THE UNIVERSITY ZAMBIA
UNIVERSITY EXAMINATIONS NOVEMBER/DECEMBER 1994
MINES

1.	Physical Geology theory paper I	GG 210
2.	Physical Geology practical paper II	GG 210
3.	Engineering Geology	CG 423
	Principles of Geology	GG 213
4.	Mineralogy and Petrology paper I Theory	GG 310
5.	Stratigraphy and photogeology practical paper II	GG 321
6.	Principles of Geology II theory paper I	GG 323
7.	Principles of Geology II Practical paper II	GG 323
8.	Structural Geology paper I Theory	GG 332
9.	Structural Geology II paper II Practical	GG 332
10.	Igneous and Metamorphic Petrology Theory paper	GG 410
11.	Igneous and Metamorphic Petrology Practical paper	GG 410
12.	Sedimentology paper I Theory	GG 421
13.	Sedimentology Practical paper II	GG 421
14.	Structural Geology paper I Theory	GG 432
15.	Structural Geology paper II Practical	GG 432
16.	Economic Geology of Metalliferous ores paper I Theory	GG 441
17.	Mining Geology of Zambia paper II Practical	GG 462
18.	Mining Geology of Zambia paper II Practical	GG 462
19.	Geochemistry paper I	GG 470
20.	Geochemistry paper II	GG 470
21.	Geology of Zambia	GG 522
22.	Hydrogeology	GG 531
23.	Engineering Geology	GG 542
24.	Applied Geophysics	GG 561
25.	Economic Geology of Non-Metallic Mineral Deposits	GG 571
26.	Introduction to Mine Development	MI 213
27.	Rock Mechanics	MI 313
28.	Underground Mine Design	MI 413
29.	Surface Mine Design	MI 423
30.	Operations Research	MI 433
31.	Mine Environment	MI 443
32.	Mineral Economics	MI 453/MM 543
33.	Coal Mining Methods	MI 523
34.	Geostatistics	MI 533
35.	Minerals Handlings	MI 543
36.	Introduction to Metallurgy	MM 213
37.	Physical Metaturgy I	MM 313
38.	Chemical Metallurgy	MM 320
39.	Chemical Metallurgy paper II	MM 320
40.	Mineral Processing I	MM 410
41.	Mineral Processing II	MM 410
42.	Mineral Processing	MM 413
43.	Hydrometallurgy	MM 423
44.	Hydrometallurgy	MM 433

45.	Transport Phenomena	MM 443
46.	Physical Metallurgy II	MM 453
47.	Process Control and Instrumentation	MM 463
48.	Ferrous Metallurgy	MM 473
50.	Foundry	MM 523
51.	Fuels. Furnaces and Refractories	MM 533
52.	Special Topics in Extractive Metallurgy	MM 544
53.	Process Design	MM 553
54.	Special Topics in Mineral Processing	MM 554.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG210

PHYSICAL GEOLOGY

THEORY PAPER 1

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ANY FIVE QUESTIONS USING NEAT SKETCHES WHENEVER POSSIBLE. ALL QUESTIONS CARRY EQUAL MARKS.

---

1. Name and describe the six (6) main structural classes of silicates giving at least one mineral example for each class.

2. (a) On What basis are igneous rocks classified and identified?

   (b) Name the main classes of igneous rocks and describe briefly the characteristics of each class, giving one rock example.

   (c) Compare and contrast the following:

   (i) Phaneritic and aphanitic
   (ii) Pophyritic and equigranular
   (iii) Cryptocrystalline and microcrystalline
   (iv) Lava and Magma

   (d) What conclusion can be drawn from two igneous rocks one of which is phaneritic and the other aphanitic?

3. (a) Briefly describe the processes involved in the formation of sedimentary rocks.

   (b) What interpretations can you draw from sedimentary structures such as cross-bedding, graded bedding and oscilation ripples?

   (c) Write brief notes on the following sedimentary rocks:

   (i) Arkose (ii) Orthoquartzite

   Comment on the maturity and length of transportation of these rocks.

(d) Petroleum forms in shales and accumulates in sandstones, why?

4. (a) Compare and contrast the three (3) types of metamorphism.

(b) What does the following sequence of metamorphic rocks indicate?

Slate Phyllite Schist Gneiss

(c) Which metamophic rock underlies the most part of Lusaka? What are some of its uses?

(d) The rock named in (c) is crystalline yet it is able to retain vast amounts of underground water. Discuss the processes and features which facilitate the location of water in such a rock.

5. (a) Name and briefly describe two fundamental concepts which formed the basis for the plate tectonics theory.

(b) Name and briefly describe the three types of plate boundaries paying attention to their characteristics.

(c) How do you think the young mountain ranges such as the Andes (South America) and the Rockies (North America) were formed?

6. (a) Zambia structurally is made up of several mobile belts. Name the four belts and also indicate at least one type of mineralisation of economic importance or potential associated with each of the belts.

(b) What is an industrial mineral? List at least five (5) industrial minerals/rocks currently being worked in Zambia and state their use.

(c) Tin mineralization in Choma, Zambia, is associated with veins. How do the veins form?

7. Open Pit Mining, such as Coal Mining at Maamba, has many environmental problems associated with it. Discuss some of these problems and suggest some difficulties that may hinder their control.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

CE 423 - ENGINEERING GEOLOGY
GG 213 - PRINCIPLES OF GEOLOGY I

PAPER I: THEORY

TIME: THREE HOURS

INSTRUCTIONS:

ANSWER ANY FIVE (5) QUESTIONS USING NEAT SKETCHES WHEREVER POSSIBLE. ALL QUESTIONS CARRY EQUAL MARKS.

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1. (a) Define the terms crystal and mineral.

   (b) List the seven crystal systems and state the symmetry elements which characterise each of the systems.

   (c) List six physical properties of minerals and define two of these.

2. (a) Define the term metamorphism.

   (b) Write brief notes on the three types of metamorphism.

   (i) Contact
   (ii) Dislocation
   (iii) Regional

   (c) Generally what metamorphic rock types would form by subjecting the following rocks to contact metamorphism:

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

   (d) Briefly describe what pneumatolysis is, giving two mineral examples which may form as a result of this process.

3. Write brief notes on the mineralogy, texture and industrial uses of the following rocks:

   (a) Limestone
   (b) Slate
   (c) Sandstone
   (d) Basalt
   (e) Granite

4. (a) What is weathering?

(b) Briefly describe what causes the following types of weathering:

(i) Mechanical
(ii) Chemical
(iii) Biological

(c) Name and write short notes on the four processes which facilitate chemical weathering.

(d) What do you think are the main products of weathering?

5. (a) Name the two broad categories of deformation taking place in the earth's crust.

(b) Describe the differences between an anticline and a syncline.

(c) What are the differences between a joint and a fault.

(d) Write short notes on a normal fault and a reverse fault.

(e) Describe briefly how a rift valley on graben forms.

6. (a) Describe briefly how the following affect the strength of geological materials:

(i) Burial
(ii) Uplift
(iii) Fractures
(iv) Mineral composition

(b) Define the following atterberg limits and state their use in Engineering:

(i) Liquid limit
(ii) Plastic limit
(iii) Plasticity index

(c) Using Fig. 1 classify the following materials:

(i) Sandy silt
(ii) Silt
(iii) Silty clay
(iv) Clay

7. (a) The design of ground anchor systems in rock is dependent on the availability of certain geological data. State four geological factors needed for this.

(b) A block of rock weighing 6000 N lies on a joint surface dipping 70° into a road tunnel. An attempt is made to support this block by using an anchor system. This system involves the use of a steel rod passed through a hole drilled at 40° and grouted at the end of the hole. A force of 2000 N is applied to the rod by tightening a nut at the other end. Determine whether or not the block is safe and give reason(s).

END OF EXAMINATION

UNIVERSITY OF ZAMBIA EXAMS-NOV. 1994

CE 423-ENGINEERING GEOLOGY

GG 213-PRINCIPLES OF GEOLOGY I

THEORY PAPER I

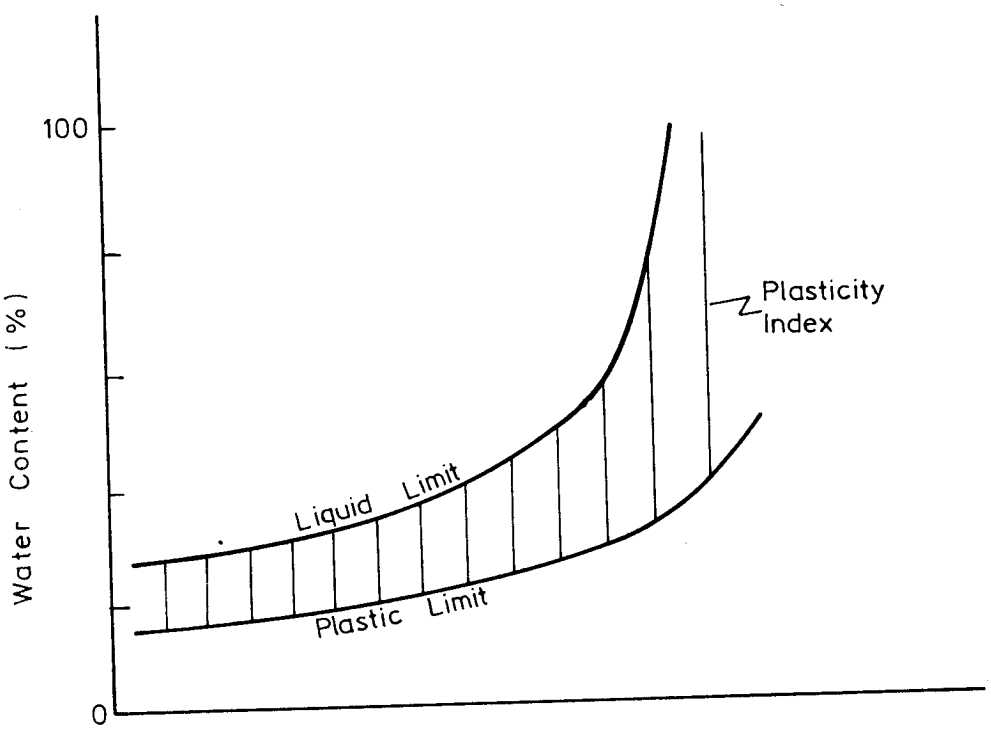

Fig. 1: Atterberg limits classification diagram

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UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG210

PHYSICAL GEOLOGY

PRACTICAL PAPER II

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS

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1. (a) Determine all the elements of symmetry present on crystal models A and B. Classify these crystals into crystal systems. Make neat sketches of these models indicating on them the essential elements of symmetry.

   (b) Convert the following Weis's parameters into Miller indices showing all the stages
   (i) $\infty a, \frac{1}{2}b, \frac{1}{3}c$ (ii) $\frac{1}{7}a, \frac{1}{2}b, \frac{2}{3}c$ (iii) $a, \frac{1}{3}b, c$
   (iv) $\frac{1}{2}a, \infty b, \infty c$

   (c) Name mineral specimens 1-3 giving the distinguishing physical properties in each case

   (d) Name rock specimens 4-6 giving the distinguishing features in each case. State with reason(s) whether the rock specimen is igneous, sedimentary or metamorphic.

2. (a) Study Figure 1 very carefully and do the following:

      (i) Group the various rocks into igneous, sedimenta and metamorphic.

      (ii) Write an account of the Geological History.

   (b) Consider Figure 2 carefully and do the following:

      (i) Draw structure lines for each contact and label these lines carefully. Determine the strike, dip and dip direction of the rocks.

      (ii) Draw a cross section along line A-A' and determine true thickness of layers W,X, and Y.

(iii) Shade on the figure and section where you would locate a borehole that would interest all the lithologies.

(iv) Write a brief account of the Geological History of the area.

3. A magnetic survey was conducted in an area whose geology is shown in Figure 3.1. The result of this survey, a magnetic contour map, is given in Figure 3.2. Interpret the magnetic anomalies with reference to the geology, giving reasons why these anomalies are attained and why they are not continous.

Draw a magnetic profile along line BB'. If a gravity survey was undertaken over the same area, would you expect a similar picture? Explain.

END OF EXAMINATION

UNIVERSITY OF ZAMBIA EXAMS - NOV. 1994

GG 210 – PHYSICAL GEOLOGY

PRACTICAL PAPER II

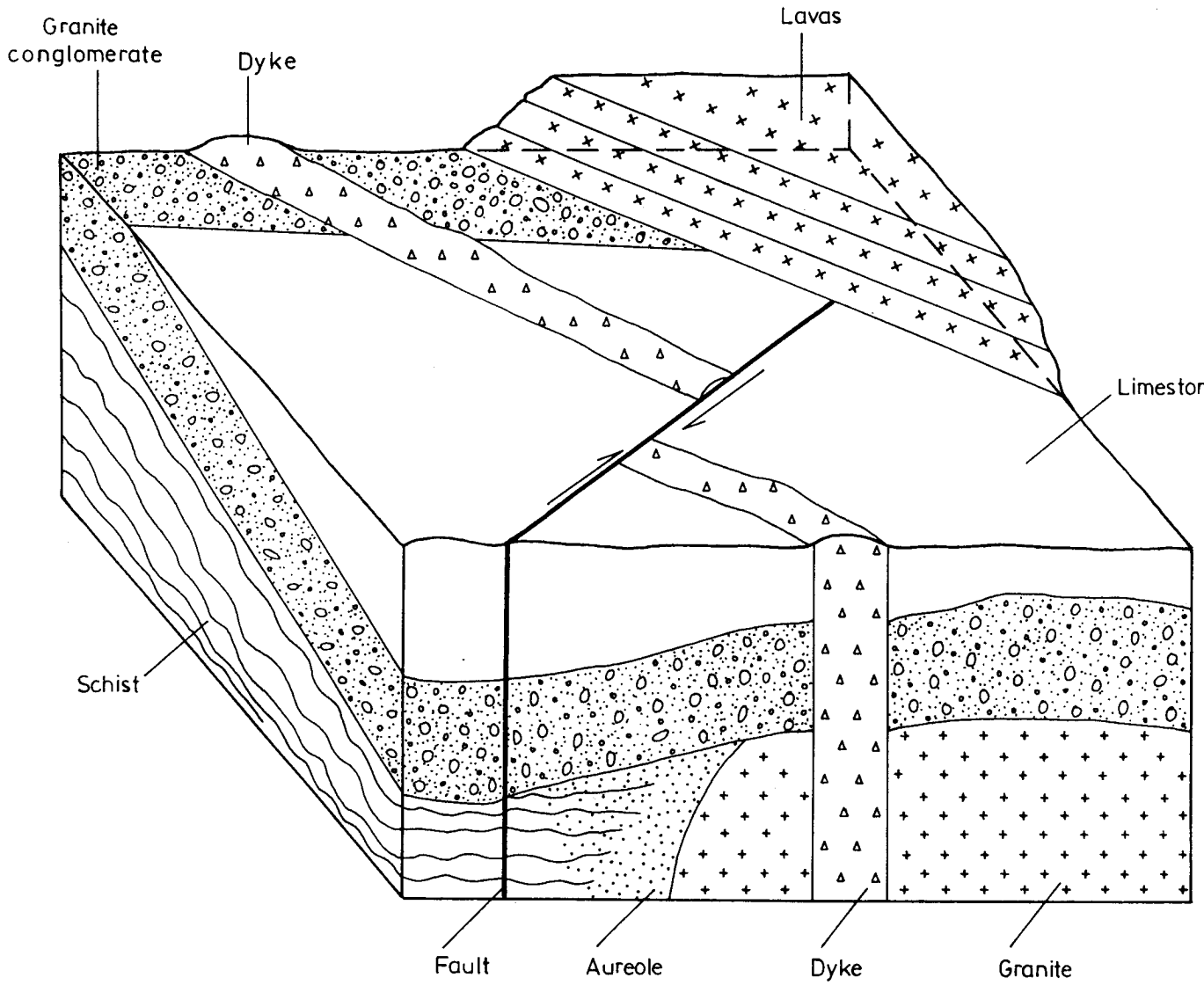

Fig 1 Block diagram for question 2 (a)

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GG 210 - PHYSICAL GEOLOGY

PRACTICAL PAPER II

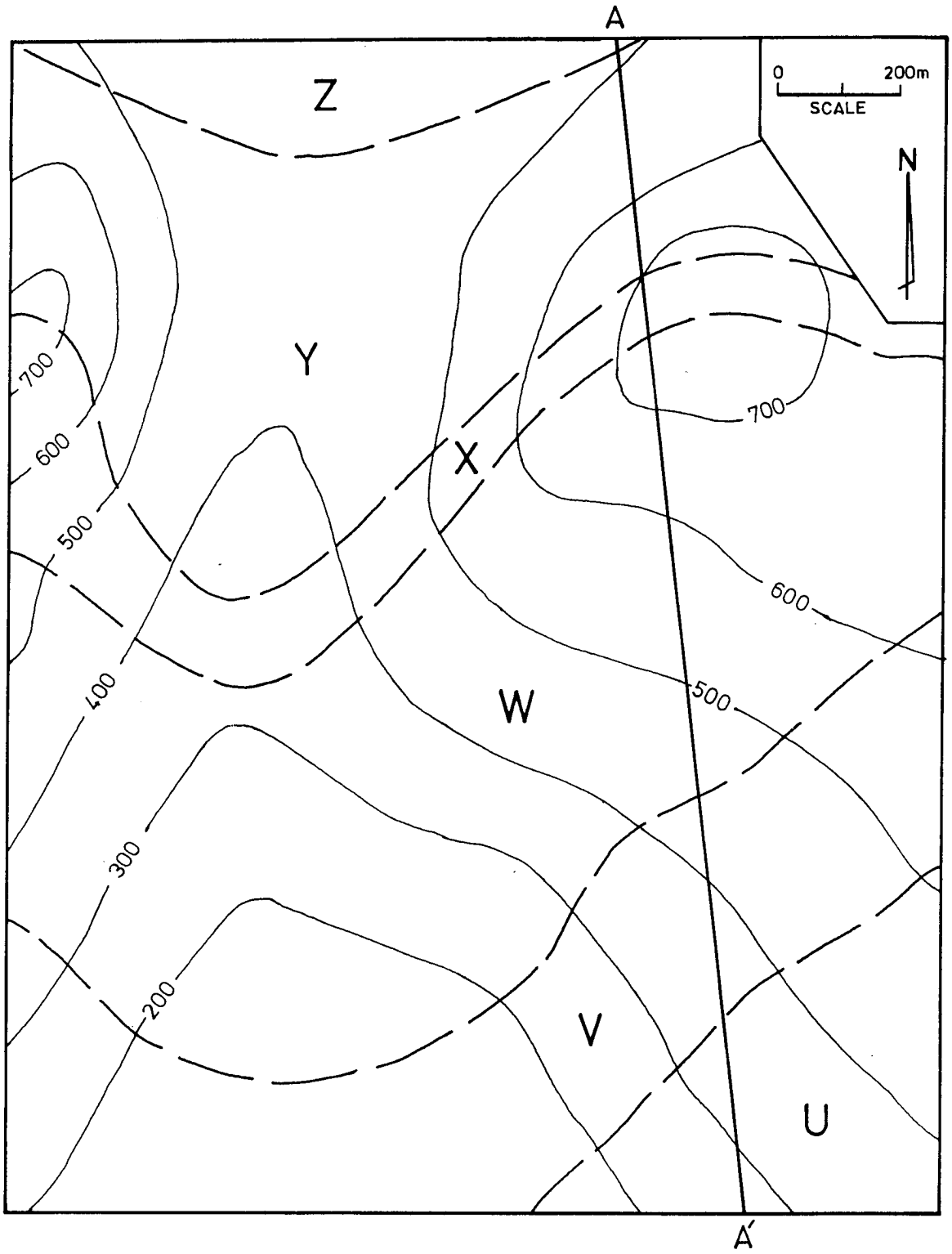

Fig. 2: Geological map

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GG 210 PHYSICAL GEOLOGY

PRACTICAL PAPER II

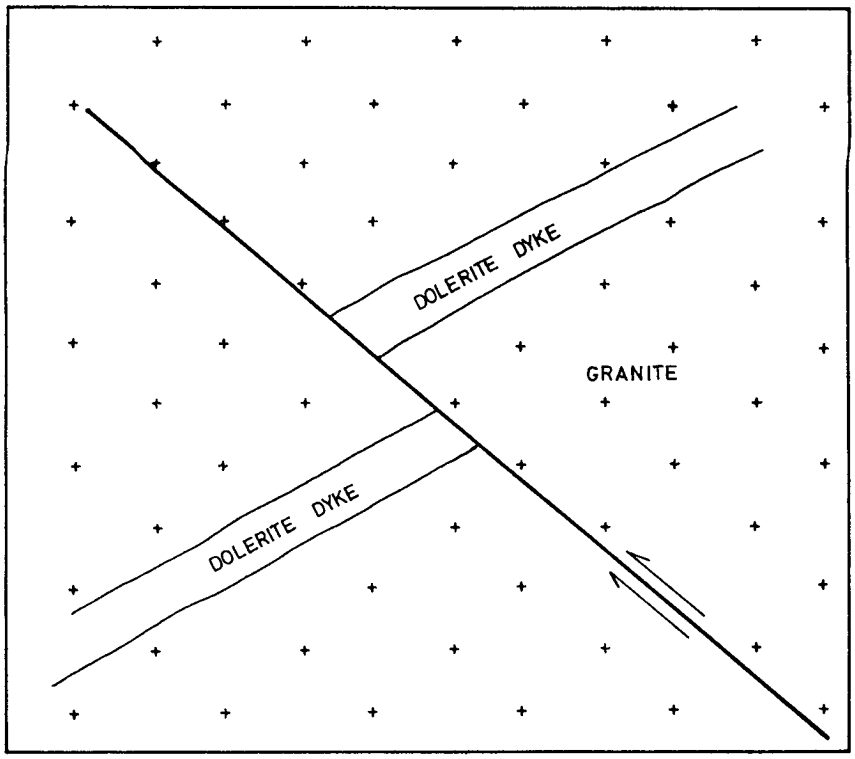

Fig. 3.1 Geological sketch map of the Survey Area

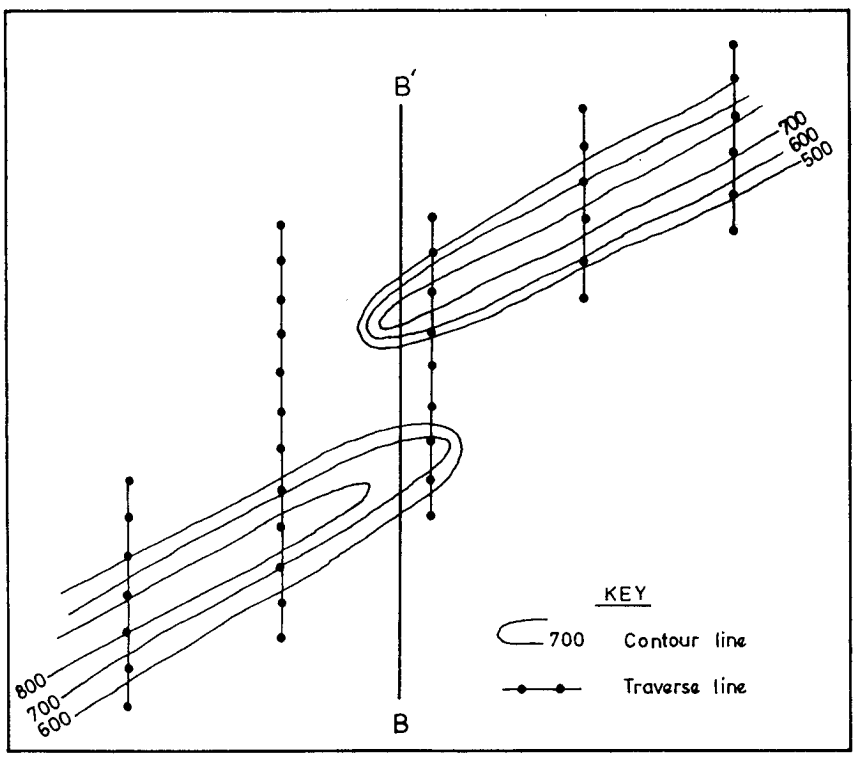

Fig. 3.2 Sketch of a magnetic anomaly detected over the Survey Area

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UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

GG 310

MINERALOGY AND PETROLOGY

PAPER I: THEORY

TIME: THREE HOURS

ANSWER: ALL QUESTIONS

ILLUSTRATE YOUR ANSWERS WITH SKETCHES WHEREVER POSSIBLE

SECTION A

CRYSTALLOGRAPHY AND MINERALOGY

1. Discuss the classification and chemistry of the feldspar group. Explain how temperature controls the crystal structure and chemical composition of the feldspars. (20%)

2. Describe the structure and mineralogy of the following mineral groups:-

   (a) pyroxene group
   (b) olivine group
   (c) mica group
   (d) amphibole group (30%)

SECTION B

PETROLOGY

Answer all questions

1. Give brief account on the followings:-

   (a) Andesite
   (b) Ophitic texture
   (c) diagenesis
   (d) Retrograde metamorphism
   (e) gneisses (15%)

2. What are the main modes of occurrences of igneous rocks? (15%)

3. (a) Briefly give the main characteristics of arenaceous rocks.

   (b) Discuss briefly the main characteristics of contact metamorphism. (20%)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - AUGUST 1994

GG 321

STRATIGRAPHY AND PHOTOGEOLOGY

PRACTICAL

PAPER II

TIME: THREE HOURS

ANSWER: ALL QUESTIONS

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1. (a) What is the principal point of an air photograph?

   (b) What is a nadir point of vertical air photographs?

   (c) How do you obtain the scale of an air photograph?
   (10 marks)

2. What affects the appearance of an air photograph?
   (10 marks)

3. Provide a fully annotated photogeological interpretation on the central air photograph of the three photographs supplied.

   - Indicate the air photo numbers and define the working boundary on the provided transparent paper.

   - Write a brief account of the photogeology of the annotated area. (80 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG323

PRINCIPLES OF GEOLOGY II

THEORY PAPER 1

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ANY FIVE QUESTIONS USING NEAT ILLUSTRATIONS WHENEVER POSSIBLE. ALL QUESTIONS CARRY EQUAL MARKS

---

1. (i) Define the following:

   (a) Structural Geology
   (b) Stress
   (c) Strain
   (d) Elastic deformation
   (e) Plastic deformation
   (f) Confining pressure
   (g) Rapture
   (h) Differential forces
   (i) Fold
   (j) Fault

   (ii) Discuss how the following factors affect the behaviour of materials:

   (a) Temperature
   (b) Time
   (c) Pore pressure
   (d) Solutions

2. (a) What is stereographic projection?

   (b) Structures such as folds, faults, mineral lineations are represented in stereographic projection by making use of Pi-diagrams and B-diagrams. Describe how these diagrams are constructed and discuss their use and limitations.

   (c) If the number of Schistosity planes is 30, what would be the number of intersections?

(d) Show how a plane striking NE-SW and dipping SE would plot as a pole in the plane of projection.

3. Describe the following structural domains in Zambia in terms of the major rocks underlying them, their ages, major structural trends and the associated mineralisation:

(a) The Lufilian Arc
(b) The Irumide Belt
(c) The Mozambique Belt
(d) The Mid-Zambezi Valley

4. Describe and discuss briefly what is involved in the five stages of exploration for a sulphide mineral deposit in an area of say 46,000Km^2. Particular attention should be given to methods that would be employed at various stages.

5. Review the main types of ore deposits associated with internal magmatic processes.

6. (a) What is an energy mineral? (Give an example)

(b) How does oil in shales form?

(c) Would a sandstone form a good reservoir rock? Explain.

(d) Describe the various types of traps which facilitate the retention of oil in rocks.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG323

PRINCIPLES OF GEOLOGY II

PRACTICAL PAPER II

TIME: ONE AND HALF ($1\frac{1}{2}$) HOURS

INSTRUCTIONS: ANSWER ALL QUESTIONS.

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1. The apparent dips on a sandstone bed were measured in two vertical joints. One joint strikes N50°E and its apparent dip is 40°NE. The other joint trends due North and its apparent dip is 30°S, determine:

   (a) The attitude of the sandstone bed

   (b) The apparent dip of the sandstone bed as seen in a vertical joint trending N38°W.

   (c) The bearing and plunge of the apparent dip as seen in a joint striking N90°E and dipping 20°N.

   (d) The true angle between intersections of the sandstone bed and the two vertical joints.

2. An aeromagnetic survey conducted over an area, the Geology of which is represented by Fig 1, produced a contour map shown in Fig. 2. Study the two figures carefully and do the following:

   (a) To which rock types can anomalous values of over 750 Gamma be attributed and why?

   (b) Which areas on Fig. 2 would you recommend for follow up by ground magnetic methods?

   (c) Sketch a profile along line AB.

END OF EXAMINATION

UNIVERSITY OF ZAMBIA EXAMS - NOV. 1994

GG 323 - PRINCIPLES OF GEOLOGY II

PRACTICAL PAPER II

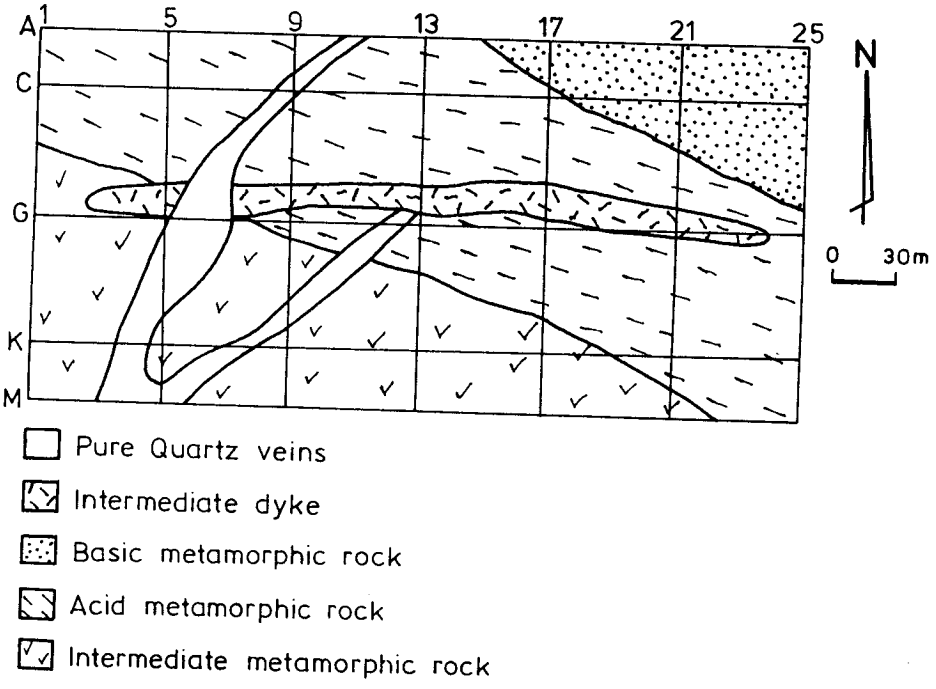

Fig. 1: Geological map of a surveyed area

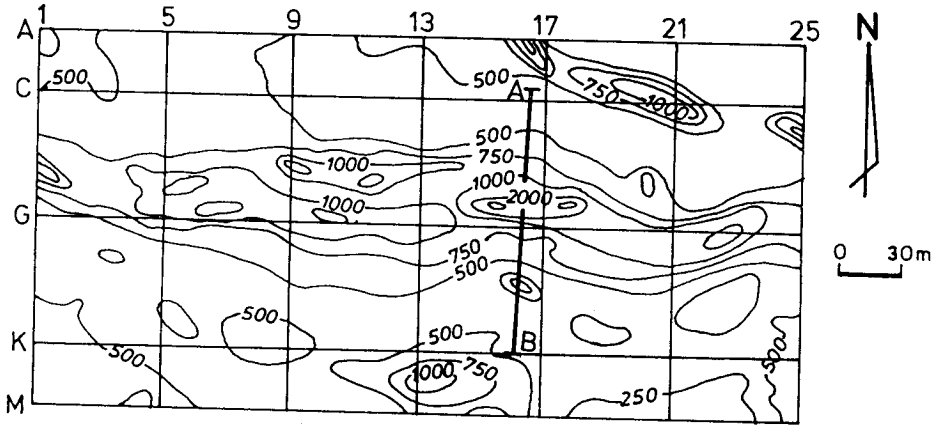

Fig. 2: Aeromagnetic map over a surveyed area; Contours join points of equal magnetic intensity (gamma)

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UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG 332

STRUCTURAL GEOLOGY

PAPER 1 THEORY

TIME: THREE HOURS

ANSWER: QUESTIONS 1 AND 2 AND ANY OTHER THREE QUESTIONS. EACH QUESTION CARRIES EQUAL MARKS

---

1. Define brittle and ductile behavior. For each type of behavior:

   (a) Show a typical stress - strain curve.

   (b) In what part of the Earth's crust do rocks display this type of behaviour?

   (c) Describe the characteristic types of structures that are produced.

2. Use the appropriate classification scheme to name precisely the structures in Figure 1 (a to m).

3. Assume that during the course of geological mapping you found certain strata to be repeated and you suspect the presence of a fault. What features would you look out for to confirm this?

4. Use a Mohr circle to find the normal stress and shear stress on planes inclined at an angle of 30° and 45° with respect to $\overline{\sigma_1}$, when $\overline{\sigma_1}$ = 600kg/cm^2 and $\overline{\sigma_3}$ = 300 kg/cm^2.

