THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS OCT/NOV 1995

SCHOOL OF MINES

1. Physical Geology paper 1 ---------------------- GG 210
2. Principles of Geology 1 Theory paper 1----------- GG 213
3. Mineralogy and petrology paper theory ---------- GG 310
4. Stratigraphy and photogeology Theory paper 1---- GG 321
5. Structural Geology 1 paper 1 Theory ------------ GG 332
6. Igneous metallic petrology paper 1 Theory ------- GG 410
7. Sedimentology Theory paper 1 ------------------ GG 421
8. Sedimentology practice paper 2 ----------------- GG 421
9. Geology of Zambia paper 1 Theory ------------ GG 422
10. Economic Geology of metalliferous ores paper 1 -- GG 442
11. Engineering Geology --------------------------- GG 542
12. Applied Geophysics (mid year) ------------------ GG 561
13. Chemical metallurgy ---------------------- MM 320/MM 321
14. Hydrometallurgy ---------------------------------MM 421
15. Transport Phenomena ------------------------------MM 441
16. Special Topics in mineral processing -------------MM 554

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - OCTOBER/NOVEMBER 1995

GG210

PHYSICAL GEOLOGY

PAPER I

THEORY

TIME: THREE (3) HOURS

INSTRUCTIONS: ANSWER QUESTION ONE (1) AND ANY FOUR (4) OTHER QUESTIONS USING NEAT SKETCHES WHEREVER POSSIBLE. ALL QUESTIONS CARRY EQUAL MARKS.

---

1. (a) On figure 1 indicate the following structural domains:

   Bangweulu Block, Ubendian Belt, Zambezi Belt, Mozambique Belt, Lufilian Belt and Irumide Belt.

   (b) Give the General Zambian stratigraphy in termsaof supergroups.

   (c) Where in the Zambian stratigraphy is each of the following mineralisation types found?:

   (i) Lead/zinc in Kabwe
   (ii) Sedimentary copper in the Copperbelt Province
   (iii) Coal in Maamba
   (iv) Tin and Amethyst in Choma/Kalomo area.
   (v) Manganese in Mansa.

   (d) What are the main host rocks and geological structures for the Lead/zinc mineralisation in Kabwe?

2. (a) The geological time scale was established without the aid of radiometric dating. What two principles were employed to develop the time scale?

   (b) Contrast the asthenosphere and the lithosphere.

(c) (i) What is plate tectonics?

(ii) Plate tectonics unifies two earlier theories. Name these theories.

(d) There are 3 main plate boundaries. Name these boundaries and describe what occurs at each of these boundaries.

(c) Would expect the oceanic crust to become younger or older away from the mid-oceanic ridge? Explain.

3. (a) What is the building block of silicate minerals? Give 4 examples of silicate minerals.

(b) Name 6 physical properties of minerals and describe any two.

(c) (i) Give chemical formulae for the following minerals: Galena, Anhydrite, Calcite, Halite, Magnetite, Pyrite, Diamond and Chalcopyrite.

(ii) On what basis are the above minerals classified?

(d) (i) Define the term crystal

(ii) Classify crystals A and B into crystal systems, giving reason(s) for your classification:

A - 6 Diads, 9 Planes, Centre, 4 Triads, 3 Tetrads

B - 3 Planes, Centre, 3 Diads

4. (a) Define the following and describe briefly how they come about?

(i) Amygdale (ii) Cross-bedding (iii) Metamorphic Aureole (iv) Foliation (v) Porphyritic Texture (vi) Xenolith

(b) Write brief notes on the following rocks in terms of texture and main mineral constituents:

(i) Basalt (ii) Peridotite (iii) Arkose

(iv) Orthogneiss (v) Eclogite.

(c) What geological structures result from plastic and bruttle deformation of the crust?

(d) Describe how veins form.

5. (a) What is weathering?

(b) Granite and Basalt are exposed at the surface in a hot, wet region.

(i) Will chemical or mechanical weathering predominate? Why?

(ii) Which of these rocks will weather more rapidly? Why?

(c) Briefly describe the following:

(i) Rockslide (ii) Earthflow (iii) Mudflow (iv) Creep.

(d) Briefly describe how mass wasting processes contribute to the development of river valleys.

(e) What is base level of a river? Where would you expect the base levels of the Kafue and Luangwa rivers to be? Why?

(f) Distinguish between perosity and permeability.

6. (a) Briefly how each of the following mineral deposits form:

(i) Hydrothermal (ii) Silarm (iii) Pegmatite (iv) Placer

(b) If you were contracted to search for a placer deposit of heavy minerals, such as Gold, along a river. Where would you look and why?

(c) (i) Define ore?

(ii) Name an ore mineral for each of the following: Lead, Zinc, Mercury, Iron, Copper, and Aluminium.

(d) Open pit mining of copper ore at Nchanga has caused several environmental problems. Briefly state three main problems and suggest ways in which these problems could be addressed.

7. (a) Petroleum is a very critical energy resource. Describe how it forms and migrates.

(b) For petroleum to be accessible to man, it must be entrapped. Describe the following oil traps:

(i) Anticlinal (ii) Fault (iii) Pinchout

(iv) Unconformity

(c) List 6 other sources of energy known to man.

(d) Groundwater is another important resource to man. Name and describe briefly a geophysical method which would be effective in locating groundwater in an area underlain mostly by marble, such as Lusaka.

END OF EXAMINATION

UNIVERSITY OF ZAMBIA – 1995 EXAMINATIONS
GG 210 -- PHYSICAL GEOLOGY

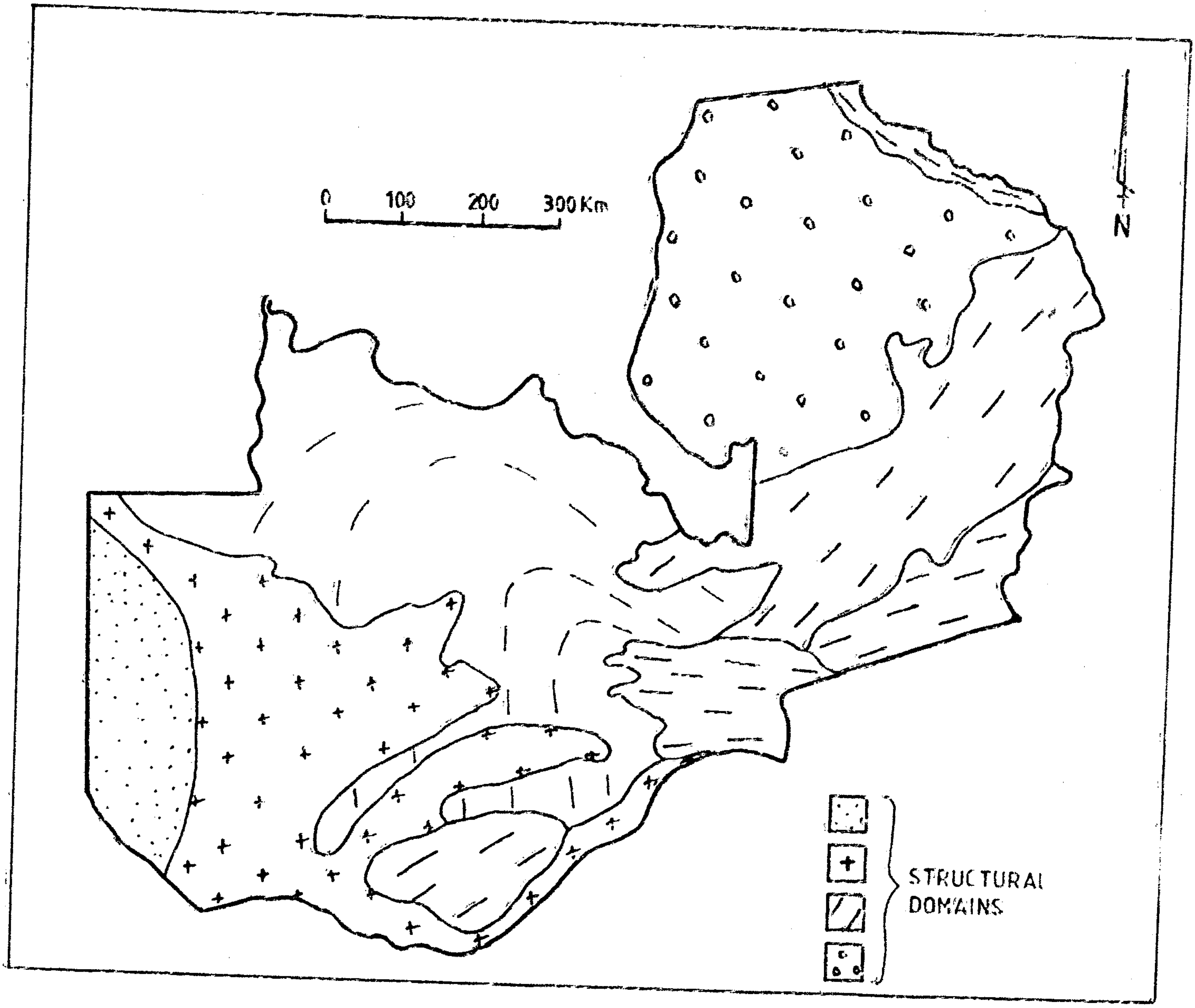


Figure 1. Map of Zambia Showing Structural Domains

THE UNIVERSITY OF ZAMBIA

UNIVERSITY MID-YEAR EXAMINATIONS - JUNE 1995

GG 213

PRINCIPLES OF GEOLOGY I

THEORY - PAPER I

TIME: THREE HOURS

ANSWER ANY FIVE QUESTIONS (ALL QUESTIONS CARRY EQUAL MARKS)

---

1. Describe five physical properties used in the identification of minerals.

2. Define the following terms:

   (a) Plane of symmetry
   (b) Axis of symmetry
   (c) Centre of symmetry
   (d) Unit cell
   (e) Twin plane

3. Describe the "Bowen's reaction series" of magmatic differentiation. Name three rock types that may be produced by differentiation of mafic magma.

4. (a) Name the two main categories of sedimentary rocks.

   (b) State the properties of each of the following rocks and describe the features that you would look for in order to identify them in outcrop:

   (i) Conglomerate
   (ii) Shale
   (iii) Limestone
   (iv) Sandstone

5. (a) Name the three factors which govern metamorphism.

   (b) How can one distinguish between a regionally metamorphosed and a contact metamorphosed rock?

   (c) What rock types would you expect to form from regional metamorphism of:

   (i) Granite (ii) Limestone (iii) Shale

6. (a) Name the three main types of geological structures formed by deformation of rocks in the earth's crust.

(b) Briefly describe the following:

(i) Thrust fault
(ii) Block faulting
(iii) Sinistral fault
(iv) Monocline
(v) Dip and strike

7. What sedimentary processes cause the natural concentration of economically important minerals? Give examples of mineral deposits that may be formed by each of these processes.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - OCTOBER/NOVEMBER 1995

GG310

MINERALOGY AND PETROLOGY

PAPER I

THEORY

TIME: THREE HOURS

ANSWER: QUESTION 1 AND ANY OTHER QUESTION FROM SECTION A, QUESTIONS 4 AND 5 AND ANY OTHER QUESTION FROM SECTION B.

ALL QUESTIONS FROM SECTION C.

SECTION A - CRYSTALLOGRAPHY

1. Explain why the angles between corresponding faces, measured in a plane normal to the edge between them, is always the same in any two crystals of the same substance.

10%

2. (i) Crystal faces are described with reference to a set of coordinates termed crystallographic reference axes. Explain with the aid of a sketch the following terms:

   (a) parametral plane

   (b) parameters

   (c) axial ratios

   (ii) Determine the Miller Indices if the intercepts of a face in a hexagonal crystal are:

   a = 4cm, b = 1cm,

   μ = 1cm, c = 4cm.

3. (i) The Herman - Mauguin notation is used to define the minimum symmetry of a crystal class. Give the meaning of the following symmetry symbols:

   (a) x / m   (b) xm

   (c) x 2   (d) x/m m.

   (ii) Indicate with the aid of a sketch the Herman - Mauguin notation for an orthorhombic lattice.

SECTION B - MINERALOGY

4. Calculate the mineral formula and unit cell from the given data.

Element weight %		Atomic weight
Fe	18.25	55.847
Mn	2.66	54.938
Cd	0.28	112.41
Zn	44.67	65.38
S	33.57	32.07

5. Compare and contrast the amphibole and pyroxene groups of minerals in terms of:

   (a) crystal structure

   (b) chemical composition

   (c) occurrence in igneous rocks.

6. Colour is an important diagnostic feature related to the chemical composition and electronic structure of minerals. Explain the following and indicate at least three (3) examples of each:

   (a) allochromatic mineral
   (b) idiochromatic mineral
   (c) chromophore

10%

7. Cleavage is a manifestation of weaker bond strength along certain directions within a mineral structure. Explain with the aid of a diagram, how this relation is particulary apparent in micas. 10%

SECTION C - PETROLOGY

8. Briefly give the main characteristics of the granite family in terms of:

   (a) mineralogy

   (b) textures

   (c) mode of occurrence 11%

9. (a) What are the main agents of metamorphism?

   (b) State briefly the different types of metamorphism.

   (c) Give at least one example of a typical rock type produced by each type of metamorphism.

10. Describe the main types of detrital rocks.

END OF EXAMINATION

(c) What are the formal units of biostratigraphy? How are they defined and what are their time-significance?

5. (a) List the formal units of chronostratigraphy in descending order of scale giving examples for each unit.

(b) Outline the materials that make up the fossils and how these materials have very different preservation potential.

(c) Give three reasons for the non-preservation of fossils?

6. (a) Outline the five main activities responsible for forming most trace fossils.

(b) In sequence stratigraphy, why do we study sea-level fluctuations and what is the contribution of seismic stratigraphy?

