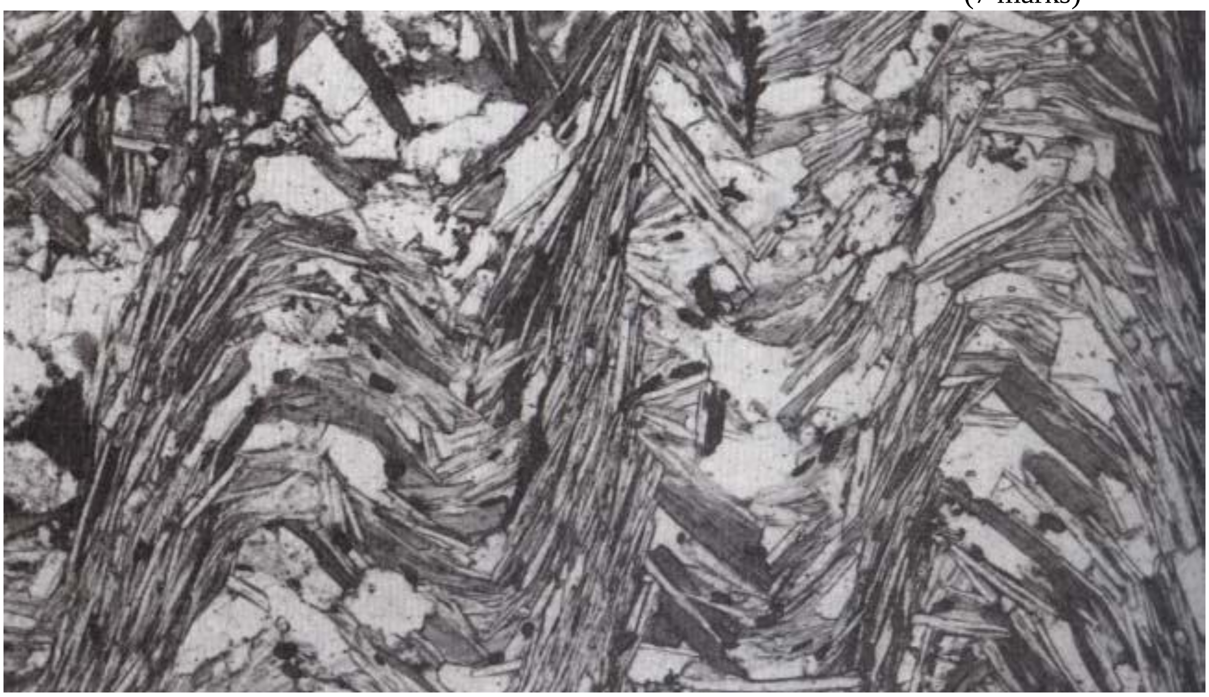
4c. From the stress ellipse which you have drawn, deduce what type of fault is shown. What is the sense of movement? (4 marks)

Right handed strike slip.
Fault.

4

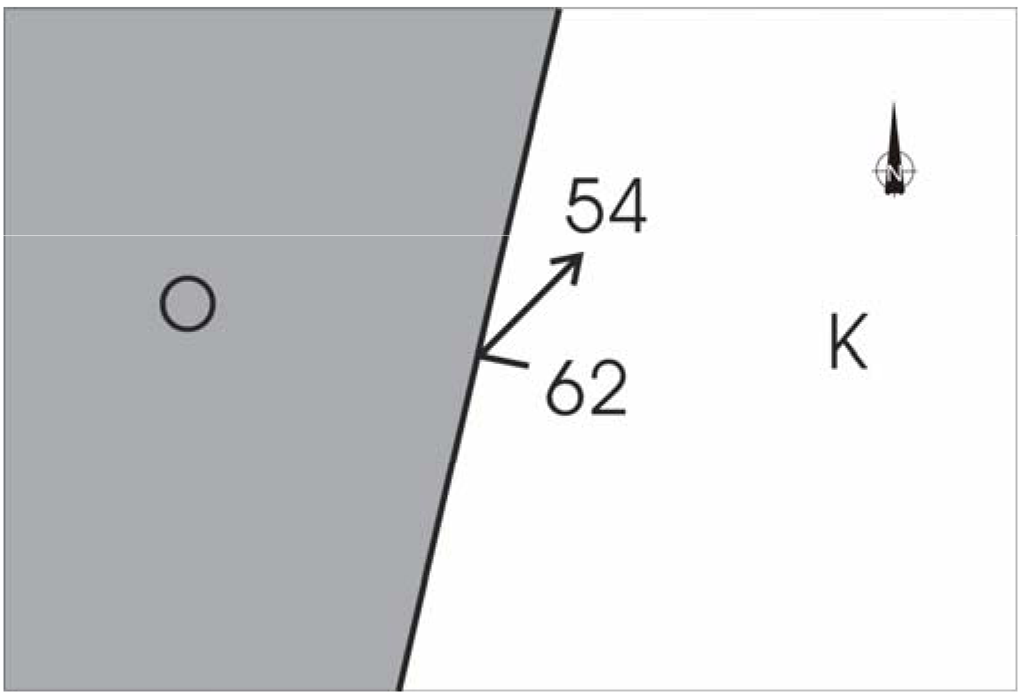
Question 5: Examine the following photomicrograph, which shows a thin section of slate. Make a sketch of the thin section, and label a cleavage plane and a microlithon zone. Write brief notes explaining what the cleavage and microlithon represent, and the significance. Show the shortening direction to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