5. Define the following terms:

   (a) progressive deformation

   (b) Young's modulus

   (c) hinge surface

   (d) chevron fold

   (e) shear joints

   (f) graded bedding

(g) ripple marks

(h) angular unconformity

(i) fault slip

(j) slickensides

6. Describe the main types of foliation and describe how they are formed.

7. Describe the main types of lineations and state how they are formed.

END OF EXAMINATION

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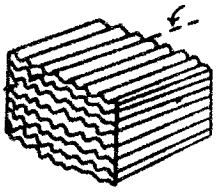

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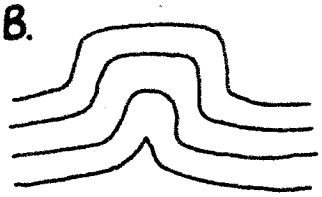

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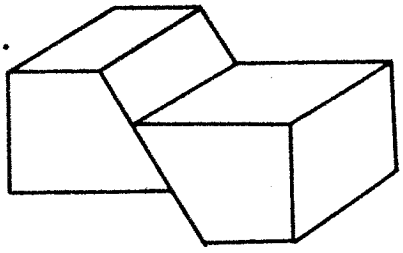

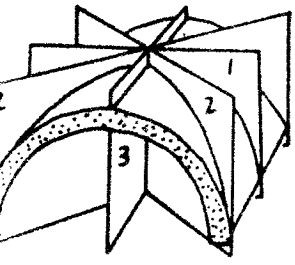

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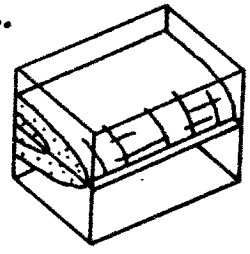

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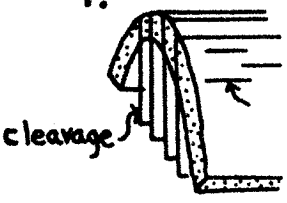

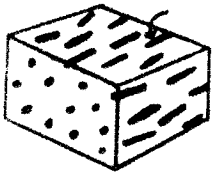

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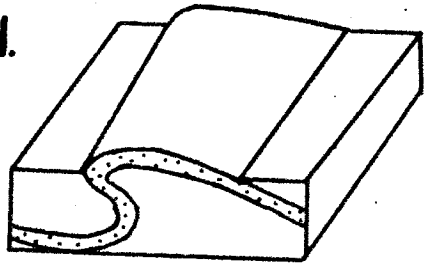

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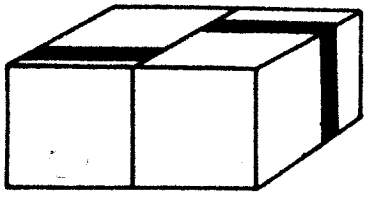

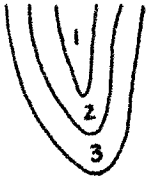

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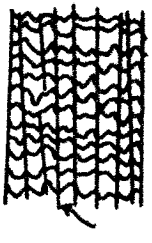

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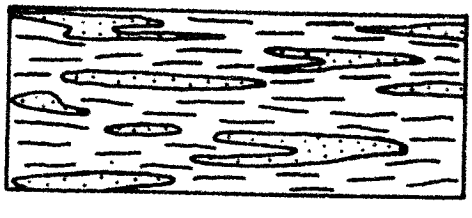

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG 332

STRUCTURAL GEOLOGY II

PAPER II PRACTICAL

TIME: THREE HOURS

ANSWER: ALL QUESTIONS

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1. A geological map is provided (Fig. 1).

   (a) Draw cross-section A-B to natural scale.

   (b) Determine the attitude of the fault.

   (c) Determine the attitudes of the beds.

   (d) Make a geological account of the area.

2. The attitude of a limestone bed is N345E/275W on a slope inclined 15° to the E.

   (a) Determine the thickness of the limestone if the outcrop width is 245m.

   (b) Determine the thickness of the limestone if the outcrop width measured oblique to the strike (at an angle of 35°) is 350m.

3. On Figure 2 borehole A passes through a coal seam at a depth of 50m and reaches a lower seam at a depth of 150m. Boreholes B and C reach the lower seam at depths of 50m and 150m, respectively.

   (a) Determine the strike and dip of the seams, assuming the vertical separation remains constant (100m).

   (b) Draw in the outcrops of the seams.

   (c) The upper seam can be strip-mined where the overburden is less than 50m. Indicate this area on the map.

END OF EXAMINATION

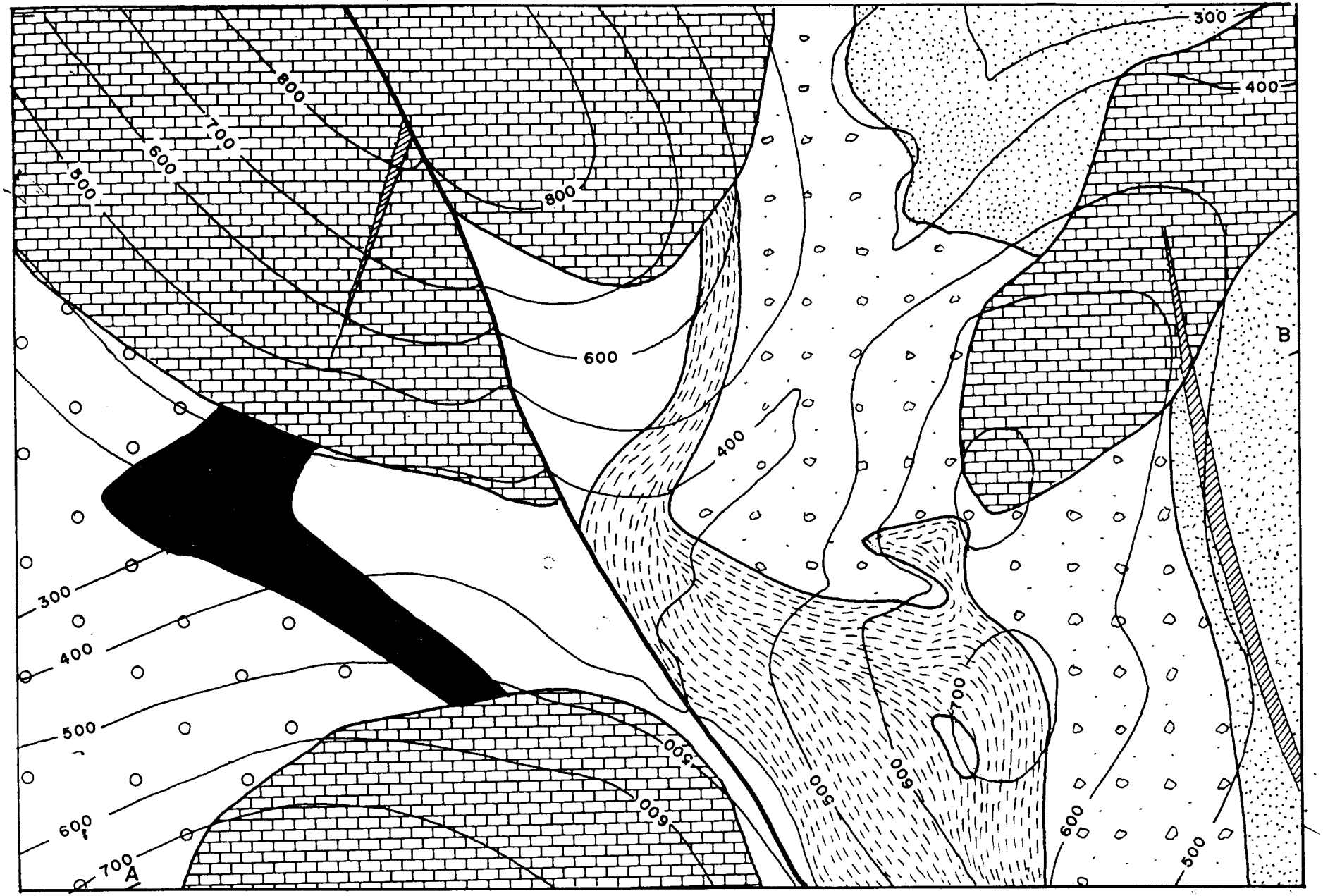

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Figure 1

GG 332 PAPER II

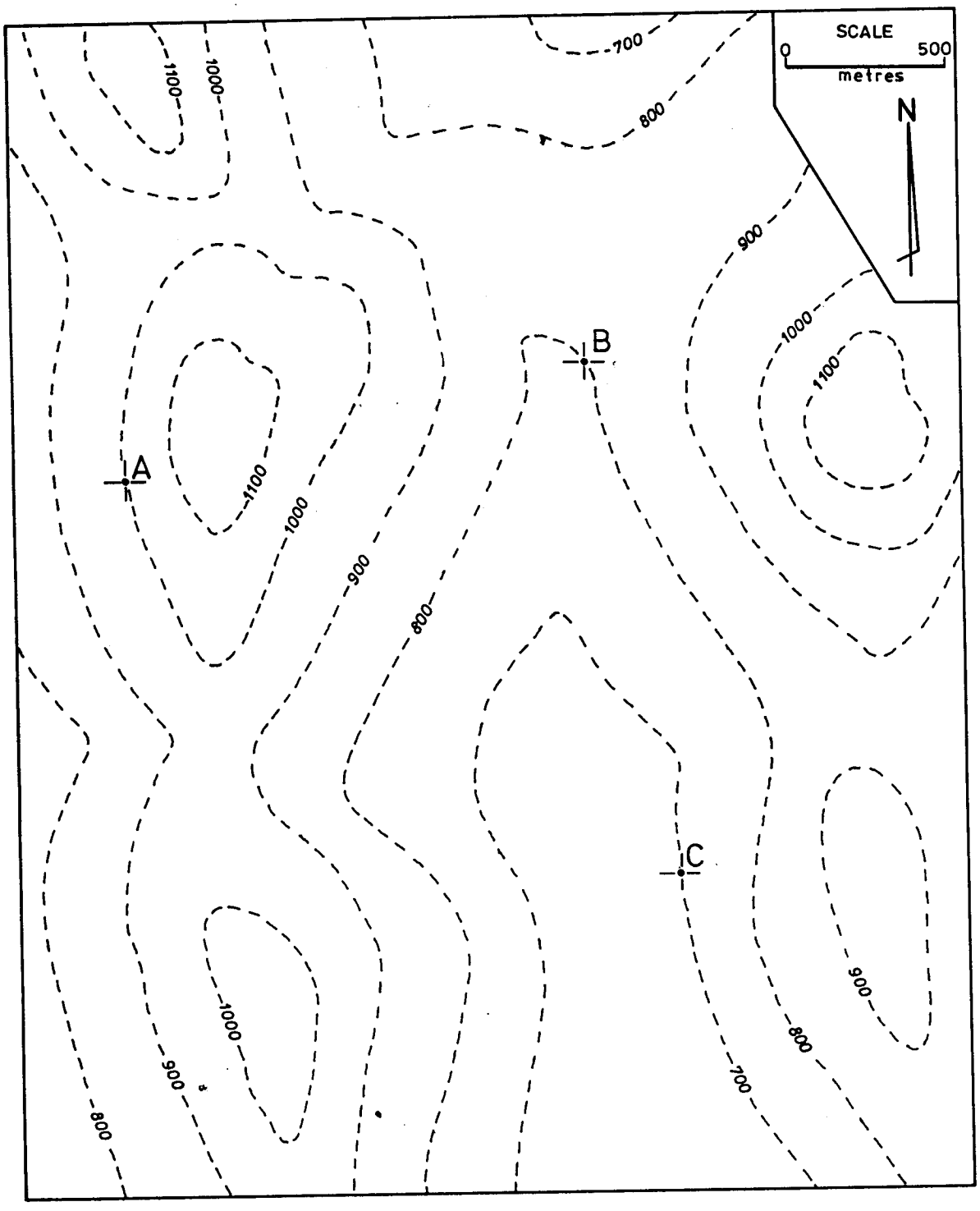


Figure 2

Legend for figure 1

Sandstone

Mudstone

Shale

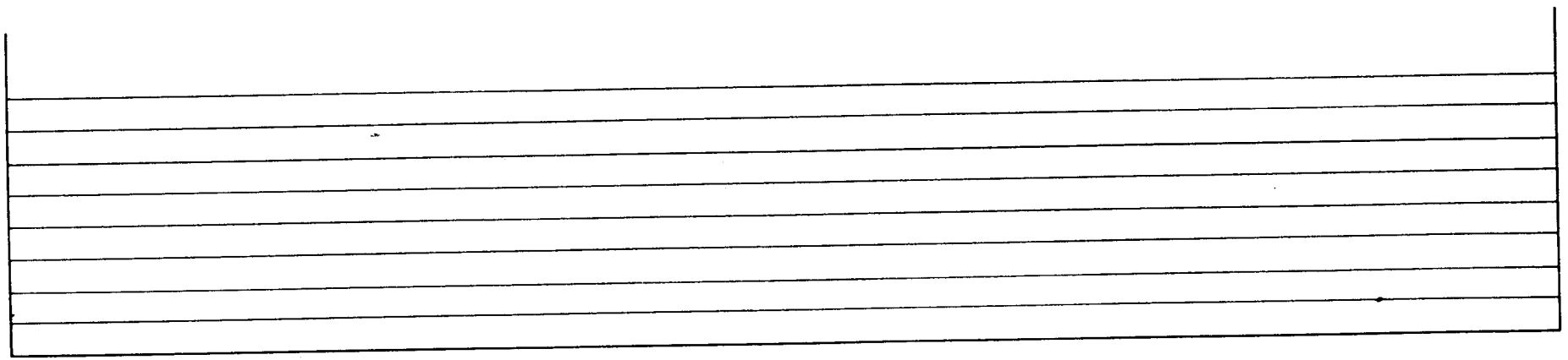
Limestone

Schist

Conglomerate

Quartzite

Dolerite



THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG410

IGNEOUS AND METAMORPHIC PETROLOGY

THEORY

PAPER I

TIME: THREE HOURS

ILLUSTRATE YOUR ANSWERS WITH SKETCHES WHEREVER POSSIBLE

SECTION A

Answer question ONE and any other two questions

1. (i) Explain the difference between hypersolvus and subsolvus granites 10%

   (ii) Give brief account of the following

   (a) Reaction rim (corona) texture

   (b) geothermal gradient 10%

2. Various processes can account for the diversity of magmas that may be derived from one single parent magma. Describe these processes and indicate their relative importance. 15%

3. Summarise the characteristics of the following rocks or rock suites and indicate their usual plate tectonic setting

   (a) tholeiitic basalts

   (b) shoshonites

   (c) lamprophyres 15%

4. Give the sequence of the layers that constitute the oceanic crust and briefly explain the origin of the layering. Where would it be possible to sample study oceanic crust at the earth's surface? 15%

SECTION B

Answer all questions.

1. Name the facies of regional metamorphism. Describe the characteristic minerals assemblage of each facies for pelitin and basic rocks paying most attention to those minerals which are diagnostic for each facies. 15%

2. Define and discuss briefly:-

   (a) Metasomatism

   (b) Anatexis

   (c) paired metamorphic belt

   (d) Migmatite

   (e) Index mineral 15%

3. (a) Use the thermodynamic data given below to determine whether wollastonite would be formed in the system $CaCo_3$- $S10_2$ under STD conditions.

	$\Delta Hf°$	$S°$
Calcite	-288,592	22.15
Carbon dioxide	-94,051	51.06
Wollastonite	390,640	19.60

   (b) Discuss briefly the role of pressure and temperature on the stability of phases in the systems $CaCo_3$-$S10_2$ and Al_2S10_5

   (c) A calcareous shale whose chemical composition is given in table 1 is intruded by a dry magma. Use table 1 to construct an AFC diagram. Determine the equilibrium mineral assemblage which you would expect to form in the shale near the contact with the intrusion.

Table 1

SiO_2	25.05%
Al_2O_3	8.28%
Fe_2O_3	0.27%
Fe O	2.41%
MnO	4.11%
MgO	2.61%
CaO	27.87%
P_2O_5	0.08%
Co_2	24.20%

20%

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG410

IGNEOUS AND METAMORPHIC PETROLOGY

THEORY

PAPER I

TIME: THREE HOURS

ILLUSTRATE YOUR ANSWERS WITH SKETCHES WHEREVER POSSIBLE

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END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG410

IGNEOUS AND METAMORPHIC PETROLOGY

PRACTICAL

PAPER II

TIME: THREE HOURS

ANSWER: ALL QUESTIONS

---

1. Thin Section A:-

   (a) On the description form provided, fully describe all minerals.

   (b) Estimate the modal composition

   (c) Classify the rock according to the IUGS system

   20%

2. Thin Section B

   Give a complete petrographin description of thin Section D, emphasizing on the following

   (a) mineralogy

   (b) texture

   (c) metamorphic history

   (d) metamorphic grade

   30%

3. Thin Section C ~~and D~~:-

   Discuss the textures of thin sections C ~~and D~~ and name the rocks accordingly

   20%

4. Use the whole rock analysis given in table 1 to answer the following questions:-

   (a) Classify the rock units on the basis of silica content, ~~silica saturation~~ and alumina saturation.

   (b) Calculate the CIPW normative composition of one of the rock units.

Table 1

SiO_2	50.78%	75.4%
TiO_2	0.77	0.1
Al_2O_3	20.40	13.3
Fe_2O_3	1.75	0.3
FeO	6.2	0.74
MnO	0.09	0.08
MgO	6.49	0,12
CaO	10.24	0.48
Na_2O	2.24	4.1
K_2O	0.45	4.5
P_2O_5	0.05	0.01
H_2O	0.65	0.46

30%

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - AUGUST 1994

GG 421

SEDIMENTOLOGY

PAPER I

THEORY

TIME: THREE HOURS

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

---

1. (a) What is the difference between cement and matrix regarding clastic sedimentary rocks? Outline the different types of matrix observable in clastic sedimentary rocks and list the common cement types found.

   (b) Distinguish between matrix and cement of carbonate rocks.

   (c) Define four of the following:

   (i) bioturbation
   (ii) sphericity vs roundness
   (iii) antidunes
   (iv) imbrication
   (v) desiccation cracks

2. (a) Discuss the significance of cross-stratification.

   (b) What are the main distinctive cross-bedding styles.

   (c) Outline five processes from which a number of common structures are formed. Give an example of a structure for each process.

   (d) Outline the forms of movement of grains in bedload transport.

3. (a) Contrast between braided stream and meandering in terms of

   (i) common elements to the model
   (ii) in channel deposits and
   (iii) sequences

   (b) Distinguish between proximal and distal trends on an alluvial fan setting.

4. (a) Outline the various factors that govern the the distribution of sediments in deltas.

   (b) Briefly outline the three processes in a fluvial dominated delta.

5. (a) What is a turbidite?

   (b) What are the expected proximal to distal changes in turbidites.

6. Describe the important features of aeolian deposits characteristic in Desert environments.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - AUGUST 1994

GG 421

SEDIMENTOLOGY

PRACTICAL

PAPER II

TIME: THREE HOURS

ANSWER: ALL QUESTIONS

---

1. Briefly define the following terms:

   (a) grain size limits
   (i) medium sand
   (ii) granule
   (iii) very fine sand

   (b) Skewness

   (c) Standard deviation

   (d) Sorting (6 marks)

2. (a) Name three graphic representation of grain sizes and the parameters calculated.

   (b) What is the sigificance of these parameters? (6 marks)

3. Distinguish between textural and compositional maturity. (3 marks)

4. (a) Describe the five handspecimens and corresponding thin sections; providing the full mineralogy, structures, features, etc. (You are to spend about 30 minutes on each sample/thin section and pass it to your friend). (75 marks)

   (b) Classify the rocks in (a) using appropriate classification and state the possible depositional environment for each rock. (10 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

GG 432

STRUCTURAL GEOLOGY

PAPER I: THEORY

TIME: THREE HOURS

ANSWER: QUESTIONS 1 AND 2 AND ANY OTHER THREE QUESTIONS.

ILLUSTRATE YOUR ANSWERS WHEREVER POSSIBLE.

---

1. Explain how the movement of lithospheric plates relative to each other can be determined from the study of paleomagnetism.

2. (a) Explain the origin and development of divergent plate boundaries.

   (b) Describe the dominant structures that form in areas of crustal extension and lithospheric thinning.

   (c) Give an example of present day rifting and explain its evolution.

3. Fold-and-thrust belts are structural assemblages found in specific plate-tectonic settings.

   (a) Describe and illustrate a fold-and-thrust belt, indicating the typical structures observed in such a belt, the geotectonic environment in which it is formed, and the crustal elements that are involved.

   (b) The deformation style in fold-and-thrust belts is also known as 'thin-skinned' tectonics. Why?

   (c) Give an example of a Zambian fold-and-thrust belt.

4. One of the processes by which rocks may deform in response to stress is by intracrystalline translation gliding.

   (a) Briefly explain how deformation of a rock is achieved by this process.

(b) Translation gliding is counteracted by processes of recovery and recrystallization, acting simultaneously. Briefly define these processes and discuss how they influence translation gliding.

(c) The effects of all these processes may be observed microscopically. List the features that are indicative of these processes.

5. (a) What is a ductile shear zone and how can you recognise it in the field?

(b) Where are these shear zones formed?

(c) How can you deduce the sense of shear from larger scale (outcrop scale) features?

(d) How can you deduce the sense of shear from small scale (hand specimen and microscopic scale) structures?

6. Cratons are surrounded or cut by mobile belts on the geotectonic map of Africa. Describe in general terms how such a geotectonic assemblage may have evolved.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG 432

STRUCTURAL GEOLOGY

PAPER II PRACTICAL

TIME: THREE HOURS

ANSWER: ALL THREE QUESTIONS. USE TRANSPARENT OVERLAYS FOR STEREOGRAPHIC PROJECTION

---

1. Figure 1 is a map showing the rock outcrops in a flat area of deformed metasediments.

   (a) Indicate the solid geology on the map and add enough map symbols to make the structure clear. Discuss all evidence.

   (b) What is the attitude of the fold axes and axial planes of folds present?

   (c) How can the folds be characterized in terms of attitude and tightness?

   (d) How does the direction of necking of the boudins relate to the larger structure? Sketch this relation schematically.

   (e) Draw a cross section to scale from A to B using the same horizontal scale as on the map.

2. Figure 2 and 3 (on transparencies) show structure - contour maps for the depth of the top and bottom of a porose sandstone on the basis of drillhole information.

   (a) With the aid of these maps construct an isopachyte map (simplified as an isochore map) for the sandstone on th tracing paper provided.

   (b) Indicate on the map where you would propose to drill for oil and explain why.

   (c) Illustrate your answer with a suitable cross-section.

3. The following strike and dip measurements were taken at a series of stations across a folded surface. The trend and plunge of lineations developed on this surface were also recorded at each station.

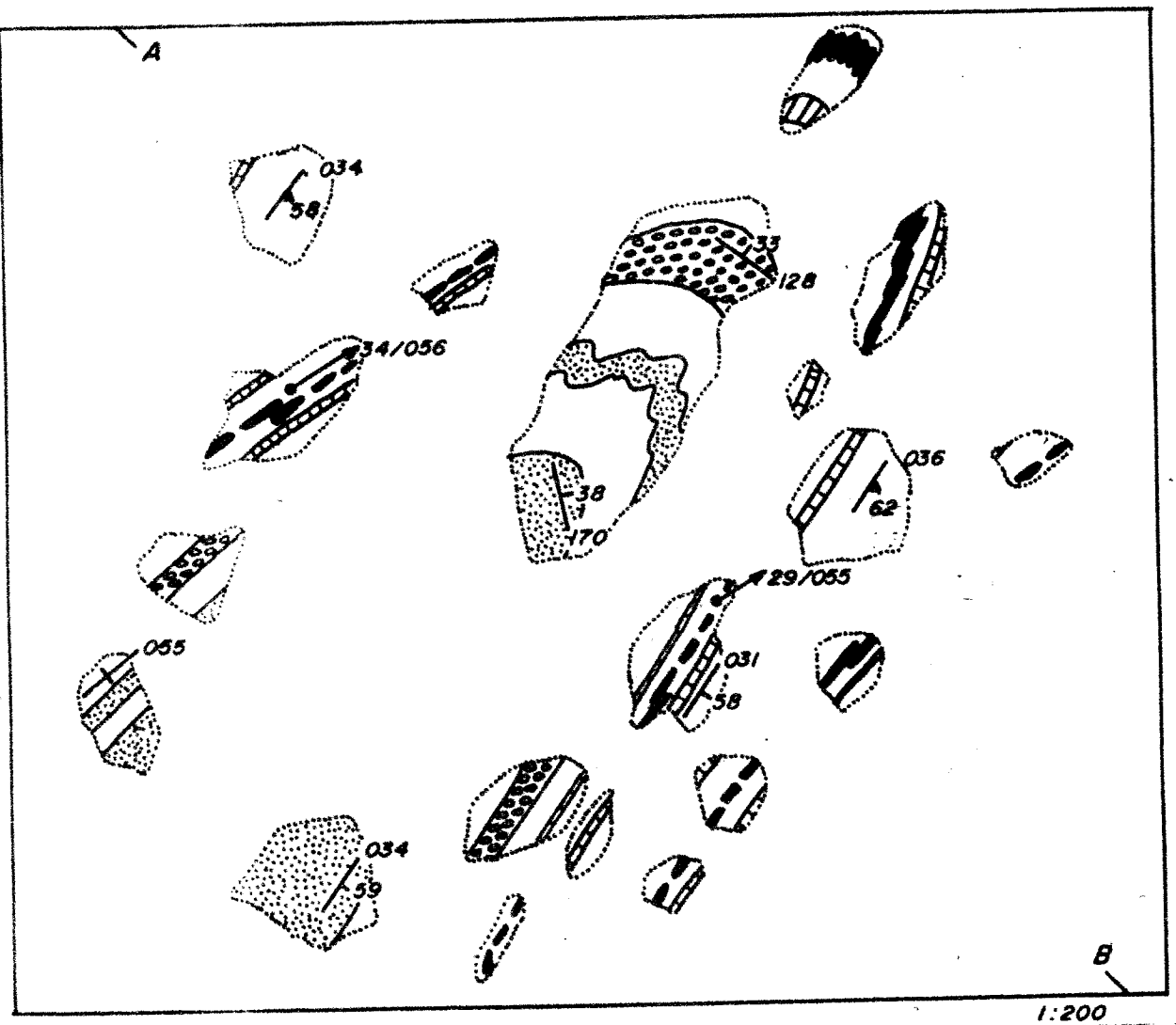
Plot this data on a stereographic projection and use it to answer the following questions:

(a) Do the lineations predate or postdate the folding? State your evidence.

(b) What can you say about the mechanism of folding based on the lineation distribution?

Station	Attitude of layer	Attitude of lineations
1	308°, 02SW	02, 180°
2	129°, 18SW	14, 178°
3	310°, 50SW	36, 167°
4	133°, 10 NE	08, 002°
5	311°, 24 NE	18, 358°
6	130°, 40 NE	30, 353°

END OF EXAMINATION



- Mica schist
- Quartzite
- Conglomerate with stretched pebbles
- Calcite marble bands
- Dolomite marble bands

- Bedding
- Folation
- Direction of boudinage necking

Figure I

structure contours for bottom of porose sandstone

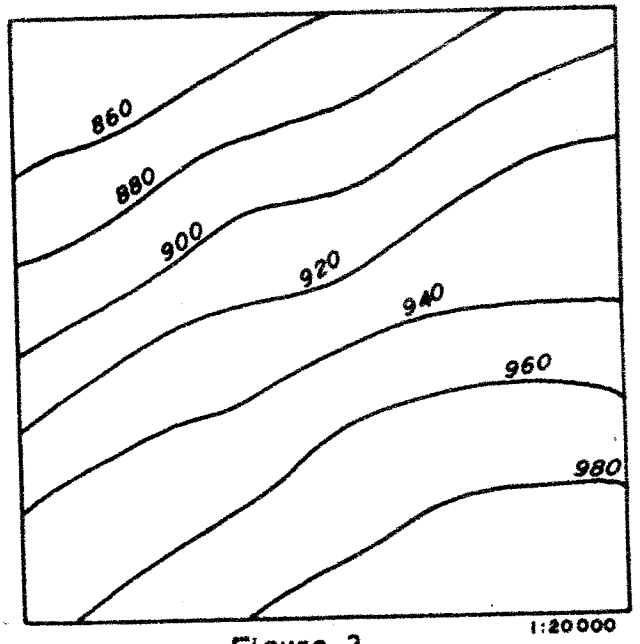


Figure 2

structure contours for top of porose sandstone

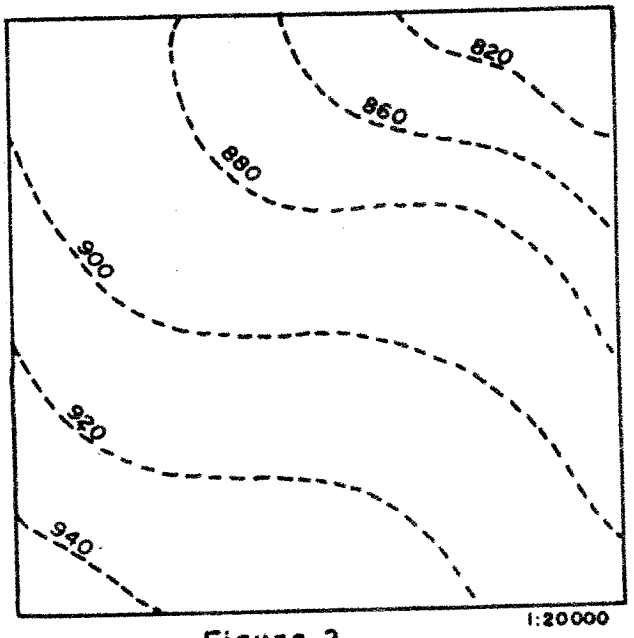


Figure 3

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - AUGUST 1994

GG 441

ECONOMIC GEOLOGY OF METALLIFEROUS ORES

PAPER I

THEORY

TIME: THREE HOURS

ANSWER: ANY FOUR QUESTIONS. ILLUSTRATE YOUR ANSWERS WITH SKETCHES WHEREVER POSSIBLE. ALL QUESTIONS CARRY EQUAL MARKS.

---

1. Give two geological-economic classifications of mineral reserves and resources.

2. Discuss titanium oxide ores in anorthosites with respect to the following:

   (a) tectonic setting
   (b) types of anorthosites
   (c) orebody morphology
   (d) ore mineralogy
   (e) formation of Ti-Fe minerals
   (f) expoloration guides

3. Compare and contrast porphyny-type deposits with respect to the following:

   (a) tonnage and grade
   (b) principal products and by-products
   (c) associated igneous rocks
   (d) mineralization and alteration patterns
   (e) tectonic setting.

4. Discuss the origin of volcanogenic massive sulphide deposits and indicate characteristic features used in the exploration for such deposits.

5. Describe the geological occurrence of the gold placers of the Witwatersrand basin and discuss the genetic theories explaining the origin of the gold.

6. Discuss the geological environment, genesis and controls of stratabound uranium mineralisation on the Zambian Copperbelt.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG462

MINING GEOLOGY OF ZAMBIA

PAPER 1 THEORY

TIME: THREE HOURS

ANSWER: QUESTION 1 AND FOUR OTHERS. ALL QUESTIONS CARRY EQUAL MARKS

---

1. The final stages of mineral exploration involves diamond drilling, core logging, data plotting and interpretation. A well planned and executed diamond drilling programme should bring out important data on a mineral deposit. Discuss the main parameters of a mineral deposit which can be obtained from a diamond drilling programme.

2. Give a classification of ore reserves for an operating underground mine such as Nkana Mine. What is the role of a geologist in avoiding dilution of run-of-mine (rom) ore fed to the milling plant. Discuss in detail with examples.

3. Nchanga Open Pit in Chingola has in the past years accounted for more than 60% of copper production for ZCCM Limited. Discuss the following:
   (a) How ground stability is maintained to a depth of 100 metres?
   (b) How does water accumulated into the pit not hinder copper production?
   (c) How would you dispose off the water from such a pit?
   (d) What health hazards would be caused by dust in the pit and how would you mitigate against such hazards?

4. Lead occurrences have been identified in 30 of the 52 African countries and Zinc in 21 countries. However, production took place in 7 countries in 1983 as follows (metal contained in concentrates).

'000 Tonnes

South Africa	137.3	Morocco	97.3
Zaire	74.7	South Africa	87.5
Zambia	41.6	Namibia	33.8
Algeria	12.0	Zambia	14.6
Morocco	7.5	Tunisia	4.9
Tunisia	7.5	Congo	4.0
		Algeria	3.0
	313.9	Total Africa	245.1
	6,537.7	Total World	3,449.8

Determine the following:

(a) Africa's production as a ratio of total world production.

(b) Zambia's lead and zinc production as a ratio of Africa's production.

(c) Zambia's lead and zinc production as a ratio of world production.

(d) Lead and zinc production (tonnes) for countries south of the equator.

(e) Express your answer in (d) as a ratio of (i) world production (ii) Africa's production.

(f) Discuss the main industrial uses of (i) lead and (ii) zinc.

(g) What environmental problems are associated with lead?

(h) Since Kabwe mine was closed on 30th June, 1994 where do you suggest more exploration work should be carried out and why?

5. Figure 1 shows a mining layout for gravity stoping at No. 1 shaft of Konkola Mine in Chililabombwe. A stope being delimited from a Footwall Haulage level on the upper level (2200'L) to the next Footwall Haulage level on the lower level (2400'L).

(a) Describe what the following are used for at Konkola Mine No. 1 shaft;

(i) Footwall Drive
(ii) Orebody Drive
(iii) Cut out raise
(iv) Footwall Haulage

(b) Why is the drain drive sited in the Argillaceous sandstone?

(c) Explain whether any accesses should be sited in the Porous Conglomerate giving reasons why?

(d) How would you dewater the hanging wall aquifer? Suggest where you would site the drain drive for the Hanging wall aquifer.

6. Kabwe Mine (1906-1994) closed mining operations under ZCCM Limited, on 30th June, 1994. Discuss the importance of an orderly closure of a mine taking into consideration the following:

(a) Social impact on the residents of Kabwe.

(b) Economic impact on the retrenched employees.