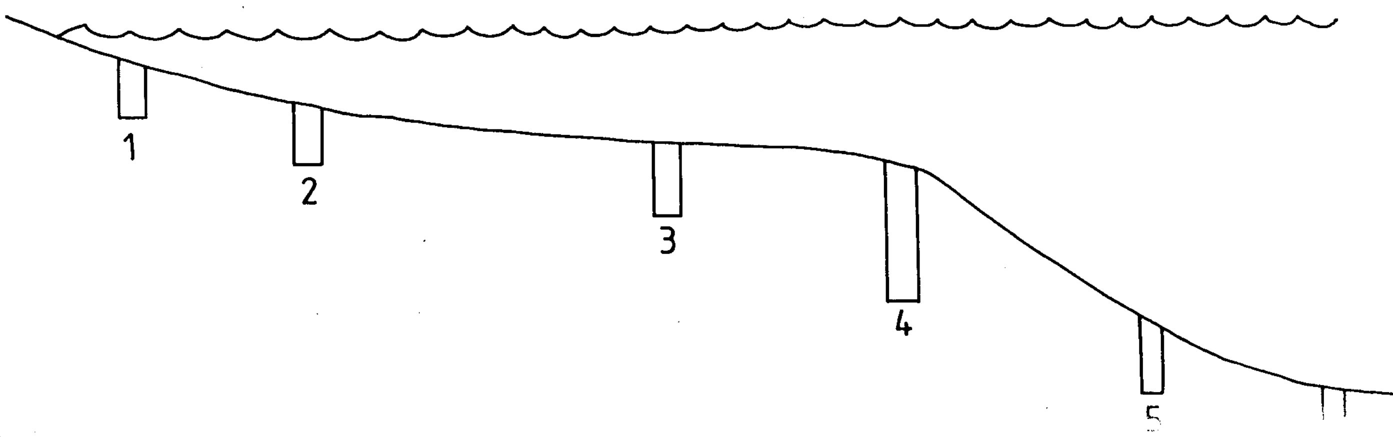
(c) List and comment briefly on the major stratal units of sequence stratigraphy.

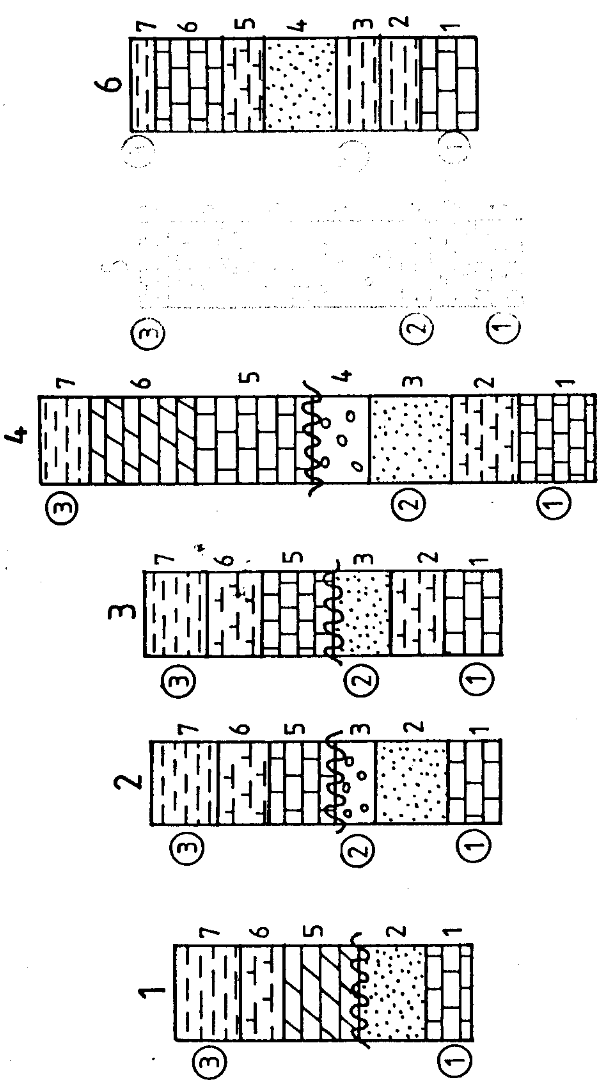
(d) Outline four radiometric dating methods, highlighting their limitation.

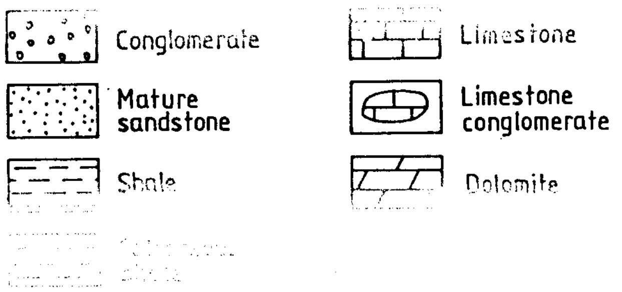
END OF EXAMINATION

Question 5a

Six sections, whose geographical positions are shown in the cross-section below, were measured along a shelf and slope environment of deposition. 3 different index fossils (①, ② and ③) were found in those sections.







a. What is the tectonic setting of these beds ?

b. Why is index fossil ② not found in section 1 ?

c. Why is section 4 much thicker than sections 1 , 2 or 3 ?

d. Locate all the unconformities (∿∿∿)
What type are they and what bed(s) is (are) missing ?

e By joining the contacts with dashed lines correlate all the sections.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - OCTOBER/NOVEMBER 1995

GG 332

STRUCTURAL GEOLOGY I

PAPER I - THEORY

TIME: 3 HOURS

INSTRUCTIONS:

PART A = STRESS AND STRAIN
PART B = STRUCTURES

ANSWER 7 QUESTIONS IN TOTAL

FROM PART A - ANSWER Q1 AND ANY TWO OTHERS
QUESTIONS 2 TO 5 CARRY EQUAL MARKS

FROM PART B - ANSWER Q6, Q7 AND Q8 AND CHOOSE ONE FROM Q9 AND Q10.
QUESTIONS 9 AND 10 CARRY EQUAL MARKS

NOTE: USE DIAGRAMS AND SKETCHES WHEREVER POSSIBLE

PART A - STRESS AND STRAIN

Q1. (a) Define the following terms, using diagrams wherever possible. Please be brief.

(i) A biaxial stress system - what is the maximum shear stress in this case?

(ii) Triaxial stress system. Give the value of the maximum shear stress.

(iii) Lithostatic pressure at a depth h.

(iv) The Deviatoric stress.

(b) (i) On the Flinn Diagram, the areas are divided into constriction zone, constant volume deformation and flattening zone.

What is meant by constant volume deformation? Use a sketch to illustrate your answer.

(ii) In an area where a geologist was mapping he encountered multiple veins that criss-crossed the gneissic terrane. The gneiss exhibited a strong N-S foliation, whereas the veins had an E-W and NE-SW trend.

What is the general orientation of σ_1 during the formation of the gneissic foliation and during the formation of the vein system. (Use diagrams).

(iii) Give the orientations of σ_1, σ_2, and σ_3 during the formation of a:

(a) Thrust Fault
(b) Strike-slip fault
(c) Normal Fault

Q2. (i) Given a general state of stress, find the magnitudes and orientation of the principal stresses.

σ_x = 10 Mpa, σ_y = 6Mpa, τ_{xy} = 2Mpa

(ii) Define the following terms:

(a) Axial symmetric extension
(b) General strain
(c) Plane strain
(d) Heterogeneous strain deformation
(e) Rigid body deformation

Q3. (i) In a shear failure experiment, the Mohr envelope of a granite body was found to record a "ϕ" of 45°. The Numerical value of the cohesive strength was 150 Mpa. Find the critical shear stress and maximum shear stress if σ = 500 Mpa.

(ii) Given σ_1 = 800 bars

σ_2 = 500 bars

σ_3 = 500 bars

Calculate poisson's ratio for this rock at depth.

(iii) Distinguish between the mean stress and the accurate lithostatic pressure at depth that takes into account poisson's ratio.

Q4. (i) What type of deformation is characterised by ductile shear zones?

(ii) Refer to figure 4 and answer the questions that follow.

(a) What type of deformation has the rectangle experienced from a to b, and b to c.

(b) Calculate the shear strain it has experienced in each of the stages.

(c) What is the stretch and longitudinal extension of the line AC to A'C and A"C.

(iii) In a shear failure experiment, σ_n was found to be 800 Mpa, τ_c = 500 Mpa, find the cohesive strength of the rock.

Q5. (i) Indicate one ductile/brittle structure which would be a product of

(a) high strain rates at low temperatures (circa 300°C) e.g. in granite

(b) high strain rates at high temperatures (circa 700°C) e.g. in a quartzo-feldspathic gneiss

(c) low strain rates at low temperature (300-350°C) in limestones.

(ii) Define steady state conditions of deformation.

(iii) Hookian deformation is given by $\sigma = E\epsilon$ whereas Newtorian deformation is given by $\sigma = \eta\dot{\epsilon}$ What is the difference in the mechanism between the two types of deformation?

PART B: STRUCTURES

Q6. Using the diagrams supplied, delete as appropriate

A. Sinistral-Dextral-Normal-Reverse-Thrust-Slip-Fault
B. Sinistral-Dextral-Normal-Reverse-Thrust-Slip-Fault
C. Synformal-Antiformal-Syncline-Anticline
D. The synform is to the North - South
E. The antiform is to the North - South
F. X = Synformal-Antiformal-Syncline-Anticline
Y = Synformal-Antiformal-Syncline-Anticline
Z = Synformal-Antiformal-Syncline-Anticline

Q7. - Complete the formlines of the structures given in figures A,B and C. Name them and determine if they are overturned or upright structures. Briefly explain your answers.

- Indicate for each of the figures D,E and F, the younging direction. Briefly explain your answers.

- Name the type of fault for each of the two block diagrams G and H. Assume the black layer to be at the same stratigraphic level.

Q8. Suppose you are employed by an exploration company in the area shown in the figure.

Describe each of the features you will be looking for on outcrops A,B and C to prove the existence and attitude of the features depicted on the map.

Q9. Define and describe the following features. Provide three different and/or specific examples for each.

- Lineation
- Fold

Give a short definition and/or description of the following features:

- Ptygmatic folding
- Listric faulting
- Kink band
- Polymarmonic fold
- Culmination

Q10. Define and describe the following features. Provide three different and/or specific examples for each.

- Fault
- Foliation

Give a short definition and/or description of the following features:

- Crenulation cleavage
- Diastem
- Load cast
- Hybrid joint
- Pseudotachylite

END OF EXAMINATION

BEST WISHES!

FIGURE 4 FOR QUESTION 4 (FOUR), GG 332 I

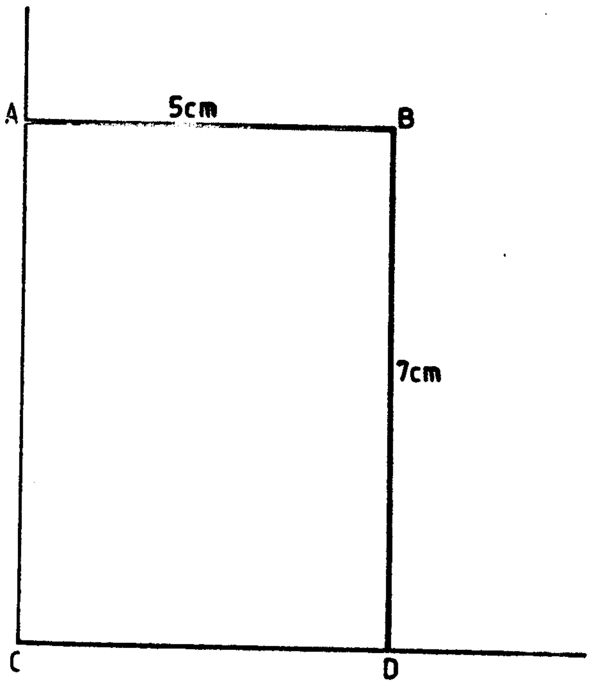


Figure 4(a) Before deformation

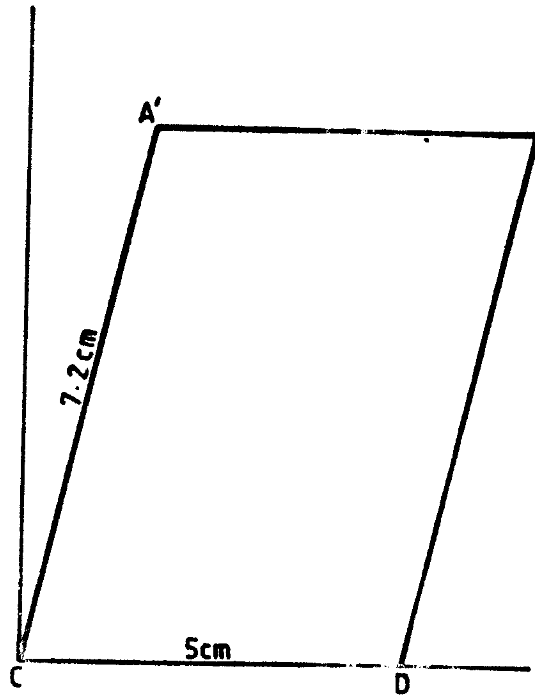


Figure 4(b) After deformation

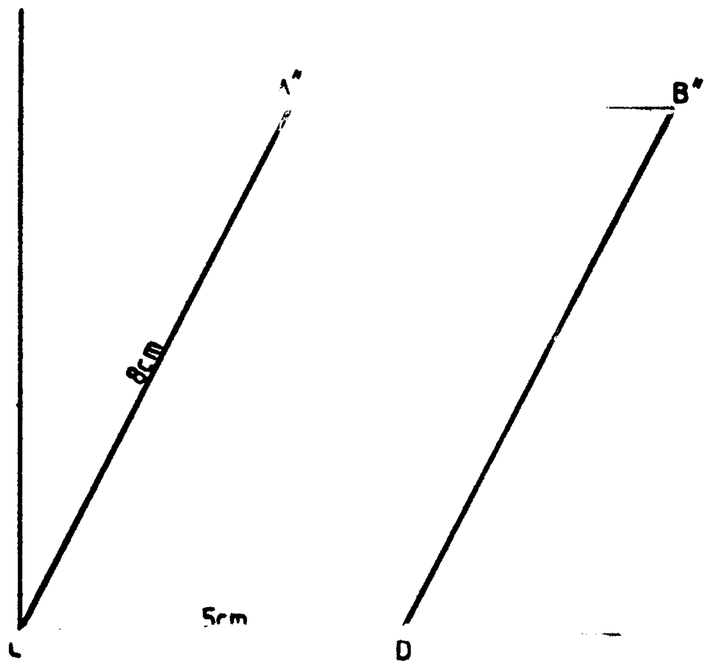
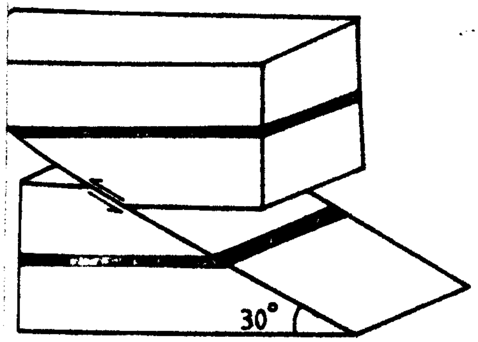
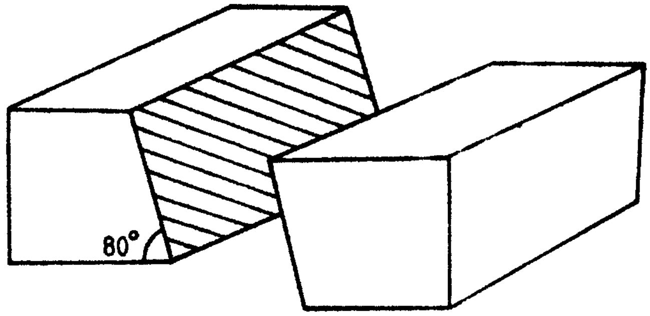