(7 marks)

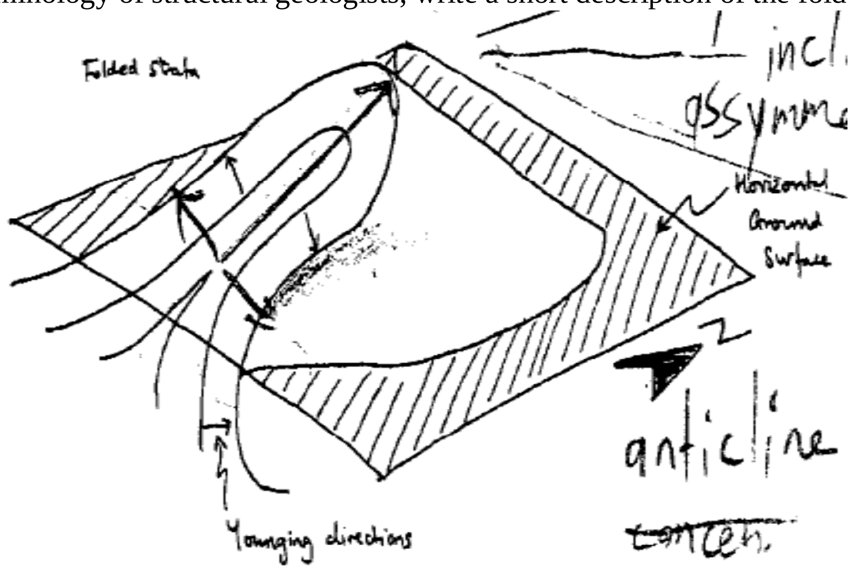


Question 5: Examine the following *map*, which shows Ordovician strata (O) and Cretaceous strata (K) in contact along a fault. The strike, dip and dip-direction of the fault plane are indicated, and the trend and plunge of slickenside lineations on the fault plane are indicated. What type of fault is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

(5 marks)