(c) Environmental impact both

(i) Underground
(ii) On the surface of the mine

(d) Mineral resources are wasting assets and therefore, all mines will close at some stage; suggest how the life of a mining town can continue after a mine closure.

END OF EXAMINATION

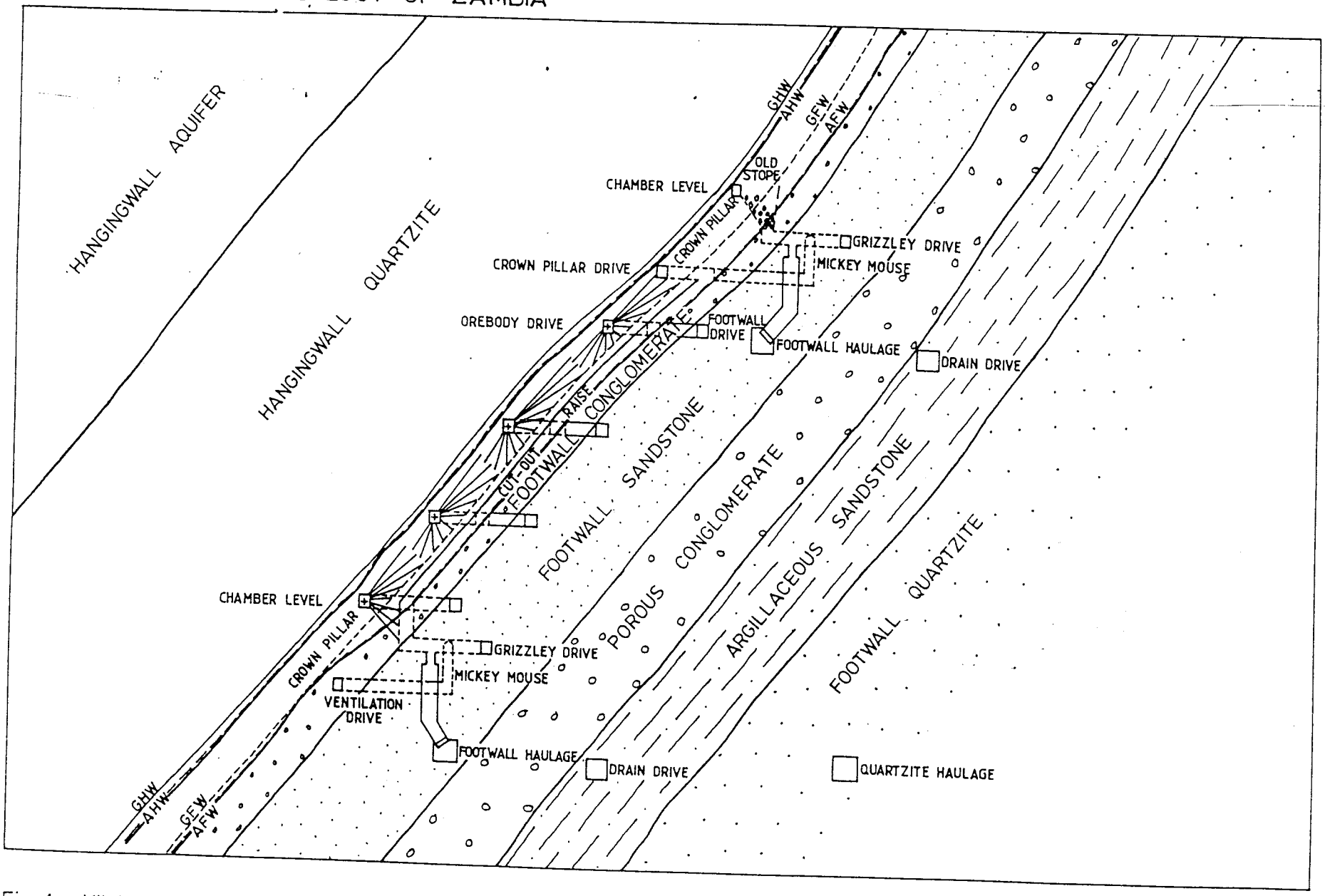


Fig. 1: MINING LAYOUT FOR GRAVITY STOPING AT No. 1 SHAFT - KONKOLA MINE

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG462

MINING GEOLOGY OF ZAMBIA

PAPER II: PRACTICAL

TIME: THREE HOURS

ANSWER: ALL QUESTIONS, ILLUSTRATING YOUR ANSWERS WITH NEAT SKETCHES WHEREVER APPROPRIATE

---

1. Figure 1 below gives a geochemical map showing geology, topography, zinc values and trench/drill holes from a public domain map. The rocks occurring in the map area are given in the legend. Order of magnitude of the geochemical data is given by the dots. Carry out the following:

   (a) Outline the geochemical anomalies (10 marks)

   (b) Colour the map according to lithologies and draw a section through line A-A' (10 marks)

   (c) Where do you think the mineralisation is, and why? (10 marks)

2. Figure 2 shows a geological plan and section of Alalobuka Micaceous copper deposit in the Lusaka East Area. The Scales in both diagrams are given in feet. (1 foot = 0.3048 metres). Answer the following;

(a) If you wanted to determine contacts between granite gneiss, decomposed mica schist and the sulphide ore, where would you drill your boreholes?

Indicate this on your plan and section. How deep should such boreholes be to the contact with granite gneiss, decomposed mica schist and the sulphide ore? (Give your answers in metres) (20 marks)

(b) How would you determine the tonnage of the decomposed Mica Schist lying above the sulphide orebody. (10 marks).

(c) Suppose that the Mica Schist was drilled at regular interval of 25m apart and the following data is available.

Borehole BH 01 to BH 04 drilled in one line across the orebody and Borehole BH 05 to BH 08 and Boreholes BH 9 to BH 12 represent another two lines. Determine the ore reserves represented by such a block taking into consideration that each borehole represents equal volume and that Bulk Factor = 2.50 (15marks).

SAMPLE NO.	AVERAGE OREBODY WIDTH (m)	ASSAY %Cu
BH 01	1.0	1.5
BH 02	6.0	3.0
BH 03	8.0	4.5
BH 04	1.5	1.7
BH 05	2.5	1.8
BH 06	5.0	2.8
BH 07	7.0	2.9
BH 08	2.0	1.4
BH 09	2.0	4.6
BH 10	5.5	4.5
BH 11	4.0	1.9
BH 12	1.7	1.3

(ii) Calculate the weighted average copper grade for the block. (10 marks)

(iii) Calculate the total amount of contained copper metal in the block (5 marks)

(d) A new mine is planned to be opened for Alalobuka Micaceous copper deposit to mine sulphide ore only. Where would you site the open pit for optimal removal of the over burden? Show this both on the plan and in the section. (10 marks)

3. Describe in detail the various stages involved in mineral exploration up to the stage when ore reserves and grade are proven (30 marks)

END OF EXAMINATION

GG 462 : MINING GEOLOGY OF ZAMBIA

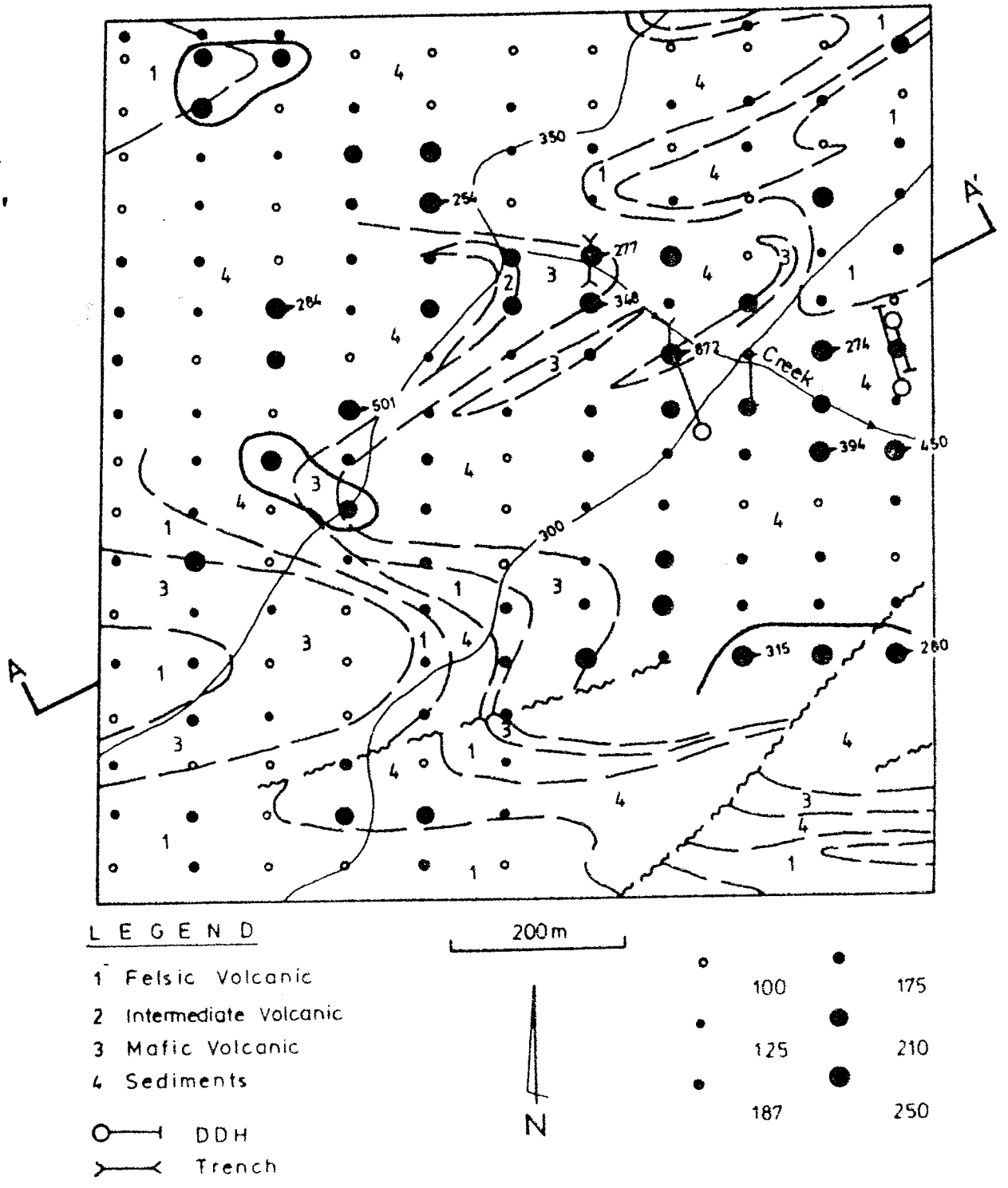
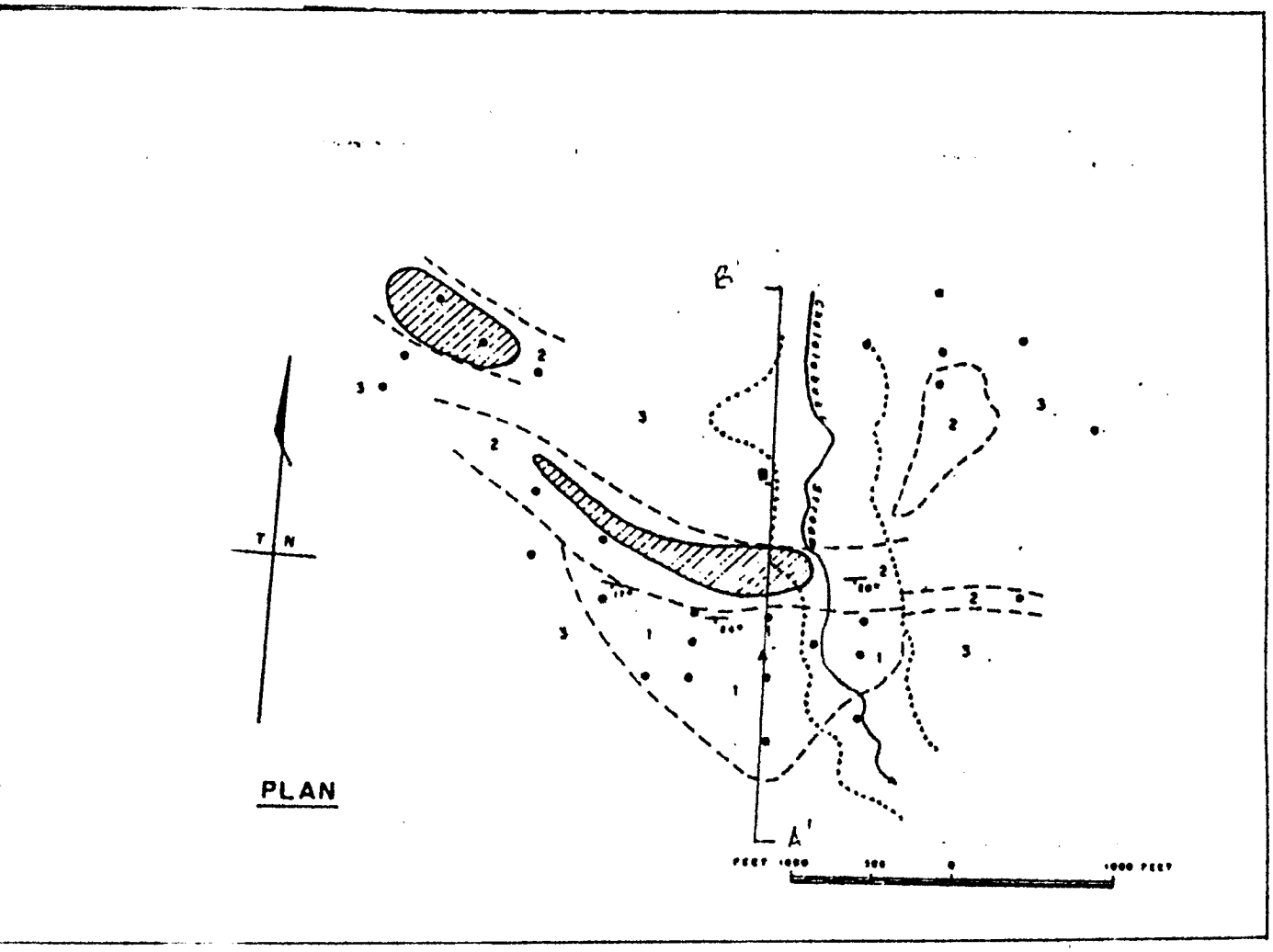


Figure 1 A geochemical map showing geology, topography, Zinc values and trench / drill holes from a public domain map



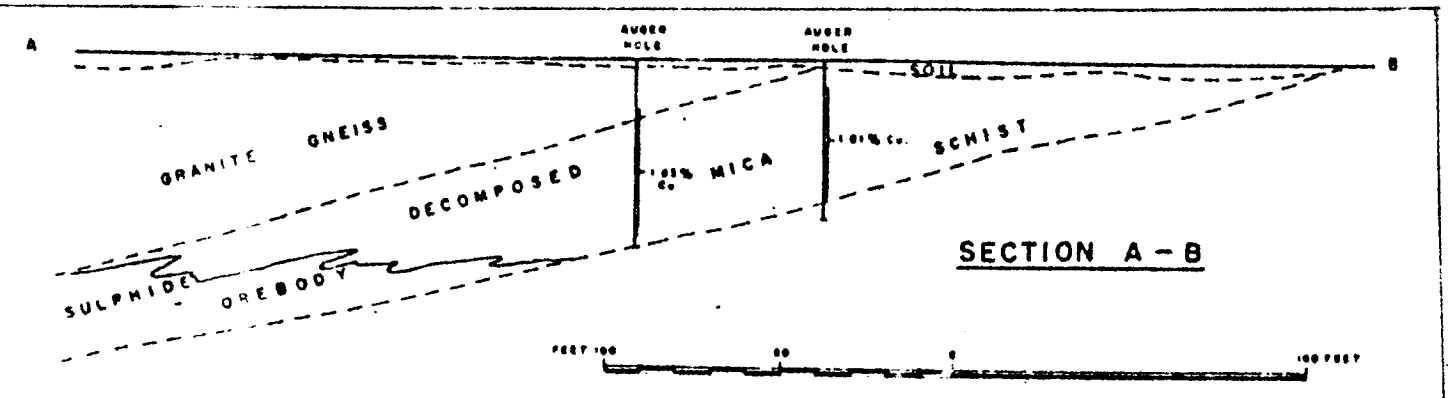


Fig. 2

EOLOGICAL PLAN AND SECTION
OF
OBUKA MICACEOUS COPPER DEPOSIT
LUSAKA EAST AREA

Legend

- 3 Granite gneiss.
- 2 Weathered biotite schist.
- 1 Sulphide mineralization.
- Strike and dip of bed
- Geological contact (approximate)
- Diamond drill holes.
- +1% Copper in surface soils

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG470

GEOCHEMISTRY

PAPER 1

TIME: THREE HOURS

ANSWER: ONE QUESTION FROM SECTIONS A, B, C AND TWO QUESTIONS FROM SECTION D.

SECTION A

1. (a) With the help of a periodic table (Table 1) discuss briefly the geochemical classification of chemical elements.

   (b) Discuss briefly the conditions which are required for isomorphic substitution of a minor/trace element for a major element in a crystal structure.

   (c) Discuss briefly the role of ionic potential and electronegativity on the mobilities of elements during magmatic differentiation and chemical weathering of rocks.

   (d) Name and give examples of three major applications of geochemical data in the study of igneous rocks.

   (e) Discuss briefly the most likely modes of occurence of Ti, P, Ba, Co, Ni, Cr, V, Ga, Zr, in rocks whose representative analyses are given in table 2.

   (f) Explain briefly the type of mineral deposits which are likely to be associated with rock 1 and rock 2 (Table 2) respectively.

(30%)

SECTION B

2. (a) Discuss briefly the factors which determine the rate of chemical weathering of rocks in the secondary environment.

(b) With the help of chemical equations describe briefly how a deposit of Kaolinite would develope in an area underlain by massive pegmatite.

(c) Why are clay-rich soils generally more fertile than those which are rich in sand.

(d) Discuss briefly how the presence of clay minerals in the soil profile may affect the rate of infiltration of dissolved heavy metal pollutants into shallow aquifers.

(e) With the help of equations explain why most lateritic soils in Zambia have not evolved to bauxite. (20%)

3. (a) The composition of water in an interland basin is given in table 3.

(i) make the necessary calculations to determine whether any of the common evaporite minerals is crystallising in this basin.

(ii) calculate the percent age reduction in volume required for precipitation of halite to take place.

(iii) calculate the ionic strength of this water and discuss its effect on the activity coefficients of the ions.

(b) Discuss briefly the effect of three chemical factors (temperature, concentration of brine, pressure) on the stability of sulfate minerals in the $CaS\theta_4$- H_2O system.

(c) Explain briefly why inorganic precipitation of dolomite does not normally take place in highly supersaturated seawater.

(20%)

SECTION C

4. The distribution of heavy metals in the top soil of an industrial town is given in figure 1. On the basis of the information provided in figure 1 answer the following questions.

   (a) What are the major pollutants in this area.

   (b) Name the most likely source of pollutants in this area and mark its position in figure 1.

   (c) Assuming that there are dumping sites for slag; ore and waste in the given area discuss briefly how the dispersion patterns in figure one are likely to have been developed.

   (d) Identify a non-metallic element which the heavy metals are most likely to be associated with in the zone of primary mineralisation.

   (e) Discuss briefly which elements you would use as ore guides at reconnaissance and detailed stages of geochemical prospecting in this area.

(20%)

5. (a) Use the U-Pb isotopic data in table 4 to calculate the 238/206 and 235/207 model ages for the two granitic rock units of the hook granite massif. Assume that there is no significant component of inherited Pb in Zircon grains.

   (b) Discuss briefly whether the calculated ages of the two rock units are concordant or discordant.

   (c) Use the data given in table 4 to plot a concordia diagram for one of the rock units and establish the absolute age of crystallisation.

   (d) Explain briefly why the U-Pb method is more reliable for dating plutonic rocks which have been affected by post-magmatic alteration processes than the K-Ar and Rb-Sr methods.

SECTION D

6. With reference to the Zambian Copperbelt discuss briefly the role of geochemical processes in the formation of sediment hosted copper deposits.

(15%)

7. (a) Discuss briefly the major factors which control the Eh and pH values of natural materials/environments.

(b) Derive expressions to outline the stability field of water on Eh - pH diagram using the following equations.

$$Eh = E^\circ + \frac{0.059}{N} \log \frac{\text{products}}{\text{reactants}}$$

$H_2O \rightleftharpoons \frac{1}{2} O_2 + 2H^+ + 2e \quad E^\circ = 1.23V$

$H_2 \rightleftharpoons 2H^+ + 2e \quad E^\circ = 0.00V$

(c) On the Eh-pH diagram indicate approximate positions for the stability of the following materials. Pyrite in shale, sedimentary manganese deposit, mine waters, water-logged soil.

(d) Discuss briefly the role of Eh and pH in the formation of sedimentary deposits of iron and manganese from ultrabasic rocks. (15%)

8. (a) Use chemical equations and an appropriate Temperature - composition diagram to explain how hydrothermal alteration of K-feldspar may lead to the formation of argillic and potassic alteration zones.

(b) Discuss briefly the role of hydrothermal processes in the formation of metallic deposits of Sn, W, Pb, Ag and Au.

(c) Explain why tin deposits are always associated with wet granitic magmatic rocks.

(15%)

END OF EXAMINATION

UNIVERSITY OF ZAMBIA EXAMS - NOV. 1994

GG470

PAPER I

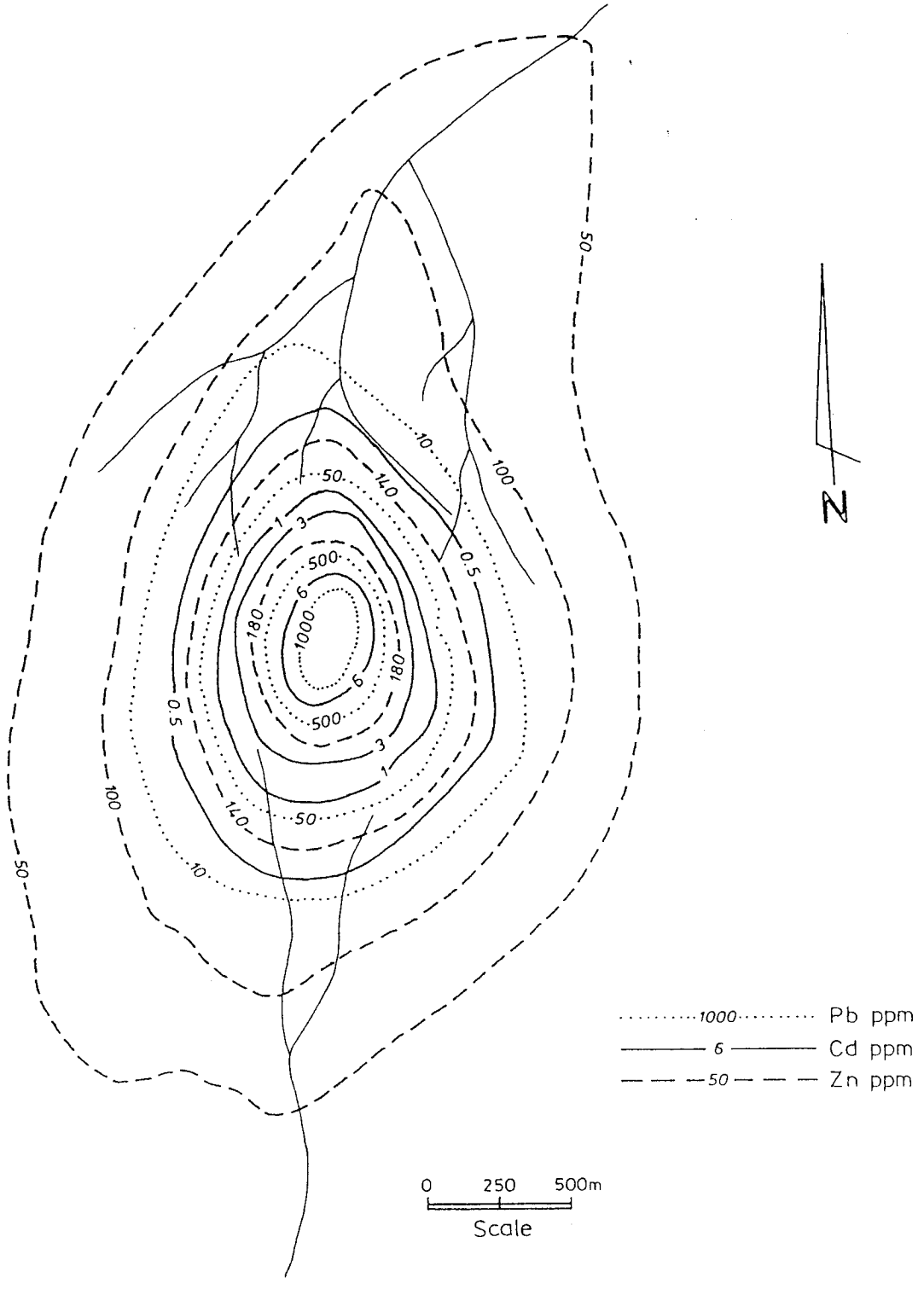


Figure 1

TABLE 1 Ionic Radii after Goldschmidt (1926) and Ahrens (1952).* In Brackets Electronegativities after Pauling (1961).

0.78 Li^{+} [1.0]	0.34 Be^{2+} [1.5]	*0.23 B^{3+} [2.0]											0.2 C^{4+} [2.5]	0.15 N^{5+} [3.0]	1.32 O^{2-} [3.5]	1.33 F^{-} [4.0]
0.98 Na^{+} [0.9]	0.78 Mg^{2+} [1.2]	0.57 Al^{3+} [1.5]											0.39 Si^{4+} [1.8]	0.35 P^{5+} [2.1]	1.74 S^{2-} [2.5]	1.81 Cl^{-} [3.0]
1.33 K^{+} [0.8]	1.06 Ca^{2+} [1.0]	0.83 Sc^{3+} [1.3]	0.64 Ti^{4+} [1.5]	0.4 V^{5+} [1.6]	0.64 Cr^{3+} [1.6]	0.91 Mn^{2+} [1.5]	0.82 Fe^{2+} [1.8]	0.82 Co^{2+} [1.8]	0.78 Ni^{2+} [1.8]	*0.96 Cu^{+} [1.9]	0.83 Zn^{2+} [1.6]	0.62 Ga^{3+} [1.6]	0.44 Ge^{4+} [1.8]	0.69 As^{3+} [2.0]	1.91 Se^{2-} [2.4]	1.96 Br^{-} [2.8]
1.49 Rb^{+} [0.8]	1.27 Sr^{2+} [1.0]	1.06 Y^{3+} [1.2]	0.87 Zr^{4+} [1.4]	0.69 Nb^{5+} [1.6]	0.68 Mo^{4+} [1.8]	*0.56 Tc^{7+} [1.9]	0.65 Ru^{4+} [2.2]	0.68 Rh^{3+} [2.2]	*0.80 Pd^{2+} [2.2]	1.13 Ag^{+} [1.9]	1.03 Cd^{2+} [1.7]	0.92 In^{3+} [1.7]	0.74 Sn^{4+} [1.9]	0.90 Sb^{3+} [1.9]	2.11 Te^{2-} [2.1]	2.20 I^{-} [2.5]
1.65 Cs^{+} [0.7]	1.43 Ba^{2+} [0.9]	1.22–0.99 La–Lu [1.1–1.2]	0.84 Hf^{4+} [1.3]	0.68 Ta^{5+} [1.5]	0.68 W^{4+} [1.7]	*0.56 Re^{7+} [1.9]	0.67 Os^{4+} [2.2]	0.66 Ir^{4+} [2.2]	*0.80 Pt^{2+} [2.2]	*1.37 Au^{+} [2.4]	1.12 Hg^{2+} [1.9]	1.49 Tl^{+} [1.8]	1.32 Pb^{2+} [1.8]	*0.96 Bi^{3+} [1.9]	*0.67 Po^{6+} [2.0]	 At^{-} [2.2]
*1.80 Fr^{+} [0.7]	1.52 Ra^{2+} [0.9]	*1.18 Ac^{3+} [1.1]	1.10 Th^{4+} [1.3]	*0.98 Pa^{4+} [1.5]	1.05 U^{4+} [1.7]	*1.1– Np–No [1.3]										

Table 2

	RocK Unit 1	RocK Unit 2
SiO2 %	49.84	75.38
TiO2	0.86	0.10
Al2O3	15.29	11.42
Fe2O3	11.09	1.68
MnO	0.18	0.03
MgO	7.62	0.12
CaO	11.34	1.00
Na2O	2.64	3.26
K2O	0.24	6.14
P2O5	0.06	0.03
Ba ppm	100	217
Cl	4405	326
Co	141	69
Cr	358	2
Cu	142	48
W	2	40
Ga	31	21
Ni	449	3
Sn	0.5	7
S	615	66
Sr	131	13
Be	0.3	3
Zr	21	181
Pb	4	62
Rb	12	391

Fe2O3 = Total Fe Oxide

TABLE 3

Ion	Total molality	Activity Coefficient	Percent Free Ion
Ca^{2+}	0.00998	0.26	90
Mg^{2+}	0.0523	0.29	87
CO_3^{2-}	0.00027	0.2	9
SO_4^{2-}	0.033	0.23	55.3
Na^+	0.459	0.38	98.9
Cl^-	0.535	0.34	100

$CaMg(CO_3)_2 \rightleftharpoons Ca^{2+} + Mg^{2+} + 2CO_3^{2-}$ $\quad K_{sp} = 10^{-16.7}$

$CaCO_3 \rightleftharpoons Ca^{2+} + CO_3^{2-}$ $\quad K_{sp} = 10^{-8.4}$

$NaCl \rightleftharpoons Na^+ + Cl^-$ $\quad K_{sp} = 38$

$CaSO_4 \rightleftharpoons Ca^{2+} + SO_4^{2-}$ $\quad K_{sp} = 2.5 \times 10^{-5}$

Table 4 Zircon U – Pb isotopic data

Fraction	Pb ppm	U ppm	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{204}Pb/^{206}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$
Rock Unit 1							
(a)	23	309	0.14772	0.0642	0.000373	0.07081	0.57384
(b)	23.5	307	0.15103	0.06459	0.000391	0.07285	0.59173
(c)	22	274	0.13934	0.06197	0.000204	0.07754	0.63082
(d)	28.3	353	0.13423	0.06069	0.00011	0.07795	0.63506
Rock Unit 2							
(a)	39.5	638	0.14059	0.14059	0.07164	0.000895	0.05851
(b)	34	504	0.1195	0.06063	0.000163	0.06705	0.5387
(c)	33	392	0.12313	0.06444	0.000402	0.08182	0.6582

Decay constants for ^{238}U and ^{235}U are 1.5512×10^{-10} and 9.8485×10^{-10} respectively.

$^{238}U/^{235}U = 137.88$

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG470

GEOCHEMISTRY

PAPER II

TIME: THREE HOURS

ANSWER: ALL THE QUESTIONS

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1. Four rock samples were submitted to the analytical laboratory and two replicate measurements of SiO_2 content were made on each sample by two analysts using two different methods. The data which was obtained by the two analysts is given in table 1. You are required to compute the pooled standard deviation for each method and to determine the 95% confidence limits for the means of the first sample. Which of the two methods is the most suitable for use in the survey for glass sand.

   Table 1

Sample number	Analyst 1 (%)		Analyst 2 (%)	
1	75.6,	75.2	75.1,	77.2
2	79.4,	78.8	78.3,	77.6
3	70.3,	69.2	70.8,	72.7
4	50.1,	48.2	49.8,	53.6

(20%)

2. In order to monitor the stability of the X-ray spectrometer a series of measurements (Table 2) have been made on a gold monitor standard, under the following operating conditions:

   current = 30 μA; Voltage = 50 KV; Crystal = Si111

   detector = flow counter; time = 20 seconds

Table 2

Angle (2θ)	Intensity readings (C/20 Seconds)			
137.30	45627;	45698;	45773;	45599
137.29	45323;	45214;	45772;	45651
137.28	45884;	46175;	45883;	45995
137.27	46389;	46514;	46432;	46158
137.26	46157;	46655;	46672;	46255
137.25	46399;	46414;	46970;	46427
137.24	46398;	46429;	46784;	46118
137.23	46132;	46104;	46359;	46192

(a) Make a graph of angle against intensity (C/S).

(b) Determine the peak angle for the Au Ma spectral line.

(c) On the basis of the data in table 2 discuss briefly whether it is necessary to change the peak angle for Au Ma if it is currently set at 137.27.

(20%)

3. In an attempt to determine the percentage of sodium in three granitic samples (R_1, R_2, R_3) the following data (table 3) was obtained using X-ray spectrometric method of analysis.

Table 3

Rock type	Intensity	Na_2O
granite (G1)	3500	2.93%
" (R1)	4308	?
basalt (B1)	8080	5.24
" (B2)	7129	4.68
granite (R2)	4112	?
" (R3)	3746	?
" (G2)	4564	3.71
" (G3)	4028	3.54

(a) Use the appropriate data to construct a calibration curve and formulate a linear regression model.

(b) Estimate the content of Sodium in samples R1, R2 and R3.

(c) Discuss briefly how you would determine the suitability of this linear model for analysis of pyroxene.

(20%)

4. The results of a small scale reconnaissance geochemical survey are shown in figure 1 and table 4. Use this data to answer the following questions:

(a) What type of intrusion is likely to be associated with mineralisation in this area.

(b) Discuss briefly the mineral potential of this area.

(c) Name three metallic minerals which are most likely to be dominant in the zone of primary mineralisation.

(d) Discuss briefly the association of iron with other elements (Ni, Cu, V, Cr, Co) in the collected samples.

(e) Which heavy mineral is most likely to be controlling the contents of trace elements in the stream sediment samples.

(f) Which elements would you use in a hydrogeochemical survey?