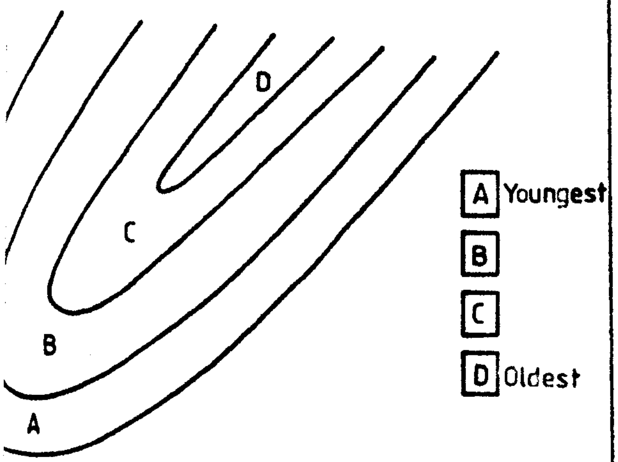
Figure 4(c)



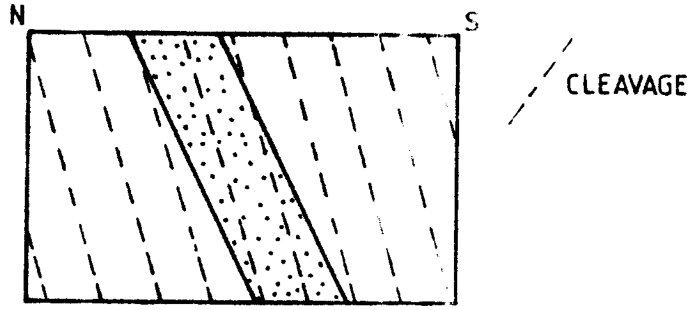
B

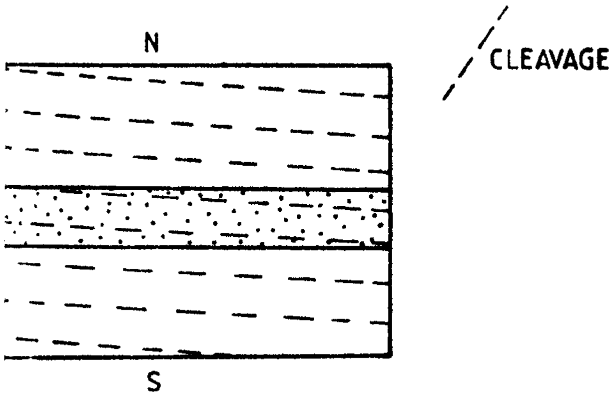
NOTE: THE TWO BLOCKS ARE STILL IN CONTACT



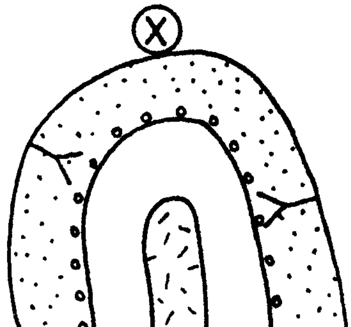
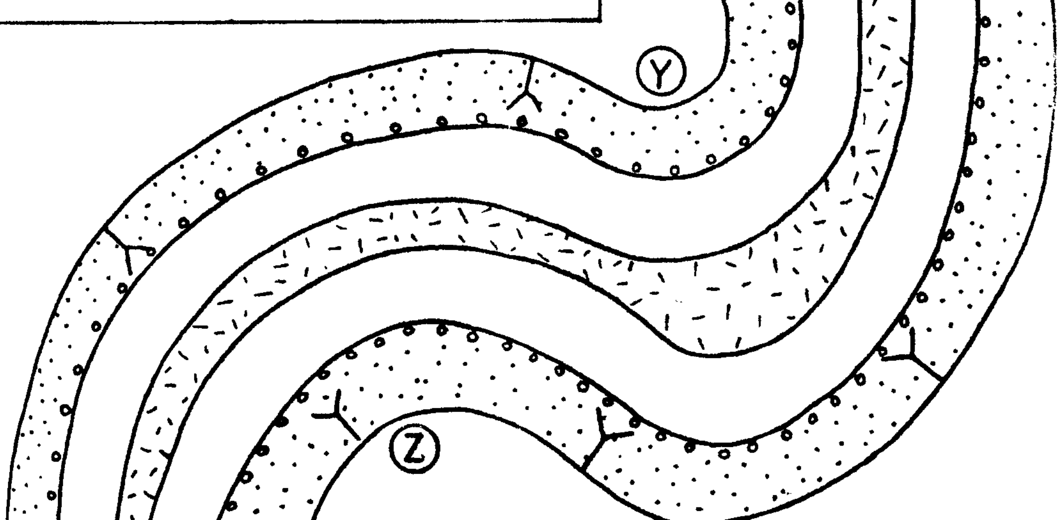


D



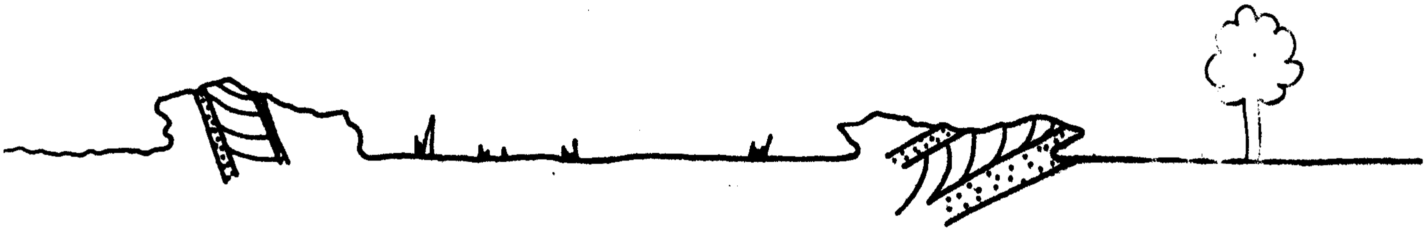


F

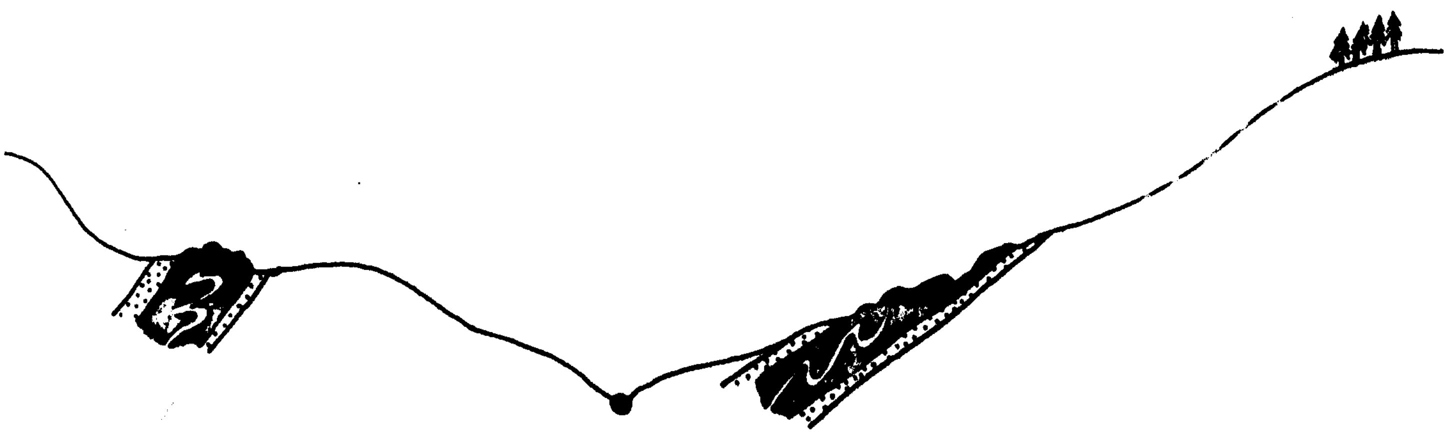



FIGURES FOR QUESTION 7 (SEVEN), GG 332I

A



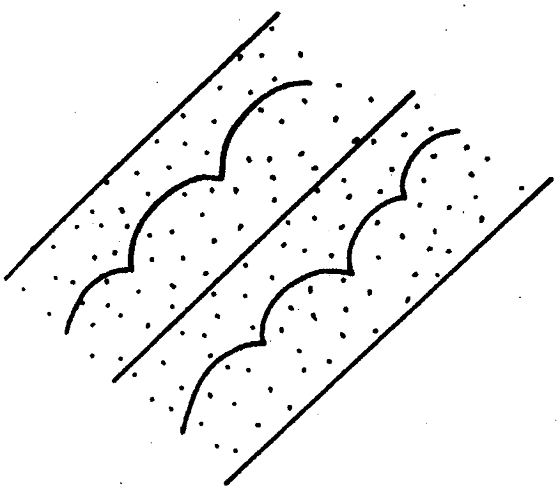
B

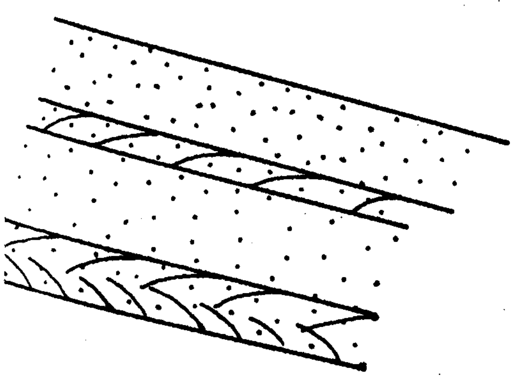


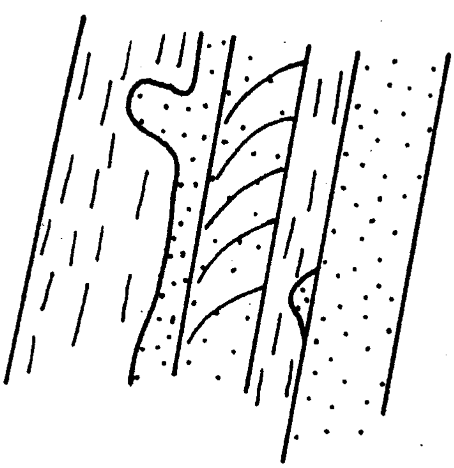
C

FIGURES FOR QUESTION 7 (SEVEN) (cont.), GG 332I

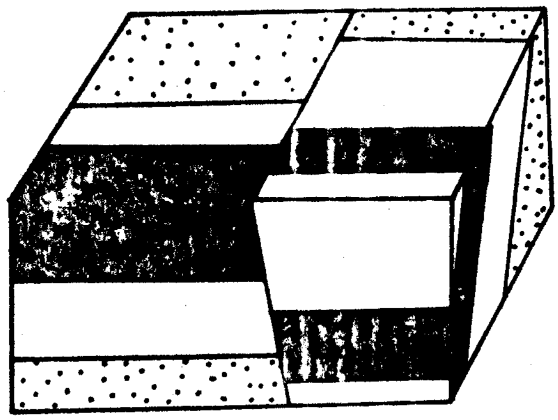
)







