

**ROYAL CIVIL SERVICE COMMISSION  
BHUTAN CIVIL SERVICE EXAMINATION (BCSE) 2012  
EXAMINATION CATEGORY: TECHNICAL**

**PAPER III: SUBJECT SPECIALIZATION PAPER for GEOLOGY**

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| <b>Date</b>             | : 14 October 2012                        |
| <b>Total Marks</b>      | : 100                                    |
| <b>Examination Time</b> | : 150 minutes (2.5 hours)                |
| <b>Reading Time</b>     | : 15 Minutes (prior to examination time) |

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**READ THE FOLLOWING INSTRUCTIONS CAREFULLY:**

1. Write your Roll Number clearly on the Answer Booklet in the space provided.
2. The first 15 minutes is being provided to check the number of pages, printing errors, clarify doubts and to read the instructions. You are NOT PERMITTED TO WRITE during this time.
3. Use either Blue or Black ink pen or ball point pen for the written part and Pencils for the sketches and drawings.
4. All answers should be written on the Answer Booklet provided. Candidates are not allowed to write anything on the question paper or any other materials.
5. All answers must be labeled with appropriate question numbers (Section, Question and sub-Question Numbers wherever applicable). Unlabelled answers will not be assessed.
6. This paper is divided into two sections-namely SECTION A and SECTION B.
7. SECTION A consists of two parts: Part I and Part II.

Part I consists of 30 Multiple-Choice Questions carrying one (1) mark each and is compulsory. The answer of your choice should be clearly written in whole along with the question and option number on your answer booklet. Eg. 31(c).

Part II consists of four (4) short answer questions of five (5) marks each and all questions are compulsory.

8. SECTION B consists of two Case Studies. Choose only ONE case study and answer the questions under your choice. Each case study carries fifty (50) marks in total.
9. This Paper consists of NINE (9) pages including this Instruction page.

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**SECTION A**

**PART I - Multiple Choice Questions**

Choose the correct answer and write down the letter of the correct answer chosen in the Answer Sheet against the question number. E.g. 31 (c). Each question carries ONE mark.

1. Polymorphism in minerals means:
  - a) same chemical formula but different crystal structures
  - b) same crystal structure but different chemical formulas
  - c) biotite, muscovite, and phlogopite
  - d) none of the above
  
2. Fossiliferous limestone is a:
  - a) sedimentary rock
  - b) igneous rock
  - c) metamorphic rock
  - d) none of the above
  
3. Ophiolites are pieces of:
  - a) continental crust
  - b) oceanic crust
  - c) island arc
  - d) none of the above
  
4. In the northern hemisphere, morning shadows point to the west direction while shadows right before the sunset point to the east direction. At noon, shadows will point:
  - a) south
  - b) north
  - c) do not point in any direction
  - d) none of the above
  
5. The average thickness of an oceanic crust is:
  - a) 10 km
  - b) 20 km
  - c) 30 km
  - d) 40 km
  
6. Gneiss is a textural term that indicates:
  - a) low temperature metamorphism
  - b) rocks experienced temperature high enough to segregate felsic and mafic minerals

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- c) nothing to do with metamorphism
- d) relics of sedimentary features

7. Protolith of paragneiss is:

- a) sedimentary rock
- b) igneous rock
- c) metamorphic rock
- d) none of the above

8. Foliation and lineation are examples of:

- a) rock fabrics
- b) sedimentary structure
- c) igneous texture
- d) metamorphic reaction texture

9. According to the law of original horizontality:

- a) sedimentary rocks form horizontal or near horizontal layers
- b) sedimentary rocks do not form horizontal or near horizontal layers
- c) sedimentary rocks are inclined
- d) sedimentary rocks are bent

10. Composition zoning in minerals tell us:

- a) minerals are homogeneous
- b) multiple stages of mineral growth
- c) one stage of mineral growth
- d) none of the above

11. Good example of oceanic-continental collision is:

- a) the Himalayas
- b) the Andes
- c) Mariana trench
- d) Appalachian mountains

12. The statement "The summit of Mt. Everest is marine limestone" tells us that:

- a) Mt. Everest was once under the sea
- b) Mt. Everest was never under the sea
- c) Mt. Everest was always at its elevation
- d) none of the above

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13. Joints and faults are distinguished by:

- a) offset
- b) veins
- c) folds
- d) none of the above

14. In a strike-slip fault, the hanging wall:

- a) moves horizontally relative to the foot wall
- b) moves downwards relative to the foot wall
- c) does not move relative to the foot wall
- d) none of the above

15. The correct order of ages (oldest-youngest) in geologic time scale is:

- a) Devonian, Silurian, Ordovician, Cambrian
- b) Cambrian, Ordovician, Silurian, Devonian
- c) Permian, Carboniferous, Devonian, Silurian
- d) Silurian, Devonian, Ordovician, Cambrian

16.  $\text{CaMg}(\text{CO}_3)_2$  is a chemical formula for the mineral:

- a) gypsum
- b) talc
- c) dolomite
- d) limestone

17. Key factors determining metamorphism are:

- a) pressure and temperature
- b) grain size and crystal structure
- c) pressure, temperature, and composition
- d) none of the above

18. The term foliation is applied to a:

- a) sedimentary rock
- b) metamorphic rock
- c) igneous rock
- d) none of the above

19. The softest mineral is:

- a) calcite
- b) talc

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- c) gypsum
- d) apatite

20. 360° azimuth is same as .....