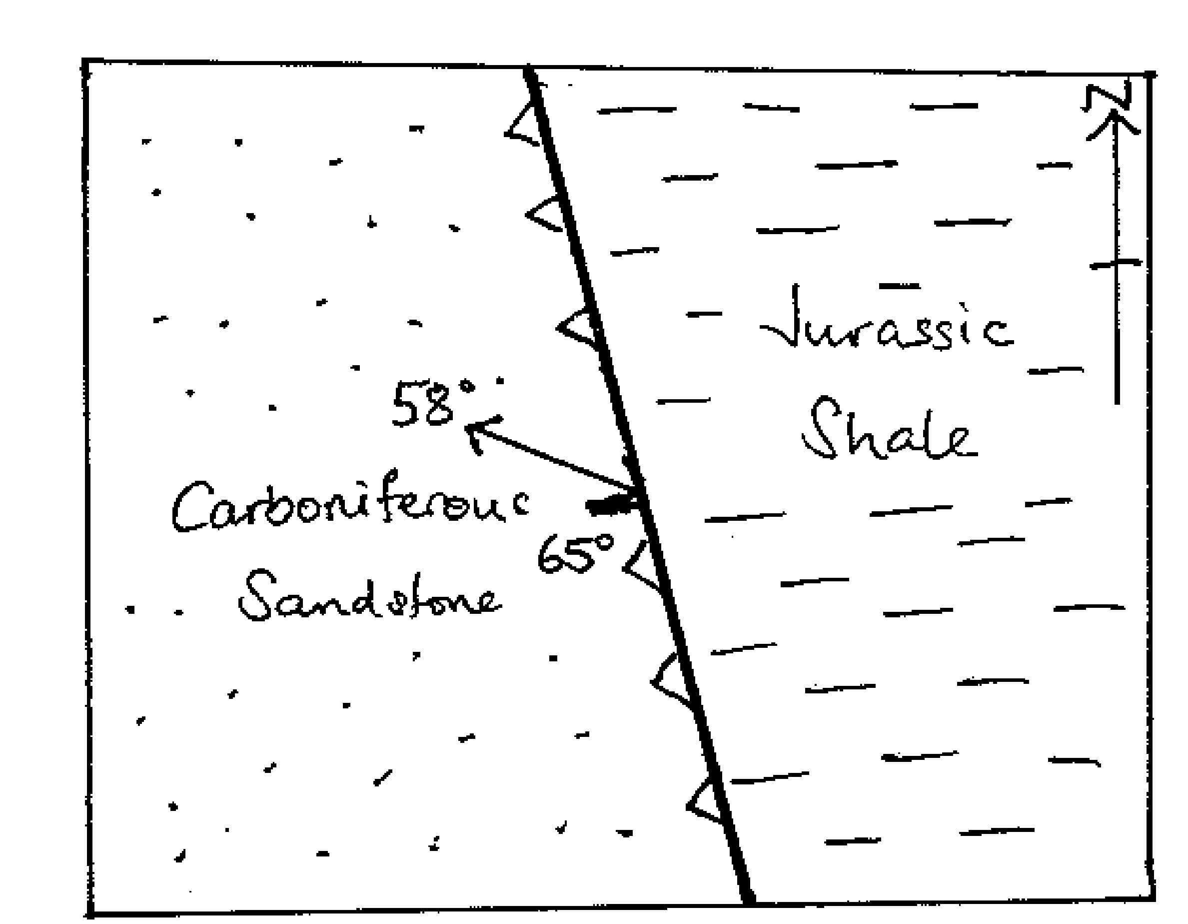


Question 5: Examine the following field sketch of a folded sequence of strata. Using the established terminology of structural geologists, write a short description of the fold describing its geometry.



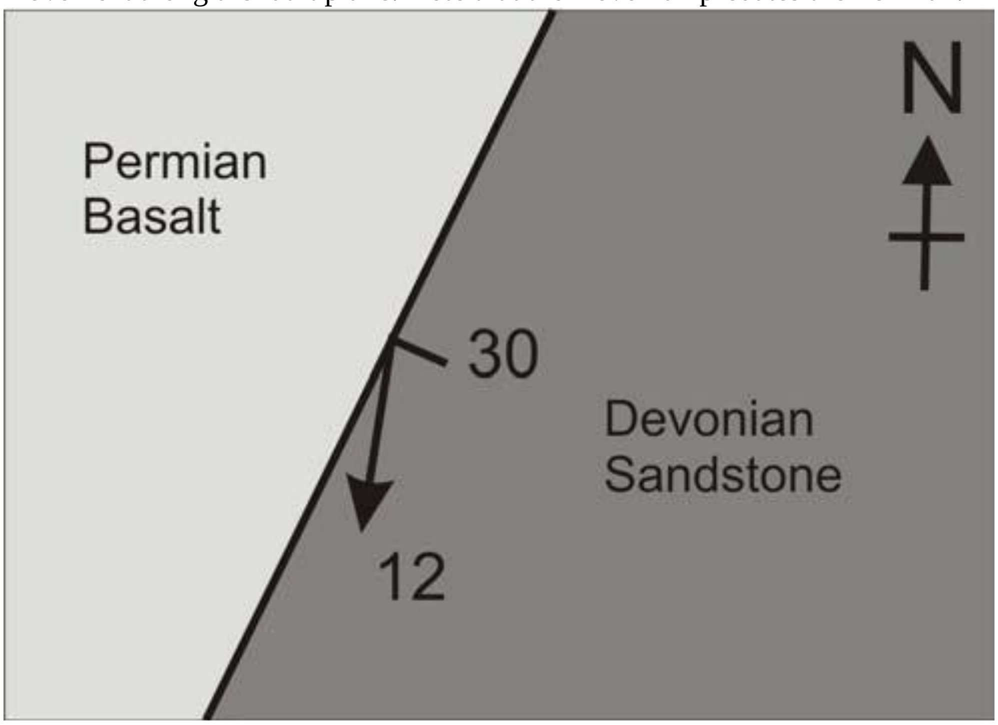
(4marks)

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 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 Devonian predates the Permian.