G



H

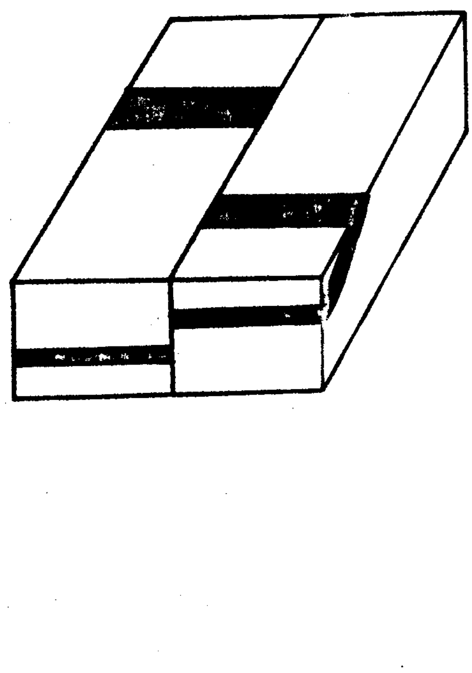
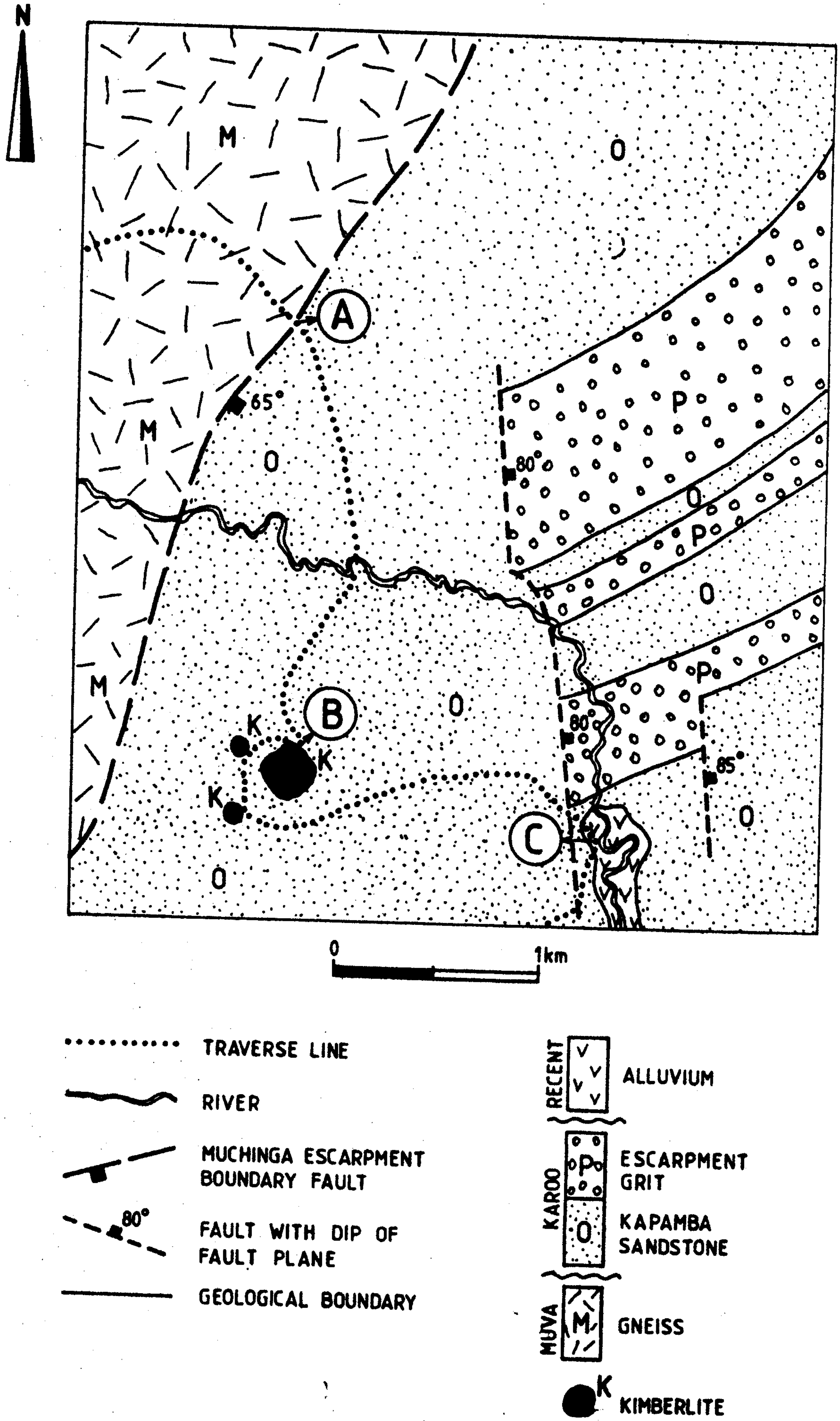


FIGURE FOR QUESTION 8 (EIGHT), GG 332 I



THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - OCTOBER/NOVEMBER 1995

GG 410

IGNEOUS AND METAMORPHIC PETROLOGY

PAPER I - THEORY

TIME: THREE HOURS

INSTRUCTIONS: ILLUSTRATE YOUR ANSWERS WITH SKETCHES WHEREVER POSSIBLE.

SECTION A - IGNEOUS PETROLOGY

Answer questions ONE and any other two questions.

1. Figure 1 is an illustration of the binary system MgO - SiO at P = 1 atm.

   (a) (i) Describe the crystallization of liquid A assuming equilibrium conditions. What is the mineralogy of the resulting rock A. 6%

   (ii) Discuss the mineralogical and chemical differences that would result from the removal of olivine from liquid A during its crystallization. 8%

   (b) Define the following terms:

   (i) Ophitic texture 2%
   (ii) Eutectic crytallization 2%
   (iii) Cryptic layering 2%

2. Describe the petrology of the following igneous rocks and indicate the geological environment (or environments) in which each is likely to occur.

   (a) rhyolite (b) syenite (c) andesite 15%

3. Batholiths have been subdivided into three structural types by Buddington. Give the names and a short characterization of each. 15%

4. Briefly discuss the main characteristics of Kimberlites and discuss their petrogenesis. 15%

SECTION B - METAMORPHIC PETROLOGY

ANSWER ALL QUESTIONS

1. Compare/constrast metamorphic rocks and magmatic rocks with regard to

   (a) material involved (e.g. liquid, solid, gas)
   (b) texture
   (c) chemical composition 15%

2. A schistose rock composed of mainly quartz and biotite contains 5% garnet and 3% staurolite, both minerals occuring as porphyroblasts:

   (a) What name would you give to this rock?
   (b) To what chemical types does it belong?
   (c) In which of the Barrovian Zones can it be found?

   Another gneissose metamorphic rock in which the minerals are coarse grained and grew as a result of metamorphism contains 65% hornblende, 25% plagioclase of andesine composition, 10% quartz and accessory opaque minerals.

   (d) What is its name?
   (e) What is the chemical type?
   (f) To which metamorphic facies would you attribute this rock? 15%

3. Briefly define the terms

   (a) Mylonite
   (b) Isochemical
   (c) Gneissic banding
   (d) Polygonal-granoblastic texture 10%

4. Given two AFM diagrams (Figure 2 and 3), answer the following questions:

   (a) What are the mineral assemblages of fields X, W, Y and Z? 2%

   (b) Assign a metamorphic facies to X and W. Approximate the P-T conditions to which the rocks have been exposed. 2%

   (c) What is the tectonic setting of X, Y and Z? What metamorphic reactions would occur if rock X moved to rock W as a result of P-T changes? 6%

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
UNIVERSITY EXAMINATIONS OCTOBER /NOVEMBER , 1995
GG410 : IGNEOUS AND METAMORPHIC PETROLOGY, THEORY
SECTION A - Igneous Petrology

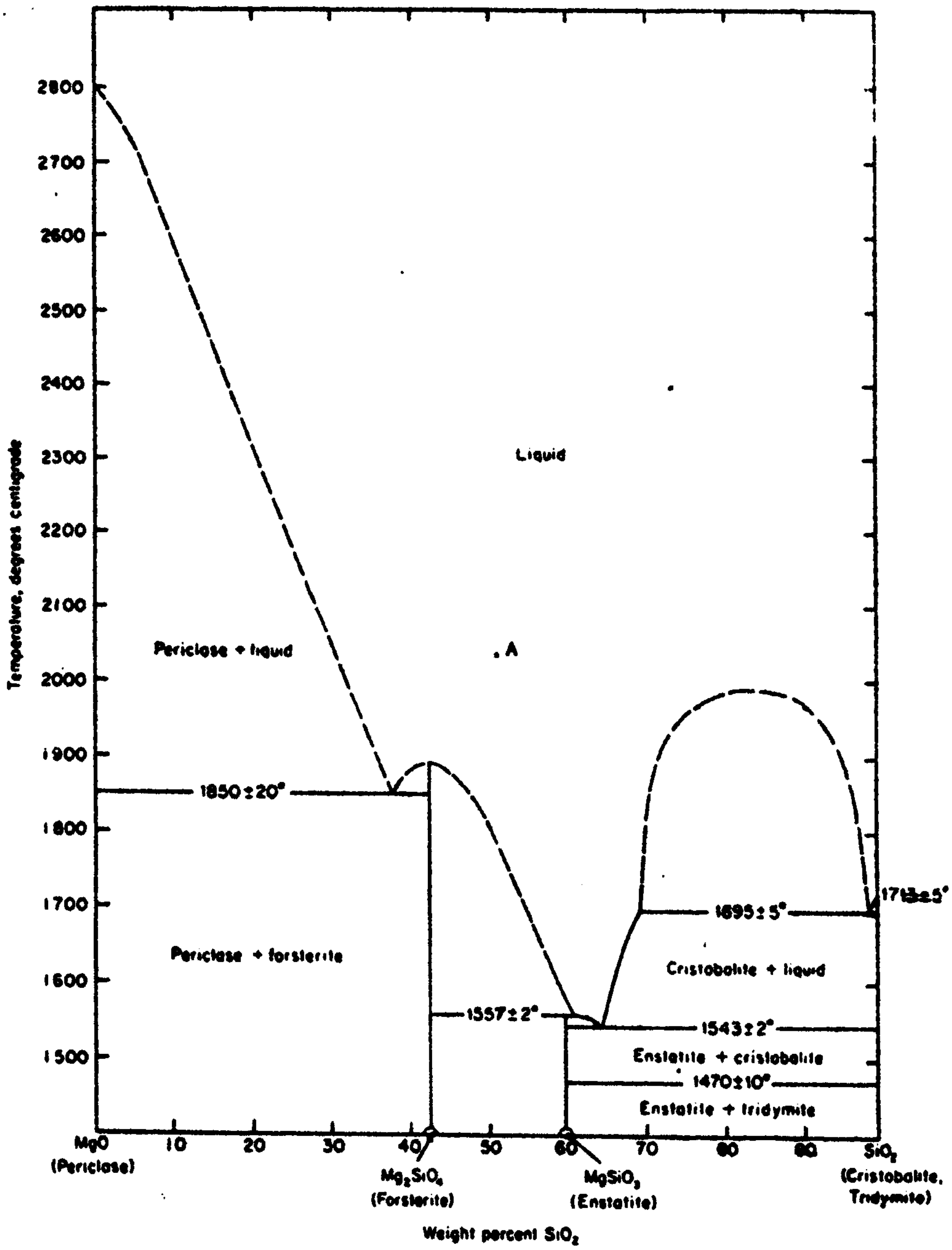


FIGURE 1

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS OCT/NOV. 1995

GG 410 : Igneous and Metamorphic Petrology

Section B - Metamorphic Petrology

FE-CRP = Fe - Carpholite

ctd = chlorotoid

PY = pyrophyllite

Chl = Chlorite

gnt = garnet

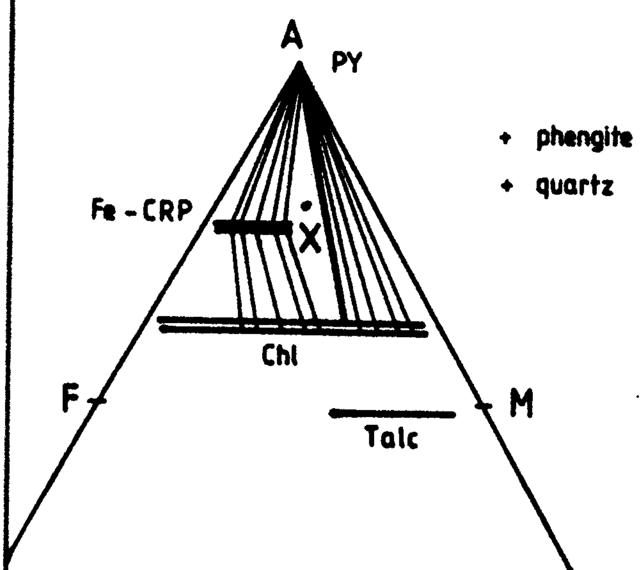


Fig. 2

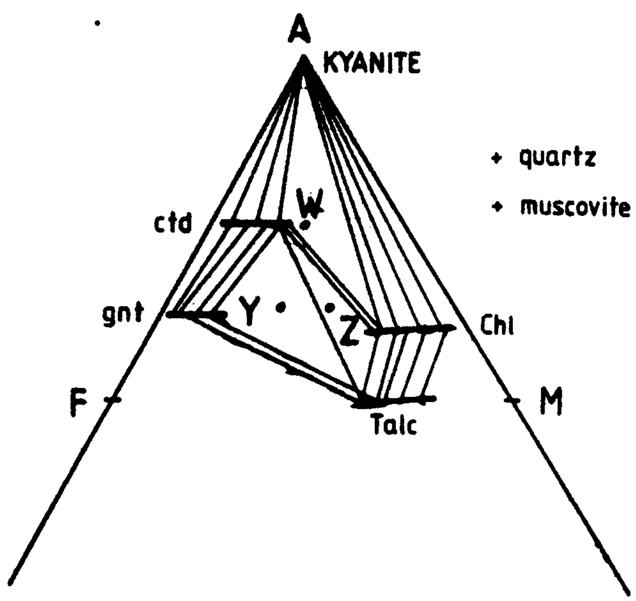


Fig. 3

THE UNIVERSITY OF ZAMBIA

UNIVERSITY MID-YEAR EXAMINATIONS - JUNE 1995

GG421

SEDIMENTOLOGY

THEORY - PAPER I

TIME: THREE HOURS

ANSWER:

ANY FIVE QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS.
USE SKETCHES WHERE POSSIBLE.

---

1. (a) Distinguish between siliciclastic rocks and non-siliciclastic (carbonate) rocks.