(g) Mark the positions of 10 sampling sites in fig. 1 for additional stream sediment samples and five sites for hydrogeochemical samples.

(40%)

END OF EXAMINATION

UNIVERSITY OF ZAMBIA EXAMS-NOV. 1994

GG470

PAPER II

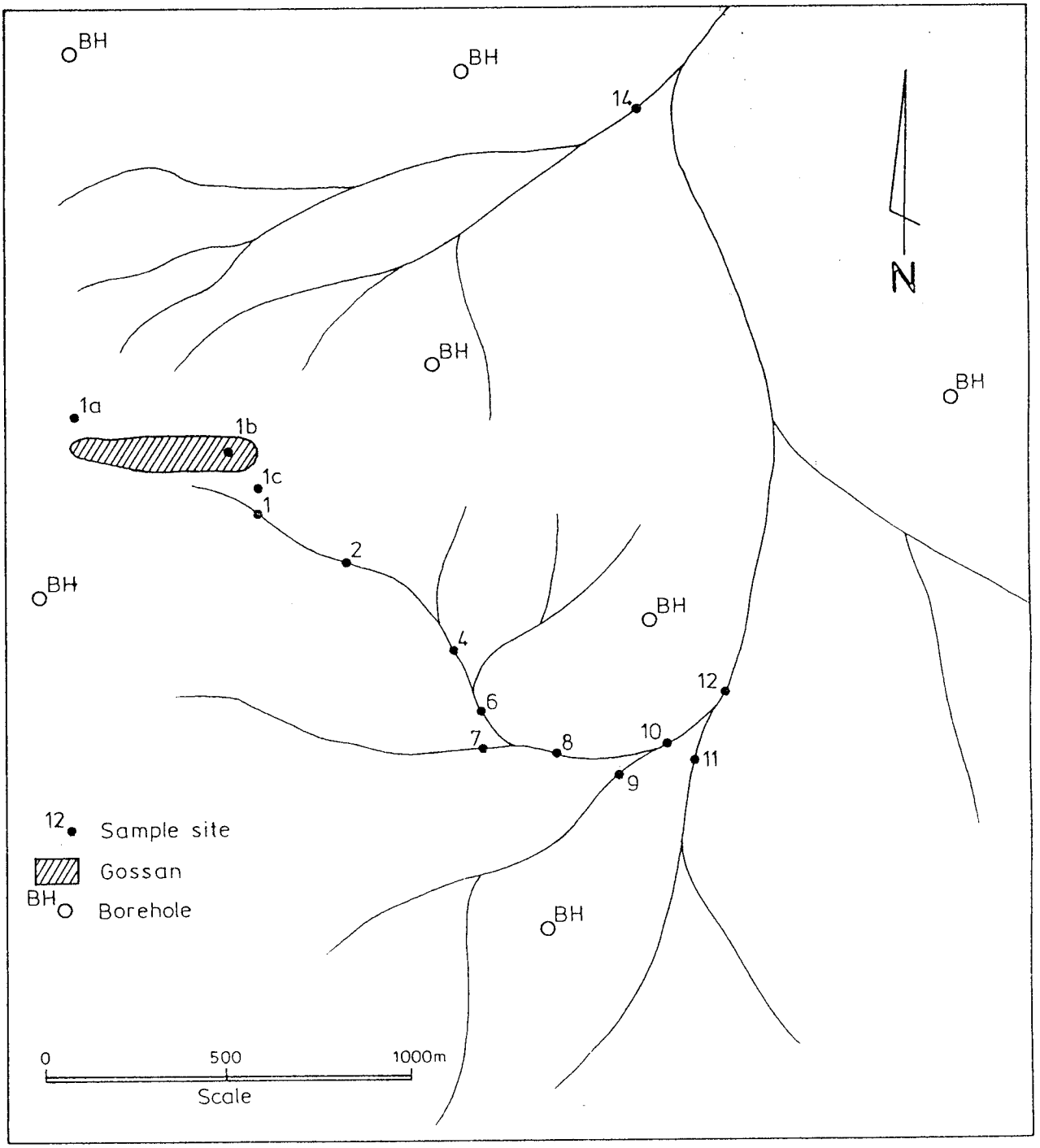


Figure 1

Table 4

Sample number	Sample Type	Fe %	Ni ppm	Cu ppm	S ppm	V ppm	Cr ppm	Co ppm
1 a	rock	12.03	2068	164	600	338	591	147
1 b	ironstone	66.36	8020	423	2652	70	<50	<30
1 c	rock	11.49	1972	201	650	358	632	149
1	stream-sediment	52.28	506	266	<50	3441	368	296
2	''	38.17	274	152	<50	2024	461	129
4	''	32.78	192	170	<50	1534	495	119
6	''	23.13	119	140	86	965	311	<30
7	''	12.33	43	40	<50	400	206	30
8	''	16.86	108	42	<50	725	227	<30
9	''	10.14	38	37	<50	380	192	41
10	''	15.54	87	102	<50	676	222	<30
11	''	9.05	33	34	<50	363	180	45
12	''	13.89	61	74	<50	450	209	33
14	''	28.34	85	85	<50	567	325	63

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

GG 522

GEOLOGY OF ZAMBIA

TIME: THREE HOURS

ANSWER: QUESTION 1 AND FOUR OTHERS

ILLUSTRATE YOUR ANSWERS WITH NEAT DIAGRAMS WHEREVER POSSIBLE. ALL QUESTIONS CARRY EQUAL MARKS.

---

1. In our review of the continental sediments of Africa, we looked at the stratigraphic divisions in Afica. Answer the following.

   (a) Fill in the Rock Stratigraphic Units in Zambia together with the corresponding Geologic Time (Geochronologic) Units, Time Stratigraphic Units together with their absolute age in the table provided.

   (b) Outline the major groups of African Continental sediments.

   (c) Show in the table provided in (a) the major orogenies that played a major role in the Stratigraphic Units (lithostratigraphic units) and comment briefly on the significance of each.

2. (a) Discuss the evolution of the Stratigraphic nomenclative used by the Geological Survey Department of Zambia.

   (b) Describe and discuss the Stratigraphy of Zambia with respect to two of the following:

   (i) the Basement complex
   (ii) the Katanga supergroup
   (iii) Kalahari supergroup

   emphasising, geographic distribution and economic significance of each supergroup.

3. (a) Discuss the sedimentation patterns of the Karoo supergroup in the mid-Zambezi valley in relation to tectonics. What other factors were important in the emplacement of the Karoo?

(b) Uranium, coal (mined) and probably hydrocarbons (petroleum and gas) are some of the important mineral and energy resources in the Karoo. Discuss the environments in which these resources could have been formed. How do tectonics and climate favour such deposits?

4. (a) List the eight (8) main characteristic features used in the delineation of Structural Provinces.

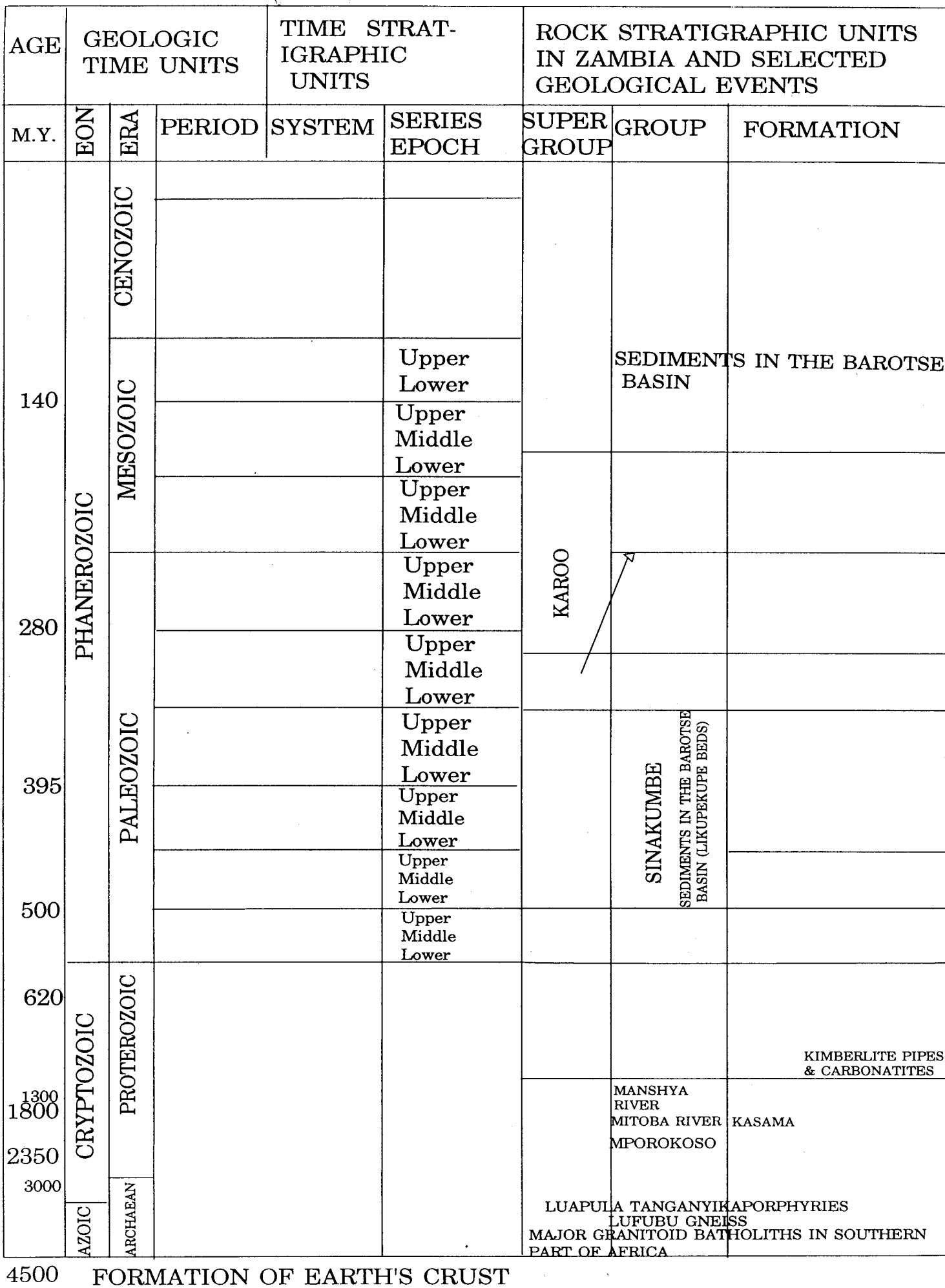
(b) Using the data in 2(a) above, describe the five (5) main Structural Provinces of Zambia. (Illustrate your answer with a sketch map of Zambia).

5. (a) Describe and discuss either the main carbonatite occurrences or the main syenite occurrences in Zambia. (Illustrate your answer with a sketch map of Zambia).

(b) Describe and discuss the economic significance of either the carbonatites or syenites identified in (a) above.

6. Discuss the geology of pegmatites and their role in Zambia's economy.

END OF EXAMINATION


AGE
GEOLOGIC TIME UNITS
TIME STRAT-IGRAPHIC UNITS
ROCK STRATIGRAPHIC UNITS IN ZAMBIA AND SELECTED GEOLOGICAL EVENTS
M.Y.
EON
ERA
PERIOD
SYSTEM
SERIES EPOCH
SUPER GROUP
GROUP
FORMATION
PHANEROZOIC
CENOZOIC
MESOZOIC
PALEOZOIC
PROTEROZOIC
CRYPTOZOIC
ARCHAEAN
AZOIC
Upper
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Lower
SEDIMENTS IN THE BAROTSE BASIN
KAROO
SINAKUMBE
SEDIMENTS IN THE BAROTSE BASIN (LIKUPEKUPE BEDS)
KIMBERLITE PIPES & CARBONATITES
MANSHYA
RIVER
MITOBA RIVER
MPOROKOSO
KASAMA
LUAPULA
TANGANYIKA
PORPHYRIES
LUFUBU GNEISS
MAJOR GRANITOID BATHOLITHS IN SOUTHERN PART OF AFRICA
140
280
395
500
620
1300
1800
2350
3000
4500
FORMATION OF EARTH'S CRUST

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

GG 522

GEOLOGY OF ZAMBIA

TIME: THREE HOURS

ANSWER: QUESTION 1 AND FOUR OTHERS

ILLUSTRATE YOUR ANSWERS WITH NEAT DIAGRAMS WHEREVER POSSIBLE. ALL QUESTIONS CARRY EQUAL MARKS.

---

1. In our review of the continental sediments of Africa, we looked at the stratigraphic divisions in Afica. Answer the following.

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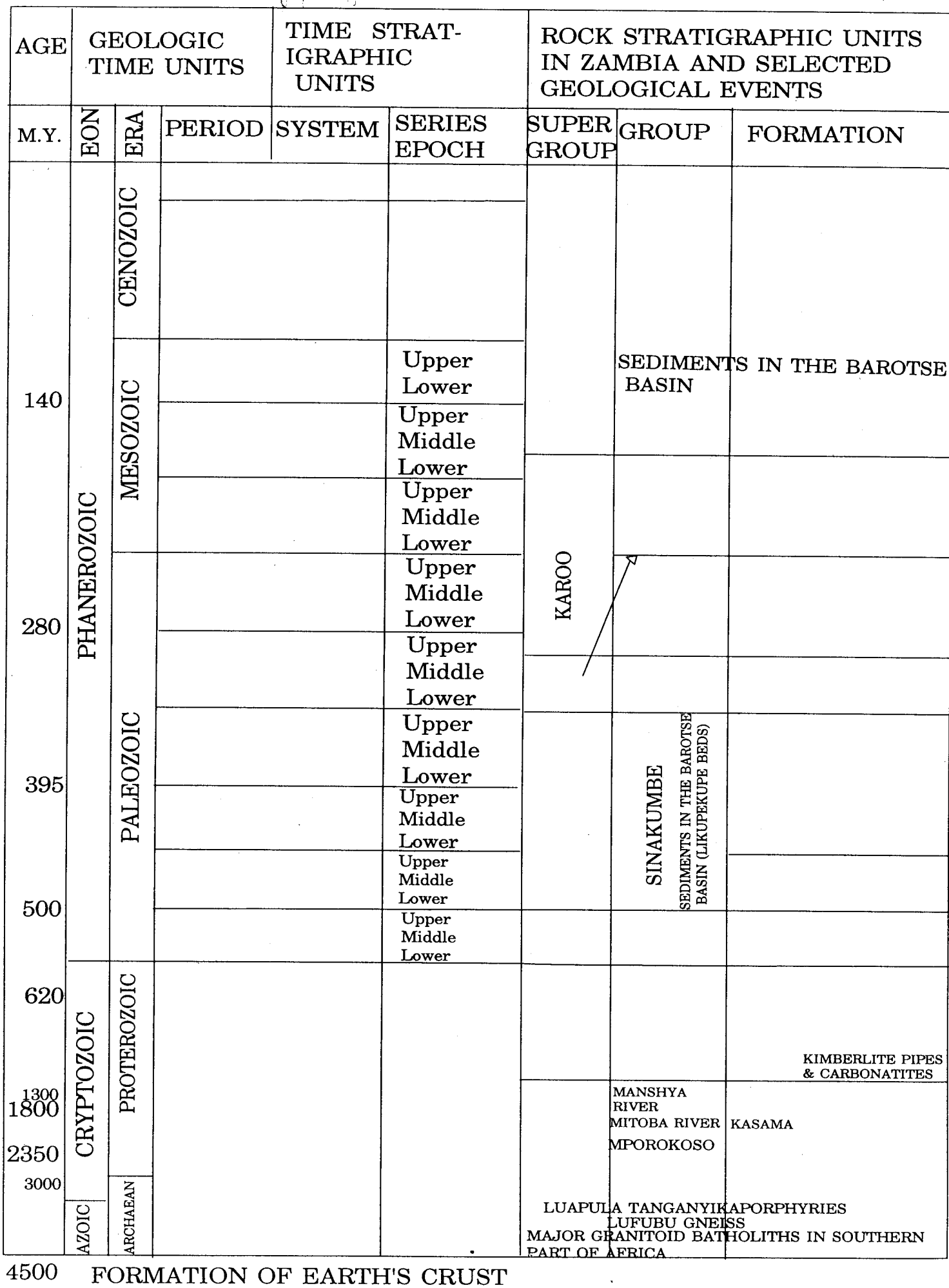
END OF EXAMINATION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SEDIMENTS IN THE BAROTSE BASIN
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MAJOR GRANITOID BATHOLITHS IN SOUTHERN PART OF AFRICA
FORMATION OF EARTH'S CRUST

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - AUGUST 1994

GG 531

HYDROGEOLOGY

TIME: THREE (3) HOURS

ANSWER: QUESTION 1 AND ANY OTHER THREE QUESTIONS

---

1. It has been established that the undergroundwater at Konkola Mine is due to surface sources and also to underground sources.

   Examine the geology of Konkola Mine particularly in terms of the lithogies and the structural setting. Identify the possible surface sources of water and explain how they would contribute to the water problem underground, in shaft 3.
   (Note: Map of Konkola Mine is attached) (40 marks)

2. (a) Derive the Continuity Equation, defining all terms.
   (b) Reduce the Equation to Laplace in Cartesian Coordinates, in three dimensions. (20 marks)

3. It takes one hour for 5 litres of water in a constant head permeameter to flow through a porous medium 50 centimetres thick with a cross section radius of 10 centimetres. The constant water level is 2 metres above the medium.
   Determine the permeability K. (20 marks)

4. The University of Zambia has about ten (10) boreholes drilled randomly over the Campus Grounds.

   Indicate how you would measure the average velocity of groundwater. Explain any limitations in your technique. (20 marks)

5. Discuss the role of surface and groundwater hydrology in the Zambia's Food Production programmes. What hydrological data is required and how do you obtain it? (20 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

GG542

ENGINEERING GEOLOGY

TIME: THREE HOURS

ANSWER: ANY FOUR QUESTIONS

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1. Explain the following

   (a) Stress and strain

   (b) Creep

   (c) Liquid limit and plastic limit

   (d) Cohesion

   (e) Young's modulus and poisson's ratio.

2. Suppose a Donor Government donated to the Geology Department the following laboratory equipment:

   (a) An Oedometer

   (b) Triaxial Apparatus

   (c) Shear Box Apparatus

   (d) Schmidt Hammer

   (e) Penetrometer

   In each case, by means of diagrams, briefly describe how and what for you would use the equipments.

3. Given the Drawdown Measurements obtained in an observation well (See Table 1) during a simple dewatering programme the following is given:

   (a) Pumping rate, Q = 2,000 litres per minute

   (b) Distance of observation well from pumped well is 100 metres.

   After how many minutes of continuous pumping will draw down of 1 metre be attained?

4. You have been requested to select a subsurface waste disposal site of very dangerous fluids. The site is to be located within twenty kilometres of the Town Centre. From your knowledge of the geological and hydrogeological setting of Lusaka where would you recommend the site. Give reasons for selecting such an area.

5. Compare and contrast the usefulness of the following geophysical methods as applied to subsurface engineering geological studies. In each case give examples of how the method is used.

   (a) Resistivity technique

   (b) Seismic Refraction

END OF EXAMINATION

TABLE: I - DRAWDOWN MEASUREMENTS IN OBSERVATION WELL

Time since pump started in minutes	Drawdown,s, in ft.
1.0	0.16
1.5	0.27
2.0	0.38
2.5	0.46
3.0	0.53
4.0	0.67
5.0	0.77
6.0	0.87
8.0	0.99
10	1.17
12	1.21
14	1.30
18	1.43
24	1.58
30	1.70
40	1.88
50	2.00
60	2.11
80	2.24
100	2.38
120	2.49
150	2.62
180	2.72
210	2.81
240	2.88

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - AUGUST 1994

GG 561

APPLIED GEOPHYSICS

TIME: THREE HOURS

ANSWER: ANY FOUR QUESTIONS

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1. (a) Define the following, listing measurable parameters.

   (a) Geophysics
   (b) Geology
   (c) Geodesy
   (d) Geotechnics
   (e) Geothermometry (10 marks)

   (b) Explain geological situations in which Geophysics finds applications in Zambia. (15 marks)

2. You are provided with the sounding data (Table 1 attached) obtained from a farm somewhere in Zambia. Plot and interpret the geo-electrical section. What possible lithology would underlie the sounding site? Explain. (25 marks)

   (Note: 3 cycle log-log paper should be provided)

3. (a) What is meant by a "geophysical anomaly." Explain your answer listing possible "pitfalls" in interpretations of geophysical anomalies. (10 marks)

   (b) Sketch a profile that would be obtained over a gabbro/granite contact using magnetics. (15 marks)

4. Explain by use of diagrams the principles behind the following geophysical equipment.:

(a) vibroseis source
(b) gravity meter
(c) seismograph
(d) satellite remote sensor
(e) geophone (25 marks)

5. (a) Draw a generalised flow chart of modern seismic data processing.

(b) Describe in detail the processing steps of:

(i) Normal Moveout (NMO)
(ii) Correction to zero phase
(iii) Denconvolution (DECON) (25 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - AUGUST 1994

GG 571

ECONOMIC GEOLOGY OF NON-METALLIC MINERAL DEPOSITS

TIME: THREE HOURS

ANSWER: QUESTION 1 AND FOUR OTHERS.
All questions carry equal marks. Illustrate your answers with diagrams wherever possible.

---

1. The building and construction industry all over the world consume a considerable amount of building materials every year. Describe all the raw materials listed below stating important properties for their use:

   (a) Sand and gravel
   (b) Common rocks worked as aggregate
   (c) Gypsum in Zambia
   (d) Limestone used for cement manufacture

2. Describe the modes of occurrence and important uses of four of the following:

   (a) Fluorite
   (b) Barite
   (c) Manganese
   (d) Zeolite
   (e) Apatite
   (f) Pyrite
   (g) Trona
   (h) Nepheline syenite

3. The glass industry is an important consumer industry catering for containers, sheet glass and special glasses including optical glass. Discuss the following:

   (a) Types of raw materials used for glass manufacture.

   (b) Properties and roles played by each raw material in the glass mix.

   (c) Techniques of glass examinations.

   (d) The five stages of glass manufacture.

4. Write some notes on the Zambian Gemstone Industry stating clearly the following:

   (a) Name and geological setting of each resource

   (b) Gemstone resources presently being mined

   (c) Scale of mining

   (d) Marketing arrangements

   (e) Some problems this industry is presently facing.

5. Describe the changes in chemical composition of coal on progressing through the humic coal series.

6. Write some notes on the properties and uses of four of the following:

   (a) Sulphur

   (b) Salt

   (c) Talc

   (d) Asbestos

   (e) Ball clay

   (f) Fire clay or china clay

   (g) Fuller's Earth

7. Either describe three types of abrasive minerals and their geological occurrence or three types of refractory minerals and their geological occurrence.

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - AUGUST 1994

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END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

MI 213

INTRODUCTION TO MINE DEVELOPMENT

TIME: THREE HOURS

ANSWER: ANY FIVE QUESTIONS (ALL QUESTIONS CARRY EQUAL MARKS

---

1. Discuss the operation of shaft-sinking by conventional method. (20)

2. What is meant by "opening up" underground ore deposits? With the help of sketches discuss the various methods used to open up deposits that are deep-seated. (20)

3. Write short notes on:

   (a) Free-faces (05)

   (b) Bore-hole pressure (05)

   (c) Detonation and deflageration. (05)

   (d) ANFO (Ammonium-nitrate-fuel-oil) (05)

4. (a) Discuss the object of prospecting and give some of the methods used to establish the existence of mineral deposits under the earths surface. (10)

   (b) What do you understand by:

      (i) Preliminary proving and sampling (05)

      (ii) Detailed proving. (05)

5. You have been asked to install a belt conveyor for the transportation of open pit materials. Discuss the factors affecting the capacity of the conveyor and also the characteristics of the material which affect the selection of a conveyor belt system. (20)

6. Discuss the principal factors to be considered in selecting an underground mining method. (20)

7. Explain the various patterns of cutholes in blasting hard rock in development headings. Give their applications. (20)

END OF EXAMINATION

GOOD LUCK

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

MI 213

INTRODUCTION TO MINE DEVELOPMENT

TIME: THREE HOURS

ANSWER: ANY FIVE QUESTIONS (ALL QUESTIONS CARRY EQUAL MARKS

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END OF EXAMINATION

GOOD LUCK

2 COPIES

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

MI 413

UNDERGROUND MINE DESIGN

TIME: THREE HOURS

FULL MARKS: 100

ANSWER: ANSWER ANY FIVE QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS.

---

1. (a) What are the geological and structural information required for mine planning? Discuss the geostatistic method for ore reserve calculation. (10)

   (b) Calculate (i) the unit profit of mining and processing and (ii) cutoff grade for copper deposit from the information given below:

   - Copper content in the ore = 60%
   - Selling price of copper in the concentrate = $1.65/kg
   - Unit costs = $7.80/tonne
   - Overall recovery = 95%

   (10)

2. (a) Extraction of ore as final operation (STOPING) depends upon several factors. Discuss these factors. (10)

   (b) A deposit has a width of 50m, a length of 2000m and a depth of 1000m. The average ore density is $3.5 t/m^3$. It is required to build a new haulage level at a probable depth of 100, 150 or 200m. The production is estimated at 4 million tonne per year of ore. The fixed investment is estimated at $ 50 million and the variable at $25 million per 100m. The interest rate is 15%. Find the best depth for the new level. Assume recovery 80%. (10)

3. (a) How a mining method is selected using the numerical approach? Which method of mining would you recommend for the total points obtained by the numerical approach given below:

34; 29; 24; -20; -18 (12)

(b) How the knowledge of time-dependent strain (creep) characteristics can be utilized for underground mine design? (8)

4. (a) State the conditions in which Block Caving mining system is most suited. (10)

(b) Describe, with the help of neat diagrams, the <u>three</u> methods of draw commonly used in Block Caving method in today's operation. (10)

5. (a) A non-coal deposit at 450m depth has the following other features:

- Deposit dip - Perfect flat
- Deposit shape - Tabular
- Ore Uniformity - Fairly uniform
- Ore strength - Weak
- Rock strength - Strong (10)

Explain in brief, using suitable diagrams a suitable method for mining such deposit.

(b) Determine the (i) yearly production rate and (ii) area exploited in hectares per year in a room and pillar mining for the following condition:

- Working place = 1.8m x 5.4m
- Working time = 7hr/shift; 2 shifts/day; 250 days/year.
- Advance/cut = 3.6m
- Cuts/shift = 12
- Tonnage factor = $0.7m^3$/tonne (10)

6. (a) How the pillars and stopes are extracted in Vertical Crater Retreat (VCR) system of mining? Explain with the help of diagrams. (12)

(b) State the advantages of VCR method over the other methods of mining. (3)

7. (a) Discuss the conditions that influence the selection of a loading and hauling machine. (10)

(b) Find (i) the net productivity per hour and (ii) % of theoretical for an overshot loader of 180 bucket loads per 60 - min hr. The other information are given below: (10)

Factor	% Deration
. Actual operating time (50 - min hr)	$\frac{(60 - \text{Oper. min per hr}}{60 \text{ min per hr}} \times 100$
. Coarse muck	10%
. Average automation	15%
. Air pressure (586KPa)	10%

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

MI313

ROCK MECHANICS

TIME: THREE HOURS

INSTRUCTIONS: ANSWER ANY FIVE QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS

Q1. Three samples of rock were subjected to diametral point load tests. The pressure gauge readings at rupture were $17.24 \times 10^2 KN/m^2$, $48.26 \times 10^2 KN/m^2$ and $124.11 \times 10^2 KN/m^2$. If the ram area is $13.36 cm^2$ and the diameter of the cores tested was 54mm, (a) Calculate an estimate for the unconfined compressive strength of each rock. (10 marks)

(b) Perform a size correction for the values calculated in (a) above. (10marks)

Q2. In many engineering applications it is often required to get an idea of the time dependence of the rock in which underground structures are excavated.

Plot the strain-time curves for a twenty period during which period a stress of $68.947 \times 10^2 KN/m^2$ acts during the first ten-minutes and zero stress acts during the second ten minutes on:

(a) A Maxwell body with $E = 206.84 \times 10^2 KN/m^2$
$\eta = 500 \times 10^8$ poise

(b) A Kelvin Body with $E = 206.84 \times 10^2 KN/m^2$
$\eta = 500 \times 10^8$ poise

Make general comments on these tests. (20 marks)

Q3. A rock sample in a uniaxial compression test failed at a compressive stress of $275.79 \times 10^2 KN/m^2$. The failure plane made an angle of 60° with the major principle plane. Assuming the shear strength varies linearly with the normal stress, calculate:

(a) the shear strength of the rock on a plane with zero normal stress. (5 marks)

(b) the shear strength under the test conditions on a plane at 30° to the major principal plane in the above test. (5 marks)

(c) the angle of internal friction (5 marks)

(d) the normal and shear stresses on the failure plane. (5 marks)

Q4. The following strains have been measured at a point on the free surface of a solid body:

Direction	Angle θ	Strain ε
a	0°	0.002
b	120°	0.002
c	240°	-0.001

(a) Draw the Mohr's circle for the state of strain specified above, (4 marks)

(b) From the Mohr's circle of strain, determine the maximum shear strain value. (6 marks)

(c) Mark on the Mohr's circle the following corresponding strain components: (4 marks)

$\varepsilon = 2.6 \times 10^{-3}$, $\gamma = -2.4 \times 10^{-3}$

(d) What is the magnitude of the strain components ε and γ when $\theta = -30°$ measured from the direction of the major principal strain? (6 marks)

Q5. Two gauge marks 5cm apart are made along the axis of a cylindrical rock specimen 6cm long and 7cm² cross-sectional area. The specimen is then subjected to a compressure force of 100KN.

Calculate the following:

(a) The stress (2 marks)

(b) The Strain (2 marks)

(c) Contraction between gauge marks (4 marks)

(d) Total contraction of the specimen (4 marks)

(e) the total change of volume of the specimen (4 marks)

(f) the change in the cross-sectional area of the specimen. (4 marks)

Take E = 69GPa and ν = 0.3

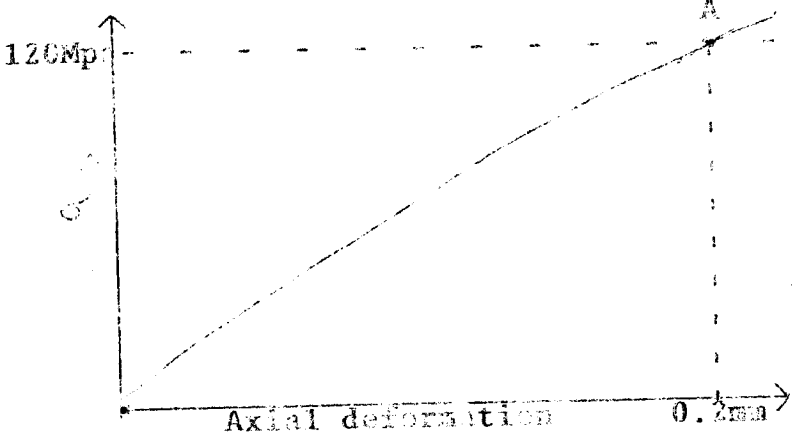
Q6. A cylindrical sample of rock (diameter 40mm, length 80mm) was subjected to a uniaxial compression test. The stress deformation curve obtained is shown in this figure below.

(a) If the rock is assumed to be elastic up to point A. What is the value of the secant modulus of elasticity?

(b) What is the total strain energy in the sample at point A?

(c) If point A is taken to represent failure of the sample, what is the maximum shear stress in the sample at failure?

(d) What is the direction of the plane on which the maximum shear stress acts? (5 marks each)



Q7. A rectangular element of material has sides 10cm and 5 cm long parallel to the X and Y coordinate axes respectively. When loaded, the element assumes the form of a parallelogram with side lengths 10.102 and 4.975 cm. The angle of the left-hand bottom corner of the element is changed to 89.657°.

1 poise = 1 Ns/m^2

Compute the values of:

(a) The strain components Ex, Ey, γxy (7 marks)

(b) The stress components σx, σy, Txy (7 marks)

(c) The magnitude and direction of the principle stresses. (6 marks)

Take $\sigma_z = \tau_{yz} = \tau_{zy} = 0$

E = 50GPa

ν = 0.28

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

MI 423

SURFACE MINE DESIGN

TIME: THREE HOURS

FULL MARKS: 100

ANSWER: ANY FIVE QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS

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1. (a) Discuss the major factors of open pit mine planning and pointout their interdependence with each other, if any. (10)

   (b) What are the essential elements of a feasibility report? Why is it necessary to have a feasibility report for a mine? (10)

2. (a) State the objectives of development drilling. Describe its basic types and discuss their relative merits and demerits. (10)

   (b) Following copper grades were obtained from development drilling programme.

Borehole No.	CO-ORDINATES N	E	Grade % Cu
1	1800	2500	2.5
2	1600	2300	1.5
3	1400	2100	0.5

   Estimate the grades at X(1500, 2400) and Y(1000, 2200) by Inverse Distance Square (IDS) method. (Graph paper supplied). (10)

3. (a) Explain the following using figures where necessary (10)
   (i) Break-even point
   (ii) Cut-off grade
   (iii) Stripping ratios and their types

(b) How ultimate pit design is obtained? What are its implications in surface mine planning and design? (10)

4. (a) Describe the interpolation technique used in the mineral inventory. (8)

(b) Plot at least <u>three</u> stripping curves from the following data and comments on the curves obtained. (Graph paper supplied).