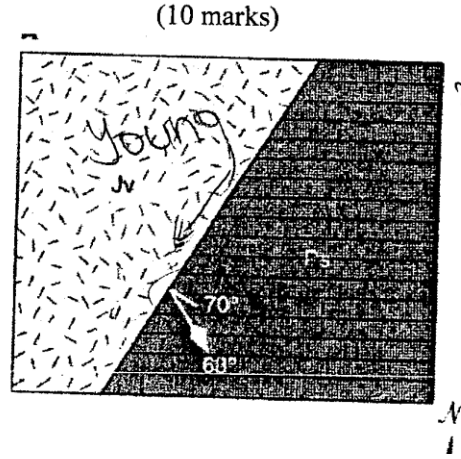


(10 marks)

- ✓ **Devonian (old) juxtaposed against Permian (young) slickenside lineation have a pitch of 80^0 (plunge $=12^0$)**
- ✓ **Therefore a fault is a left-handed reverse slip fault**
- ✓ **Dip slip is the largest component**
- ✓ **And strike slip is the smallest component**

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 Fau
because dip is > 45°.
Direction of dip is given - SE

- ✓ **Permian (old) juxtaposed against Jurassic (young) slickenside lineation have a pitch of 80^0 (plunge $=68^0$)**
- ✓ **Therefore a fault is a left-handed reverse slip fault**
- ✓ **Dip slip is the largest component**
- ✓ **And strike slip is the smallest component**