   (b) What is texture? List the grain properties that are included in texture.

   (c) Define the following:

   (i) matrix as applied to carbonate rocks
   (ii) cement as applied to siliclastic rocks
   (iii) coarsening-upward sequence
   (iv) syneresis cracks
   (v) convolute lamination

2. (a) Discuss the significance of sedimentary structures.

   (b) Outline the proposed methods for classifying sedimentary structures.

   (c) Outline the three general categories of internal structures.

   (d) Write short notes on the following (include in your answers the physical conditions under which these bedforms are being deposited):

   (i) ripples
   (ii) sand waves
   (iii) dunes
   (iv) plane beds
   (v) antidunes

3. (a) Outline the three main depositional types associated with an Alluvial fan system.

(b) What are the main features of proximal alluvial fans?

(c) Discuss the meandering river system in terms of:

(i) in-channel processes
(ii) in-channel deposits
(iii) overbank processes
(iv) overbank deposits

4. (a) Discuss the lacustrine environment in terms of:

(i) clastic sedimentation controls
(ii) biological and chemical activity
(iii) end members (facies) in the general model of lacustrine deposition.

(b) (i) What are the 4 main groups of glacial depositional systems.
(ii) Outline three mechanisms of subglacial deposition.
(iii) Discuss briefly the deposition of glaciofluvial sediments.

5. (a) What are the three main types of deltas?

(b) Discuss the river-dominated deltas in terms of:-

(i) significant factors that play a major role in these environments.
(ii) deposits of river-dominated deltas.

(c) (i) What are the principal beach sub-environments where significant accumulation of shallow marine siliciclastic deposits can take place?

(ii) Outline the transgressive model for an offshore bar/barrier island system.

6. (a) The marine environment can be divided into three geomorphological domains. With the aid of a sketch name and label these domains.
~~label these areas.~~

(b) Outline the general features, conditions and processes in the three named domains in (a) above.

(c) List (with short explanation) the features that are collectively thought to typify ancient shelf sequences.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY MID-YEAR EXAMINATIONS - JUNE 1995

GG 421

SEDIMENTOLOGY

PRACTICAL PAPER II

TIME: THREE HOURS

ANSWER: ALL QUESTIONS

---

1. Briefly define the following terms:

   (a) sparite versus micrite (1 mark)
   (b) wackestone (1 mark)
   (c) provenance (1 mark)
   (d) cement (outline the most common types in clastic rocks) (3 marks)
   (e) quartz overgrowth (1 mark)
   (f) grain fabric (1 mark)
   (g) sphericity vs roundness (what are the six classes of roundness?) (3 marks)
   (h) porosity versus permeability (1 mark)
   (i) grain size limits for (i) cobble
   (ii) fine sand
   (iii) coarse silt
   (3 marks)

2. Grain size analysis. After having collected a stream sediment sample, the grains were separated using a system of 11 sieves. They were then dried and weighed. The results are listed below.

Grain size	Weight	Weight %	Cumulative Weight %
-4 ø	73g		
-3 ø	282g		
-2 ø	870g		
-1 ø	1698g		
0 ø	514g		
+1 ø	97g		
+2 ø	35g		
+3 ø	11g		
+4 ø	8g		
+5 ø	2g		
+6 ø	1g		

(a) Using part of the graph size paper, build a frequency histogram of the grain distribution (weight % vs grain size). (4 marks)

(b) On the same graph paper draw a cumulative weight % vs grain size curve. (4 marks)

(c) What is the modal grain size of the sample? (2 marks)

(d) Find the median grain size. (4 marks)

(e) Calculate the precise arithmetic mean for the sample. (5 marks)

(f) Find a quantitative value used in defining the sorting of a sample. In your opinion, is it a well or poorly sorted deposit? (4 marks)

(g) By first finding the skewness of the deposit, do you think that the grains are mostly concentrated in the coarser or finer grain fraction? (5 marks)

(h) With all the calculations already done do you think that this deposit is a mature or immature deposit? Why? (2 marks)

3. (a) Describe the three handspecimens and corresponding thin sections, providing the full mineralogy, structures, features, provenance, etc. (You are to spend about 25 minutes on each sample/thin section and pass it to your neighbour. (50 marks)

(b) Classify the rocks in 3(a) using appropriate classification procedures and state the possible depositional environment for each rock. (5 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - OCTOBER/NOVEMBER 1995

GG 422

GEOLOGY OF ZAMBIA

PAPER I - THEORY

TIME: 3 HOURS

SECTION A: CRUSTAL EVOLUTION OF AFRICA (15%)

ANSWER EITHER QUESTION 1 OR QUESTION 2

1. (i) What evidence indicates that plate-tectonics operated during Archean times in Southern Africa? (3 marks)

   (ii) What is the significance of the granulite facies metamorphism in the Limpopo mobile belt? (2 marks)

   (iii) By what process was the Limpopo belt formed? (2 marks)

   (iv) What craton marks the emergence of the first continental lithosphere in Southern Africa? By what process did this happen? (4 marks)

   (v) The Karoo basalts are widespread in Southern Africa. What tectonic process would produce such an extensive basalt cover? (2 marks)

   (vi) What is the significance of these basalts in terms of global tectonics? (2 marks)

2. (i) Give two major magmatic events that mark an extensional phase in the evolution of the Southern African continent during Early Proterozoic times (Circa 2.0 Ga to 2.5 Ga) (3 marks)

   (ii) Why are komatiites most common in the Archean geological record? (3 marks)

   (iii) Why is the Karoo locally 9 km thick (sedimentary sequence)? (3 marks)

(iv) Which widespread orogeny established zones of crustal weakness that controlled the geometry of the subsequent Cape, Karoo and Cretaceous sequences of Southern Africa? (2 marks)

(v) Which orogeny was responsible for the assembly of Gondwanaland? (2 marks)

(vi) By what process was the Witwatersrand basin formed? (2 marks)

SECTION B: STRUCTURAL PROVINCES OF ZAMBIA (75%)

PART I: ANSWER TWO OUT OF THE FOLLOWING QUESTIONS (3,4 AND 5)

3. Some of the oldest rocks in Zambia are considered to occur in the Bangweulu Block which has been considered a craton comparable with the Archean cratons.

(a) Briefly describe the main features which characterise a typical Archean craton? (5 marks)

(b) How does the Bangweulu craton differ from a typical Archean craton? (5 marks)

(c) What role did the Ubendian shear phase (climax c. 1860 Ma) play in the evolution of the Bangweulu craton? (5 marks)

4. The crystalline rocks of the Bangweulu craton are overlain by a younger sedimentary cover, the Muva Supergroup which has been subdivided into several lithostratigraphic units, among them the Mporokoso Group and the Kasama Formation.

(a) Why are the sediments of the Mporokoso Group regarded as first cycle and those of the Kasama Formation as second cycle? (5 marks)

(b) Which are the inferred source areas for the sediments of these two units? (5 marks)

(c) What is the significance of intercalations of felsic tuffs within the lower sediments of the Mporokoso Group? (5 marks)

5. The Lufilian fold belt is an example of a Neoproterozoic orogenic belt whose geological evolution has been interpreted using either ensialic or modern-day plate tectonic models.

(a) What do you understand by the term orogenic belt and how can it be distinguished from a mobile belt? (5 marks)

(b) Describe the features which suggest that the Katangan rocks were formed in a rift setting. (5 marks)

(c) Cite the main evidence which has been used to postulate large-scale thrusting in the Lufilian Arc and briefly discuss why the identification of these thrusted units is of importance. (5 marks)

SECTION B - PART 2

ANSWER QUESTION 6 AND QUESTION 7

(GIVE BRIEF SHORT ANSWERS, PREFERABLY OF NOT MORE THAN THREE SENTENCES).

6. (i) What dating system(s) would you recommend to date granites that have been affected by both the Kibaran and Pan African orogenies? Why is this system good for such rocks? (3 marks)

(ii) What system would you use to date uplift events in an orogenic belt? (2 marks)

(iii) What is the tectonic/sedimentary significance of the abundant scapolite found in the Zambezi belt? (1 mark)

(iv) What tectonic process led to the formation of the Mozambique belt? What evidence supports this model of plate tectonics? Name some remnant lithologies. (5 marks)

7. (i) Sm - Nd model ages range between 900 - 2900 Ma in the Mozambique belt. What does this range of dates tell us about the tectonic cycles in the belt since Archean times. (3 marks)

(ii) What is the significance of bi-modal volcanism in the Katangan rocks of Southern Zambia? Where in the stratigraphy is this bi-modal volcanism observed? (2 marks)

SECTION B: PART 3

ANSWER ONE QUESTION FROM 9, 10 AND 11 (ALL THREE QUESTIONS CARRY EQUAL MARKS = 20 MARKS)

9. (a) Outline the establishment of a lithostratigraphic unit indicating the information that should be published to give formal validity to the named unit.

(b) Use the information in (a) to describe fully the lithostratigraphy of the Siankondobo Sandstone Formation of the Lower Karoo Group in a logical manner.

10. Discuss the formations of the Lower Karoo Group with respect to the following:

(i) stratigraphy
(ii) depositional environments
(iii) economic significance

11. Discuss the Sinakumbe Group with respect to the following:

(i) stratigraphy (briefly only)
(ii) depositional environments
(iii) tectonic framework

PART C: SPECIAL IGNEOUS ROCKS

ANSWER QUESTION 12 (10 MARKS)

12. (a) How would you distinguish a sedimentary limestone from a carbonatite using field mapping data and petrography? (5 marks)

(b) Briefly discuss four minerals of economic potential associated with Zambia's carbonatites and give examples of where each of the four minerals could be used in industry. (5 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - OCTOBER/NOVEMBER 1995

GG442

ECONOMIC GEOLOGY OF METALLIFEROUS ORES

PAPER I

THEORY

TIME: THREE HOURS

ANSWER: QUESTION ONE AND ANY OTHER THREE QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS

---

1. The origin of the Copperbelt Cu-Co ores in Zambia has been hotly debated for many years. Discuss the major metallogenic theories with respect to the following:

   (a) Time of emplacement of metals within the sediments.

   (b) Relationship between granitic rocks and the Katangan metasediments.

   (c) Zonation of Cu - Co - Fe sulphides parallel to the paleoshorelines.

   (d) Metal sources for the mineralization.

2. The Bushveld Igneous Complex is a layered mafix intrusion (LMI) greater than 67000km^2 in areal extent. Describe the following aspects of the complex:

   (a) types of metals produced

   (b) morphology of mineralisation

   (c) mineralogy and significance of the Merensky reef.

   (d) age and environment of emplacement

   (e) ultramafic rocks of the Main Zone.

   (f) origin.

3. (a) With the aid of a sketch describe the morphology and facies of diamond pipes.

   (b) Indicate the mineralogical composition of kimberlites.

   (c) Give the indicator minerals used in diamond prospecting in stream sediments and soil samples.

   (d) What xenoliths indicate the deep derivation of kimberlites?

   (e) Explain why not all kimberlites are diamondiferous.

4. Porphyry Cu deposits provide more than 50% of the world's copper. Discuss the following aspects of these deposits:

   (a) tonnage and grade

   (b) metals produced and by-products

   (c) associated plutonic instrusions

   (d) pattern of hydrothermal alteration of the host rocks

   (e) tectonic setting

   (f) origin

5. Zoning is a common aspect of pegmatites:

   (a) Discuss the mineralogy and texture of four major types of zones in pegmatites

   (b) With the aid of a sketch, indicate the change in composition of plagioclase, tourmaline and beryl in a zoned pegmatite.

   (c) Explain the origin of the Zonal Structure in pegmatites.

6. Kuroko ores are examples of volcanogenic massive sulphide deposits.

   (a) Sketch a genetic model of a Kuroko deposit, indicating ore types and associated rock types.

(b) Discuss their genesis with respect to metal sources, fluid transport and ore deposition.

(c) Indicate the tectonic setting of the Kuroko ores in Japan.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - OCTOBER/NOVEMBER 1995

GG 542

ENGINEERING GEOLOGY

TIME: THREE HOURS

ANSWER: FOUR QUESTIONS

QUESTIONS CARRY EQUAL MARKS

---

1. (a) What is a pyconometer; and describe how it is used. (10 marks)

   (b) Describe a variable Head Permeameter. In what circumstances is this type of permeameter used and give one example. (15 marks)

2. (a) Suppose you are required to design the Konkola Deep Mining Shaft. One of the problems you are to solve is to determine how deep the shaft is to be; assuming the rock type is entirely limestone.

   In order to have "feel" of the forces involved at depth, the problem is treated as that of piling limestone blocks, in the form of cubes, with dimensions of 1 metre, one on top of the other.

   Calculate the maximum height of the limestone column possible before failure.

   Notes:

   (a) Density of limestone is 2000 kg/Cu. metre
   (b) Foundation Stress of limestone is 30 MPa
   (c) It is assumed the shaft is constructed entirely in limestone. (15 marks)

   (b) Describe the Triaxial Test. (10 marks)

3. (a) Present in Tabular form the Effects of Modifying Ground conditions by Natural and Engineering processes. (15 marks)

   (b) Describe a case history, in Zambia, where many lives were lost as a result of "withdrawal of support" due to an engineering activity. (10 marks)

4. It is said that the difference between a "pure geologist" and an "engineering geologist" is that the former tries to understand the history (genesis) of rocks, whereas the latter looks to the future, trying to predict and control the behaviour of anything made of, in, or on rock.

Can you as an engineering geologist relate the above statement to the Batoka Hydroelectric project taking into account what you would consider should be done to:

(a) determine ground characterization of the site.

(b) predict and monitor rock behaviour.

(c) predict the seismic activity due to a combined loading effect of the Kariba and Batoka Dams.

5. (a) Derive an expression for Poisson's Ratio in terms of compressional waves (α) and transverse waves (β).