- Maximum selling price P = 8.5 mu/kg
- Total recovery along production line a = 0.85
- Ore cost K = 5.50 mu/tonne
- Waste cost W = 2 mu/tonne
- Ore grade variation d = 0.25 (25%) (12)

5. (a) Discuss the factors on which selection of mining equipment is made for surface mining. (10)

(b) List the major and ancillary equipment required for a surface mine producing 5 million tonnes copper a year. (10)

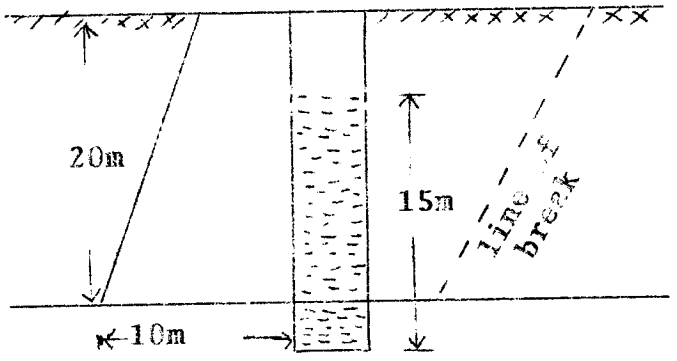
6. (a) What are the rock properties considered important for determining drillability of rock? Describe, how <u>two</u> of these properties may be determined. (10)

(b) Calculate the (i) number of holes required and (ii) hole spacing for the bench of a surface mine from the following data:

- Sp. Wt. of copper = 2.5t/m^3 (10)
- Bank length = 70 m
- Other parameters: Shown in Figure
- Explosive: ANSlurry
- 4 tonnes of rock broken by 1kg of explosive

. Height of charge in each hole = 15m

. Hole diameter: 30cm



7. (a) What are the different types of draglines currently in use in open pit mining? Discuss the factors that may affect the output of a dragline. (10)

(b) Where would you recommend the use of the following:

(i) a power shovel

(ii) a dragline

(iii) a Bucket Wheel Excavator (BWE).

Give reasons for your choice (10)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY OF ZAMBIA EXAMINATIONS NOVEMBER/DECEMBER 1994

MI 433

OPERATIONS RESEARCH

TIME: 3 HOURS

ANSWER ALL QUESTIONS. QUESTION NO. 1 CARRIES 10 MARKS, QUESTION NOS. 2 TO 6 CARRY 18 MARKS EACH.

Question 1

Discuss the relevance (or irrelevance) of the use of Operations Research in Mining, giving two examples from your exposure to mining to date. (10 marks)

Question 2

A company operates a central chrome smelter which processes chromite ore to produce ferrochrome. The ferrochrome alloys are produced by direct smelting of pre-mixed charges of chromite ore, quartz and coke. The ores from the various mines are of different compositions. Two types of ferrochrome are produced: Low Carbon Ferrochrome (LCFeCr) and Ferrosilicon Chrome (FeSiCr). Optimum operation of the furnaces are obtained when the ore feed has a Cr/Fe ratio of 2,15 or more.

The following table gives the mine capacities, unit costs and Cr/Fe ratios from seven supplying mines. Formulate an optimization model for determining the ore tonnage to be delivered from each of the seven mines in a given month to give the minimum total cost while satisfying the Cr/Fe ratio quality requirement. Operational conditions in Mines - 2, -5, and - 6 are such that each must produce at least two hundred (200) tonnes of ore per month. The smelter feed requirement of five thousand (5000) tonnes per month must be met. (18 marks)

/2...

Table to Question No. 1

Mine	Production (tonnes/month)	Costs ($/tonne)	Quality (Cr/Fe)
1	1600	291	1,94
2	500	590	1,94
3	2000	140	1,94
4	520	157	1,92
5	670	520	2,48
6	670	540	2,48
7	980	218	2,48

Question 3

The National Explosive Company manufactures two types of slurries for use in wet blasting conditions. The selling price and the associated unit variable costs for "high-sensitive" and "normal" are shown in the following table.

Production	Selling Price (Z$/5-litre Pk)	Unit variable cost (Z$/5-litre Pk)
Normal	13,0	9,0
high-sensitive	16,0	10,0

Each 5-litre pk. of normal requires six minutes of skilled labour and each 5-litre pk of high-sensitive requires 12 minutes of skilled labour. In a given day there are 400 man hours of skilled labour available. Also, there are 100 kg of an important blending chemical available each day, where each 5-litre pk of normal needs 0.05kg of the blending chemical and each 5-litre pk of high-sensitive needs 0.02 kg of the chemical. The processing capacity at the plant is limited to fifteen thousand (15,000) litres a day.

The company is commited to supplying a leading mine with 5000 5-litre pks. of normal and 2500 5-litre pks. of high-sensitive each working week (consisting of five days). In addition, there is an agreement with the unions that at least 2000 5-litre pks. are produced each day. The company would like to determine the daily production volume for each of the two types of slurries that will maximise total contribution.

Required:

(a) Develop a linear model of the production problem facing the National Explosive Co. (6 marks)

(b) Using a semi graphical approach determine the optimum daily production plan and the consequent contribution. (6 marks)

(c) The union is pressing for an overtime wage of Z$20 per hour above the wage rate for skilled labour.

(i) Justify whether the company find this a profitable possibility or not? (3 marks)

(ii) If it was possible to pay overtime, how many overtime hours per day would be worth employing? (3 marks)

Question 4

Saturnite (pvt) Ltd are to initiate a project to study the feasibility of a new shaking table for treating river bed gold bearing sand and gravel. The end result of the feasibility project will be a report recommending the action to be taken for the new product. The activities to be carried out to complete the feasibility project are given below.

Required:

(a) Draw a network for the scheme of activities set out above and determine the shortest duration of the project. (6 marks)

(b) Assuming the project start at time zero and that each activity commences at the earliest start date, construct a chart showing the number of staff required at any one time for this project. (6 marks)

(c) The management of Saturite has decided that it does not want more than 9 staff involved in this project at any one time. Describe how this can be achieved within the shortest duration time found in (a)
(6 marks)

Table to Question No. 4

Activity	Description	Immediate Predecessors	Time (weeks)	No. of Staff
A	Preliminary design	-	5	3
B	Market Research	-	3	2
C	Obtain Eng. Quotes	A	2	2
D	Construct Prototype	A	5	5
E	Print marketing papers	A	3	3
F	Costing	C	2	2
G	Product testing	D	4	5
H	Pilot survey	B,E	6	4
I	Pricing estimates	H	2	1
J	Final Report	F,G,I	6	2

Question 5

A building contractor purchases 5000 (= five thousand) tonnes of one type of aggregate (F) and 10000 (= ten thousand) tonnes of a second type (G) in each year of 48 weeks from small workers.

From the the regular suppliers (= a group of co-operatives), F costs $25 per tonne.

From another group of regular suppliers, G costs $32 per tonne.

Because of the characteristics of the stones, the cost of ordering, receiving and testing each batch of either F or G has been estimated at the relatively high amount of $150 for F and $150 for G.

/5....

A third group of suppliers has recently offered to supply both F and G on a regular monthly, i.e. twelve times per annum, basis. They however quote the same price per tonne for both F and G, and the contractor has estimated the cost of ordering, receiving and testing each monthly batch at $250 per month for F and $250 per month for G also.

Whichever supplier is used, the storage costs are $2 per tonne per annum based on the average annual stock. Assume certainty of demand, lead time and costs.

You are required to:

(a) Calculate and state the EOQ for F ang G from the present supplier. (6 marks)

(b) Calculate and state the total minimum cost for F and G for the year from the present supplier. (6 marks)

(c) Calculate and state the price for F and for G if a change to the new supplier is to be worthwhile. (6 marks)

Question 6

An underground mine uses a belt conveyor ore transport system delivering ore to a shaft bunker (bin). Ore is then hoisted to the surface using skips. Ore production from the active faces is on the basis of two shifts and amounting to 9000 (nine thousand) tonnes per day. The ore production shifts are:

Morning shift	06.00 - 14.00 hours
Afternoon shift	15.00 - 23.00 hours

The shaft hoisting operation is on the basis of three shifts per day:

Morning shift	07.00 - 15.00 hours
Afternoon shift	15.00 - 23.00 hours
Night shift	23.00 - 07.00 hours

Discuss how you would conduct a simulation study to examine the haulage and hoisting systems. State any assumptions you consider important and illustrate how you would select the capacity of the bin based on your simulation study. (18 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

MI443

MINE ENVIRONMENT

TIME: THREE HOURS

ANSWER: 5 QUESTIONS, QUESTION 2 IS COMPULSORY

---

1. (a) Define the following:

(i) Environment
(ii) Ecology
(iii) Ergonomics (6) points

(b) What are the four broad areas of Mining and the Environment? (4) points

(c) Describe in one sentence the approach towards control of environmental degradation? (2) points

(d) What is the main goal of ventilation, and how relevant is ventilation in terms of dust, and toxic and explosive gases? (4) points

(e) When is air conditioning necessary? (4) points

2. (a) What is air? (2) points

(b) Tabulate the chemical composition of so-called pure dry air at sea-level, by volume and by weight. (6) points

Between weight and volume compositions, what is normally used for ventilation calculations? (2) points

(c) State the six main categories of impurities in mine air, and give at least two examples of impurities in each category. (8) points

Which of these categories/impurities are the most dangerous to health? (2) points

3. (a) What is blackdamp, and when is blackdamp heavier than air? (4) points

(b) Analysis of a sample of air from old workings is reported as follows: Oxygen (15.50%), Carbon Dioxide (2,50%), Methane (1.50%) and Nitrogen (80.50%). Determine whether blackdamp is heavier or lighter than air, with all steps of analysis clearly shown. (16) points

4. (a) Itemize

(i) The scope of ventilation survey

(ii) The importance of ventilation survey. (8) points

(b) What is involved in the measurement of quantity of airflow? (2) points

(c) Itemize at least five techniques used to measure air velocity, and briefly describe the principle involved in each method. (6) points

(d) Discuss briefly the methods of velocity measurement. (4) points

5. (a) Given the gas law equation (for dry air) as

$$PV_o = R_oT \qquad (I)$$

where P = pressure of air in Pa,
V_o = volume of 1 kmol of air in cubic meters
T = temperature of air in K
and R_o = universal gas constant = 8314.4 J/kmol/K.

(i) Taking air to have the composition by volume as given in the compulsory Question 2(b), and molecular masses of Oxygen, Carbon dioxide, Nitrogen and Argon (including other rare gases) as 32, 44, 28, 40 respectively;

Determine the characteristic gas constant Ra.

(ii) Re-writing equation (I) in terms of characteristic gas constant of air as in equation (II),

$$PV = R_a T \qquad \text{(II)}$$

Show that

$$\rho_a \text{ (density of dry air, kg.m}^{-3}) = \frac{P}{287.1} T$$

(8) points

(b) For a pitot-static tube, what relation can be used to obtain velocity from the velocity pressure?

(4) points

A standard pitot-static tube placed at the centre of a 400 mm diameter circular duct records a velocity pressure of 250 Pa. Calculate the quantity of air flowing in the duct if the air temperature is 303 K and the barometer reads 108 kPa. Assume the air to be dry and the method factor to be equal to 0.85, and the correction factor K for the particular pitot-static tube = 1.

(8) points

6. (a) What are the three chief properties of dust affecting the development and severity of lung diseases?

(2) points

(b) What is the most important parameter of dust that governs its physiological effect? (2) points

(c) In what three ways can dust concentration be expressed?

(2) points

(d) Classify the present-day air-borne dust sampling methods based on the principle of operation. (4) points

(e) Wet suppression of dust usually utilizes sprays of water for wetting fine particles suspended in the air.

(i) Illustrate arrangements of mist curtain as commonly used in German mines for suppressing air-borne dust after blasting.

(ii) What are the disadvantages of wet dust suppression? (10) points

7. (a) What is meant by terminal settling velocity? (2) points

(b) The terminal settling velocity for streamline motion is given by

$$V_T = 3.03 \times 10^4 \rho D^2$$

where ρ = density of particle in kg per cubic meter
D = diameter of particle in m

Design a settling chamber for separating quartz dust down to 50 μm size from a stream of air flowing at the rate of 3 cubic meters per second. Assume velocity of air in the chamber as Va = 0.3 meters per second with its respective eddy factor as 0.5, and height (h) = breadth (b) of chamber. The density ρ = 2500 kg per cubic meter. (18) points

8. (a) What constitutes mine climate? (2) points

(b) What are the main sources of heat in mine air? (2) points

ATTEMPT EITHER

(c) What are the three types of mine refrigeration plants? Discuss their use, stating their respective advantages and disadvantages. (16) points

OR

(d) State at least six desirable features of a ventilation system.

What are the three types of ventilation systems? State the advantages and disadvantages of one of them. (16) points

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

MI 453/MM 543

MINERAL ECONOMICS

TIME: 3 HOURS

ANSWER 5 QUESTIONS ONLY (QUESTION 1 IS COMPULSORY)
ALL QUESTIONS CARRY EQUAL MARKS.

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1. A fesibility study was carried out on a granite property to develop it into a stone quarry. The total tonnage of granite is 923,362 tonnes. Only 95% of this reserve is minable due to boundary constraints. It is envisaged that mining and plant recovereis will be 90% and 95% respectively.

Detailed market study indicates that 150,000 tonnes of crus stone, of all size ranges, will be sold per annum at a price of K10,000 per tonne for the first production year with subsequent increase of K5,000 per tonne per year.

The capital cost for the mine, plant and other facilities are estimated at K1.5 billion. The operating cost for the first year of production is estimated as K900 million and increasing by 5% per annum.

(a) Calculate:-

(i) the total minable reserves

(ii) the total life of the project, allowing for two years pre-production period

(iii) the operating cost for each production year. (5 marks)

(b) Assuming the SYD method of depreciation is to be used with Zero salvage value, calculate the depreciation allowance for each year. (5 marks)

/2....

(c) The royalties to be paid are fixed at 5% of gross revenue and income tax is at 45% of taxable income. The capital expenditure is to be spread evenly over the two-year pre-production period.
Set out, in a neat tabular form annual cash flows for the project. (10 marks)

(1 billion = 1,000,000,000)

2. A custom iron smelter has fixed cost (FC) of $1000 and, as variable factors are added, output expands. The cost schedules are as shown in the table below.

Out put per week (tonnes)	Total Fixed Cost TFC ($)	Total Variable Cost TVC ($)	Total Cost TC ($)
0	1000	-	1000
10	1000	200	1200
20	1000	340	1340
30	1000	440	1440
40	1000	540	1540
50	1000	675	1675
60	1000	860	1860
70	1000	1100	2100
80	1000	1400	2400
90	1000	1790	3790
100	1000	2300	3300
110	1000	2960	3960
120	100	3800	4800

(a) Complete the table by computing the Marginal Cost, Average Fixed Cost, Average Variable Cost and Average total cost schedules. (6 marks)

(b) Plot the MC, ATC, AVC and AFC curves on the same axes. (6 marks)

(c) Calculate:

(i) the equilibrium output of the smelter if the Marginal revenue (MR) is $ 45 (4 marks)

(ii) the maximum productivity (4 marks)

3. (a) List and explain five factors which justify the charging of interest. (5 marks)

(b) Solve the following:-

(i) If K6,500 will be needed in 5 years, how much should be invested now at an interest rate of 7½% compounded annually? (5 marks)

(ii) If payments of K2,500 are made every 6 months to a fund paying 8% per annum compounded quarterly, how much will accumulate in 5 years. (5 marks)

(iii) Revenue from sulphric acid sale from a copper smelter are presently K1,400 million per year. For an annual interest rate of 8% determine the present value of such revenue over the next 10 years if

(a) Sales rise by K150 million

(b) sales rise by 10% per year (5 marks)

4. Annual cash flow from a proposed small gold teaching operation is expected to be $ 360,000 per year for 8 years. Initial expenditure for plant equipment is estimated to be $1.16 million. The salvage value of this investment is expected to be roughly $90,000, if the property is offered for sale for $450,000, calculate the approximate return for this investment. Assume that the property payments would be made immediately, but the remaining capital investment would be divided equally over a two year pre-production period. (10 marks)

(b) A certain coal stripping operation presently uses three dozers for reclamation work. To reduce costs, three alternatives are being considered for this job in the future: rebuild present equipment, purchase new dozers, and employ a contractor.

Details for the alternatives are:

	Rebuild	Purchase	Contract
No. of units	3	2	N/A
Initial cost	360,000	920,000	0
Annual costs			
Maintenance	140,00	85,000	
Labour	240,000	160,000	525,000
Supplies	58,000	42,000	
Life	8 years	8 years	8 years
Salvage Value	0	120,000	0

All monetary units are in dollars.
If the interest is 8% annually which alternative should be selected? (10 marks)

5. Consider the arguments for and against exchange rate devaluation for a country in Balance of Payments difficulties. (20 marks)

6. The law of comparative costs suggests that complete freedom of trade should be beneficial yet in reality foreign trade is influenced by restrictions. Why should this be so? (20 marks)

7. Write short notes on:-

(a) Economics (05 marks)
(b) Wealth (05 marks)
(c) National wealth (05 marks)
(d) Factor of production. (20 marks)

5. A processing Plant is considering producing Gold by two different processes; CIP or Cynidation. It is felt that there is a 60% probability that the cynidation process will have a first cost of $50,000, a life of 5 years and zero salvage value. There is a 40% probability that the CIP process will be selected with a life of 5 years and zero salvage value. With either process, there is a 50% probability that annual profit will be $20,000 for the 5 year project life and 25% probabilities that the annual profits will be $15,000 or or $25,000 per year.

(a) In the form of a decision tree, show the number of outcome possibilities in the plant's production plan. (3 marks)

(b) In a neat tabular form, calculate the ROR for each of the possibilities with their respective probability of occurence. (10 marks)

(c) Plot project ROR versus probability of occurence assuming the parameter values are independent of each other. (4 marks)

(d) From your plot or otherwise find

(i) the most probable project ROR and its probability of occurence. (3 marks)

(ii) the probability that the ROR will be 28.7% or above. (2 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

MI 523

COAL MINING METHODS

TIME: THREE HOURS

ANSWER: FIVE QUESTIONS
NO TEXT BOOKS OR NOTES ALLOWED
CALCULATORS, ALLOWED

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1. Write notes on the following:-

   (a) Spontaneous Combustion (4 marks)

   (b) Cleat (3 marks)

   (c) Gas wells (3 marks)

   (d) Methane Drainage (4 marks)

2. (a) What are the reasons for undercutting a coal face in the conventional room and pillar mining method? (7 marks)

   (b) What precautions and regulations govern blasting operations in Coal Mines? (7 marks)

3. (a) Explain why the full production potential of the continous miner is often not achieved in room and pillar coal mining and discuss ways of improving this productivity. (7 marks)

   (b) What is meant by "ONE WEB BACK" operation and what are its principal advantages? (7 marks)

4. Briefly describe the principle features and functions of the various items of face equipment you would need to mine a 600 ft long retreating long wall face in a 7 Fr thick coal seam. (14 marks)

   (Do not include equipment required for development)

/2...

5. (a) Discuss the advantages and disadvantages of diesel equipment for face haulage in the room and pillar method. (7 marks)

(b) Discuss the five hazards associated with the use of conveyor belts in underground coal mines, stating what steps are taken to minimise these hazards. (7 marks)

(Total marks 70)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER, 1994

MI533

GEOSTATISTICS

TIME: THREE HOURS

ANSWER ANY FIVE QUESTIONS

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1. (a) Write down the expression for the spherical semi-variogram with nugget effect and explain all the elements in the expression. (8)

(b) The experimental semi-variogram for a lead/zinc deposit was computed and tabulated as shown below.

Distance between samples(m)	γ^* $(\%)^2$	No. of pairs	Distance between samples(m)	γ^* $(\%)^2$	No. of pairs
12.5	5.8	58	125.0	16.3	46
25.0	7.9	56	137.5	13.5	45
37.5	12.0	54	150.0	12.9	44
50.0	15.6	52	162.5	15.1	43
62.5	17.7	51	175.0	18.0	42
75.0	20.0	50	187.5	18.9	41
87.5	19.5	49	200.0	18.7	40
100.0	19.0	48			
112.5	18.1	47			

(i) Plot the experimental semi-variogram for the data (5)

(ii) Fit an appropriate theoretical semi-variogram to the experimental variogram. (3)

(iii) From your fitted model or otherwise calculate:-

1. the sill
2. the range
3. the nugget (4)

2. The table below shows the frequency distribution of gold values in g/t.

Class interval	frequency
1.5 - 1.9	4
2.0 - 2.4	4
2.5 - 2.9	7
3.0 - 3.4	15
3.5 - 3.9	12
4.0 - 4.4	8
4.5 - 4.9	4

(a) Construct the cummulative frequency curve (5)

(b) Calculate:

(i) the mean grade of the sample set
(ii) the variance of the sample set
(iii) the 95% confidence limits for the mean grade (10

(c) Assuming a cut-off grade of 2.5g/t, what percentage of the deposit will be above cut-off grade. (5)

3. An iron deposit is known to follow the Normal distribution with a mean of 48% iron and standard deviation 5%. This distribution was establishedcon "point" samples. The 'point' semi-variogram model is spherical with a range of influence of 100m. The mine plan is to be constructed on 20m x 20m by 10m blocks. The Sill C = $25(\%)^2$

(a) (i) Calculate the block variance (5)

(ii) Sketch the "point" and block distributions on the same axes and comment on them (3)

(b) Write down the expressions for:-

(i) the proportion of the distribution above cut-off grade (2)

(ii) the average grade above cut-off grade (2)

(c) Considering the "point" values and a cut-off grade of 44% Fe, calculate:-

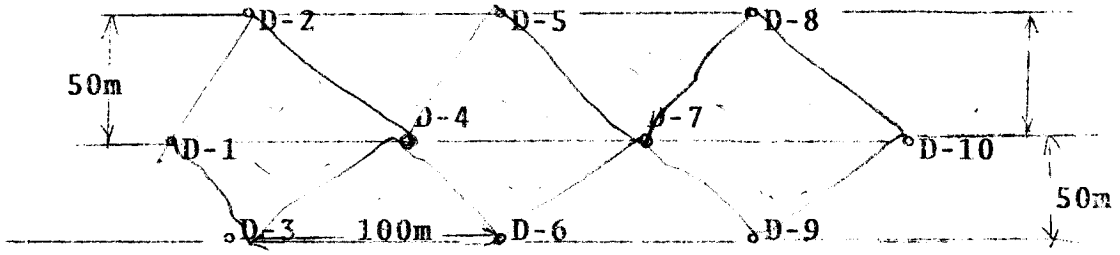
(i) the proportion of the ore above cut-off grade (2)
(ii) the average grade above cut-off grade (2)

(d) For the 20m x 20m x 10m block and the same cut-off grade, calculate:-

(i) the proportion above cut off grade (2)

(ii) the average grade above cut off grade (2)

4. A massive sulphur deposit consisting of 55% sphalerite, 10% galena and 15% pyrite was sampled using the regular drill hole pattern shown below. The hole spacings are also shown.



The value and thickness of each hole are tabulated below.

Hole NO.	Grade (%) Sulphur	Thickness (m)
D - 1	6.93	35
D - 2	5.01	33
D - 3	10.86	30
D - 4	5.71	25
D - 5	8.91	38
D - 6	11.21	34
D - 7	21.00	41
D - 8	10.97	42
D - 9	10.85	39
D -10	7.57	40

(a) Using the triangular method of ore reserves estimation show how the triangles could be laid out for easy reserves calculation (2)

(b) Given the specific gravities of sphalerite, galena and pyrite as 4.1, 7.5, 5.0 respectively, Calculate the tonnage factor for the block. (5)

(c) By tabulating your calculations, show

(i) the average value of sulphur in the sampled area

(ii) the total tonnage in the sampled area (10)

(d) Give two reasons why the average value of sulpur calculated by this method is inferior to any of the predictive methods. (3)

5. A set of gold values in cm.g/t is given below.

55; 15; 280; 143; 1350; 95; 386; 4787; 203; 275; 615; 193; 64; 892; 362; 103: 205; 488; 136; 72; 163

(a) (i) By choosing an appropriate class interval, construct a frequency distribution table for the above data and plot the histogram. (8)

(ii) Comment on the histogram. (2)

(b) Transform the data by taking the natural logarithm values of the data set and construct another frequency distribution with the transformed values. (Hint: Don't use the same class interval as above) (8)

(ii) By inspection or otherwise confirm your comment in a(ii) (2)

6. On a particular underground level a stoping block 40m by 30m is to be estimated. The block has been developed on two adjacent drives and the following information is available:

average grade along 40m drive = 2.34%Cu
average grade along 30m drive = 3.01%Cu

The deposit can be modelled by the spherical semi-variogram with a = 60m, C = 0.75(%)^2 and Co = 0.10(%)^2.

(a) Calculate the standard deviation of the deposit (2)

(b) Write down the expression for the extension variance (4)

(c) Calculate the following auxilliary functions for the block.

(i) F (40)

(ii) F (30)

(iii) H (40, 30) (6)

(d) Calculate the Extension variance (3)

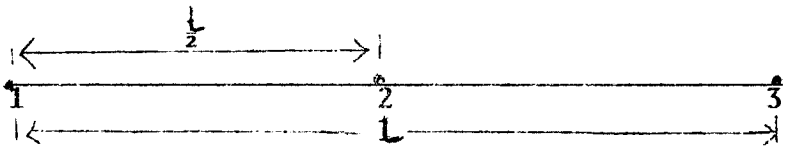
(e) Calculate the standard error (2)

(f) Assuming that the grade of the deposit is Normaly distributed, calculate the 95% confidence limits for the average grade of the block. (3)

7. (a) What is point Kriging (4)

(b) Write down the general Kriging system of equations in matrix form for ordinary point Kriging (2)

(c) The figure below shows three point samples 1, 2, 3 used to estimate the value of the line segment length L. The samples are assigned weights W_1, W_2, and W_3 respectively. The semi-variogram is of the form $\gamma(h) = ph$. With P = 4 and L = 10m.



(i) Derive the Kriging system of equations and the Kriging variance for this estimation. (6)

(ii) Compute the weights to be used to obtain the BLUE of the grade. (6)

(iii) If 1 = 2.50% Cu 2 = 3.05% Cu and 3 = 0.52% Cu. Calculate the Kriged estimate for the line. (2)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

MI 543

MATERIALS HANDLING

TIME: THREE HOURS

ANSWER ANY FIVE QUESTIONS

ALL QUESTIONS CARRY EQUAL MARKS.

Q 1. (a) Under which hoisting system is use of a tail rope recommended? What purposes are achieved from the use of such a tail rope ? (5 marks)

(b) For a cylindrical drum winding system calculate

(i) the load torque and

(ii) the rope torque from the data give below:

- Hoist/wind (pay load) = 4t
- Weight of the cage, cage chains and suspension gear = 6t
- As the loaded cage comes up the empty cage goes down with 2 mine cars. The cage used has 2 decks, each deck accommodate one mine car of 0.75t tare.
- Depth of shaft = 700m
- Rope - Weight = 6 kgf/m
- Weight of Winding drum = 30t
- Dia. of headgear pulleys = 4.2 M (each)
- Dia. of cylindrical drum = 4.4m
- The duty cycle consists of:

  Acceleration = 10 sec

  Constant speed = 30 sec

  Deceleration = 10 sec (15 marks)

/2.....

Q 2. (a) With the aid of a sketch, identify and describe the main structural components of a Rope Shovel paying special attention to the functional description of each component.

(b) An open pit Iron-ore mining operation intends to employ a shovel and truck excavation and haulage system on both ore and waste.

Given

(i) Rope shovel data:-

Type ..... Marion 204M
Dipper size ..... $24m^3$
Dipper fill-factor..... 0,9
Bulking factor..... 1,5
Average cycle time..... 45 seconds
Time use factor..... 0,9

(ii) Operation data:-

Total volume to be handled (ore and waste)..... 25 million m^3/ann
Number of working hours per day.. 3x8hr shift
Number of available days per year..... 265
Transportation distance..... 5000m
Truck travel speed-empty..... 35km/hr
Truck travel speed-loaded..... 20km/hr
Average manoeuvre time (at dump and shovel)..... 2,5min

You are required to determine the hourly performance of the rope shovel and the total number of rope shovels necessary to handle the ore and waste in one year.

(5 marks)

Knowing that the SG of both ore and waste is $2,85gm/cm^3$, determine the truck size you would match the shovel with, and consequently the number of trucks per shovel. What is the required total fleet for loading and hauling?

(15 marks)

Q 3. (a) Write Brief notes on the principle and application of ripping in mining and state the basic methods of production estimation. (10 marks)

(b) Due to the material and terran characteristics, a mining contractor decides to employ a wheel tractor scraper ripping dozer tandem operation in order to move 6 million m^3 of overburden per annum.

The equipment specifications (dozer and scraper) he opts for are as given below:-

(i) Dozer

Type..... Cat D9L with single ripper shank

Average speed (including slippage and stall..... 1,8km/hr

Rip spacing 975mm

Ripper penetration..... 725mm

Rip distance 500m

Manoeuvre time..... 0,45min

Assume 60 min-hour

Ownership and Operating costs..... $150/hr (operator's salary inclusive)

(ii) Wheel tractor Scraper

Type..... Cat 660B

Capacity..... $30,6m^3$

Travel speed 25km/hr

Travel distance..... 4500m

SG of material..... $\delta = 2,45gm/cm^3$

Scraper Bowl fill-factor..... $k_1 = 1,3$

Material bulking factor..... $k_2 = 1,20$

Time to load 3,5min

Time to discharge..... 0,5min

Ownership and Operating costs ....$110/hr (Operators salary inclusive)

Knowing that the contractor is to operate on a 3 x 8 hrs shifts per day and 5 days per week basis, the shift time use factor on both ripping and scraping being 0,85, you are required to:-

- Determine the production on ripping and scraping and state whether the matching of the wheel tractor scraper to the dozer is justifiable. What is the production cost in $/BCM on ripping and scraping? (5 marks)

- Determine the number of dozers and corresponding wheel tractor scrapers required to fullfill the contractual obligation of moving the 6 million m^3 in one year? (5 marks)

Q 4. Given a BWE of following operating parameters and specification is chosen for the excavation of coal in an open pit mine.

- Single bucket capacity ..... $2,5m^3$
- Number of buckets on the wheel..... 15
- Duration of a shift..... 7,25 hrs
- Number of shifts per day.....3.0
- Time use factor 0,90
- Bucket fill-factor..... 1,50
- Bulking factor 1,25
- Wheel diameter 18,5m
- Cutting speed 1,25m/s

(a) Estimate the theoretical and effective annual output of the BWE knowing that the total number of days available is 265. (10 marks)

(b) Is a trank conveyer belt of specifications given below - capable of evacuating the material excavated by the BWE?

Justify your answer with the aid of corresponding sketches and calculations ,Conveyor specifications

Belt width	2100mm
Troughing angle	30°
Materials angle of repose	$= 15^{\circ}$
Specific weight of material.....	$2,15gm/cm^3$
Belt speed speed	2,5m/s
Belt loading factor.....	0,80 (5 marks)

(c) If answer to (b) is NO what conveyor belt design alterations would you consider in order to accomodate the BWE production? (5 marks)

Q 5. (a) Write brief notes on the principles and purposes of drilling in mining with regard to rock loosening and fragmentation paying special attention to the following sub-headings:-

- Percussion drilling - applications and limitations
- Rotary drilling - applications and limitations
- Roto-Percussion drilling exemplified by DTH - drills - applications and limitations. (10 marks)

(b) List and describe the factors influencing the the performance of a rotary blast hole drill-rig as applied in hard-rock open pit mining. (10 marks)

Q 6. (a) In case of a centrifugal pump what will be the effect on

(i) Quantity

(ii) Pressure and

(iii) Power if the speed of the pump is increased by 1.5 times the original speed? (5 marks)

(b) Calculate the power in (kw) for a motor to drive a turbine pump for raising 3 m^3 per minute s water against a total head of 350m. Assume 80% pump efficiency. (15 marks)

Q 7. Write brief notes on Rail road haulage as applied in mining under the following sub headings:-

(i) General applicability and determinant physical conditions

(ii) Basic design and equipment data

(iii) Surface mine application and special operating problems. (20 marks)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

MM 213

INTRODUCTION TO METALLURGY

Time: Three hours

Answer: ALL questions

Part A: Thirty-six multiple-choice questions (27 %)

Read the questions carefully. Four possible answers are proposed. On the answer sheet, circle the answer (a, b, c or d) that you consider correct.

note: If you do not know the answer, or you are in doubt, you are advised to take a chance and guess. In the marking of these multiple-choice questions it will be assumed that one out of four of the answers (25 %) will be answered correctly anyway, just by chance.

1 The SIMA-layer of the earth's crust is

(a) the lower layer that is only present under the oceans;
(b) the upper layer that forms the continents and extends under the oceans;
(c) the lower layer that is present under both oceans and continents;
(d) the upper layer that forms only the continents.

2 The dip of a plane (layer or bed) is

(a) A depression in the layer formed by the action of dripping water;
(b) A sink structure in a limestone terrain;
(c) The inclination of the plane measured in the direction perpendicular to the strike of the plane;
(d) The inclination of the plane, measured in the direction parallel to the strike of the plane.

2/.....

3 An unconformity is formed

(a) when movement along a fault brings two layers of different age in contact with each other;
(b) when new deposits are laid down on an erosional surface that cuts through older tectonic structures;
(c) when a fold is overturned so that older layers lie above younger layers;
(d) when two layers belong to different formations.

4 The copper ores from the Zambian Copperbelt were deposited in

(a) the Upper Precambrian (Lifilian belt);
(b) the Karoo Basin (Permian period);
(c) the Kalahari Basin (Cretaceous period);
(d) recent river deposits (Kafue flood plains).

5 If a body is isotropic for hardness, this means that

(a) the hardness is the same in each direction;
(b) the hardness is different in different directions;
(c) the body has two different hardnesses;
(d) the hardness is not a characteristic property of the body and may vary between wide limits.

6 If the transmission of light through a crystal is the same in all directions, then

(a) the crystal is opaque;
(b) the crystal is opaque in one direction and translucent in the other directions;
(c) the crystal is anisotropic for the transmission of light;
(d) the crystal is isotropic for the transmission of light.