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

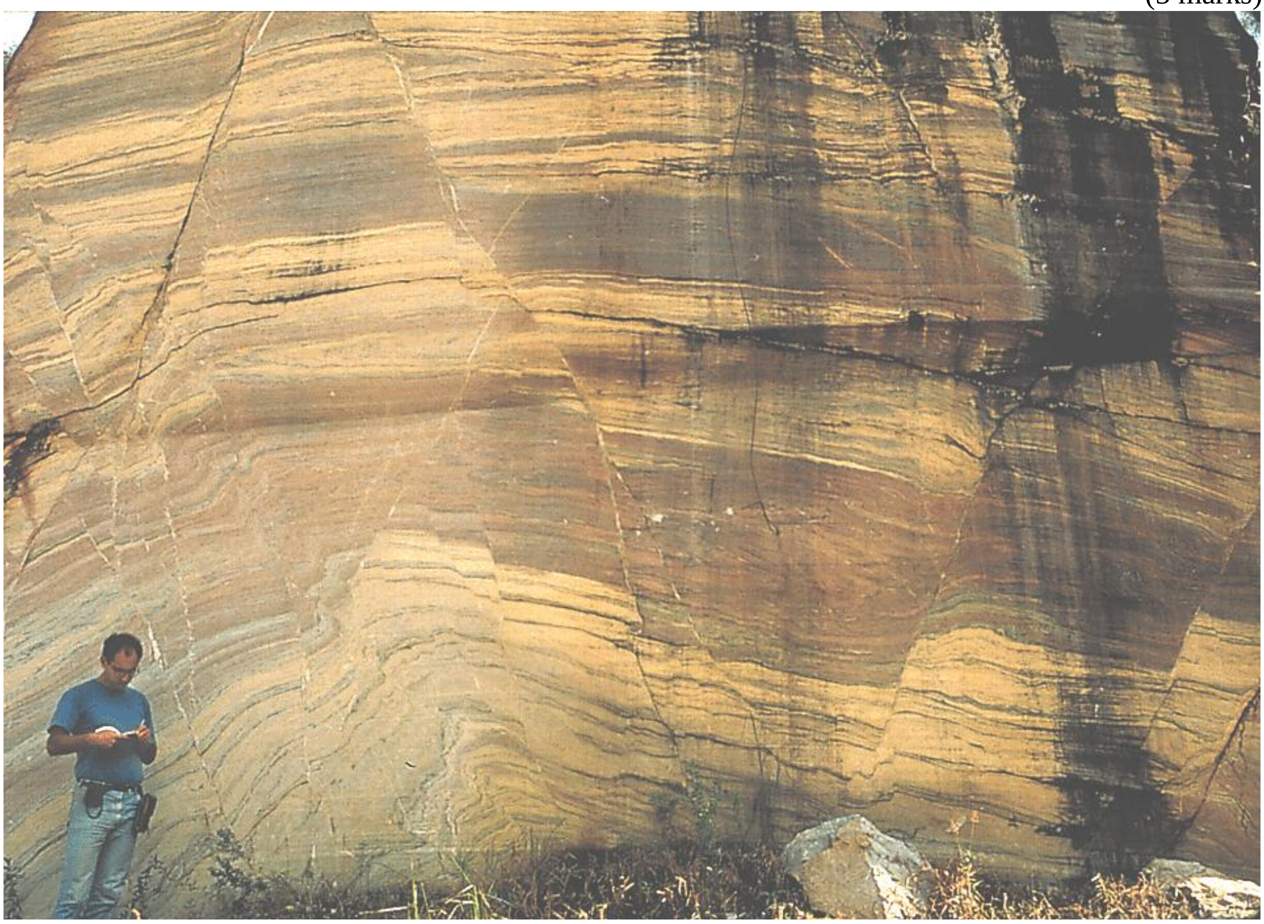
a.) Axial planar cleavage

b.) Sigmoidal foliation in a shear zone
c.) Left-handed displacement across a brittle fault
d.) S-C foliation
e.) Normal fault

(10 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)



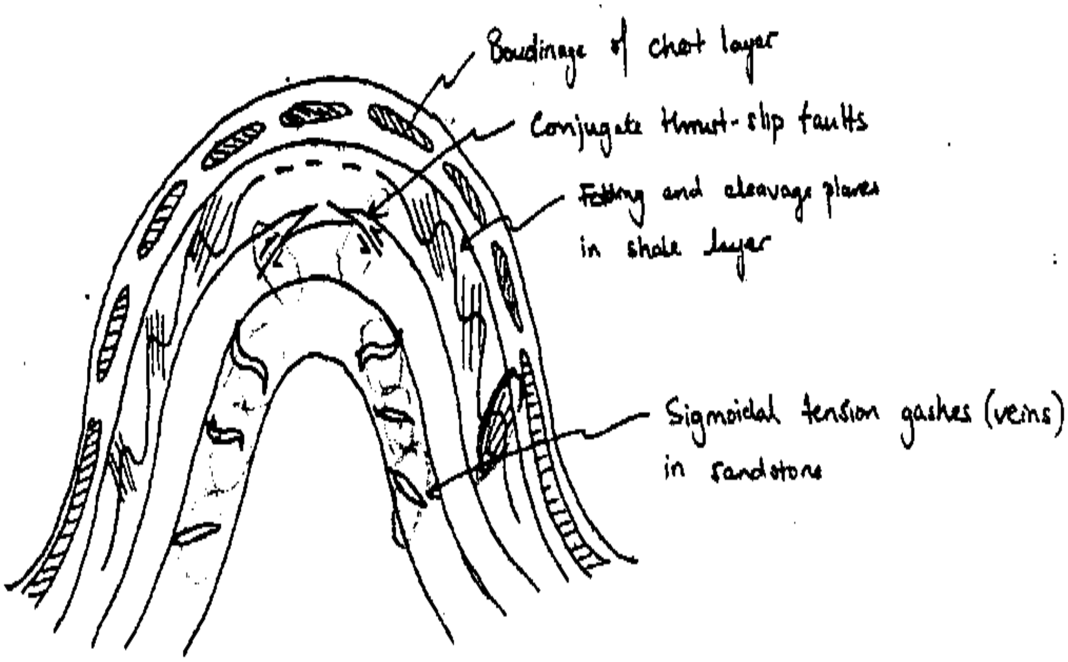
Host-graben fault system

In places where two adjacent normal faults dip toward one another, the fault-bounded block between them drops down, creating a graben.

Where two adjacent normal faults dip away from one another, the relatively high footwall block between the faults is called a horst.

Horsts and grabens form because of the interaction between synthetic and antithetic faults in rift systems.

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.