(15 marks)

(b) Calculate Poisson's Ratios for the following:

(i) Granite (Vp = 5 km/sec; Vs = 3 km/sec)

(ii) Water (Vp = 1.5 km/sec; Vs = student to provide value)

(10 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY MID-YEAR EXAMINATIONS - JUNE 1995

GG 561

APPLIED GEOPHYSICS

TIME: THREE (3) HOURS

ANSWER: ANY FOUR QUESTIONS

---

1. (a) Define briefly the following geophysical terms:

   (i) Magnetic permeability
   (ii) Latitude correction
   (iii) Universal constant
   (iv) Magnetometer
   (v) Resistivity (10 marks)

   (b) Explain the principles behind the La Coste Romberg gravimeter giving factors that influence gravity readings. (15 marks)

2. (a) Calculate the resistance of a cylindrical core of limestone (marble) 10 cm long having a radius of 1 cm, with resistivity of ten thousand (10,000) ohmmetres. (10 marks)

   (b) Describe the type of instrumentation used in D.C. Resistivity Surveying. (15 marks)

3. Compare and contrast the following two geophysical methods of groundwater investigation, VLF and VES, in relation to the following:

   (a) type of source
   (b) resolution
   (c) favourable types of targets
   (d) speed of field survey
   (e) ease of interpretation of results (25 marks)

4. Calculate the value of gravitational acceleration at a horizontal axis x = 0, due to a thin fault (i.e. small displacement); given that;

   (i) density contrast is 2 gm/cc
   (ii) displacement (t) is 0.1 kilofeet
   (iii) depth of overburden is 0.01 kilofeet
   (25 marks)

5. Describe all the corrections required to be made in order to obtain a Bouguer Map. Give all the details.
(25 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS JUNE 1995

MM 320 I / MM 321

CHEMICAL METALLURGY

TIME: THREE Hours

ANSWER: FIVE Questions

All questions carry equal marks

$R = 8.314$ J/(mol)(K)
$= 0.08206$ (litre)(atm)/(K)(mol)

1 litre-atm = 1.013×10^2 joules

$C_v = 3/_2 R$, $C_p = 5/_2 R$ for an ideal gas

---

1. (a) A quantity of an ideal gas occupies 10 litres at 10 atm and 100 K. It undergoes a reversible adiabatic expansion to 1 atm. Calculate (i) the work done by the system, (ii) the heat entering or leaving the system and (iii) the internal energy and enthalpy changes.

(b) Suppose the gas in part (a) underwent an adiabatic sudden reduction in pressure to 1 atm, calculate the entropy that would be produced in this irreversible expansion.

2. (a) For the reaction

$$Pb_{(l)} + \tfrac{1}{2} O_{2(g)} = PbO_{(s)}$$

$$\Delta H^\theta_{298} = -219\,000 \text{ joules}$$

Calculate ΔH^θ_{1000}. Use the following heat capacity data: $Cp = a + bT + cT^{-2}$ J/(mol)(K)

Substance	a	bx10^3	c x 10^{-5}
$PbO_{(s)}$	37.9	26.8	0.0
$O_{2(g)}$	30.0	4.18	-1.7
$Pb_{(l)}$	32.4	-3.1	0.0
$Pb_{(s)}$	23.6	9.75	0.0

Melting point of lead = 600 K
Heat of fusion of lead = 4810 J at 600 K

(b) In an investigation of the thermodynamic properties of α-manganese, the following heat contents were determined:

$$H^{\theta}_{700} - H^{\theta}_{298} = 12\,113 \quad J/mol$$

$$H^{\theta}_{1000} - H^{\theta}_{298} = 22\,803 \quad J/mol$$

Find a suitable equation for $H_T^{\theta} - H^{\theta}_{298}$ and also for Cp as a function of temperature in the form a + bT. Assume no phase transformations in this temperature range.

3. Calculate the entropy changes of the system and the surroundings for the case of the isothermal freezing of one mole of supercooled liquid silver at 850°C, when the surroundings are also at the same temperature. You are given the following additional data:

Melting point of silver = 1234 K

Heat of fusion of silver at 1234 K = 11 255 J/mol

Cp for Ag(s) = $21.30 + 8.54 \times 10^{-3}T$ J/(mol)(K)

Cp for Ag(l) = 30.54 J/(mol)(K)

4. (a) With the help of the auxiliary functions, show that the internal energy per mole U and the enthalpy per mole H of a perfect gas are independent of the pressure and volume of the system at constant temperature.

(b) In the transition $CaCO_3$ (aragonite) → $CaCO_3$ (calcite) ΔG^{θ} = −800 J/mol at 298 K and ΔV = 2.75 cm^3/mol. Calculate the pressure that must be applied to aragonite at 298 K in order to bring about its transformation to calcite.

5. (a) Comment on the significance of the fugacity.

(b) The virial equation for hydrogen is given as follows:

$$PV = RT\,(1 + 6.4 \times 10^{-4}P)$$

Calculate:

(i) the fugacity of hydrogen at 500 atm and 298 K,

(ii) the pressure at which the fugacity is twice the pressure,

(iii) the free energy change resulting from the compression of 1 mole of hydrogen at 298 K from 1 atm to 500 atm,

(iv) the contribution to (iii) arising from the nonideality of hydrogen.

6. The basic reaction in the cracking of ammonia is as follows:

$$2NH_{3(g)} = N_{(g)} + 3H_{2(g)}$$

Calculate the percent of NH_3 dissociated at equilibrium under conditions of (a) constant pressure of 0.5 atm and 400°C and (b) constant pressure of 1 atm and 400°C. For the reaction we have:

$$\Delta G^{\theta} = 87030 - 25.8\,T\,\ell n\,T - 31.7T \text{ joules}$$

END OF FINAL EXAMINATION IN MM 321

THE UNIVERSITY OF ZAMBIA
UNIVERSITY EXAMINATIONS - FIRST SEMESTER, 1995

MM 421
HYDROMETALLURGY

TIME: THREE HOURS.
ANSWER: ALL QUESTIONS. THE CREDIT FOR A FULL ANSWER IS SHOWN IN BRACKETS BESIDES EACH QUESTION.

1.a. Given the data shown below, construct a hydrogen precipitation diagram for cobalt (cation activity 10^{-4} to 1). Assume a temperature of 30 °C and a H_2 partial pressure of 50 atmospheres. (Faraday constant = 96500 C/mol) (8%)

$Co^{2+} + 2e^- = Co$ $E° = -0.28$ V
$2H^+ + 2e^- = H_{2(g)}$ $E° = 0$ V

b. What do you think the intersection point on the diagram you have constructed represents? (3%)

c. (i) Indicate schematically the shift (if any) of the lines in your diagram when the partial pressure of hydrogen is reduced to 25 atmospheres. (3%)

(ii) If pH, H_2 pressure, and initial cobalt concentration in solution are kept constant, how would an increase in precipitation temperature affect the level of residual cobalt in solution? (3%)

d. (i) For a process in which cobalt metal is recovered from an acid leach solution by precipitation using H_2, explain what measures you would take to obtain a much lower residual cobalt concentration in solution. (4%)

(ii) Explain qualitatIvely what differences and similarities there would be if cobalt in acid leach solutions is precipitated using hydrogen sulphide gas instead of hydrogen. (4%)

2.a. Study Figures 1 and 2 which show Eh-pH diagrams for Au-H_2O and Au-CN-H_2O systems, respectively, then answer the following questions.

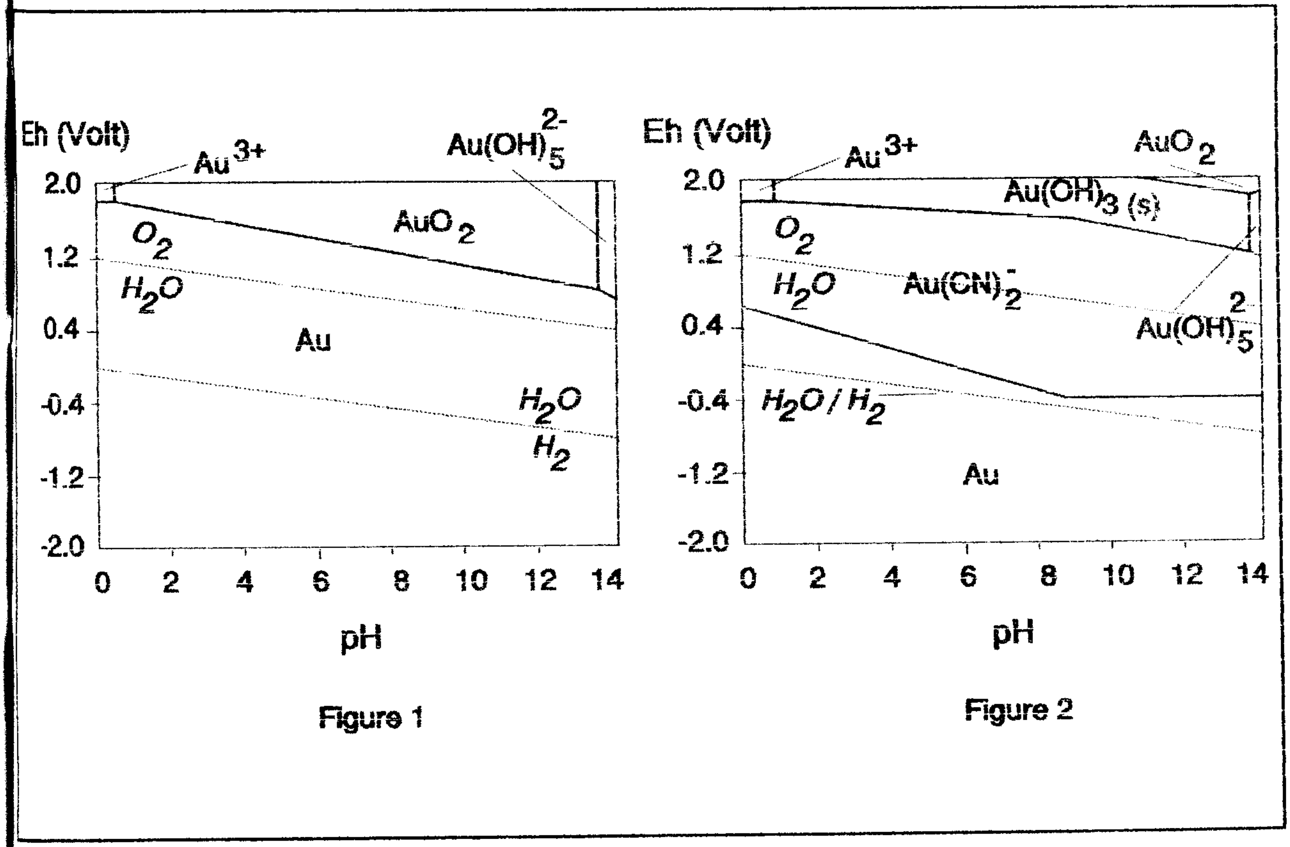
(i) Is $Au(OH)_3$ stable in air? If not, why does gold leaching with cyanide require aeration? (3%)

1.a. (ii) Why does the presence of sulphides in the ore interfere with cyanide leaching of gold? (5%)

(iii) Does Fig. 2 explain why commercial gold leaching with cyanide occurs at a pH ≥ 10? If yes, why? if not, why not? (3%)

b. Explain the mechanisms by which gold adsorption on activated carbon is said to occur. (5%)

c. What are the advantages of carbon-in-pulp technology as compared to cementation with zinc dust for the recovery of gold from cyanide leach solutions? (4%)



Figures 1 and 2 showing Eh-pH diagrams of Au-H_2O and Au-CN-H_2O systems, respectively, drawn for the concentrations [Au]=10^{-3} M and [CN]=10^{-3} M.

3.a. As applied to the leaching of concentrate particles, explain how in general, each of the undermentioned influences the kinetics of leaching: (7%)

(i) Temperature, (ii) Particle geometry, iii) Bath agitation, (iv) Solute concentration in the liquor, (v) Particle size distribution.

b. Consider the case of leaching a concentrate with spherical particles in which the reaction proceeds topochemically. Assuming that the rate determining step during leaching is the chemical reaction at the interface and that the reaction obeys first order kinetics, show that in the initial stages of leaching the following relationship is valid:

$$\log (1 - \alpha) = K - 3\log t$$

where α is the fraction reacted at time **t** and K is a constant. State any other assumptions made in your derivation. (8%)

c. Carefully explain how you would attempt to find out whether a leaching reaction is rate determined by diffusion or by chemical reaction at the interface. (5%)

4.a. Electrowinning of zinc is done at a cell voltage of 3.5 V. Given that the current efficiency is 90%, calculate the energy consumption in kWh per kg Zn plated out. (5%)

b. An electrowinning cell has 38 anodes and 39 cathodes of 1 m^2 arranged alternately and connected electrically in parallel. How much zinc is electrowon in one day if the operating current density is 200 A/m^2 and the current efficiency is 90%? (5%)

c. Copper anodes invariably contain, among other impurities, Ni, Au, Se, As, and Ag. Outline the behaviour of the named impurities during electrorefining of copper anodes. Where applicable, indicate the measures which can be taken to prevent the impurities from building-up in the electrolyte. (5%)

5.a. A leach solution with 0.975 g/l Cu^{2+} is used to study Cross-current extraction with LIX 864 dissolved in Escaid as the organic phase. At each stage of extraction, 30 cm^3 of fresh organic is equilibrated with the aqueous phase. If in the first stage of extraction 100 cm^3 of the leach solution is used yielding at equilibrium an extract and raffinate with 1.98 and 0.381 g/l copper respectively, determine the least number of equilibrium (Cross-current) stages required to yield a final raffinate with not more than 0.012 g/l copper. Assume a constant distribution coefficient of copper at each stage and that the organic and aqueous phases are immiscible. (10%)

b. With reference to equilibrium extraction isotherms used in solvent extraction, answer the following questions:

(i) Explain what these isotherms are. (3%)

(ii) How are they determined? (4%)

(iii) Of what use are they? (3%)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS JUNE 1995

MM 441

TRANSPORT PHENOMENA

TIME: THREE hours

ANSWER: FIVE questions

ALL questions carry equal marks

---

1. (a) A cube of material 300 mm on edge weighing 445 N is lowered into a tank containing a layer of water over a layer of mercury. Determine the position of the block when it has reached equilibrium in mm in water. Density of water is 10^3 kg/m^3 and the specific gravity of mercury is 13.6.