7 Which of the following relationships is true for the orthorhombic system ?

(a) $a_o = b_o = c_o$ $\alpha = \beta = \gamma = 90°$
(b) $a_o = b_o \neq c_o$ $\alpha = \beta = \gamma = 90°$
(c) $a_o \neq b_o \neq c_o \neq a_o$ $\alpha = \beta = \gamma = 90°$
(d) $a_o \neq b_o \neq c_o \neq a_o$ $\alpha = \gamma = 90°$ $\beta \neq 90°$

8 A crystal has a two-fold rotation axis if

(a) the crystal has to be turned 90° around this axis before a congruent position is found;
(b) the crystal has to be turned 180° around this axis before a congruent position is found;
(c) the crystal has to be turned two times around this axis before a congruent position is found;
(d) the crystal has two rotation axis, perpendicular to each other.

9 The number of possible Bravais lattices is

(a) 7
(b) 14
(c) 32
(d) 230

10 A plane with Miller indices (120) is

(a) an inclined plane with regard to all three crystallographic axes;
(b) a plane that cuts two periods off the b-axis;
(c) a plane that is perpendicular to the c-axis;
(d) a plane that is parallel to the c-axis.

11 The following three planes lie in one crystal zone:

(a)	(001)	(010)	(100)
(b)	(100)	(110)	(010)
(c)	(001)	(011)	(111)
(d)	(110)	(011)	(101)

12 A crystal plane in the cubic system, that is perpendicular to the crystallographic c-axis, can have the following Miller indices:

(a) (001)
(b) (011)
(c) (110)
(d) (111)

13 A crystal with a pinacoidal habit looks like a

(a) cube
(b) needle
(c) nodule
(d) blade

14 A dendritic aggregate looks like

(a) a bunch of grapes;
(b) kidneys;
(c) the branches of a tree;
(d) fish roe.

15 Pseudochromatic colours are caused by

(a) dispersion of light on microscopically fine inclusions of foreign substances in the mineral;
(b) interference of light against crystal planes, cleavage planes, twin planes or other surfaces;
(c) typical ions or groups of ions in the make-up of the crystal that absorb certain wavelengths;
(d) impurities of certain heavy metals in the mineral.

16 A mineral with vitreous lustre has

(a) a low refraction index and absorbs most of the light;
(b) a high refraction index and reflects most of the light;
(c) a high refraction index and absorbs most of the light;
(d) a low refraction index and reflects most of the light.

17 The cleavage of a mineral is controlled by

(a) the crystallographic structure of the mineral;
(b) the crystal form of the mineral;
(c) the conchoidal fracture plane;
(d) the direction in which the maximum stress is applied.

18 The following three minerals are arranged in decreasing hardness according to Mohs' hardness scale:

(a) fluorite - topaz - gypsum
(b) fluorite - gypsum - topaz
(c) topaz - fluorite - gypsum
(d) gypsum - topaz - fluorite

19 The term polymorphic is used for

(a) a mineral that can appear in several different forms;
(b) two minerals having the same form but different chemical compositions;
(c) two different minerals having the same chemical composition;
(d) two minerals having the same structure but different chemical compositions.

5/.....

20 The minerals in the subclass of the phyllosilicates are made up by SiO_2 tetrahedra that are arranged to form:

(a) rings
(b) sheets
(c) chains
(d) independent tetrahedra

21 A laccolith is a

(a) horizontal sheet-like rock body;
(b) large equi-dimensional deep-seated rock body;
(c) intrusive body with a flat floor and up-arched roof;
(d) foreign rock body, found in an igneous rock.

22 An acidic rock is

(a) a rock that gives a high pH upon dissolution;
(b) an igneous rock with a relatively high SiO_2 content;
(c) an igneous rock with a relatively low SiO_2 content;
(d) a sedimentary rock that reacts with dilute HCl.

23 A basalt is

(a) an acidic volcanic rock;
(b) an intermediate intrusive rock;
(c) a basic plutonic rock;
(d) a basic extrusive rock.

24 A rock that is classed as aphanitic

(a) consists entirely of glass;
(b) is very fine-grained;
(c) consists essentially of the mineral aphanite;
(d) has a phaneritic texture.

25 Which of the pairs of rocks listed below have a similar composition but a different texture ?

(a) granite diorite
(b) gabbro basalt
(c) rhyolite andesite
(d) syenite peridotite

26 Transportation of the products of weathering brings about a separation of materials, so that, in the direction away from the source, the following sequence of rocks can be expected:

(a) shale - sandstone - conglomerate;
(b) sandstone - shale - conglomerate;
(c) conglomerate - sandstone - shale;
(d) conglomerate - shale - sandstone.

6/.....

27 A sediment with a graded bedding structure is formed by

(a) continuous supplies of equally sized material;
(b) continuous supplies of unsorted material;
(c) periodical supplies of unsorted material;
(d) deposition from shifting current directions.

28 A graywacke is a

(a) medium-sized sandstone with a high content of other minerals;
(b) fine-grained, thin-layered rock, consisting mainly of clay minerals;
(c) fine-grained, grayish, dense limestone;
(d) coarse-grained rock, consisting mainly of rounded fragments of other rocks in a scant matrix.

29 The foliated fabric of a schist is caused by

(a) the fact that sheet-like minerals deposited in water will arrange themselves parallel to their plane of maximum stability;
(b) high temperature, resulting in the formation of sheet-like minerals, such as mica;
(c) preferential pressure, that forced sheet-like minerals to recrystallise with their shortest axis perpendicular to the direction of pressure;
(d) preferential pressure, that forced sheet-like minerals to recrystallise with their shortest axis parallel to the direction of pressure.

30 A carbonatite is

(a) a granular igneous rock consisting mainly of rock-forming carbonates;
(b) an ultrabasic rock with porphyritic texture, that occurs in the form of pipes with diamonds as accessory minerals;
(c) a granoblastic endured carbonate rock formed by the thermal metamorphism of limestone or dolomite;
(d) the highest-ranking product of the coalification of decay-resistant organic debris.

31 A strata bound ore deposit is characterised by

(a) the fact that its mineralisation is restricted to certain lithological horizons;
(b) the fact that its mineralisation is restricted to certain lithological horizons and the deposit displays a sheet-like geometry;
(c) the fact that the deposit displays a sheet-like geometry;
(d) the occurrence of the same ores in different individual smaller deposits.

7/.....

32 The Zambian-Zairean Copperbelt ore deposits are nowadays classed in the following genetic association:

(a) Ores of mafic and ultramafic association;
(b) Base metal sulphide veins of igneous association;
(c) Stratiform sulphides of marine and marine-volcanic association;
(d) Strata bound ores of sedimentary affiliation.

33 Bauxite is

(a) a residual soil, enriched in aluminium;
(b) a leached and oxidized surface found at the top of sulphide ore deposits;
(c) an aluminium ore formed through metamorphic processes;
(d) a mineral species (aluminium hydroxide).

34 The following three metals are arranged in order of their relative abundance in the earth's crust (the metal with the highest relative abundance comes first):

(a) iron - lead - titanium;
(b) titanium - copper - gold;
(c) aluminium - gold - vanadium;
(d) gold - aluminium - lead.

35 The following three metal sulphides are often found together in the same ore deposit:

(a) chalcopyrite, bornite, pyrite;
(b) galena, sphalerite, willemite;
(c) wolframite, scheelite, cassiterite;
(d) chalcosite, molybdenite, haematite.

36 The mineral cerussite is a

(a) mercury sulphide;
(b) titanium oxide;
(c) lead carbonate;
(d) zinc silicate.

End of Part A.

To answer Parts B and C, look at the specimens in your box.

8/.....

Part B. Refer to the two crystal models in your box and to Table 1. (3%)

For each of the crystal models in the box, write on your answer sheet:

(1) the number on the model;
(2) the symmetry elements present and the number of each symmetry element;
(3) the Hermann-Mauguin symbol of the class to which the crystal model belongs;
(4) the name of the the crystal class to which the model belongs.

Part C: Refer to the five mineral specimens in your box. (15 %)

For each of the mineral specimens in the box, write on your answer sheet:

(1) the number that is written on the bottom of the box, on which the mineral specimen is placed;
(2) the name of the mineral;
(3) the approximate chemical formula of the mineral;
(4) the distinctive properties of the mineral that lead to its identification;
(5) the economic or geological importance of the mineral.

note: Ensure that you replace each mineral specimen on the same number in the box on which you found it (this must correspond to the number on your answer sheet).

End of Parts B and C.

Answer the questions in Part D in the answer book provided.

9/.....

Part B Answer ALL of the following four questions, but note that in questions '3' and '4' you have a CHOICE. You may answer either question 3(A) or question 3(B) and you may answer either question 4(A) or 4(B).

Use the answer book provided for these questions.

1 State briefly what you understand by the following terms, used in mineral processing and extractive metallurgy:

- industrial minerals
- secondary metal
- a batch operation
- the sphericity of a particle
- comminution
- a fume
- dross
- raffinate

(12 %)

2 Consider the simple crushing/screening circuit shown in the diagram of Figure 1. As part of a survey of this circuit, representative samples were taken of the gyratory crusher feed and product, of the shaking screen oversize and undersize and of the cone crusher product, and screen analyses were made of these samples.

The mass flow rates of the process streams in this circuit are represented by the capital letters F, P, U etc. in the diagram and the cumulative weight percentages that were passing the separating size of the shaking screen (25 mm) in the screen analyses of the corresponding samples are represented by the small letters f, p, u, etc. The values of these percentages are given in Figure 1.

(a) How high is the circulating load over the cone crusher, expressed as a percentage of the fresh feed F ?

(b) If F is 280 tonnes per hour (dry), how high is U and how high is O ?

(c) What is the efficiency of this screening operation ?

(12 %)

3 CHOICE

Choose ONE only of the following two questions; answer either question 3(A) or 3(B).

(A) (a) Briefly discuss the main objectives of 'roasting'.

(b) Give the equation of the general roast reaction for the roasting of metal sulphides.

(c) What are the three main types of roasting furnace ?

Briefly state their main characteristics and draw a rough sketch of each of these three types of furnace, indicating the most important zones and the flows of material in each of these sketches.

(d) What do you understand by 'oxygen enrichment' ?

Explain briefly why oxygen enrichment is common practice nowadays in the roasting of metal sulphide ores and concentrates.

(e) What is the difference between 'roasting' and 'sinter-roasting' ?

or:

(B) (a) Describe briefly, but clearly, how purification and concentration of a leach solution can be done by 'solvent extraction'.

(b) Why are processes such as leaching and solvent extraction usually carried out in stages ?

(c) What is the main chemical equation, governing the solvent extraction of copper ?

(d) What conditions are used during 'extraction' and what conditions are used during 'stripping' ?

(e) Draw a rough flowsheet for the hydrometallurgical extraction of copper, using the sequence: leaching - solvent extraction - electrowinning.

Indicate the main process streams with arrows and give the name of the feed or product that forms each of these streams.

(14 %)

4 CHOICE

Choose ONE only of the following two questions and answer that question in a description of about one written page (not more than two written pages !).

(A) Winning of copper

Name four of the most common economic copper minerals and give their chemical formulas.

Then give a brief description of the most common extraction processes for the production of marketable copper metal from copper ore.

or:

(B) Winning of aluminium

Explain briefly why aluminium metal can not be recovered by electrowinning from an aqueous solution of aluminium ions.

Give a brief description of the Bayer process for the production of alumina from bauxite and give the main chemical reaction equation in this process.

Then give a brief description of the Hall-Heroult process for the production of aluminium metal from alumina. Illustrate this with a rough diagram of the equipment used in this process.

(12 %)

When you have finished, check your answers, check that the mineral specimens are replaced in their proper place in the box, check that your name and computer number are on your answer sheet (for Parts A,B and C) and on your answer book (for Part D), place your answer sheet, your answer book and Table 1 in the box and leave the box on the table. The invigilator will collect them.

- END OF EXAMINATION MM 213 -

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

MM313 PHYSICAL METALLURGY I

TIME: 3 HOURS
ANSWER: ALL THE QUESTIONS

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1. (a) Determine the indices (hK) for the lines in figures 1 and 2.

   (b) Draw a tetragonal unit cell and insert the directions $[\bar{1}01]$ and $[11\bar{1}]$.

2 (a) Derive an expression for the energy barrier to homogeneous nucleation of a spherical particle.

   (b) How is the energy barrier to nucleation minimised?

3 (a) Compare and contrast the mechanism of interstitial diffusion and substitutional diffusion in very dilute alloys. Your answer must include a discussion on the mechanisms and factors which control the kinetics of diffusion.

   (b) The diffusion coefficient of carbon in austenite can be approximated by the expression

$$D = 0.2 \exp -\left[\frac{138,000\ J/mole}{RT}\right]\ cm^2/sec$$

   (i) How long would it take to attain a penetration distance of 1mm at 920°C?

   (ii) What temperature of anneal would be required to double the penetration distance in the same time?

4 (a) Why was the crystal defect "dislocation" proposed before there was any direct evidence for its existence?

   (b) State the differences between a screw dislocation and an edge dislocation.

   (c) Consider the $(\bar{1}11)$ plane of an fcc crystal. What are the Burgers vectors of the dislocations that can glide on this plane? (Assume that the dislocations are perfect - of the form $\frac{a}{2}\langle 110\rangle$).

5. Figure 3 is the Columbium-Nickel phase diagram

(a) What are the atomic ratios (i.e. Ni_xCb_y) for the β and γ intermetallic phases?

(b) Describe <u>in detail</u> the equilibrium cooling behaviour of an Ni-50 w/o Cb alloy.

(c) Draw schematic free energy/composition diagrams at 1000°C and 1500°C.

(d) Draw a cooling curve for an Ni-30 w/o Cb alloy. Each part of the curve must be labelled.

END OF EXAMINATION IN MM313

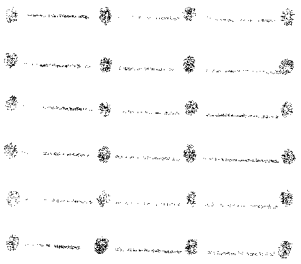

Figure 1

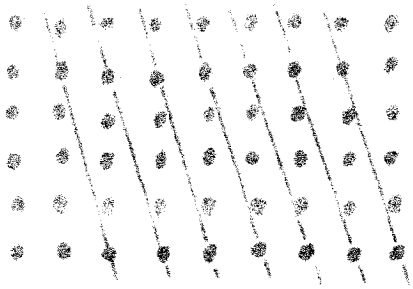

Figure 2

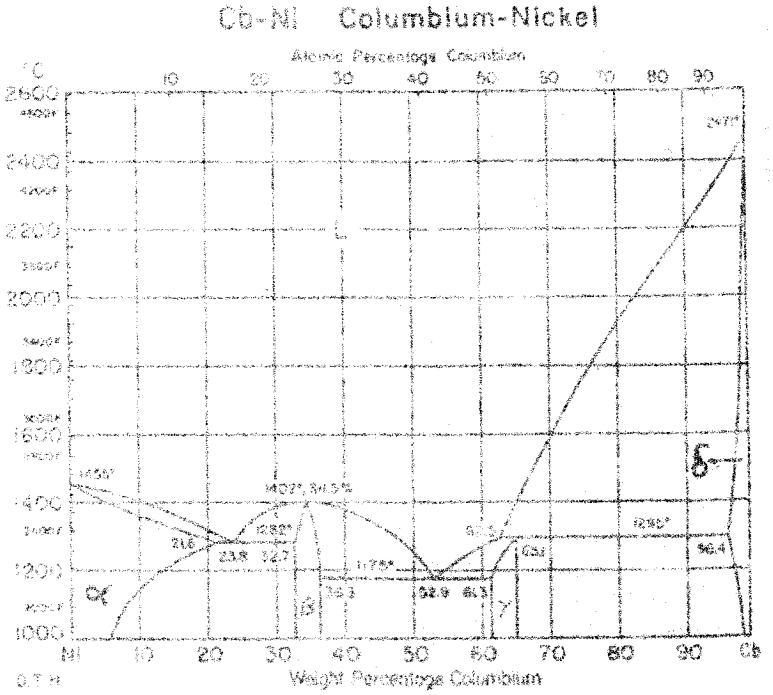

Figure 3

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1993/94

MM320/321 PAPER I

CHEMICAL METALLURGY

TIME: 3 HOURS

ANSWER: FIVE QUESTIONS

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1. Benzene and toluene form solutions that are almost ideal in behaviour. At 30°C pure benzene has a vapour pressure of 118.2 mm Hg and toluene has a vapour pressure of 36.7 mm Hg. Calculate the partial pressures and the total pressure over a solution composed of 300 grams of bezene and 600 grams of toluene. What would be the composition of a solution of benzene and toluene at 30°C if the vapour in equilibrium with it has a composition such that the mole fraction of the toluene is 0.35. Molecular weight of benzene is 78.14 and that of toluene is 92.14.

2. The partial pressures of A exerted by A-B alloys at 1000 K are given in Table 1 below:

Table 1.

X_A	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2
P_A 10^6	5	4.4	3.75	2.9	1.8	1.1	0.8	0.6	0.4

Determine (a) the composition range over which Henry's law is obeyed by the solution and (b) The value of Henry's law constant at 1000 K. If the temperature variation of the Henry's law constant is given as

$$\log K_A = -\frac{109.3}{T} - 0.2886$$

(c) calculate $\bar{\Delta}H_A^M$ in the composition range over which A obeys Henry's law

(d) write an equation for the variation of ΔH^M with composition over the same composition range.

3(a) The excess partial molar free energy of zinc in liquid Cu-Zn alloys at 1027°C (1300 K) can be represented as

$$G^{XS}_{Zn} \text{ (cal/mole)} = -5150\ (1 - x_{Zn})^2.$$

Calculate the activity of copper at 1027°C (1300 K) in an equiatomic solution.

(b) Liquid brases conform to the following relationship:

$$RT \ln \gamma_{Zn} = -5000 \times {}^{2}_{Cu}$$

where R and T are in cal/deg/mole and K respectively. The vapour pressures of pure copper and pure zinc (in mm Hg) are given as

$$\log P_{Cu} = \frac{-17520}{T} - 1.21 \log T + 13.21$$

and $$\log P_{Zn} = \frac{-6850}{T} - 0.755 \log T + 11.24.$$

Calculate (i) the vapour pressure of copper over a brass containing 40 atom % zinc at 1227°C (1500K) and (ii) The vapour pressure of zinc over the above brass at the same temperature.

4(a) The partial molar entropy of mixing of gold in solid Au-Cu alloys, determined at 500°C (773 K) over the complete solution range, is tabulated below.

x_{Au}	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$\overline{S}^{M}_{Au}$, Cal/deg/mole:	4.56	2.87	2.20	1.84	1.42	1.04	0.72	0.44	0.21
S^{M}_{Au}, J/K/mole	19.08	12.00	9.20	7.70	5.94	4.35	3.01	1.84	0.88

Calculate the partial molar entropy of mixing of copper and integral molar entropy of mixing of the solution containing 40 atom% copper.

(b) The excess partial molar free energy of iron at 1600°C (1873 K) in Fe-Ni solutions at different compositions is given below.

x_{Ni}	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$\overline{G}^{xs}_{Fe}$, cal/mole	0	-15	-40	-90	-260	-620	-1330	-2030	-2730
($\overline{G}^{xs}_{Fe}$, J/mol	0	-63	-167	-377	-1088	-2594	-5565	-8494	-11422)

Calculate the excess partial molar free energy of nickel in an equiatomic solution.

5(a) The EMF of the cell

$$Ag_{(s)}|AgCl_{(s)}|Cl_2(1\ atm),Pt$$

is found to be

$$\epsilon(volts) = 0.977 + 5.7 \times 10^{-4}(350-t) - 4.8 \times 10^{-7}(350-t)^2$$

in the temperature range t = 100° C to t = 450°C. Calculate the value of Δc_p for the cell reaction.

(b) At 25°C, the EMF of the cell

$$Pb|PbCl_2|Hg_2Cl_2|Hg$$

is +0.5357 volt and the temperature coefficient is 1.45×10^{-4} volt/degree. Calculate:

(i) The maximum work available from the cell at 25°C per mole of Pb reacted

(ii) The entropy change of the cell reaction

(iii) The heat abosorbed by the cell at 25°C per mole of Pb reacted when the cell is operating reversibly.

The Hg electrode in the cell is replaced by an Hg-X alloy in which X_{Hg}=0.3 and where X is inert. The cell EMF at 25°C is found to increase by 0.0089 volt. Calculate the activity of Hg in the alloy at 25°C.

6(a) Drive the Gibbs-Helmholtz Equation and explain the terms.

(b) Derive the expression for the lowering of the freezing point of a solvent A due to a small amount of solute B assuming no solid-solid solubility. The expression should be in the form

$$\Delta T_f = K_f\ m_B$$

where K_f = molal freezing point depression constant

m_B = molality of component B.

END OF EXAMINATION - MM320/321 PAPER I

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

MM320 : PAPER II

CHEMICAL METALLURGY

TIME: 3 HOURS

ANSWER: FIVE QUESTIONS

1(a) The reaction of a cadmium-calomel cell is represented as

$$Cd + Hg_2Cl_2 = Cd^{++} + 2Cl^- + 2Hg,$$

where all the components are present in their standard states. The reversible e.m.f. (in V) of the above cell varies with temperature (in K) according to the following relation:

$$E^0 = 0.67 - 1.02 \times 10^{-4} (T-298) - 2.4 \times 10^{-6} (T-298)^2.$$

Calculate the values of ΔG^0, ΔS^0 and ΔH^0 for the above reaction at 40°C (313 K).

(b) The rate constants of fluorination of uranium oxide at various temperatures are listed below.

Temp.,°C :	600	630	660	690	720
(Temp., K :	873	903	933	963	993
Rate constant x 10^3 g/cm^2/min	0.69	1.21	2.10	3.46	5.37
(Rate constant x 10^3, kg/m^2/min	0.12	0.20	0.35	0.58	0.90)

Determine the activation energy for fluorination.

2(a) Find the order of the reaction between compounds A and B using the following data:

T(Min)	0.0	10.0	30.0
X(% of reacted components)	19.8	46.7	74.0

(b) Find the activation energy for oxidation of sulphur dioxide to sulphur trioxide over a vanadium catalyst if the reaction rate constant is 6.3s^{-1} at 455°C, 12.0s^{-1} and 470°C and 26.2s^{-1} at 490°C.

3. A galvanic cell is set up with electrodes of solid aluminum and solid aluminum-zinc alloy and an elecrolyte of a fused $AlCl_3$-NaCl mixture. When the mole fraction of Al in the alloy electrode is 0.38, the EMF of the cell is 7.43 millivolts at 380°C, and the temperature coefficient of the EMF is 2.9×10^{-5} volt/degree. Calculate:

a) The acitivity of Al in the alloy
b) The partial molar free energy of mixing of Al in the alloy
c) The partial molar enthalpy of mixing of Al in the alloy

4. Liquid iron, contained in an Al_2O_3 crucible under a gaseous atmosphere of $Po_2 = 3 \times 10^{-12}$ atm at 1600°C, contains its equilibrium contents of dissolved oxygen and aluminum. To what value must the Po_2 in the equilibrating gaseous atmosphere be raised in order that solid hercynite ($FeO.Al_2O_3$) appears in equilibrium with the melt and solid Al_2O_3? What is the activity of Al (with respect to the 1 wt% in iron standard state) in this state? How many degrees of freedom does this equilibrium have at 1600°C? Given

$$\tfrac{1}{2}O_{2(g)} = O_{(1\ wt\ \%\ in\ Fe)} \qquad \Delta G^0 = -111{,}070 - 5.87T \text{ joules}$$

$$Al_{(l)} = Al_{(1\ wt\ \%\ in\ Fe)} \qquad \Delta G^0 = 43{,}100 - 32.26T \text{ joules}$$

$$FeO.Al_2O_{3(s)} = Fe_{(l)} + O_{(1\ wt\ \%\ in\ Fe} + Al_2O_{3(s)}$$

$$\Delta G^0 = 146{,}230 - 54.35T \text{ joules}$$

5(a) The following conjugate mixtures are found in the Pb-Ag-Al system at 750°C:

Top phase			Pb phase		
Pb	Al	Ag	Pb	Al	Ag
0.1	83.5	16.4	99.5	0.3	0.2
0.2	71.7	28.1	99.4	0.3	0.3
0.4	56.3	43.3	99.0	0.1	0.9
0.8	33.8	65.4	98.0	0.1	1.9
1.8	20.2	78.0	96.0	0.1	3.9

(a) Construct the miscibility gap of the ternary sysetem Pb-Al-Ag at 750°C. Draw in the tie lines.

(b) A Pb bullion contains 25% Ag. Determine the content of the desilverised bullion after a first addition of 10 wt % Al and a second addition to the first stage desilverised Pb of 7 wt % Al.

6(a) A conductivity cell filled with 0.1 molar KCl at 25°C has a measured resistance of 24.36Ω. Distilled water is used to make up the solutions. The conductivity K of 0.1 molar KCl is $1.1639 \Omega^{-1}\ m^{-1}$. Filled with 0.1 molar acetic acid, the cell resistance is 1982Ω at 25°C. Calculate the molar conductance Λ of 0.01 molar acetic acid.

(b) A 0.01 M silver nitrate solution is used with silver electrodes in a determination of the transference number of the Ag^+ ion by the Hittorf method; 32.10 mg of silver are deposited in a silver coulometer in series with the Hittorf cell. At the end of the run the 20.09 gm of solution in the anode compartment are found to contain 39.66 mg of Ag; the 27.12 gm of solution in the cathode compartment contain 11.44 mg of Ag. Calculate the Ag^+ transference number.

END OF EXAMINATION MM320 : PAPER II

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

MM 410 I

MINERAL PROCESSING

Time: Three hours.

Answer: All three questions from Section A.
Any three questions from Section B. (choice)

The relative weight of the questions in Section A is indicated in brackets. All questions in Section B carry equal weight (12 %).

SECTION A. Answer all the three following questions.

1. State briefly what you understand by the following terms, used in mineral processing:

   - a granular particle
   - the angle of nip in a crushing operation
   - the crushing angle on a jaw crusher
   - the angle of repose of a mass of loose material
   - the angle of surcharge on a belt conveyor
   - the angle of wrap on a belt conveyor
   - the intensity of turbulence
   - consolidation trickling
   - the wash ratio in filter cake washing (two definitions)
   - reslurry washing

   (20 %)

2. (a) Give an equation that expresses the 'area principle' in sedimentation, state what the symbols, used in this equation, represent, and explain this principle in a few words.

   (b) Which operations, and what equipment, used in mineral processing, are based upon this area principle ?

   (c) Draw a functional sketch of a rake classifier in operation, showing its main parts and the various zones that can be distinguished.

   Indicate in your sketch where the feed enters and where the products leave the classifier.

   Next, describe briefly how this type of classifier functions.

contd. .....

2/.....

Question 2 (contd.)

(d) What operating controls can be used on a rake classifier ?

State briefly how each of these controls influences the separating size in the classifier operation.

(e) What is understood by the 'critical dilution' of the feed to a rake classifier ?

Explain briefly, preferably with a simple diagram.

(f) The efficiency of classification is expressed in terms of sharpness of particle size separation. In general, hydraulic classifiers give a sharper size separation than mechanical classifiers, which, in turn, give a higher efficiency of separation than hydrocyclones.

In a few words, give the reason(s) why hydraulic classifiers generally give a sharper size separation than mechanical classifiers, and the reason(s) for the comparatively low separation efficiency in cyclones.

(g) In spite of their generally lower efficiency, hydrocyclones are usually preferred to mechanical classifiers in concentrators and hydraulic classifiers are comparatively rare in industrial plants.

Give some reasons for this preference.

(26 %)

3. A sample of fine particles, of uniform composition and of fairly uniform shape (sphericity ψ = 0.6) is split into size fractions by sedimentation in a cylinder with water of 25 °C, in which the particles are first uniformly dispersed into a very dilute suspension and then separated by repeated settling, decantation and re-pulping. The height, over which the particles are made to settle during timed intervals, is 45 cm. The density of the particles is measured separately and determined as 3200 kg m^{-3}.

(i) Calculate the separating size for the two fractions that are obtained after a settling time of 1 minute.

You may take the SG of water as 1.0 and the viscosity of the water as 1.0 cP. The acceleration of gravity may be taken as 9.81 m s^{-2}.

Note that, because it is anticipated that settling in this particular range is not really under laminar flow conditions, you should use an alternative to using Stokes's equation for calculating the particle size that corresponds with the terminal velocity of separation. The attached graph of $C_D Re^2$ and $C_D Re^{-1}$ vs Re has to be used.

(ii) What would you obtain as separating size if you use Stokes's equation ?

(18 %)

3/.....

SECTION B. Choose any three of the following five questions. All these questions have the same weight (12 %).

4. Give a brief discussion on the segregation that occurs when broken ore is fed into a storage bin, and when it is withdrawn from such a bin.

Briefly describe the main causes of such segregation and give reasons why such segregation is undesirable.

Suggest possible solutions to minimise the occurrence of such segregation.

5. (i) Briefly describe three types of equipment used to feed broken ore into a storage reservoir or bin, and give their field(s) of application.

(ii) State briefly why all longer belt conveyors and all inclined belt conveyors should be equipped with a belt take-up.

Briefly describe the three main types of belt take-up and make rough sketches as illustration.

6. Briefly explain the reasons for using double-deck screens rather than single-deck screens in concentrator crushing plants,

Explain briefly why the angle of inclination of the screen decks in a multiple-angle multiple-deck screen, such as a Mogensen sizer, is made successively larger in the lower decks.

Explain briefly why the angle of inclination of the screen deck on a multiple-angle single-deck screen decreases from feed end to discharge end.

4/.....

7. Describe briefly, but clearly, why all equipment in a continuously operating section of an industrial plant, such as the crushing/screening section of a concentrator, should be interlocked electrically.

Describe briefly what will happen in such an electrically interlocked section of the plant if one of the items of equipment trips out, e.g. on overload.

Briefly describe the procedure that is followed in starting up such an electrically interlocked section of the plant, and the procedure that is followed in shutting down the plant.

Describe briefly what you understand by an electrical 'lock-off' system of equipment in an industrial plant.

8. Show that the power number of an impeller rotating in a fluid, is effectively a drag coefficient or friction factor for the impeller.

Show how you can achieve different effects upon a fluid in a mixing vessel with geometrically similar impellers with the same power input but with different combinations of impeller speed and impeller diameter.

How would you achieve a large volumetric circulating rate and relatively little turbulence in impeller mixing ?

How would you achieve a high fluid shear rate, but a low circulating capacity ?

END OF EXAMINATION MM 410 I

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

MM 410 II

MINERAL PROCESSING

Time: Three hours.

Answer: All questions from Section A.
Two questions from Section B. (choice)

The relative weight of each question in Section A is indicated in brackets. All questions in Section B carry equal weight (12 %).

SECTION A. Answer ALL of the following three questions.

1. In order to determine the efficiency of separation in a coal washing plant, laboratory heavy liquid tests were carried out on representative samples of the float (clean coal) and sink (ash) fractions. The results are given below. The yield of clean coal was determined as 41.6 %.

SG fraction	float (kg)	sink (kg)
- 1.30	13.21	0.22
1.30 - 1.32	7.84	0.20
1.32 - 1.34	4.33	0,36
1.34 - 1.36	3.56	1.12
1.36 - 1.38	1.25	2.48
1.38 - 1.40	0.12	2.87
1.40 - 1.42	0.03	2.64
1.42 - 1.44	0.02	2.38
1.44 - 1.46	0.01	2.42
1.46 - 1.48	0.01	2.23
1.48 - 1.50	0.01	1.80
+ 1.50	0.01	9.35

(i) Calculate the partition coefficients for the various SG fractions and plot these against the corresponding nominal SG's.

(ii) From this partition curve, determine the effective density of separation.

(iii) Determine the probable error of separation.

(20 %)

2. (a) Briefly describe the operation of a pinched sluice and illustrate your description with a rough sketch

(b) Briefly describe the operation of a Reichert cone concentrator and illustrate your description with a rough sketch.

(c) Describe briefly how minerals can be separated on a shaking table.
Describe and explain the action of the water flowing over the inclined deck, the action of the riffles and the action of the shaking motion given to the deck.

(d) Make a rough sketch of the deck of a shaking table and indicate where the various products should be collected.

(e) In which part of a flowsheet for the concentration of minerals by gravity methods would you use pinched sluices, where would you use Reichert cones and where would you use shaking tables ?

Explain your answers briefly.

(16 %)

3. (a) Why is it necessary to thicken a mineral pulp prior to industrial filtration ?

(b) In cake filtration, what is the relation between the mean specific cake resistance, the cake resistance coefficient, the cake compressibility coefficient and the pressure drop across the filter ?

(c) What can you say about the effect of the pressure differential upon the rate of filtration with very compressible cakes ?

(d) (i) Draw a typical 'through-the-cake' washing curve for the case that cake washing starts immediately after cake formation and show the various stages, that can be distinguished, in your diagram.

Referring to your diagram, briefly describe and explain this cake washing process.

(ii) In the same diagram, draw a typical washing curve for the case that cake washing starts after an air dewatering stage.

Briefly explain the difference(s) between these two washing curves.

(e) Draw a schematic diagram of a horizontal belt filter used in a countercurrent cake washing operation. Clearly indicate the routing of the various process streams in your diagram.

Referring to your diagram, briefly describe and explain this operation.

(20 %)

4. (a) What do you understand by a 'surface-active agent', and what do you understand by a 'surfactant' ?

(b) What do you understand by the 'critical pH' of a particular collector/mineral combination ?

How can one make use of differences in critical pH in mineral separation ?
Give a simple example.

(c) What do you understand by a 'unit flotation cell' in a grinding circuit ?

What is the objective of such a unit flotation cell ?

(d) What is the main consideration in a 'scavenger' circuit, and what is the main consideration in a 'cleaner' circuit ?

(e) What should you do on a bank of eight mechanical flotation cells in operation if you want to increase the grade of the concentrate from the first two cells of the bank ?

What should you do if you want to increase the grade of the concentrate from all eight cells of the bank ?

Explain briefly.