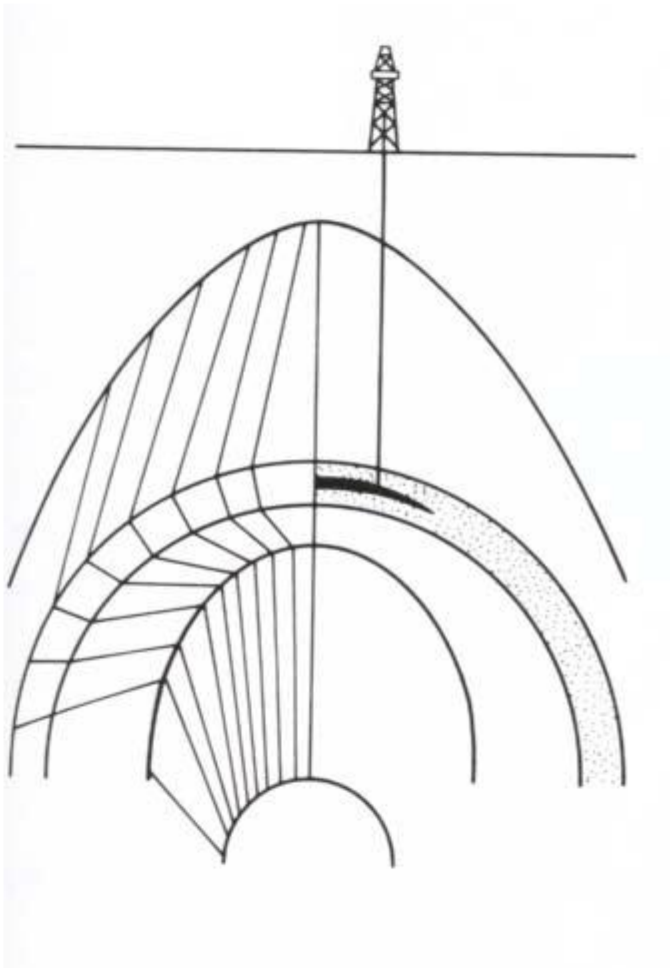


(10 marks)

Question 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?

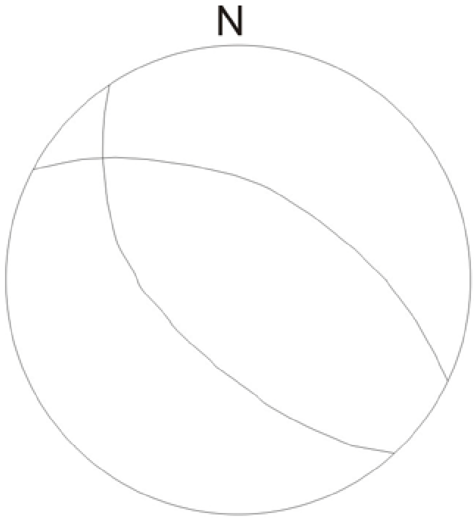
(4 marks)

Dip isogons…..
Lines connecting points of equal inclination on outer and inner bounding surfaces.
Reveals differences in outer and inner arc curvature
Single structure can contain a variety of differently folded layers