   (b) A storage vessel is well stirred and contains 500 kg of total solution with a concentration of 5.0% salt. A constant flow rate of 900 kg/h of salt solution containing 16.67% salt is suddenly introduced into the tank and a constant withdrawal rate of 600 kg/h is also started. These two flows remain constant thereafter. Derive an equation relating the outlet withdrawal concentration as a function of time. Also calculate the concentration after 2 hours.

2. Water at 298 K discharges from a nozzle and travels horizontally hitting a wall inclined at 45^0 with the vertical. The nozzle diameter is 12 mm and the water leaves at a velocity of 6 m/s. The flow is frictionless. Assume no loss in energy i.e. $v_1 = V_2 = V_3$. The amount of fluid splitting in each direction along the plate can be determined by using the continuity equation and a momentum balance. Calculate the force on the wall.

3. Hot water in an open storage tank at 82.2^0C is being pumped at the rate of 0.379 m^3/min from this storage tank. The line from the storage tank to the pump suction is 6.1m of 50-mm steel pipe ($e = 4.6 \times 10^{-5}$m) and it contains three 90^0 elbows. The discharge line after the pump is 61m of 50-mm pipe and contains two 90^0 elbows. The water discharges to the atmosphere at a height of 6.1m above the water level in the storage tank.

(a) Calculate the total friction losses in metres.

(b) Calculate W_s for the pump in J/kg.

(c) Calculate the kW power of the pump if its efficiency is 75%.

Density of water = 970 kg/m^3

Viscosity of water = 0.345×10^{-3} Pa.s

$$h_L = 2 f_f \frac{L}{D} \frac{v^2}{g}$$

$$g = 9.81 \ m/s^2$$

$$h_c = 0.056 \left(1 - \frac{A_2}{A_1}\right) \frac{v_2^2}{2}$$

$\frac{Le}{D}$ for each 90^0 elbow = 35

4. A fluid of constant density is flowing in laminar flow at steady state in the horizontal x direction between two flat and parallel plates. The distance between the two plates in the vertical y direction is $2y_0$. Using the Navier-Stokes equations, derive, for a distance L in the x direction, the following:

(a) the velocity profile within this fluid assuming a constant pressure drop in the x direction,

(b) the maximum velocity.

(c) the ratio of the average velocity to the maximum velocity.

5. A cold storage room is to be constructed of an inner layer of 19.1 mm of pine wood, a middle layer of cork board, and an outer layer of 50.8 mm of concrete. The inside wall surface temperature is -17.8^0C and the outside surface temperature is 29.4^0C at the outer concrete surface. The mean thermal conductivities are for pine, 0.151; cork, 0.0433; and concrete, 0.762 W/(m)(K). The total inside surface area of the room to use in the calculation is approximately $39m^2$ (neglecting corner and end effects). Calculate

(a) the thickness of cork board needed to keep the heat loss to 586 W,

(b) the interfacial temperatures with the given heat loss.

6. (a) Derive the relationship for the heat flow through a counterflow heat exchanger.

   (b) A reaction mixture having a Cp_m = 2.85 kJ/(kg)(K) is flowing at a rate of 7260 kg/h and is to be cooled from 377.6 K to 344.3 K. Cooling water at 288.8 K is available (Cp = 4.187 kJ/kg.K) and the flow rate is 4536 kg/h. The overall U_0 is 653 W/m^2 K. For counterflow, calculate the outlet water temperature and the area A_0 of the exchanger.

7. Ammonia gas (A) and nitrogen gas (B) are diffusing in counterdiffusion through a straight glass tube 0.610 m long with an inside diameter of 24.4 mm at 298 K and 101.32 kPa. Both ends of the tube are connected to large mixed chambers at 101.32 kPa. The partial pressure of NH_3 in one chamber is constant at 20.0 kPa and 6.666 kPa in the other chamber. The diffusivity at 298 K and 101.32 kPa is 2.30 x 10^{-5} m^2/s.

   (a) Calculate the diffusion of NH_3 in kg mol/s.

   (b) Calculate the diffusion of N_2.

   (c) Calculate the partial pressures at a point 0.305m in the tube.

$$R = 82.057 \times 10^{-3}\ (m^3)(atm)/(kg\ mol)(K)$$

END OF EXAMINATION IN MM 441

[illegible]-1

THE EQUATION [illegible]INUITY IN SEVERAL COOR[illegible] SYSTEMS

Rectangular coordinates (x, y, z):

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}(\rho v_x) + \text{[illegible]}) + \frac{\partial}{\partial z}(\rho v_z) = 0 \qquad (A)$$

Cylindrical coordinates (r, θ, z):

$$\frac{\partial \rho}{\partial t} + \frac{1}{r}\frac{\partial}{\partial r}(\rho r v_r) + \text{[illegible]}_\theta) + \frac{\partial}{\partial z}(\rho v_z) = 0 \qquad (B)$$

Spherical coordinates (r, θ, ϕ):

$$\frac{\partial \rho}{\partial t} + \frac{1}{r^2}\frac{\partial}{\partial r}(\rho r^2 v_r) + \frac{1}{r \sin\theta}\frac{\partial}{\partial \text{[illegible]}} \text{[illegible]} \theta) + \frac{1}{r \sin\theta}\frac{\partial}{\partial \phi}(\rho v_\phi) = 0 \qquad (C)$$

θ direction

$$\rho\left(\frac{\partial v_\theta}{\partial t}+v_r\frac{\partial v_\theta}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta}+\frac{v_r v_\theta}{r}+v_z\frac{\partial v_\theta}{\partial z}\right)$$

$$=-\frac{1}{r}\frac{\partial P}{\partial \theta}+\rho g_\theta+\mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(r v_\theta)\right)+\frac{1}{r^2}\frac{\partial^2 v_\theta}{\partial \theta^2}+\frac{2}{r^2}\frac{\partial v_r}{\partial \theta}+\frac{\partial^2 v_\theta}{\partial z^2}\right] \quad \text{(E-5)}$$

z direction

$$\rho\left(\frac{\partial v_z}{\partial t}+v_r\frac{\partial v_z}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta}+v_z\frac{\partial v_z}{\partial z}\right)$$

$$=-\frac{\partial P}{\partial z}+\rho g_z+\mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 v_z}{\partial \theta^2}+\frac{\partial^2 v_z}{\partial z^2}\right] \quad \text{(E-6)}$$

SPHERICAL COORDINATES*

r direction

$$\rho\left(\frac{\partial v_r}{\partial t}+v_r\frac{\partial v_r}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta}+\frac{v_\phi}{r\sin\theta}\frac{\partial v_r}{\partial \phi}-\frac{v_\phi^2}{r}-\frac{v_\theta^2}{r}\right)$$

$$=-\frac{\partial P}{\partial r}+\rho g_r+\mu\left[\nabla^2 v_r-\frac{2}{r^2}v_r-\frac{2}{r^2}\frac{\partial v_\theta}{\partial \theta}-\frac{2}{r^2}v_\theta\cot\theta-\frac{2}{r^2\sin\theta}\frac{\partial v_\phi}{\partial \phi}\right] \quad \text{(E-7)}$$

θ direction

$$\rho\left[\frac{\partial v_\theta}{\partial t}+v_r\frac{\partial v_\theta}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta}+\frac{v_\phi}{r\sin\theta}\frac{\partial v_\theta}{\partial \phi}+\frac{v_r v_\theta}{r}-\frac{v_\phi^2\cot\theta}{r}\right]$$

$$=-\frac{1}{r}\frac{\partial P}{\partial \theta}+\rho g_\theta+\mu\left[\nabla^2 v_\theta+\frac{2}{r^2}\frac{\partial v_r}{\partial \theta}-\frac{v_\theta}{r^2\sin^2\theta}-\frac{2\cos\theta}{r^2\sin^2\theta}\frac{\partial v_\phi}{\partial \phi}\right] \quad \text{(E-8)}$$

φ direction

$$\rho\left(\frac{\partial v_\phi}{\partial t}+v_r\frac{\partial v_\phi}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\phi}{\partial \theta}+\frac{v_\phi}{r\sin\theta}\frac{\partial v_\phi}{\partial \phi}+\frac{v_\phi v_r}{r}+\frac{v_\theta v_\phi}{r}\cot\theta\right)$$

$$=-\frac{1}{r\sin\theta}\frac{\partial P}{\partial \phi}+\rho g_\phi+\mu\left[\nabla^2 v_\phi-\frac{v_\phi}{r^2\sin^2\theta}+\frac{2}{r^2\sin\theta}\frac{\partial v_r}{\partial \phi}+\frac{2\cos\theta}{r^2\sin^2\theta}\frac{\partial v_\theta}{\partial \phi}\right] \quad \text{(E-9)}$$

* In the above equations,

$$\nabla^2=\frac{1}{r^2}\frac{\partial}{\partial r}\left(r\frac{\partial}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial}{\partial \theta}\right)+\frac{1}{r^2\sin^2\theta}\frac{\partial^2}{\partial \phi^2}$$

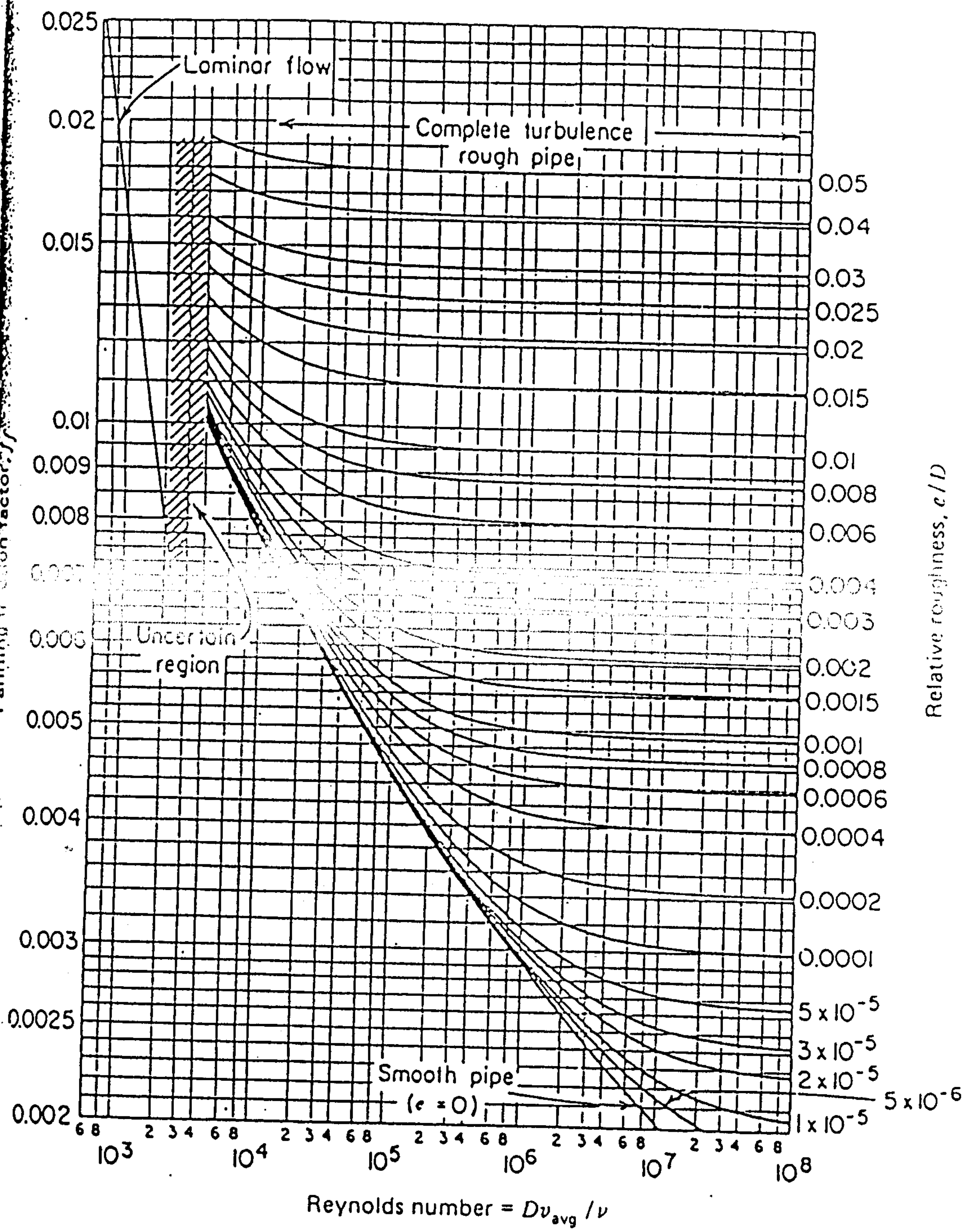


Figure 14.1 The Fanning friction factor as a function of Re and D/e.

2. As part of an investigation into the optimum treatment of a sulphide copper-cobalt ore, a number of laboratory batch flotation tests is carried out under different conditions of grind, pH, type of collector and collector doserate.

The head grade of the ore is 2.00 % Cu and 0.100 % Co. For the sake of simplicity you may assume that the copper is present in the ore as one mineral (chalcopyrite, $CuFeS_2$) only and the cobalt is present only as linnaeite (Co_3S_4). Again, for the sake of simplicity, you may take the chalcopyrite to contain 33.3 % Cu and the linnaeite to contain 50.0 % Co and no copper.

For one set of conditions the flotation tests suggested that only 90 % of the chalcopyrite and 60 % of the linnaeite are floatable under these conditions and that the following rate constants would be applicable:

chalcopyrite	$k = 0.25$	min^{-1}
linnaeite	$k = 0.15$	"
gangue	$k = 0.002$	"

(a) If you assume that this flotation process is a first order rate process, and that all the floatable chalcopyrite and linnaeite particles have the same rate of flotation, regardless of particle size and degree of liberation (assume that all the sulphide particles are free), calculate the recoveries and grades of copper and cobalt in the concentrate after 2 minutes of flotation and after a total of 8 minutes of flotation.

