ROYAL CIVIL SERVICE COMMISSION
BHUTAN CIVIL SERVICE EXAMINATION (BCSE) 2023
EXAMINATION CATEGORY: TECHNICAL

PAPER III: SUBJECT SPECIALISATION PAPER FOR GEOLOGY

Date	: October 7, 2023
Total Marks	: 100
Writing Time	: 150 minutes (2.5 hours)
Reading Time	: 15 minutes (prior to writing time)

GENERAL INSTRUCTIONS:

1. Write your Registration Number clearly and correctly on the Answer Booklet.
2. The first 15 minutes is to check the number of pages of Question Paper, printing errors, clarify doubts and to read the instructions. You are NOT permitted to write during this time.
3. This paper consists of **TWO SECTIONS**, namely SECTION A & SECTION B:
   - **SECTION A** has two parts: Part I - 30 Multiple Choice Questions
     Part II - 4 Short Answer Questions
     All questions under SECTION A are **COMPULSORY**.
   - **SECTION B** consists of two Case Studies. Choose only **ONE** case study and answer the questions of your choice.
4. All answers should be written on the Answer Booklet provided to you. Candidates are not allowed to write anything on the question paper. If required, ask for additional Answer Booklet.
5. All answers should be written with correct numbering of Section, Part and Question Number in the Answer Booklet provided to you. Note that any answer written without indicating the Section, Part and Question Number will NOT be evaluated and no marks will be awarded.
6. Begin each Section and Part on a fresh page of the Answer Booklet.
7. You are not permitted to tear off any sheet(s) of the Answer Booklet as well as the Question Paper.
8. Use of any other paper including paper for rough work is not permitted.
9. **You must hand over the Answer Booklet to the Invigilator before leaving the examination hall.**
10. This paper has **7 printed pages**, including this instruction page.

GOOD LUCK

SECTION A

PART I: Multiple Choice Questions [30 marks]

Choose the correct answer and write down the letter of your chosen answer in the Answer Booklet against the question number e.g. 31 (d). Each question carries ONE mark. Any double writing, smudgy answers or writing more than one choice shall not be evaluated.

1. Who is known as the Father of Geology?
   a) Alfred Wegener
   b) Charles Lyell
   c) James Hutton
   d) Nicolas Steno

2. The process of mountain building is known as:
   a) Weathering
   b) Subduction
   c) Volcanism
   d) Orogenesis

3. In the northern hemisphere, morning shadows point to the west direction while shadows right before the sunset point to the east direction. At noon, shadow will point:
   a) South
   b) North
   c) East
   d) None of the above

4. The type of magma that contains the least silica is:
   a) Felsic
   b) Intermediate
   c) Mafic
   d) None of the above

5. How many tectonostratigraphic zones are there in Bhutan?
   a) Two
   b) Three
   c) Four
   d) Five

6. The coal in Bhutan is found in which formation?
   a) Phuntsholing formation
   b) Manas formation
   c) Gondwana formation
   d) Siwalik formation

7. Which of the following is/are Principle of stratigraphy?
   a) Law of superposition
   b) Principle of cross cutting relationship
   c) Principle of lateral continuity
   d) All of the above

8. Protolith of orthogneiss is a _____.
   a) Sedimentary rock
   b) Metamorphic rock
   c) Igneous rock
   d) All of the above

9. In the normal 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

10. The process of chemical alteration of minerals due to exposure to water and air is called:
   a) Weathering
   b) Erosion
   c) Volcanism
   d) Metamorphism

11. Which geological era is known as the "Age of Reptiles"?
   a) Paleozoic Era
   b) Mesozoic Era
   c) Cenozoic Era
   d) Proterozoic Era

12. Which one of the following minerals is the hardest?
   a) Calcite
   b) Quartz
   c) Apatite
   d) Talc

13. Which geological eon is the most recent one, representing the time since complex life forms appeared?
   a) Archean Eon
   b) Proterozoic Eon
   c) Phanerozoic Eon
   d) Hadean Eon