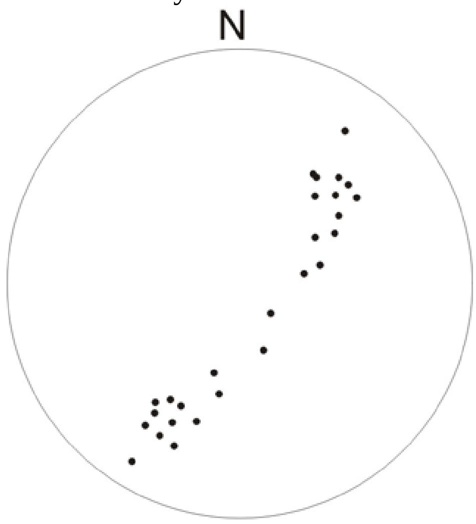


10 dip isogons

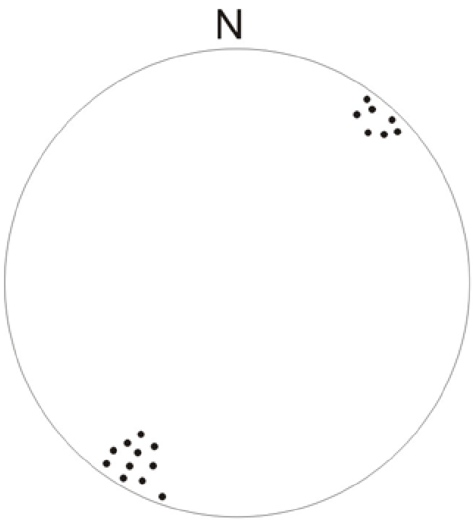
Question 6: The following stereographic projections show orientation data of a number of different secondary structures recorded in a field area underlain by Ordovician sandstone and shale. Write a brief report characterising the deformation in the area. Your report should give an indication of how each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



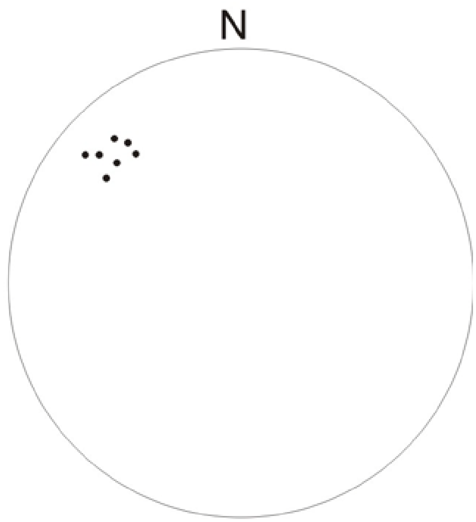
a.) Beta diagram of fold limbs



b.) Pi diagram of bedding planes



c.) Poles of axial planar cleavage planes



d.) Orientation of fold hinge lines

(20 marks)

Question 6: A stress field has the following orientation: σ_1 horizontal in an E-W direction, σ_3 horizontal in a N-S direction and σ_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: A stress field has the following orientation: σ_1 horizontal in an E-W direction, σ_3 horizontal in a N-S direction and σ_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?

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 7: A stress field has the following orientation: σ_1 horizontal in an E-W direction, σ_2 horizontal in a N-S direction and σ_3 vertical.

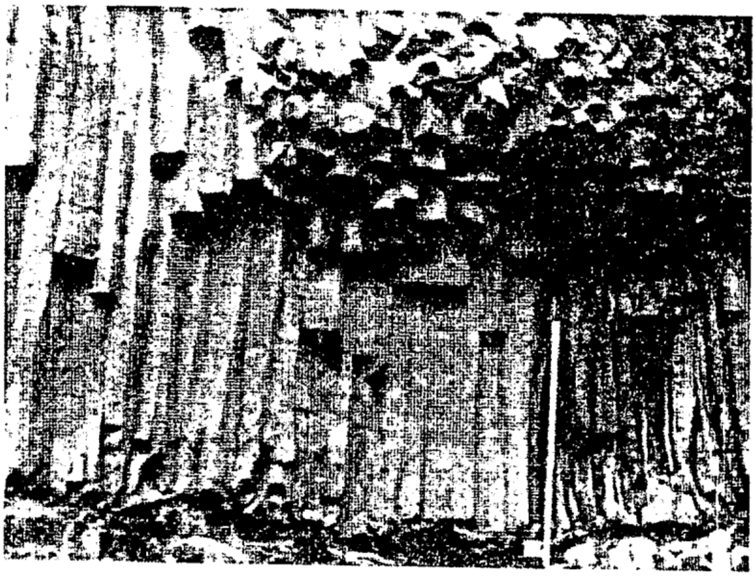
Which type of faults (according to Anderson's theory) will form in such a stress field? What are the strike(s) and dip(s) of the fault(s) that form? In what sort of plate tectonic environment might you expect this type of fault? Explain your answer.

(10 marks)

Question 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 σ_1 under these conditions?
b.) Failure of the rock occurs when the value of σ_1 given in your answer to section (a.) is reached. The resultant sinistral fault plane forms an angle of 30° to σ_1. What is the magnitude of normal and shear stress at the point of failure?
(10 marks)

Question 7:

Examine the following field photograph of basalt:



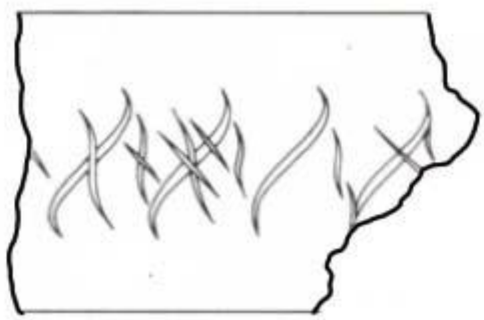
What type secondary structure is shown in the photograph? Under what circumstances did this structure form?