(b) The test results, and further microscopic examination of the flotation products, suggest that some of the chalcopyrite is present as middlings and floats at a slower rate than the rest of the cp, which is essentially free.

Recalculate the recoveries and grades of copper and cobalt after 2 minutes flotation, using the following k-values for the two chalcopyrite fractions and assuming that the slow-floating chalcopyrite fraction represents 25 % of the copper in the ore:

fast-floating cp	(75 % of total Cu)	$k = 0.35$
slow-floating cp	(25 % of total Cu)	$k = 0.08$

The middlings contain, on average, 20 % Cu.

Only 90 % of the chalcopyrite and 60 % of the linnaeite are floatable under the test conditions.

3. In a particular industrial process, a mineral suspension with an initial solids concentration (C_0) of 50 g ℓ^{-1} has to be thickened to an underflow concentration (C_u) of 340 g ℓ^{-1}.

A laboratory batch settling test on this suspension gave the following results:

time (min)	mudline height (cm)	time (min)	mudline height (cm)
0	34.0	12	10.5
1	33.0	14	9.0
2	30.5	16	8.0
3	28.0	18	7.5
4	25.5	20	7.0
5	23.0	25	6.5
6	20.5	30	6.3
7	18.0	40	6.0
8	15.5	50	5.8
9	13.5	60	5.6
10	12.0	90	5.5

(a) Plot the batch sedimentation curve for this batch settling test on the graph paper provided.

(b) What is the relationship between solids concentration and interface ('mudline') height, that was developed by Kynch and used by Talmage and Fitch in their methods for determining thickener areas required ?

(c) Show briefly how this relationship can be used to apply the data from one batch settling test to the Coe and Clevenger method of determining required thickener areas.

(d) Using the 'simplified' method of Talmage and Fitch, determine the time (t_u) required to reach the required underflow solids concentration, and the thickener unit area required from this batch settling curve.

Explain briefly how you determined the 'compression point'.

(e) Calculate the maximum solids feed rate permissable if a clear thickener overflow is required in this operation.

(f) What would you recommend if your results show that the anticipated solids feed rate will be too high for the thickener area available ?

Explain your recommendation in a few words.

4. A concentrator treats a copper ore by crushing, grinding and flotation. Because changes are envisaged in the future ore characteristics and in the mill throughput, crushing and grinding tests are carried out on the future ore, with the aim of simulating the comminution processes with simple matrix models to predict the size distribution in the ball mill product.

Using a series of six laboratory test sieves from 2 mm down to 63 µm, the following corresponding elements of a 6 x 6 breakage matrix were established by the tests:

0.2 0.3 0.2 0.1 0.05 0.05

It was further established that the probability of breakage for these six size fractions in each breakage stage will be:

1.0 1.0 1.0 0.9 0.5 0.3

If the particle size distribution in the ball mill feed is as given below, calculate the particle size distribution in the ball mill product <u>after one stage</u> of breakage <u>and after two stages of breakage</u>, on the basis of these data and with the assumption that the elements of the breakage matrix and the probabilities of breakage will be the same in each subsequent breakage stage.

ball mill feed:

sieve size (µm)	weight retained (%)
2000	0.2
1000	4.6
500	11.4
250	16.2
125	22.5
63	20.8

5. (a) Durand's correlation for the transportation of slurries can be written as:

$$v_D = F_L \left[2 g D \frac{\rho_s - \rho_l}{\rho_l} \right]^{0.5}$$

State what the various symbols in this equation represent and what their dimension is.

contd. ......

(b) A mineral slurry has to be transported through a pipeline. The SG of the solids is taken as 2.8. For the Froude number F_L for this slurry a value of 1.2 was established as acceptable. The quantity of slurry to be transported is expected to fluctuate between 600 and 900 liter per minute.

Standard steel pipe is available with internal diameters of 5 cm, 7.5 cm, 10 cm, 12.5 cm and 15 cm. Which of these diameters would you choose to minimise the risk of pipe blockages ?

Show how you arrived at your decision.

You can take the density of water as 1.0×10^3 kg m^{-3} and the acceleration of gravity as 9.81 m s^{-2}.

(c) Attached are the characteristic curves of two different pumps.

(i) Judging from the curves, what type(s) of pump are these two pumps ?

Explain your answer in a few words.

(ii) Which of these two pumps would you recommend to pump the slurry, described above (SG solids 2.8, quantity fluctuating between 600 and 900 liter per minute), if the corresponding dynamic head with the pipe that you have chosen is calculated to fluctuate between 18 and 20 metres ?

Explain your answer in a few words.

SECTION B.

6. (a) Derive Young's equation for the interfacial tensions at a three-phase interface (S-L-G).

Illustrate with a diagram for the case where the liquid 'wets' the solid and with a diagram for the case where the liquid does not wet the solid.

Show the 'contact angle' in each of these two diagrams.

(b) How can contact angle measurements be used in flotation testing ?

(c) When would you consider a solute to be 'surface active' in a solvent and when would you consider it to be 'surface inactive' ?

In each of these cases, what is the influence of the solute upon the surface tension of the solution ?

contd. ......

6/......

8. (a) What do you understand by the 'head ratio' for a centrifugal pump, used in slurry pumping, and what do you understand by the 'head depression' ?

(b) Discuss briefly how and why the presence of solids in a liquid, handled by a centrifugal pump, affects

- the head, developed by the pump;
- the mechanical efficiency of the pump.

(c) In particular, what are the effects of

- solids concentration,
- particle size,
- solids density

upon the head developed and the efficiency of the pump ?

(d) Discuss briefly how and why solids in the liquid pumped affect the head loss in the pipeline.

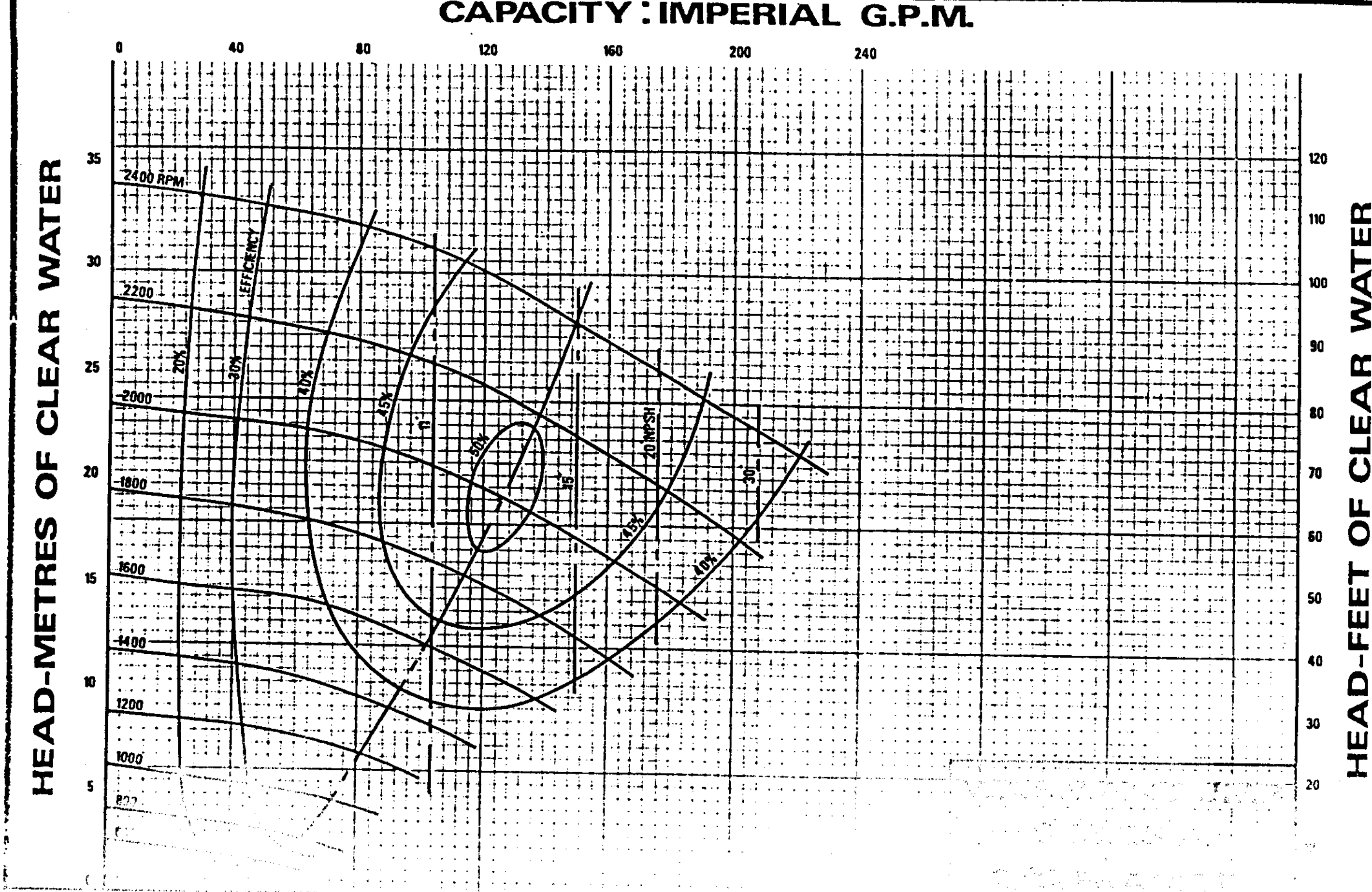
(e) The equation of Durand and Condolios can be written as follows:

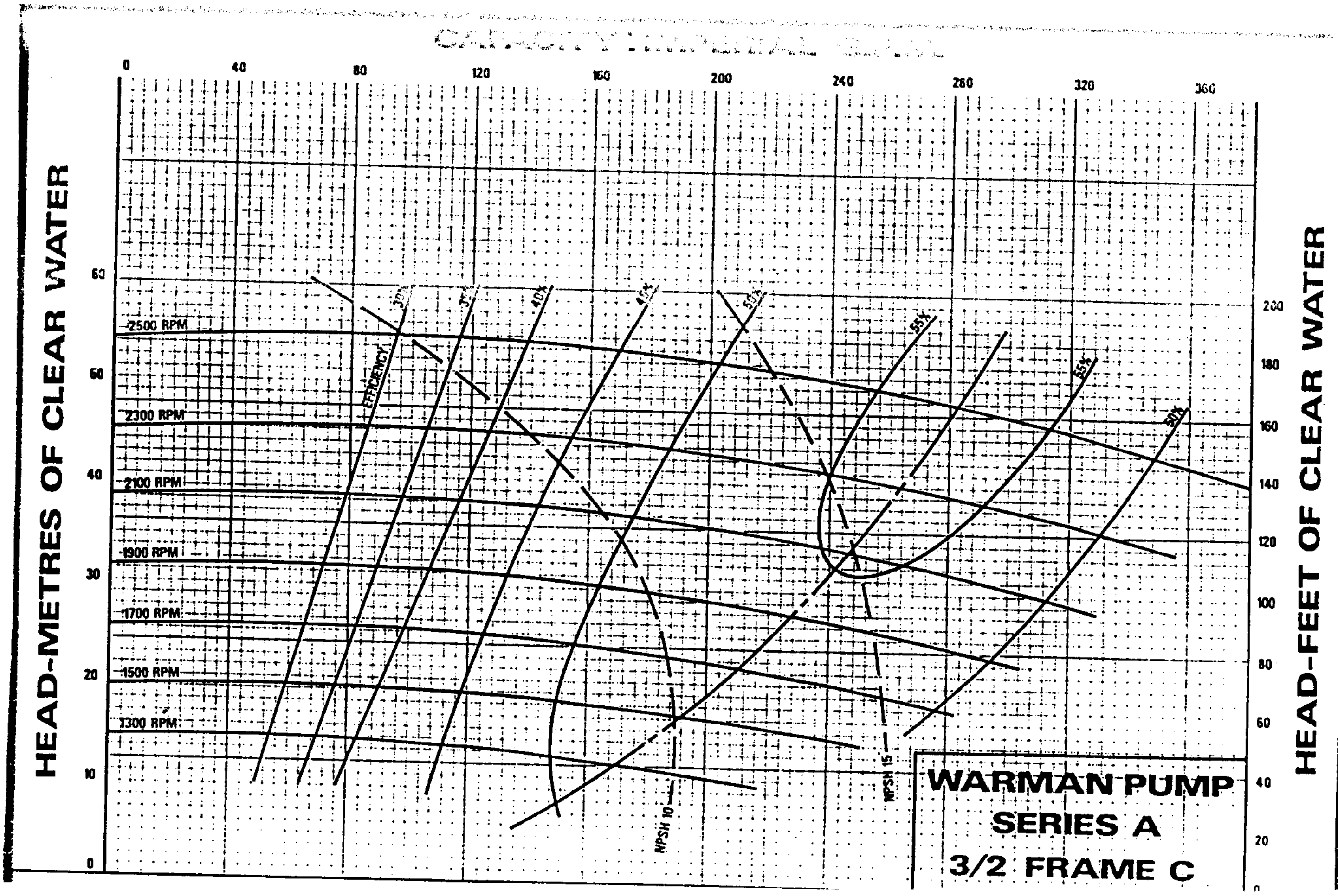
$$\frac{i_m - i_w}{C_v \, i_w} = \Phi = K \left[\frac{(\bar{v})^2}{g \, D} \; \frac{\rho_l}{(\rho_s - \rho_l)} \; C_D^{0.5} \right]^{-n}$$

(i) What do the various symbols, used in this equation, represent, and what is their dimension ?

(ii) What can you say about the coefficient K and about the exponent n ?

END OF EXAMINATION MM 554





UNIVERSITY OF ZAMBIA LIBRARY