14. The process of soil formation is known as:
   a) Weathering
   b) Erosion
   c) Pedogenesis
   d) Cementation

15. The region where Indian Plate is getting subducted beneath the Eurasian Plate is known as:
   a) Main Frontal Thrust
   b) South Tibetan Detachment
   c) Indus-Tshangpo suture zone
   d) Main Central Thrust

16. The Lesser Himalayas are composed mainly of:
    a) Granite and gneiss
    b) Sandstone and shale
    c) Limestone and dolomite
    d) Basalt and andesite

17. The Himalayan Mountain range was formed as a result of the collision between which two tectonic plates?
    a) Indo-Australian Plate and Pacific Plate
    b) Eurasian Plate and African Plate
    c) Indian Plate and Eurasian Plate
    d) North American Plate and South American Plate

18. The process by which sediments are converted into rock through compaction and cementation is called:
    a) Weathering
    b) Erosion
    c) Lithification
    d) Metamorphism

19. The Mohs scale is used to measure:
    a) Density of minerals
    b) Cleavage of minerals
    c) Hardness of minerals
    d) Lustre of minerals

20. The process of magma solidification that occurs beneath the Earth's surface is called:
    a) Intrusion
    b) Extrusion
    c) Erosion
    d) Weathering

21. The boundary between two rock layers where there is a marked change in lithology is known as:
    a) Fault
    b) Unconformity
    c) Joint
    d) Contact

22. Which type of seismic wave travels through the Earth's interior and causes the most damage during an earthquake?
    a) P-waves
    b) S-waves
    c) L-waves
    d) All of the above

23. The process of changing one rock type into another through heat and pressure without melting is called:
    a) Metamorphism
    b) Weathering
    c) Diagenesis

d) Fusion

24. The azimuth reading of 330/50 (dip direction and dip amount) is same as:
    a) S30°E/50°
    b) N30°W/50°
    c) S60°E/50°
    d) N60°W/50°

25. The largest and deepest ocean on Earth is:
    a) Indian Ocean
    b) Atlantic Ocean
    c) Pacific Ocean
    d) Arctic Ocean

26. The geologic eon that represents the largest span of time in Earth's history is the _____ Eon.
    a) Archean
    b) Proterozoic
    c) Phanerozoic
    d) Hadean

27. The contacts of vertical beds of sedimentary rocks will
    a) run parallel to contour lines.
    b) cut the contour lines with low angle.
    c) cut the contour line with 90°.
    d) 'V down' along the depression and 'V up'along the ridges.

28. The point on the Earth's surface directly above the origin of an earthquake is called the:
    a) Epicenter
    b) Focus
    c) Seismic zone
    d) Seismometer

29. Which mineral is the primary constituent of granite?
    a) Quartz
    b) Calcite
    c) Feldspar
    d) Mica

30. The layer of the Earth's interior that lies directly beneath the lithosphere is called the:
    a) Mantle
    b) Asthenosphere
    c) Outer core
    d) Inner core

PART II – Short Answer Questions [20 marks]

This part has 4 Short Answer Questions and ALL are compulsory. Each question carries 5 marks

1. What is the difference between Geological Resource and Geological Reserve?
2. Explain about the Geological Time Scale?
3. Explain the concept of plate boundaries and the geological phenomena associated with each type?
4. Briefly explain the concept of rock deformation and provide examples of different types of folds and faults observed in Bhutan/Himalayas?

SECTION B: Case Study [50 marks]

Choose either CASE I OR CASE II from this section. Each case study carries 50 marks.

CASE I

Bhutan has a huge deposit of dolomite across the country dominantly within the Manas Formation of Lesser Himalayan Sequence (LHS). The dolomites are one of the important raw materials for iron and steel, ferroalloys, glass, alloy steels, fertilizer and cement industry. One such dolomite deposit is located at Sunargaon under Phuntshopelri Gewog, Samtse Dzongkhag and it is located 8 km from Gomtu town and about 3 km from Pugli town. The occurrence of dolomite at Sunargaon is first identified by Geological Survey of India (GSI) during the regional mapping of Dolomite in 1965.
Given the demand of dolomite from the industries in India, the Department of Geology and Mines plans to undertake detailed exploration of dolomite at Sunargaon. For this exploration you are assigned as the Exploration Geologist. Write a geological report for the detailed exploration carried out. The report must be written based on detailed geological map, cross-sections, chemical assay and should comprise detailed description of following:

1. Introduction (5 Marks)
2. Regional Geology (5 Marks)
3. Material and Methods (10 Marks)
4. Results and Discussions (15 Marks)
5. Conclusions and Recommendations (10 Marks)
6. Reference (5 Marks)

The following information can be used to write the report:

1. Introduction
   - ❖ Brief background, significance and scope of the study.
   - ❖ Aim, objective or purpose of the study
   - ❖ Description of the study area including locations, accessibility, topography, drainage, climate, flora and fauna.
   - ▪ the study area falls within subtropical zone and is about 145 acres and located between Sukti stream on the west and Pugli stream on the east.
   - ▪ Information to be used for the report:
     - ✓ Area 145 acres on the scale of 1:2000
     - ✓ Geological reserve 20.7 million metric tons
     - ✓ Average grade: CaO - 30.09%, MgO - 20.71%, AI (acid insoluble) - 1.15%, R2O3 - 1.50%

2. Geological setting
   - ❖ Regional Geology
     - ▪ Study area falls within Manas formation (Baxa Group)
   - ❖ Local Geology
     - ▪ Lithology from lower to upper – 1) Dull white quartzite (15-50m thick).
       2) Dolomite (350m thick)
       3) Carbonaceous phyllite (20-30m thick)
     - ▪ Dolomite – light grey to white and grey to creamy, fine grained, feebly crystalline, thin to moderate bedded, highly jointed and fractured, massive dolomite with minor carbonaceous and dark grey dolomite interbed
     - ▪ Orientation – Strike NW-SE, Strike length – 1.5km, dip 45 to 50, Dip direction- NE

3. Detailed Exploration
   - ❖ Accurate delineation of an identified deposit.
   - ❖ Topographical survey and geological mapping in large scale. Decide mapping scale and traverse spacing based on the scope of work and area of the site.
   - ❖ Pitting and trenching. Decide pitting and trenching numbers and spacing based on scope of work and scale of mapping.
   - ❖ Diamond drilling. Decide number and spacing of boreholes based on scope of work and scale of mapping.
   - ❖ Sampling of dolomite outcrops and geochemical analysis.
   - ❖ Construction of geological cross-sections.
   - ❖ Calculation of geological reserve (proven) using cross-sectional method. Take specific gravity of dolomite as 2.7.
   - ❖ Sketch of a geological map containing structural data, delineation of rock types, location of pits, trenches, boreholes, samples or sampling lines, and cross-section lines. Include all mandatory elements of map (for e.g. Legend, Title etc.).

CASE II

Bhutan, much like the rest of the Indian subcontinent, was influenced by the Earth's tectonic forces. The country's formation can be attributed to the collision between the Indian and Asian tectonic plates that occurred millions of years ago. The geological landscape of Bhutan is characterized by the thickening of the Earth's crust and the folding and thrusting of metamorphic, metasedimentary, and sedimentary rocks. This type of geological setting exemplifies a continental-continental convergent plate boundary. As a result, Bhutan possesses valuable geological resources, including rocks and minerals, which play a crucial role in the country's industrialization and infrastructural development.
Write a report on geological setting and mineral resources of Bhutan. The report should include, but not limited to, the following:

- Orogenesis of Bhutan Himalaya. You may write down the continental drifting event since split of Gondwana till present.
- Sketch of Bhutan map showing geological setting. The map should include four major tectonostragraphic zones, Paro Formation and major structures.
- Description of the geological setting from south to north. The description of tectonostratigraphic zones should include their respective rock types and relative age.
- Sketch of Bhutan map showing mineral resources distribution.
- Description of non-metallic and metallic mineral resources of Bhutan. The details should contain names of the major mineral deposits and construction materials, their locations either related to tectonostratigraphic zones or dzongkhag or region, currently mined mineral deposits and construction materials, and major uses of the minerals and construction materials that are described.

TASHI DELEK