(5 marks)

- **Columnar joints**

- ✓ **Columnar joints form in flows, dikes, sills, and in volcanic necks in larger plutons in response to cooling and shrinkage of congealing magma**
- ✓ **Thermal gradients and contraction processes in the magma control the orientation of columnar joints.**
- ✓ **The orientation of columns is generally normal to the sides of a pluton.**
- ✓ **Columnar joints commonly have five or six planar sides**
- ✓ **Ideally, they would form hexagonal prism if the stress fields, cooling rates, and thermal gradients were perfectly uniform throughout the cooling magma body.**

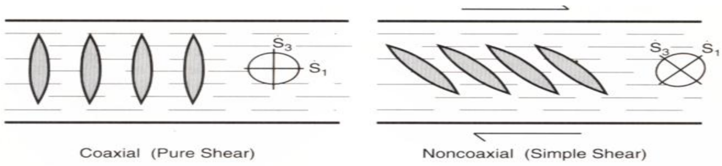
Question 9: Examine the following field sketch, which shows sets of veins outcropping within a shear zone. Draw a series of sketches to help explain how these veins have attained this shape. Assuming that the outcrop drawn is horizontal (i.e. you are looking in a 'map' view: North is to the top), use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

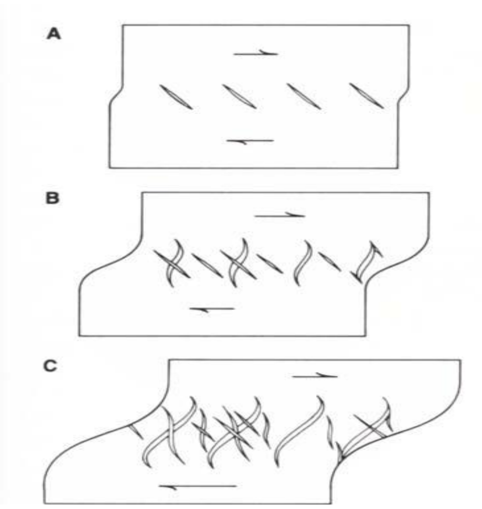


(10 marks)

✓ **Orientations of veins tell us orientation of maximum extension of instantaneous strain ellipse, and rotate to sigmoidal shape progressively.**

✓ 

✓ 

✓ 

A. Noncoaxial progressive development of veins
B. Older ones are more Sigmoidal and more deformed. Younger ones more planar.
C. Those forming do so at c. 45^0 to shear zone walls

✓ **Fibre growth in veins may also indicate a history of rotation, during a crack-seal growth of veins**

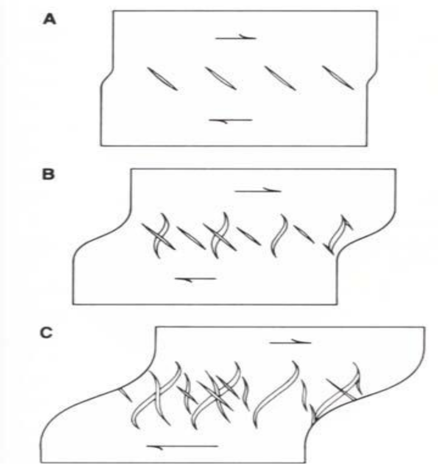
Question 9: Examine the following field sketch.

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)

- **En echelon Sigmoidal quartz veins: dextral**

✓ **Forms if a fracture fills with minerals precipitated out of hydrous solution**



✓

A. Noncoaxial progressive development of veins. Formation of a simple en echelon array.
B. Older ones are more Sigmoidal and more deformed. Younger ones more planar. Formation of Sigmoidal en echelon veins due to rotation order, central part of the vein, and growth of new vein material at 45^0 to the shear surface.
C. Those forming do so at c. 45^0 to shear zone walls

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.

(10marks)

Sigmoidal en echelon veins

Form due to rotation of the order, central part of the veins, and growth of new vein material at ~45^0 to the shear surface