(f) What do you understand by 'sands flotation' ?

What would you consider to be the necessary flotation conditions for sands flotation ?

Explain briefly.

(20 %)

SECTION B. Answer TWO only of the following four questions. All four questions carry equal weight (12 %).

5. (a) Draw a rough diagram of the cross-section through a Harz jig, used in the concentration of cassiterite, whereby the concentrate is collected 'on the screen'.

Describe the operation of this jig briefly.

(b) Draw a rough diagram of the cross-section through a Denver jig, used in the concentration of cassiterite, whereby the concentrate is collected 'through the screen'.

Describe the operation of this jig briefly.

(c) Draw a rough diagram of the cross-section through a Batac jig, used in the cleaning of coal.

Describe the operation of this jig briefly.

(d) Briefly summarize the main differences between these jigs and between their operation.

6. (a) Briefly state the differences between diamagnetic, paramagnetic and ferromagnetic substances.

Illustrate with rough graphs of the intensity of magnetisation against the applied magnetic field for each of these three groups of substances.

What can you say about the magnetic susceptibility for each of these three groups of substances ?

(b) What factors limit in practice the intensity of the applied magnetic field in magnetic separation equipment ?

(c) Apart from increasing the intensity of the applied magnetic field, what else can be done to achieve a large magnetic force upon the particles to be separated ?

Describe briefly how this is done in several modern types of magnetic separation equipment.

(d) Draw a working diagram of a three-stage induced-roll magnetic separator and explain briefly how such equipment functions.

7. (a) Draw a working diagram of a flotation column in operation, showing its main features.
Indicate the process streams with arrows in your diagram.

Then describe briefly how such a flotation unit functions.

(b) What are the main operating parameters in column flotation ?
Discuss briefly.

(c) What do you consider to be the most characteristic feature of a flotation column, as compared to a traditional bank of mechanical flotation cells ?

(d) What would you consider to be the most suitable field(s) of application for flotation columns ?

Explain your answer in a few words.

8. (a) Briefly describe the construction of tailings dumps by the spraying method and by cycloning.

Illustrate with rough sketches.

(b) Describe the construction of tailings dumps in valleys by the 'downstream' method and by the 'upstream' method.

Illustrate with cross-sections through the walls, obtained with each of these two methods.

(c) In a brief discussion, compare the merits and demerits of each of these two methods.

(d) What would you consider to be the most important precaution to be taken when starting a tailings dump with the downstream method ?

Explain your answer briefly.

(e) Briefly state the main measures that should be taken to maintain tailings dumps in a safe and environmentally acceptable condition.

- END OF EXAMINATION MM 410 II -

THE UNIVERSITY OF ZAMBIA

UNIVERSITY FINAL EXAMINATION – NOVEMBER/DECEMBER 1993/94

MINERAL PROCESSING

MM413

TIME: 3 HOURS
ANSWER: FIVE QUESTIONS

1(a) What do you understand by the term "Reduction Ratio"? Outline various ways in which the reduction reatio can be defined. Include in your answer the applications and limitations of the proposed definitions.

(b) State briefly what you understand by the following terms, used in mineral processing:

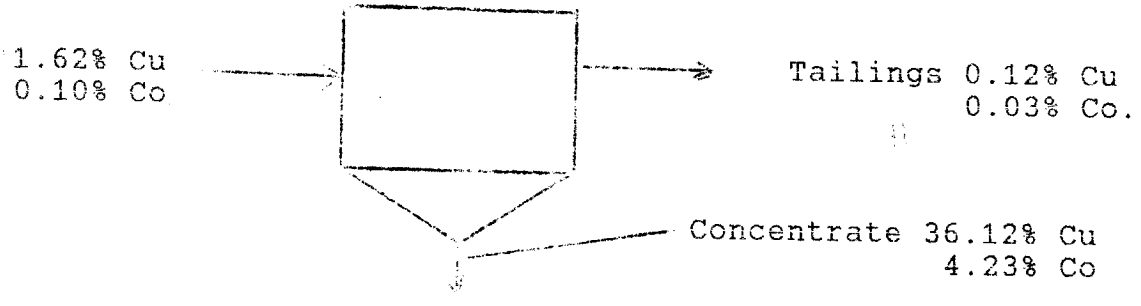
- Mineral
- Ore
- Liberation
- 80% passing reduction ratio R_{80}
- Limiting reduction ratio

(c) The two-product formular for the recovery of an ingredient is:

$$R = \frac{C.c}{F.} \times 100\% = \frac{c(f - t)}{f(c - t)} \times 100\%$$

Define the symbols R, C, F, C, f and t.

2 A copper/cobalt sulphide ore is treated in a bulk flotation circuit and the average grades of feed and products are shown:



Calculate the average recoveries of copper and cobalt from feed to concentrate.

(a) Draw a functional sketch of a double-toggle jaw crusher, showing its most important parts, and give the name of each of these parts. Next, describe briefly how rock is crushed in such a crusher.

(b) Explain in a few words why the "set" of the cone crusher is taken as the distance between the crushing media at the discharge point in the closest position.

(c) List five differences between double-toggle jaw crushers and suspended-spindle gyratory crushers which you consider to be important.

3. Three energy-size theories have been derived empirically by Rittinger, Kick and Bond.

(a) State these theories and express them by equations defining each symbol in the equations.

(b) These theories can be derived from one general equation proposed by Walker as:-

$$dE = -C\frac{dx}{x^n}$$

Derive the three theories.

(c) By means of a sketch show what size range you would expect the three relations to be valid and explain why generally Bond's relation is often used in most comminution situations.

4. Outline clearly the role of the following in the froth flotation of mineral particles giving examples where appropriate.

- contact angle.
- collectors.
- Frothers.
- Regulators.

5. Answer the following questions:

(a) Draw a circle, representing a cross-section through a ball mill in operation and indicate in which zone grinding is effected mainly by abrasion and which zone grinding is effected by impact. Indicate the direction of rotation of the mill.

(b) What is the effect of abrasion upon the sizing of mill product and what is the effect of impact?

(c) For a ball or rod in a mill of radius R meters, revolving at N r.p.m., derive an expression for the critical speed of the mill and state any assumptions.

(d) Briefly describe the grinding action of a Rodmill and indicate three cost advantages it has over a ballmill.

6. An ore contains 3% Copper in the form of chalcopyrite ($CuFeS_2$), the remainder being predominantly siliceous gangue (s.g.2.7). The ore is crushed to -12mm and sampled before being further treated. The output from the crusher is fed to storage bins via a conveyor system at an average rate of 100 tonnes per hour.

Assuming that crushed material is thoroughly mixed determine the limits of error (to the 99% confidence level) in the Cu assay introduced by taking a 1 kg sample from the conveyor at intervals of 30 minutes. A test of the ore showed that the maximum Cu content of any piece is 10%. The s.g. of chalcopyrite is 4.2. (Take shape factor as 0.5 and size factor as 0.25)

Atomic weights
Cu = 63.5
Fe = 56.0
S = 36.0

END OF EXAMINATION - MM413 PAPER

THE UNIVERSITY OF ZAMBIA
UNIVERSITY EXAMINATIONS - 1994

MM 423
HYDROMETALLURGY

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

1.a. Construct a Pourbaix diagram for the nickel-water system at 25 °C over the pH range 0 to 11 and indicate the stability regions for the various species as well as the stability region of water. Take the concentration of all Ni species in solution as 10^{-3} mol.dm^{-3}. (8%)

b. Which reducing agent, Zn or H_2, would be suitable for the production of nickel metal from solution? Explain your answer and state which pH range would be suitable for the process. Assume a zinc cation activity = 1 in solution. (6%)

c. Calculate the concentration of nickel in solution if the pH of the solution is adjusted to 12. Would it be possible to separate nickel and zinc by merely adjusting the pH of the solution? Explain your answer. (6%)

Data:

i)	$Ni^{2+} + 2e^- = Ni_{(s)}$	$E^\circ = -0.25$ V
ii)	$Ni^{2+} + H_2O = NiO_{(s)} + 2H^+$	$K = 6.607 \times 10^{-13}$
iii)	$NiO_{(s)} + 2e^- + 2H^+ = Ni_{(s)} + H_2O$	$E^\circ = 0.11$ V
iv)	$2H^+ + 2e^- = H_2$	$E^\circ = 0$ V
v)	$O_2 + 4H^+ + 4e^- = 2H_2O$	$E^\circ = 1.23$ V
vi)	$Zn^{2+} + H_2O = ZnO_{(s)} + 2H^+$	$K = 1.1 \times 10^{-11}$
vii)	$Zn^{2+} + 2e^- = Zn_{(s)}$	$E^\circ = -0.763$ V

2. A solution obtained from a typical agitation leaching operation contains 2.51 g/l Cu. Portions of this solution are equilibrated with different volumes of LIX 864 dissolved in a suitable diluent. Data obtained pertaining to these equilibrium experiments is shown below.

Phase ratio (V_O/V_A)	10/1	5/1	2/1	1/1	1/2	1/5	1/10
g/l Cu in extract	1.42	1.63	2.34	3.15	3.50	3.59	3.69
g/l Cu in raffinate	0.056	0.070	0.18	0.68	1.41	2.08	2.31

a. Construct an equilibrium extraction isotherm for LIX 864 using the data given. (6%)

b. A continuous counter-current operation is to be used for extracting copper from a solution with 2.51 g/l Cu, and it is anticipated that the stripped organic with LIX 864 entering extraction will be completely barren. Answer the following, assuming an organic to aqueous volumetric flow rate ratio of 0.9:

(i) What will be the copper content of the loaded organic? (2%)

(ii) Predict the number of stages which will be required for such an operation assuming 100% stage efficiency. (4%)

(iii) Explain why the areas of the stages in your McCabe-Thiele diagram are not equal. (2%)

c. Distinguish between the mode of action of chelation extractants and ion pair extractants. How would stripping of the loaded organic containing each of these extractants be achieved? (6%)

3.a. A company wishes to extract valuables from an ore using a hydrometallurgical method. As a metallurgist with the company, you are appointed to take charge of the development of a leaching process for the ore. Discuss fully, but concisely, what factors you would consider in order to obtain optimal results in the leaching of the ore. (8%)

3.b. As applied to the leaching of concentrate particles, answer the following questions:

(i) What is meant by the "rate determining step" and why is it valuable if such a step can be identified? (3%)

(ii) Write down the formula of Fick's first law of diffusion and explain the symbols that appear in the equation. (2%)

(iii) Assuming that Nernst's model is valid for lixiviant diffusion through the boundary layer around concentrate particles, use Fick's first law to identify the factors that would have an influence on the rate of boundary layer diffusion. (7%)

4.a. In a continuous agitation leaching operation 3.75 tonnes of solute-free lixiviant is used for every 1.25 tonnes of a concentrate. The concentrate contains 15% of leachable values, 10% moisture, and the remainder is insoluble material. All leachable values dissolve before the pulp is introduced into the first thickener of a 3 stage counter current decantation washing unit. For every 1.25 tonnes concentrate leached, six tonnes of pure wash water is added in the last thickener which yields a disposable residue.

(i) Draw a clearly labelled diagram which would best represent the operation as described above. (2%)

(ii) What is the amount of pregnant solution produced for every 1.25 tonnes of concentrate leached assuming an underflow liquid/solid weight ratio of 2 in each thickener? (5%)

(iii) Assuming a repulping efficiency of 95% and an underflow liquid/solid weight ratio of 2 in each thickener, calculate the percentage of dissolved values recovered into the pregnant solution. (8%)

b. Liquor that is due to be discarded has some copper in solution which it is desired to recover prior to solution disposal. Outline the arguments for and against the use of cementation on iron to achieve this. (5%)

5.a. With reference to the metallurgy of copper:

(i) Distinguish between electrowinning and electrorefining. (5%)

(ii) In what ways are solvent extraction electrolytes different from direct leach electrolytes and what special problems might be encountered with the first named electrolytes? (4%)

(iii) Small amounts of "organic addition agents" and sodium chloride are added to the electrolyte during copper electrorefining. What role do these reagents play? (3%)

b. Calculate the total cathode area required to electrowin 50% of the manganese as manganese metal from a feed stream with a flow rate of 1 litre/second and a manganese concentration of 30 g/l if the applied current density is 6 A/dm^2 at a current efficiency of 65%. (F = 96500 C/gmol: Mn relative atomic weight = 54.94) (8%)

END OF EXAMINATION

THE UNIVERSITY OF ZAMBIA
UNIVERSITY EXAMINATIONS - 1994

MM 433
PYROMETALLURGY

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

1.a. The Gibbs energy change for the reduction of ZnO by CO to form zinc vapour by the reaction:

$$ZnO_{(s)} + CO_{(g)} = CO_{2(g)} + Zn_{(g)}$$

is given by:

$$\Delta G^{\circ}_{1} = 46720 - 31.7T \text{ Cal}$$

If T is in Kelvin and:

$$\log P^{\circ}_{Zn}\,(atm) = -\frac{6850}{T} - 1.255 \log T + 9.45$$

Calculate:

(i) the partial pressures of Zn, CO, and CO_2 in equilibrium with solid ZnO at 1300 °C for a total pressure of one atmosphere, and determine if liquid zinc can be produced at this temperature. (10%)

(ii) the value of the total pressure that gives liquid Zn at 900 °C. (7%)

b. List what you consider to be the major advantages and disadvantages of producing zinc by the Flash furnace process es compared to its production in the Imperial smelting process. (3%)

2.a. Briefly explain why a copper-cobalt sulphide concentrate would be roasted at 700 °C. What would be the effect on metallurgical performance of deviating far from this temperature? (5%)

b. A concentrate with a dry analysis of 6% Cu, 5% Co, and 25% Fe is roasted using air by a continuous process. To maintain the roasting temperature at 700 °C, the concentrate is fed wet to the roaster.

Using the data given below, calculate the required % of water in the feed to maintain the roaster temperature. Assume that in the concentrate all Cu, Co, and Fe is present in the form of Cu_2S, CoS, and FeS_2, respectively, and that the roasting reactions are:

$$Cu_2S + SO_2 + 3O_2 = 2CuSO_4$$
$$CoS + 2O_2 = CoSO_4$$
$$2FeS + 5.5O_2 = Fe_2O_3 + 4SO_2$$

Assume also that a stoichiometric quantity of air is used and that the gangue has no combustible material. Neglect heat losses. (20%)

Thermodynamic Data

$H_2O_{(l)}$: C_p = 18.03 cal/deg/mol
H_2O : L_v = 10520 cal/mol
$H_2O_{(g)}$: $C_p = 7.17 + 2.56 * 10^{-3}T + 0.08 * 10^5 T^{-2}$ cal/deg/mol

And the enthalpy for the substances shown below is to be calculated using the formula:

$$H^0_T - H^0_{298} = aT + 0.5bT^2 + c/T + d \quad \text{cal/mol}$$

Substance	a	b * 10^3	c * 10^{-5}	d	H^0_{298}
$CuSO_4$	18.77	17.20	-	-6357	-184250
Cu_2S	20.30	-	-	-6049	-19000
SO_2	10.38	2.54	-1.42	-2729	-70940
O_2	7.16	1.00	-0.40	-2044	-
N_2	6.66	1.02	-	-2030	-
$CoSO_4$	30.09	9.91	-	-9407	-212000
CoS	10.6	2.51	-	-3270	-22600
Fe_2O_3	23.49	18.6	-3.55	-6634	-196300
FeS_2	17.88	1.32	-3.05	-4363	-41000

3.a. Draw a well labelled block flow-diagram for the production of copper from a sulphide ore via the conventional pyrometallurgical route. (3%)

b. Describe in detail each of the processes of the block flow-diagram that involves the blowing of air into a melt. (7%)

c. What benefits would be expected if El Teniente technology is used in place of the conventional copper smelting technology as drawn in part (a) above? (4%)

d. A copper matte has a (matte) grade of 50%. Discuss as fully as possible its approximate chemical and phase composition. (Atomic weights: Cu = 63.5, Fe = 55.8, S = 32.0) (6%)

4.a. A lead blast furnace produces 80 tonnes of lead per day which can be regarded as being 100% pure. In the same period, 15 tonnes of matte is also produced which has 9% Pb and 24% Cu. The slag leaving the furnace has 11% CaO while the gases contain 22% CO and 10% CO_2. Assume that lead and copper do not enter the slag and that no solids are carried over into the gas.

The feed to the furnace comprises of a roasted lead concentrate, pyrite cinder, limestone, and coke. The coke is 90% carbon and 10% SiO_2 and the amount used is 18% of the roasted concentrate charged. The composition of the other feed materials is as follows:

Roasted concentrate: 47% PbO, 23% PbS, 30% SiO_2
Pyrite cinder: 86% Fe_2O_3, 6% Cu_2S, 8% SiO_2
Limestone: 100% $CaCO_3$

Calculate:

(i) The weight of roasted concentrate and pyrite cinder smelted per day. (4%)
(ii) The composition of the slag. (7%)
(iii) The volume (in Nm^3) of gases produced per day. (4%)

Relative atomic weights: Pb = 207.2, Cu = 63.5, Fe = 55.8, Ca = 40.1, C = 12.0, S = 32.0, O = 16.0.

b. Explain the underlying metallurgical principles of the Isasmelt lead process. (5%)

5.a. Starting with molten lead containing, as impurities, silver, copper, bismuth, and zinc, how would fairly pure lead be produced? (6%)

b. Lead bullion containing tin is oxidized by bubbling compressed air through the liquid metal at 800 K. Assuming that the reaction products are pure PbO_2 solid and SnO_2 solid, what is the minimum tin in lead concentration (weight %) that can be reached by this method? (Relative atomic weights, Pb = 207.2; Sn = 118.7). (5%)

$Sn_{(l)} + O_{2\,(g)} = SnO_{2\,(s)}$ $\quad \Delta G^\circ_{(800\ K)} = -583319$ J/mol

$Pb_{(l)} + 0.5O_{2\,(g)} = PbO_{(s)}$ $\quad \Delta G^\circ_{(800\ K)} = -219475$ J/mol

For Sn in Pb at 800 K, $\quad \gamma^\circ = 2.3$

c. With the aid of an appropriate industrial example, explain the following metallurgical terms:

i. Liquation. (2%)

ii. Carbonylation. (2%)

END OF EXAMINATION

UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

MM 443 - TRANSPORT PHENOMENA

TIME: THREE Hours

ANSWER: FIVE Questions

All questions carry equal marks

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1. Water at 20°C (density 1000 kg/m^3) is flowing steadily through a 120° reducing bend. The inlet pipe diameter is 1.829 m, the outlet diameter is 1.219m and the flowrate is 8.5 m^3/s. The exit point z_2 is 3.05m above the inlet and the inlet pressure is 276 kPa gauge. Friction losses are estimated at $(0.5/2)v^2_2$ and the mass of water in the elbow is 8500 kg. Calculate the resultant force on the bend.

2. An incompressible fluid is in horizontal steady flow through a pipe of 24 mm inside diameter at a rate of 5 cm^3/s.

   (a) Calculate the pressure drop in Pa through 30 metres of pipe and the velocity in m/s at the center of the pipe.

   (b) What is the shear stress at the pipe wall in Pa?
   Density of fluid = 0.9×10^3 kg/m^3
   Viscosity of fluid = 0.65×10^{-3} Pa.s
   Assume that the flow of the fluid is <u>laminar</u>.

3. 600 cm^3/s of water at 320 K is pumped in a 40 mm i.d pipe through a length of 150 m in a horizontal direction and up through a vertical height of 10 m. In the pipe there is a control valve which may be taken as equivalent to 200 pipe diameters and other pipe fittings equivalent to 60 pipe diameters. Also in the line there is a heat exchanger across which there is a loss in head of 1.5 m of water. The main pipe has a roughness of 0.0002 m. Calculate the power (in W) that must be delivered to the pump if the unit is 60% efficient.

Density of water = 10^3 kg/m^3

Viscosity of water = 1×10^{-3} Pa.s

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

$g = 9.81$ m/s^2

4. The inner surface of a furnace will operate at 1623 K. The vertical wall of the furnace will have an overall thickness of 350 mm and is to be made up of firebrick material (k_f=0.86 W/m.K) covered with a layer of insulation (k_i=0.16 W/m.K). This insulating material has a maximum temperature of 1473 K. The ambient temperature will be 293 K and the heat transfer coefficient at the exposed surface of the insulation will be 10 W/m^2. K.

Calculate

(a) the thickness of insulation that gives minimum heat loss,

(b) the magnitude of the heat loss,

(c) the surface temperature of the insulation.

5. Helium and nitrogen gas are contained in a conduit 5 mm in diameter and 0.1 m long at 298 K and a uniform absolute constant pressure of 1.0 atm. The partial pressure of He at one end of the tube is 0.06 atm and 0.02 atm at the other end. The diffusion coefficient is 0.687×10^{-4} m^2/s and the gas constant R is 82.057×10^{-3} (m^3) (atm)/(kg-mol)(K). Calculate the following for steady-state diffusion through a stagnant gas:

(a) flux of He in (kg-mol)/(s)(m^2) and kg/(s)(m^2)

(b) flux of N_2 in (kg-mol)/(s)(m^2)

(c) partial pressure of He at a point 0.05 m from either end.

Atomic mass of He is 4.

6. In a countercurrent flow heat exchanger 1.25 kg/s of benzene (specific heat 1.9 kJ/kg.K and specific gravity 0.88) is to be cooled from 350 K to 300 K with water (specific heat 4.18 kJ/kg. K and density 10^3 kg/m^3) which is available at 290 K. In the heat exchanger, tubes (with k = 45 W/m.k) of 25 mm external and 22 mm internal diameter are employed and the water passes through the tubes. The heat transfer coefficients for the water and benzene are 0.85 and 1.70 kW/m^2. K respectively and the scale resistance can be neglected. The exit water temperature is 320 K.

(a) Derive the expression for the overall heat transfer coefficient based on the outside tube area.

(b) Calculate the total length of tube required.

7. (a) What do you understand by the terms "black body" and "grey body" when applied to radiant heat transfer?

(b) A horizontal oxidised steel pipe carrying steam and having an OD of 0.1683 m has a surface temperature of 374.9 K and is exposed to air at 297.1 K in a large enclosure. Calculate the heat loss of 0.305 m of pipe from natural convection plus radiation. For the steel, use an ε of 0.79. Also, for natural convection to a horizontal sylinder we have

$$h = 1.32\ (\Delta T/D)^{1/4}$$

(c) A space satellite in the shape of a sphere is travelling in outer space, where its temperature is held at 283.2 K. The sphere "sees" only outer space, which can be considered to be a black body with a temperature of O K. The polished surface of the sphere has an emissivity of 0.1. Calculate the heat loss per m^2 by radiation.

$\sigma = 5.676 \times 10^{-8}$ W/m^2.K^4

END OF EXAMINATION IN MM 443

TABLE 3.4–1
THE EQUATION OF CONTINUITY IN SEVERAL COORDINATE SYSTEMS

Rectangular coordinates (x, y, z):

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}(\rho v_x) + \frac{\partial}{\partial y}(\rho v_y) + \frac{\partial}{\partial z}(\rho v_z) = 0 \qquad (A)$$

Cylindrical coordinates (r, θ, z):

$$\frac{\partial \rho}{\partial t} + \frac{1}{r}\frac{\partial}{\partial r}(\rho r v_r) + \frac{1}{r}\frac{\partial}{\partial \theta}(\rho v_\theta) + \frac{\partial}{\partial z}(\rho v_z) = 0 \qquad (B)$$

Spherical coordinates (r, θ, ϕ):

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

APPENDIX E
THE NAVIER-STOKES EQUATIONS FOR CONSTANT ρ AND μ IN CARTESIAN, CYLINDRICAL, AND SPHERICAL COORDINATES

CARTESIAN COORDINATES

x direction

$$\rho\left(\frac{\partial v_x}{\partial t}+v_x\frac{\partial v_x}{\partial x}+v_y\frac{\partial v_x}{\partial y}+v_z\frac{\partial v_x}{\partial z}\right)=-\frac{\partial P}{\partial x}+\rho g_x+\mu\left(\frac{\partial^2 v_x}{\partial x^2}+\frac{\partial^2 v_x}{\partial y^2}+\frac{\partial^2 v_x}{\partial z^2}\right) \tag{E-1}$$

y direction

$$\rho\left(\frac{\partial v_y}{\partial t}+v_x\frac{\partial v_y}{\partial x}+v_y\frac{\partial v_y}{\partial y}+v_z\frac{\partial v_y}{\partial z}\right)=-\frac{\partial P}{\partial y}+\rho g_y+\mu\left(\frac{\partial^2 v_y}{\partial x^2}+\frac{\partial^2 v_y}{\partial y^2}+\frac{\partial^2 v_y}{\partial z^2}\right) \tag{E-2}$$

z direction

$$\rho\left(\frac{\partial v_z}{\partial t}+v_x\frac{\partial v_z}{\partial x}+v_y\frac{\partial v_z}{\partial y}+v_z\frac{\partial v_z}{\partial z}\right)=-\frac{\partial P}{\partial z}+\rho g_z+\mu\left(\frac{\partial^2 v_z}{\partial x^2}+\frac{\partial^2 v_z}{\partial y^2}+\frac{\partial^2 v_z}{\partial z^2}\right) \tag{E-3}$$

CYLINDRICAL COORDINATES

r direction

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

$$=-\frac{\partial P}{\partial r}+\rho g_r+\mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(rv_r)\right)+\frac{1}{r^2}\frac{\partial^2 v_r}{\partial \theta^2}-\frac{2}{r^2}\frac{\partial v_\theta}{\partial \theta}+\frac{\partial^2 v_r}{\partial z^2}\right] \tag{E-4}$$

θ direction

$$\rho\left(\frac{\partial v_\theta}{\partial t}+v_r\frac{\partial v_\theta}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta}+\frac{v_r v_\theta}{r}+v_z\frac{\partial v_\theta}{\partial z}\right)$$
$$=-\frac{1}{r}\frac{\partial P}{\partial \theta}+\rho g_\theta+\mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(rv_\theta)\right)+\frac{1}{r^2}\frac{\partial^2 v_\theta}{\partial \theta^2}+\frac{2}{r^2}\frac{\partial v_r}{\partial \theta}+\frac{\partial^2 v_\theta}{\partial z^2}\right]$$

z direction

$$\rho\left(\frac{\partial v_z}{\partial t}+v_r\frac{\partial v_z}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta}+v_z\frac{\partial v_z}{\partial z}\right)$$
$$=-\frac{\partial P}{\partial z}+\rho g_z+\mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 v_z}{\partial \theta^2}+\frac{\partial^2 v_z}{\partial z^2}\right]$$

SPHERICAL COORDINATES*

r direction

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

θ direction

$$\rho\left[\frac{\partial v_\theta}{\partial t}+v_r\frac{\partial v_\theta}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta}+\frac{v_\phi}{r\sin\theta}\frac{\partial v_\theta}{\partial \phi}+\frac{v_r v_\theta}{r}-\frac{v_\phi^2\cot\theta}{r}\right]$$
$$=-\frac{1}{r}\frac{\partial P}{\partial \theta}+\rho g_\theta+\mu\left[\nabla^2 v_\theta+\frac{2}{r^2}\frac{\partial v_r}{\partial \theta}-\frac{v_\theta}{r^2\sin^2\theta}-\frac{2\cos\theta}{r^2\sin^2\theta}\frac{\partial v_\phi}{\partial \phi}\right]$$

ϕ direction

$$\rho\left(\frac{\partial v_\phi}{\partial t}+v_r\frac{\partial v_\phi}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\phi}{\partial \theta}+\frac{v_\phi}{r\sin\theta}\frac{\partial v_\phi}{\partial \phi}+\frac{v_\phi v_r}{r}+\frac{v_\theta v_\phi}{r}\cot\theta\right)$$
$$=-\frac{1}{r\sin\theta}\frac{\partial P}{\partial \phi}+\rho g_\phi+\mu\left[\nabla^2 v_\phi-\frac{v_\phi}{r^2\sin^2\theta}+\frac{2}{r^2\sin\theta}\frac{\partial v_r}{\partial \phi}+\frac{2\cos\theta}{r^2\sin^2\theta}\frac{\partial v_\theta}{\partial \phi}\right.$$

* In the above equations,

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

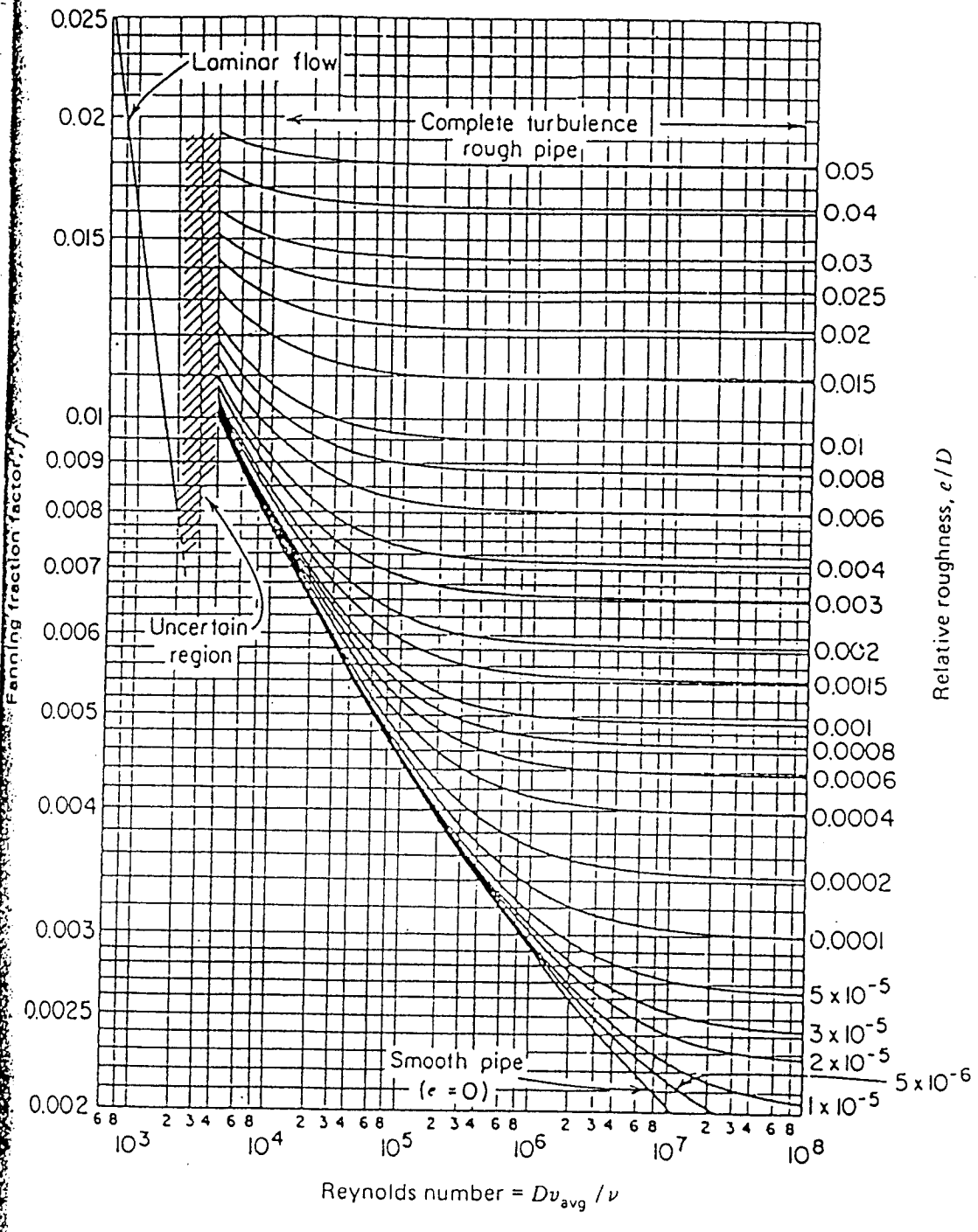


Figure 14.1 The Fanning friction factor as a function of Re and D/e.

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

MM453 PHYSICAL METALLURGY II

TIME: 3 HOURS
ANSWER: ALL THE QUESTIONS

---

1. (a) List seven features of a martensitic transformation.

   (b) What two factors make martensite in ferrous materials unique?

2. (a) What feature of a binary phase diagram is essential in determining if any of the alloys in the system are capable of precipitation hardening?

   (b) Explain the processes involved in fiber strengthening

3. (a) Explain the practical use of the term "toughness" in materials testing. Does this apply to fracture?

   (b) In what ways can specimen size affect fracture toughness?

   (c) In a steel plate 30 cm wide and 0.64 cm thick, there is a 2.5-cm-long crack along the edge ($E = 2 \times 10^{11}$ Pa and Gc = 35000 N/m)

      (i) Calculate the force required to propagate the crack the remaining 27.5 cm across the width of the plate

      (ii) Calculate the force required to break the plate in tension if there were no crack. Assume that the fracture strength is 689×10^6 Pa

4. (a) Describe the Jominy end-quench test and state its purpose.

   (b) A typical high-strength structural steel has the following composition:

   0.20 w/o C, 0.75 w/o Mn, 0.08 w/o P, 0.25 w/o Si, 0.35 w/o Cu, 0.75 w/o Ni, 0.25 w/o Cr, 0.30 w/o Mo. Compute the D_i assuming that the grain size is ASTM 6 and that the multiplying factor for Cu is 1.00

   (c) If the steel is part (b) were given a poor water quench with no agitation, what would be the actual critical diameter? How about if the steel were quenched in brine with no agitation?

   (d) From your answers in part (c), what is the effect of the two quenching media on the hardenability?

5. Magnetite, Fe_3O_4, is cubic and its x-ray powder photograph taken with FeKα radiation (λ= 1.9373A) has lines in order of increasing Bragg angle at the following values of θ:
11.67°, 19.29°, 22.74° 23.86°, 27.70°, 34.60°, 37.09°, 41.04°,.....

(a) Index the lines

(b) What is the lattice type of magnetite?