- a) 270°
- b) 090°
- c) 000°
- d) 180°

21. The Himalayan mountain range is the result of collision between:

- a) Indian and Eurasian plates
- b) Australian and Indian plates
- c) Nazca and North American plates
- d) Pacific and Australian plates

22. In sillimanite zone, mineral assemblages include:

- a) quartz, muscovite, biotite, garnet, plagioclase
- b) quartz, muscovite, biotite, garnet, staurolite, plagioclase
- c) quartz, muscovite, biotite, garnet, kyanite, plagioclase
- d) quartz, muscovite, biotite, garnet, sillimanite, plagioclase

23. Geologists agree that the age of our Earth is approximately:

- a) 4.6 Ma
- b) 4.6 Ka
- c) 4.6 Ga
- d) 15 Ga

24. Earth's radius is approximately:

- a) 6,378 km
- b) 6378 miles
- c) 6500 km
- d) 6500 miles

25. The concept that rocks at the bottom of a sedimentary sequence are the oldest is the basis for:

- a) the principle of original horizontality
- b) Newton's law of gravity
- c) the principle of superposition
- d) the principle of inclusions

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26. The principle of cross-cutting relationships states that, if rock A cuts across the boundaries of rock B, then:

- a) A is older than B
- b) B is older than A
- c) A and B are of the same age
- d) no conclusions about the relative age can be made

27. The principle of inclusions states that, if a fragment of rock A is included in another rock B, then:

- a) A is older than B
- b) B is older than A
- c) A and B are of the same age
- d) no conclusions about the relative age can be made

28. In a Barrovian sequence, a shale parent rock undergoing full sequence of metamorphism is:

- a) phyllite, slate, schist, gneiss
- b) slate, phyllite, schist, and gneiss
- c) schist, phyllite, slate, gneiss
- d) gneiss, slate, phyllite, schist

29. The Mg-endmember garnet is:

- a) Almandine
- b) Pyrope
- c) Spessartine
- d) Grossular

30. Undulose extinction and serrate grain boundaries of quartz crystals indicate:

- a) plastic deformation
- b) brittle deformation
- c) recovery of quartz crystals
- d) none of the above

**PART – II : Short Answer Questions (20 marks)**

**Answer ALL the questions. Each question carries 5 marks.**

- 1) How would you map shear zone in the field?
- 2) Differentiate pure shear from simple shear.
- 3) How are stress, strain, and deformation related?
- 4) Besides pressure and temperature conditions, what are the other important factors that control metamorphism in rocks?

**SECTION B : Case Study**

**Choose either Case 1 or Case 2 from this Section. Each Case carries 50 marks.**

**CASE 1**

The Geological Survey of India (GSI) reports high enrichment of rare earth elements (REEs) in south-central Bhutan hosted within iron-stone band of the Siwalik Group. The REE content inside the iron-stone band is anomalously high (ca. 2600-10,000 ppm) compared to its average crustal abundance (ca. 6-8 ppm). To cross-check this unique enrichment of REEs within the synorogenic sediments and evaluate economic viability, the Department of Geology and Mines intends to undertake reconnaissance mapping first and then detailed exploration involving various stages. You are assigned as a principal investigator of this exploration project, outline and describe various stages (I, II, III, and even development phase) of exploration.

Your report should follow the outline below:

1. Introduction

- what is the purpose of this project?
- why your department wants to undertake this project?
- where is the mineralized zone/area?

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### 2. Geologic Setting (based on previous work)

- Regional Geology
  - the Main Boundary thrust (MBT) that emplaces the Baxa Group atop the Siwalik Group
  - Baxa Group:
  - Siwalik Group: synorogenic sediments
- Local Geology
  - dominated by Siwalik Group
  - contains iron-stone bands (remember this is not banded iron formation)
  - iron-stone bands host REEs

### 3. Stage I: Reconnaissance study

- preliminary mapping
- grab iron-stone sample (atleast three representative samples from bottom, middle, and top of the section)

Now whether to continue with next stages will depend on several things such as grade, thickness, strike extension of mineralized bands, proximity to the existing infrastructure, and so on.

### 4. Stage II: Detailed Mapping

- stratigraphic section
- bottom section
- middle section
- top section
  
- surveying, geologic cross-section, tracing of iron-stone band
- widely spaced boreholes (drilling)
- geochemical analyses (sampling)

### 5. Stage III

- closely space boreholes
- improved geologic cross section based on bore hole data
- calculation of reserve (proven)

### 6. Stage IV: Developmental Phase



**CASE 2**

Two recent seismic events (September 21, 2009 and September 18, 2011) were a wake-up call for Bhutan and a reminder that the country is located within an active seismic zone. Considering the scale of damage inflicted to lives and infrastructure by these moderate-sized earthquakes (magnitudes of 6.3 and 6.9, respectively), the Royal Government of Bhutan has realized the urgent need for seismic hazard assessment and zonation to re-evaluate building codes. The Department of Geology and Mines is instructed to take up seismic hazard assessment as a project of national urgency. The department has nominated you as a team leader to undertake this project immediately.

Describe methods you are going to adopt;

i) Installation of seismic network

- present seismotectonic characterization
- future historical record
- crustal deformation

ii) Geodetic (GPS) measurement

- monitor India-Asia convergence rate
- decreasing convergence rate and seismic hazard

iii) Paleoseismologic study

- date past earthquakes for estimating recurrence interval
- seismic gap

iv) Mapping of active faults

- presence of active faults increases seismic hazard
- necessary for seismic zonation

v) Tectonic geomorphology

- geomorphic indices