(c) Evaluate the unit cell dimension

(d) On this photograph, the line of highest θ is a doublet.Given that λ FeKα_1 = 1.9360A and λFeKα_2=1.9399A and that the Bragg angles for the doublet are 78.02° and 78.51°, index the doublet and evaluate the unit cell dimension accurately.

END OF EXAMINATION IN MM453

40 Copies

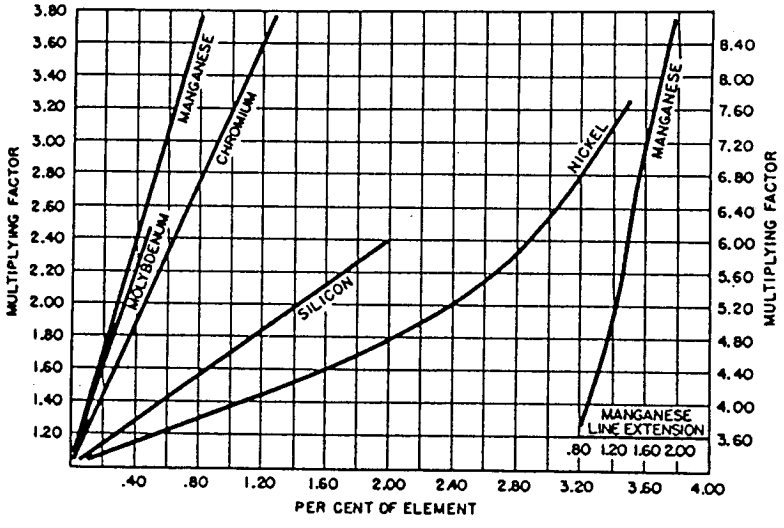
MM453

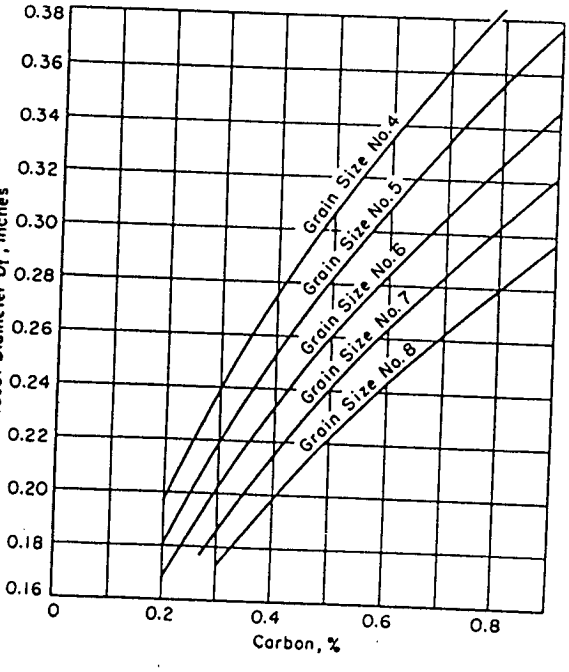
APPENDIX 10
QUADRATIC FORMS OF MILLER INDICES

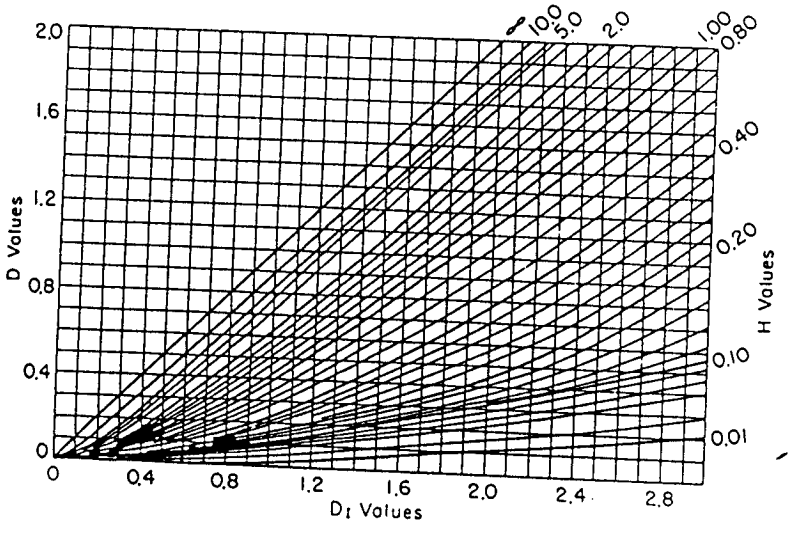
Cubic					Hexagonal	
	hkl					
$h^2 + k^2 + l^2$	Simple	Face-centered	Body-centered	Diamond	$h^2 + hk + k^2$	hk
1	100				1	10
2	110	. . .	110		2	
3	111	111	. . .	111	3	11
4	200	200	200		4	20
5	210				5	
6	211	. . .	211		6	
7					7	21
8	220	220	220	220	8	
9	300, 221				9	30
10	310	. . .	310		10	
11	311	311	. . .	311	11	
12	222	222	222		12	22
13	320				13	31
14	321	. . .	321		14	
15					15	
16	400	400	400	400	16	40
17	410, 322				17	
18	411, 330	. . .	411, 330		18	
19	331	331	. . .	331	19	32
20	420	420	420		20	
21	421				21	41
22	332	. . .	332		22	
23					23	
24	422	422	422	422	24	
25	500, 430				25	50
26	510, 431	. . .	510, 431		26	
27	511, 333	511, 333	. . .	511, 333	27	33
28					28	42
29	520, 432				29	
30	521	. . .	521		30	
31					31	51
32	440	440	440	440	32	
33	522, 441				33	
34	530, 433	. . .	530, 433		34	
35	531	531	. . .	531	35	
36	600, 442	600, 442	600, 442		36	60
37	610				37	43
38	611, 532	. . .	611, 532		38	
39					39	52
40	620	620	620	620	40	
41	621, 540, 443				41	
42	541	. . .	541		42	
43	533	533	. . .	533	43	61
44	622	622	622		44	
45	630, 542				45	
46	631	. . .	631		46	
47					47	
48	444	444	444	444	48	44
49	700, 632				49	70, 53
50	710, 550, 543	. . .	710, 550, 543		50	
51	711, 551	711, 551	. . .	711, 551	51	
52	640	640	640		52	62
53	720, 641				53	
54	721, 633, 552	. . .	721, 633, 552		54	
55					55	
56	642	642	642	642	56	
57	722, 544				57	71
58	730	. . .	730		58	
59	731, 553	731, 553	. . .	731, 553	59	

Table 18.1 Severity of Quench Values for Some Typical Quenching Conditions.

H Value	*Quenching Condition*
0.20	Poor oil quench – no agitation
0.35	Good oil quench – moderate agitation
0.50	Very good oil quench – good agitation
0.70	Strong oil quench – violent agitation
1.00	Poor water quench – no agitation
1.50	Very good water quench – strong agitation
2.00	Brine quench – no agitation
5.00	Brine quench – violent agitation
∞	Ideal quench







THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - DECEMBER 1994

MM 463

PROCESS CONTROL AND INSTRUMENTATION

TIME: THREE Hours
ANSWER: FIVE Questions
All questions carry equal marks

1.(a) Discuss the principles involved in the electrometric measurement of pH.

(b) A 40-mm sharp-edged orifice is installed in a 50-mm i.d. water line to measure the flow of cooling water to an oxygen lance. The pressure drop across the orifice (C_o=0.61) is 15 cm of mercury and the recovery fraction R is 0.6. Calculate the water flow rate in kg/s and the permanent pressure loss in kPa.

Density of water = 1000 kg/m^3

Specific gravity of mercury = 13.6

$$W_s = C_o A_o \left[2\rho (P_1 - P_2) / (1 - (Ao/A_1)^2)\right]^{1/2}$$

2(a) A resistance temperature detector (RTD) has an α(20°C) = 0.004/°C. If R (20°C) = 100 ohms, find the resistance at 15°C and 25°C.

(b) The RTD in part (a) is used in a bridge circuit. If $R_1 = R_2 = R_3$ = 100 ohms, and the supply voltage is 10 volts, calculate the voltage the detector must resolve to define a 1°C change in temperature about 20°C.

(c) If the RTD is replaced by a thermistor with R(20°C) = 100 ohms and change rate of -5 ohms/°C, calculate the voltage resolution of the detector to resolve a 1°C change in temperature.

3(a) An equal percentage control valve has a rangeability of 32. If the maximum flow is 100 m^3/h, find the flow at ⅝ and 4/5 open settings.

(b) The temperature of a reactor is controlled by an electronic (4 to 20 mA) feedback control system containing a 40°C to 90°C temperature transmitter, a PI controller with integral time set at 3 minutes and proportional band at 25, a control valve with linear trim, air-to-open action, and a valve size coefficient C_v = 4 through which cooling water flows. The pressure drop across the valve is a constant 25 psi. If the steady controller output is 12 mA, how much cooling water in gallons per minute is going through the valve? If a sudden disturbance increases reactor temperature by 2°C, what will be the controller output signal and the water rate after one minute? Assume that the current-pressure (I/P) converter is a simple gain.

4(a) Fluid flow through an orifice can be represented by the nonlinear equation

$$Q = K(\Delta P)^{\frac{1}{2}}$$

Derive the transfer function between $Q_{(s)}$ and $\Delta P_{(s)}$ and state what happens when ΔP is zero.

(b) One way to determine the rate of change of a process variable is to measure the differential pressure $\Delta P = P_{out} - P_{in}$ over a derivative unit that has a transfer function

$$\frac{P_{out\,(s)}}{P_{in\,(s)}} = \frac{\tau s + 1}{(\tau/6)s+1}$$

(i) Derive the transfer function between $\Delta P_{(s)}$ and $P_{in}(s)$.

(ii) Show that the ΔP signal will be proportional to the rate of rise in P_{in} after an initial transient period, when P_{in} is a ramp function.

5. A control loop consists of a proportional controller, a first order valve (time constant τ_v, gain K_v) and a first order process (time constant τ_1, gain K_1).

(a) Show that when the system is critically damped the controller gain is given by:

$$K_c = \frac{(E-1)^2}{4EK_vK_1} \quad \textit{where } E = \tau_v/\tau_1$$

(b) For a unit step change in set point, derive an expression for the controlled variable with critical damping.

6. A process has G_M and G_L openloop transfer functions that are as follows:

$$G_M = \frac{K_M}{(\tau s+1)^2}; \quad G_L = \frac{K_L}{(\tau s+1)^2}$$

If a PI controller is used with τ_I set equal to τ, calculate

(a) the value of controller gain that gives a closedloop damping coefficient of 0.707,

(b) the closedloop time constant, using this value of gain,

(c) the closedloop transfer function between the load variable and output variable,

(d) the steady-state error for a unit step change in load variable

7. A control system has the following openloop transfer function:

$$G(s) = \frac{1}{(s+1)(5s+1)(^1/_2 s+1)}$$

(a) Find the ultimate gain and period of the closedloop system with a proportional controller.

(b) Plot the asymptotic log modulus graph with $K_p = 1$.

END OF EXAMINATION IN MM 463

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

MM 473

FERROUS METALLURGY

TIME: THREE HOURS

ANSWER: FIVE QUESTIONS

---

1. (a) Describe three main types of iron ores. What are the unwanted impurities generally found in them? (6%)

(b) Discuss the concentration processes used to upgrade iron ores. (6%)

(c) Where does the sulphur in the hot metal originate from and how is it removed? (2%)

The desulphurisation reaction may be represented as:

$FeS + CaO + C = CaS + Fe + CO$

Give three reasons why this reaction is said to be inefficient. (3%)

(d) Draw a sketch showing the equilibrium distribution of sulphur between slag and metal in the Blast Furnace as a function of slag basicity. (3%)

2. An iron Blast Furnace is charged with the following material every second:

Sinter = 160 kg/s

Fe_2O_3 = 50%

SiO_2 = 20%

CaO = 24%

Al_2O_3 = 7%

Coke = 30 kg/s

Hot air = 95 Nm^3/s

and produces a metal with the following composition:

Fe = 95% Si = 1% C = 4%

Assuming that no iron enters the slag, calculate:

(a) the amount and composition of the metal (5%)

(b) the amount and composition of slag (8%)

(c) the amount and composition of offtake gas (5%)

Show an overall balance consisting of the input and output materials and these should be the same. (1 kg-mole gas occupies 22.4 Nm^3/s). (2%)

3. (a) Draw a sketch showing the change in metal composition during blowing of an acid Bessemer Converter. (2%)

(b) Phosphorus could not be removed from metal in the acid Bessemer (introduced in 1856), why? (2%)

(c) A later modification of the acid Bessemer was the basic Thomas Converter. What was the major change and why? (3%)

(d) Draw a sketch showing the change in metal composition during blowing of a basic Thomas Converter. (2%)

(e) Give <u>five</u> reasons why the Top Blown Oxygen Process replaced the Bessemer and Open Hearth Processes. What are the <u>three</u> disadvantages of the Top Blown Process? (11%)

4. (a) Write short notes on the following in steelmaking:

(i) Manganese distribution (3%)
(ii) Sulphur distribution (3%)
(iii) Phosphorus distribution (3%)

(b) Discuss the influence of the following elements on steel properties:

(i) Carbon (3%)
(ii) Silicon and Aluminium (3%)
(iii) Copper (2%)
(iv) Hydrogen (3%)

5. (a) Give <u>five</u> results achieved by Vacuum Degassing. (5%)

(b) In Pouring Pit Practice, what is meant by <u>Hot Top</u>?(2%)

(c) Describe the formation of Open Top in killed steel ingots and how they can be controlled. (5%)

(d) With the aid of a diagram. describe the progress of solidification in the mould during continuous casting. (8%)

6. (a) Write short notes on OPEN and SUBMERGED CASTING. (4%)

(b) Give four objectives for lubricating the mould top in open stream casting. (4%)

(c) The interposition of a tundish between the ladle and casting mould is caused by three requirements. Name them. (3%)

(d) Give three methods of preventing steel reoxidation during casting. (9%)

END OF EXAMINATION IN MM473

THE UNIVERSITY OF ZAMBIA

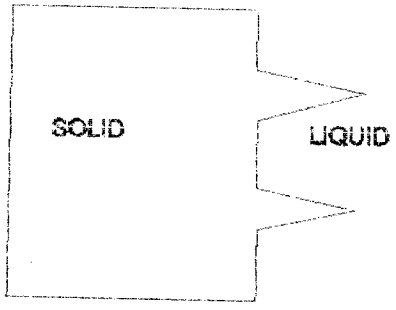
UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

MM523 - FOUNDRY

TIME: THREE HOURS

ANSWER: ALL THE QUESTIONS

1(a) A schematic illustration of two primary dendrite arms on an otherwise planar solid/liquid inferface is shown below. With the aid of suitable diagrams, discuss why secondary and tertiary arms form.



(b) The grain structure and hence the mechanical properties of a cast metal may be completely determined by the nucleation process

(i) Explain the above statement
(ii) What is the significance of the critical radius?
(iii) Explain the effect of foreign particles, such as inclusions, on nucleation.

2(a) What are the main differences between solidification of alloys and that of pure metals?

(b) A Ge-La ingot containing 10 ppm La is solidified at V = 8 x 10^{-3} cm/s with negligible convection. Show schematically, the composition along the length of the fully solidified ingot, giving the initial composition and lengths of the initial and final transients.

Assume D_L = 5 x 10^{-5} cm^2/s, K = 0.1, C_t = 27 wt % La
For the initial transient,

$$X_s = X_o \left[1-(1-K)\exp -\frac{KVx}{D_L}\right]$$

HINTS: Length of final transient is equivalent to characteristic width of concentration profile. At initial transient/steady state contact, $X_s = 0.67\ X_0$.

3(a) What is the primary function of a riser and what is its optimum shape?

(b) Why is the optimum riser shape not employed in foundry practice?

(c) How are the limitations in part (b) of the optimum riser shape accounted for in most risers?

(d) Determine the dimensions of a riser (i.e. diameter and height) that can be used to produce a casting with length, width and diameter of 10, 5 and 2 in., respectively.

4(a) Discuss the formation of interdendritic shrinkage.

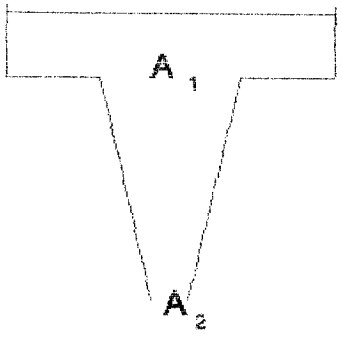
(b) Why is it so pronounced in certain types of alloys?

(c) What steps can be taken to eliminate interdendritic shrinkage?

(d) What is a pipe and how can its formation be minimised?

5(a) Why is it important that gas is not aspirated into the metal stream during casting?

(b) In the pouring cup-downsprue system shown below, derive the relationship between A_1 and A_2 which will ensure that gas aspiration into the metal stream is avoided.



(c) Why is it essential to have an optimum pouring time during casting?

(d) Calculate the pouring time of a 8 x 12 x 25 in. casting using a 1.5 x 1.5 in. ingate (or opening to the mould cavity) and a constant head of 4 in. (neglect orifice and frictional effects).

$$V = 27.7 \sqrt{h} \quad \text{inches/sec}$$

END OF EXAMINATION IN MM523

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

MM 533

FUELS, FURNACES AND REFRACTORIES

TIME: THREE HOURS

ANSWER: ALL QUESTIONS

---

1. (a) Describe four factors affecting the temperature attained in the combustion of a fuel. (8%)

(b) The heat of combustion of methane is -881.25 kJ at 298 K. Calculate the maximum theoretical flame temperature when one mole of CH_4 is completely burnt in calculated amount of air just sufficient for combustion at a constant pressure.

Data:

$$CH_4\ (g) + 2O_2\ (g) = CO_2\ (g) + 2H_2O\ (l) \qquad \Delta H^0_{298} = -881.25\ kJ$$

$$H_2O\ (l) + H_2O\ (g) \qquad \Delta H^0_{298} = 43.60\ kJ$$

$$C_p\ (CO_2) = 26.00 + 43.5 \times 10^{-3}T - 148.3 \times 10^{-7}T^2$$

$$C_p\ (H_2O_{(g)}) = 30.36 + 9.61 \times 10^{-3}T + 11.8 \times 10^{-7}T^2$$

$$C_p\ (N_2) = 27.30 + 5.23 \times 10^{-3}T - 0.04 \times 10^{-7}T \quad (12\%)$$

2. (a) Describe two ways in which oil may be burned. (2%)

(b) Sketch three typical oil burners used. (4%)

(c) Define the term Flash Point. (1%)

(d) Outline five sources of gaseous fuels and state the advantages of gaseous fuels over solid and liquid fuels. (6%)

(e) Describe the Fractional Distillation of Petroleum into its components. (8%)

3. Describe the Alumino-Silicate refractories with reference to the Al_2O_3-SiO_2 phase diagram. Outline the production of firebricks and give <u>three</u> uses. (20%)

4. (a) With the aid of a diagram show the important allotropic forms of silica. (5%)

(b) Describe <u>four</u> properties of silica bricks. (4%)

(c) What has been the <u>two</u> principal uses of silica bricks. (4%)

(d) It is almost impossible to cool a furnace with silica brickwork below 300°C. Why? (4%)

5. (a) Give a definition of Special Refractories. (2%)

(b) Describe the Sintering Process as used in the firing of most special refractories. (5%)

(c) What is the difference between Zircon and Zirconia? What are the principal minerals from which Zircon and Zirconia are obtained? Describe the manufacture of Zircon and Zirconia ware. Where are they applied? (10%)

(d) How do insulation materials derive their low thermal conductivity? Outline <u>four</u> examples of insulation raw materials. (5%)

END OF EXAMINATION IN MM533

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATION - NOVEMBER/DECEMBER 1994

MM 544 - SPECIAL TOPICS IN EXTRACTIVE METALLURGY

TIME: THREE HOURS
ATTEMPT: FIVE QUESTIONS, QUESTION NO. 4 IS COMPULSARY.

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1. What is scrap! What is the importance of metal recycling? Describe the methods of recycling of copper, tin, lead and gold in the relevant industries.

2(a) Anode copper contains the following impurities:

As, Sb, Fe, Ni, Co, Pb, Zn, Cd, Be, Au, Ag, Te, Se, Pt, Sn and In.

Based on thermodynamic considerations how can these elements be removed during fire refining of anode copper.

(b) By the use of predominance area diagram for the system Cu-Fe-S-O-SiO_2 describe the physico-chemical principles of matte smelting and converting.

(c) How do temperature, matte grade and chemical composition of slags affect copper losses? What methods are commonly used in the reduction of copper-losses in slags?

(d) By reference to the chemical reactions involved in (b) above. describe the formation of magnetite in the copper production unit.

3a. What is the Warner Process! What are the special characteristics of this new technology?

b. Write short but clear notes on the fluid/solid reaction systems in extractive metallurgy, i.e. reactions of a single nonporous solid particle, single porous particle and reactions between solids that occur with the aid of gaseous intermediates. Relate such reaction systems, for example in the calcination of limerock, and reduction of nickel and iron oxides to their respective metals.

4(a) The ratio CO/CO_2 of the top gas leaving a hemetite charged blast furnace is approximately 1. The carbon supply rate (including carbon-in-iron, 5 wt %C) is 500 kg per tonne of product Fe. What is the enthalpy supply to this furnace, assuming that the blast enters and the top gas leaves at 298K. How can this entalpy supply be increased without increasing the fuel or oxygen supplies? Draw the corresponding RIST diagram.

(b) A blast furnace is operating with dry hot air blast at 1450 K. The charge consists of hematite (5% SiO_2) sinter, CaO and coke (assume pure C). Its product metal contains 5 wt.% carbon (ignore other impurities) and its slag may be considered to consist only of CaO and SiO_2 (CaO/SiO_2 wt. ratio = 1.2). Calculate analytically for this operation:

(i) the wustite reduction zone heat demand - D^{WI}

(ii) E^{δ}: What does this term mean?

(iii) The carbon requirement per tonne of Fe;

(iv) The blast requirement per tonne of Fe; and

(v) The top gas composition.

5 The kinetics of leaching processes depends on several variables. What are these variables. Discuss the effects of each variable.

6a. Discuss the kinetics of cementation and relate it to the cementation of copper by iron as a typical example.

(b) In the cementation of copper, the copper concentration in the leaching solution can be reduced to very low levels. Assume a dilute sulphuric acid solution in which the activity coefficient of the ferrous ion in 0.2. The solution leaves the cementation launder at 25°C and contains 0.6g/l of iron. Estimate the residual equilibrium copper content of the exit stream.

END OF EXAMINATION - MM 544

UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATION - NOVEMBER/DECEMBER 1994

MM 553

PROCESS DESIGN

TIME: THREE Hours
ANSWER: FIVE Questions
All questions carry equal marks

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1. Fuel oil ($C_{18}H_{36}$) is burned in 50 percent excess dry air. The products of combustion are dried to remove all the water. Analysis of the flue gas shows a ratio of CO_2 to CO of 2, on a molar basis. Determine the flue gas composition in mole percent and the volumetric flow rate (m^3/h) at 150°C and 124 kPa after drying if 2300 kg/h of fuel oil is burned.

   The gas constant R = 8.314 J/mol.K
   Atomic weights: C, 12; H, 1; N, 14; O, 16.

2.(a) Suggest how the following sets of equations may be solved:

(i)
$$f_1(x_1, x_2, x_3) = 0$$
$$f_2(x_2) = 0$$
$$f_3(x_2, x_3) = 0$$

(ii)
$$f_1(x_1, x_2, x_3) = 0$$
$$f_2(x_1, x_3) = 0$$
$$f_3(x_1, x_4) = 0$$
$$f_4(x_1, x_3, x_4) = 0$$

(b) You are working in a laboratory and are requested to melt 100 kg of stainless steel, AISI type 304, with an analysis of 17.5% Cr, 8.5% Ni and 0.5% Mn. If there is a 10% loss in Ni from the charge during melting, calculate the charge that you would use for the following available materials:

%:	Cr	Ni	Fe	Mn
alloy scrap	68	20	10	2
ferrochromium	75		25	
electro Ni		100		
electro Fe			100	

3. A furnace burns a liquid coal for fuel derived from coke-ovens. Calculate the heat transferred (in kJ/kg of fuel) in the furnace if the combustion gases leave at 1500K. The burners operate with 20 percent excess air, average heat capacity being 28.9 kJ/kmol.K. Take the fuel supply temperature as 50°C and air temperature as 15°C.

   The properties of the fuel in wt % are:

   Carbon, 87.5; Hydrogen, 8.0; Oxygen, 3.5; Nitrogen, 1.0

Net calorific value	39 540 kJ/kg
Latent heat of vaporisation	350 kJ/kg
Heat capacity	1.6 kJ/kg.K

Cp of gases, kJ/kmol.K

$Cp = a + b\,T$

Component	a	$bx10^2$
CO_2	19.8	7.3
H_2O	32.2	19.0×10^{-2}
O_2	28.1	-3.7×10^{-4}
N_2	31.1	-1.4

Atomic weights: C, 12; H, 1; O, 16; N, 14

4.(a) Briefly give three different contexts in which depreciation may be described.

(b) For a project, estimated to last 10 years, revenue from annual sales and total annual expense over a three-year period are given in the following table:

Year	A_s	A_{TE}
	K	K
0	0	0
1	400 000	100 000
2	500 000	100 000
3	500 000	110 000

The fixed capital investment, C_{FC}, is K1 000 000. Plant items have a zero salvage value. Working capital, W_{WC}, is K90 000, and the cost of land, C_L, is K10 000. There are no tax allowances other than depreciation. The fractional rate of tax, t, is 0.50. Using straight-line depreciation accounting and a discount factor of 10%, calculate

(i) the annual discounted cash flow for each year

(ii) the cumulative net present value (NPV) at the end of each year.

5. Oil is to be warmed from 300K to 344K by passing it at 1 m/s through the pipes of a shell-and-tube heat exchanger. Steam at 377 K condenses on the outside of the pipes, which have outer and inner diameters of 48 and 41 mm respectively; but, owing to fouling, the inside diameter has been reduced to 38 mm, and the resistance to heat transfer of the pipe wall and dirt together, based on this diameter, is 0.0009 $m^2.K/W$. Take the steam side heat transfer coefficient as 10 000 $W/m^2.K$.

It is known from previous measurements under similar conditions that the oil side coefficients for a velocity of 1 m/s, based on a diameter of 38 mm, vary with the average temperature of the oil according to the table below:

Oil temperature (K)	300	311	322	333	344
Oil side coefficient of heat transfer ($W/m^2.K$)	74	80	97	136	244

The specific heat and density of the oil may be assumed constant at 1.9 kJ/kg.K and 900 kg/m^3 respectively, and any resistance to heat transfer on the steam side neglected.

Find the length of the tube bundle required for countercurrent operation and concurrent operation.

6(a) Explain briefly the significance of the "specific speed" of a centrifugal or axial-flow pump.

(b) A pump is designed to be driven at 10 Hz and to operate at a maximum efficiency when delivering 0.4 m^3/s of water against a head of 20m. Calculate the specific speed. What type of pump does this value suggest?

(c) A pump, built for these operating conditions, has a measured maximum overall efficiency of 70%. The same pump is now required to deliver water at 30 m head. At what speed should the pump be driven if it is to operate at maximum efficiency? What will be the new rate of delivery and the power required?

END OF EXAMINATION IN MM 553

THE UNIVERSITY OF ZAMBIA

UNIVERSITY EXAMINATIONS - NOVEMBER/DECEMBER 1994

MM 554

SPECIAL TOPICS IN MINERAL PROCESSING

Time: Three hours

Answer: FIVE questions
All questions carry equal weight (20 %).
At least three questions (or more, if you want to) should be answered from Section A.

SECTION A. Answer at least three questions out of the following five questions.

1. At successive stages in a concentrator, an ore has the following characteristics:

product	maximum particle size (d_{95})	grade (% TCu)	particle size distribution factor
mill feed	1.0 cm	1.0	0.25
cyclone overflow	250 µm	1.0	0.5
concentrate	250 µm	25.0	0.5
tailings	250 µm	0.1	0.5

If it may be assumed that the copper is present essentially as chalcopyrite (34 % Cu, SG 4.2), with a liberation size of 125 µm, and that the average SG of the gangue is 2.7, calculate for each of these four products the minimum sample size required if an error of 5 % in the estimation of the grade of the product is permissable.

Given: Gy's 'sampling slide rule':

l:	0.8	0.5	0.2	0.1	0.05	0.02
d/d_0:	1-4	4-10	10-40	40-100	100-400	400

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2. (a) Draw up a scheme for sampling final crusher product (80 % -10 mm) which is delivered to a concentrator mill bin on an inclined conveyor. The objective is to obtain reliable chemical analyses of shift composite samples. Briefly explain the successive sub-sampling steps that are required in your scheme.

(b) As part of a flotation plant survey, the concentrates of two parallel banks of flotation cells were sampled during one shift. The analyses (% TCu) of the two sets of hourly samples are as follows:

bank 1:	18.66 % TCu	bank 2:	19.88 % TCu
	19.78 ""		20.42 ""
	21.56 ""		21.24 ""
	20.84 ""		21.76 ""
	22.26 ""		24.14 ""
	20.94 ""		20.58 ""
	20.38 ""		20.72 ""

On the basis of these results, and at a 95 % confidence level, would you say that there is a significant difference between these two banks of cells ?

3. A phosphate ore is being tested for beneficiation by flotation. Mineralogical examination has established that the ore contains 23 % apatite and 17 % iron oxides. The remainder is essentially silicate gangue.

Flotation tests established the following half-lives for these three components:

apatite:	75 seconds
iron oxides:	4 minutes
silicates:	30 minutes

(a) What are the specific rates of flotation for the apatite, for the iron oxides and for the silicate gangue ?

(b) What are the recoveries of apatite into the concentrate that can be expected after two minutes of flotation and after a total of seven minutes of flotation ?

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(c) What concentrate grades (% P_2O_5) can be expected after two minutes of flotation and after seven minutes of flotation ?

You may assume this flotation process to be a first order rate process. For the sake of simplicity, you may assume that all the apatite particles have the same rate of flotation, regardless of particle size and degree of liberation (assume that all apatite particles are free) and that, likewise, all the iron oxide particles and all the silicate particles have the same rate of flotation.

Assume that the apatite contains, on average, 40 % P_2O_5.

4. A copper sulphide ore has been tested for beneficiation by flotation. Mineralogical examination established that the only copper mineral present is chalcosite (Cu_2S) and that the ore contains 2.40 % Cu_2S. Grinding tests established that grinding for 18 minutes in the laboratory ball mill completely liberated 50 % of the chalcosite. The middling particles then averaged 60 % Cu_2S. At this grind, 40 % of the gangue was ground to -45 µm and some of these free gangue slimes were carried over in the froth.

On the basis of these findings, calculate the recoveries and grades that can be expected theoretically if this ore, at this grind, is treated in one flotation stage, and if it is treated in four successive flotation stages.

You may assume the following simplified flotation probabilities to be applicable in each stage:

free Cu_2S:	0.5
locked Cu_2S:	0.2
liberated gangue slimes:	0.02

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.

(b) Show that F_L is, in effect, a modified Froude number for the slurry.

(c) 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 1200 and 1800 liter per minute.

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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}.

SECTION B.

6. (a) Show how the maximum possible recovery of a mineral under particular conditions of flotation in a batch flotation test can be estimated by plotting cumulative recovery against cumulative flotation time.

(b) (i) Give the equation that relates the cumulative flotation recovery of a mineral after any time to the maximum possible recovery, and define the symbols used in this equation.

(ii) Give the same equation, including a 'time correction factor'.

(iii) Why is this time correction factor often used with the interpretation of batch flotation test data ?

(iv) What is the main assumption when you use these equations in the interpretation of batch flotation test data ?

(c) Show how results from a batch flotation test can be used to establish the specific rate of flotation of the minerals floated and the proper value of the time correction factor to be used.

(d) (i) How would you define an optimum separation time for a valuable component and the gangue in a flotation process ?

(ii) Express this optimum separation time in terms of the data established by a batch flotation test.

(e) Briefly describe the main steps in the release analysis method of flotation testing.

(f) What would you consider to be the main advantage of the release analysis method over other methods of flotation testing with laboratory batch flotation tests ?

7. (a) (i) What is the relationship between solids concentration and interface height ('mudline height'), that was established by Kynch and used by Talmage and Fitch in their method for the estimation of a required unit thickener area ?

(ii) The Talmage and Fitch relationship incorporates an 'underflow time', t_u. Briefly describe two different methods to find t_u from the results of a batch settling test.

(b) The solids flux in a batch settling test consists of only one component. In a thickener in continuous operation the solids flux consists of two components.

(i) What are these two components ?

(ii) Draw a generalised diagram of solids flux against solids concentration in the thickener region below the feedwell for each of these two components and for the total resultant solids flux.

(iii) Draw the 'limiting solids flux' or 'solids handling capacity' of the thickener under these conditions in your diagram.

(iv) Describe briefly what is likely to happen if the thickener is operated above the limiting solids flux for some time.

(v) Which operating parameter controls the value of the limiting solids flux ?

8. (a) Briefly describe the difference(s) in characteristics between rotodynamic pumps with radial flow impellers and pumps with axial flow impellers.

What are typical applications for axial flow pumps ?

(b) What do you understand by the 'shut-off head' of a centrifugal pump ?

(c) Explain briefly, but clearly, why a centrifugal pump must be primed before it can pump a liquid.

(d) Discuss the effect of changes in the following fluid properties upon the performance of a centrifugal pump

- fluid density
- fluid viscosity
- fluid temperature

Where possible, illustrate with rough diagrams of the corresponding H-Q and P-Q characteristics.

(e) For what applications would you choose a centrifugal pump with a flat H-Q characteristic, and when would you choose a centrifugal pump with a steep H-Q characteristic ?

Explain your answers briefly and illustrate with (a) diagram(s), if possible.

- END OF EXAMINATION MM 554 -