ROYAL CIVIL SERVICE COMMISSION
BHUTAN CIVIL SERVICE EXAMINATION (BCSE) 2016
EXAMINATION CATEGORY: TECHNICAL

PAPER III: SUBJECT SPECIALIZATION PAPER FOR GEOLOGY

Date:	2 October 2016
Total Marks:	100
Examination Time:	150 minutes (2.5 hours)
Reading Time:	15 minutes *(prior to examination time)*

GENERAL INSTRUCTIONS

1. Write your Registration Number clearly and correctly on the Answer Booklet.
2. The first 15 minutes is being provided to check the number of pages, printing error, clarify doubts and to read instructions in Question Paper. You are NOT permitted to write during this time.
3. This paper consists of **TWO Sections, namely Section A and 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 2 case studies. Choose only **ONE** case study and answer the questions under 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 correct Section, Part and Question Number will NOT be evaluated and no marks would be awarded.
6. Begin each Section and Part in 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 are required to hand over the Answer Booklet to the Invigilator before leaving the examination hall.
10. The Question paper has 9 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 (c). Each question carries ONE mark. Any double writing, smudgy answers or writing more than one choice shall not be evaluated.

1. The age of earth is estimated as
   a. 3.6 Ga
   b. 4.6 Ga
   c. 2.6 Ma
   d. 4.6 Ma

2. In geological time scale, Miocene is
   a. younger than Eocene.
   b. younger than Holocene.
   c. older than Jurassic.
   d. older than Ordovician.

3. Oceanic crusts are relatively
   a. thicker than continental crusts.
   b. lighter than continental crusts.
   c. similar in thicknesses and densities as continental crusts.
   d. thinner and denser than continental crusts.

4. When the hanging wall moves upward relative to the footwall with angle of fault plane <45°, the fault is called
   a. normal fault
   b. strike-slip fault
   c. thrust fault
   d. reverse fault

5. _____ is a phenomenon in which, mineral changes occur in rocks due to adjustments to conditions of dropped temperature and pressure.
   a. Retrograde metamorphism
   b. Prograde metamorphism
   c. Solidification
   d. Diagenesis

6. Ore mineral of tungsten is_____.
   a. chalcopyrite
   b. pyrite
   c. scheelite
   d. galena

7. The Himalayan orogeny is a typical example of

   a. transform plate boundary
   b. divergent plate boundary
   c. continental-continental plate collision
   d. continental-oceanic plate collision

8. Bhutan geology represents a deformed (folded-thrusted) sedimentary rocks that were once deposited in

   a. northern region of Indian plate and in the Tethys sea.
   b. northern region of Indian plate.
   c. Tethys sea.
   d. southern region of Eurasian plate.

9. Thrust fault places

   a. metamorphic rocks over the igneous rocks.
   b. sedimentary rocks over the metamorphic rocks.
   c. younger rocks on top of the older rocks.
   d. older rocks on top of the younger rocks.

10. The fold-thrust belt of Bhutan Himalaya is divided into four major geo-tectonic zones bounded by major thrust faults. Which is the youngest geo-tectonic zone?

    a. Greater Himalayan Section (GHS)
    b. Lesser Himalayan Section (LHS)
    c. Sub-Himalayan Zone
    d. Tethyn Himalayan Zone

11. In general, the grade of metamorphism in Bhutan

    a. increases towards north from south.
    b. increases towards south from north.
    c. remains almost uniform from south to north.
    d. increases in the central but decreases in south and north.

12. What is the average crustal abundance of gold?

    a. 4 ppm
    b. 4 ppb
    c. 1000 ppb
    d. 1000 ppm

13. Arsenopyrite (FeAsS) is the “pathfinder mineral” to

    a. copper
    b. iron
    c. tin
    d. gold

14. The azimuth dip of limestone bed 300/35 is same as
    a. S30°W/35° SE
    b. S30°E/35° SW
    c. N30°E/35° NW
    d. N30°W/35° NE

15. To establish a litho-stratigraphy of an area, a geological traverses as far as possible must be planned in such a way that
    a. it runs along the strike direction.
    b. it runs across the strike direction.
    c. it runs along the lithological contacts.
    d. it runs across the topographic ridges.

16. Leucogranites are chiefly composed of
    a. mafic minerals
    b. felsic minerals
    c. micas
    d. plagioclase minerals

17. _____ is a rock texture that shows embedding of phenocrysts (large crystals) within groundmass (small crystals).
    a. Poikilitic texture
    b. Granoblastic texture
    c. Aphanitic texture
    d. Porphyritic texture

18. Which one is the geological map symbol of joint with attitude N45°E/45°NW?
    a. 

    b. 

    c. 

    d. 

19. Other causative factor conditions considered similar, the frequency and density of landslide occurrences will be high in areas where
    a. dip direction of beddings or foliations of bedrocks are against the slope directions of the topography.
    b. dip direction of beddings or foliations of bedrocks coincide with the slope directions of the topography.
    c. strike of beddings or foliations of bedrocks are against the slope directions of the topography.
    d. strike of beddings or foliations of bedrocks coincide with the slope directions of the topography.

20. The contacts of horizontal beds of sedimentary rocks if not faulted, thrusted or folded will
    a. cut the contour lines with 90°.
    b. cut the contour lines with low angle.
    c. run parallel to contour lines.
    d. 'V down' along the depressions and 'V up' along the ridges.

21. Quartz vein embedded with chalcopyrite is cut across by calcite vein. The chalcopyrite mineralization is
    a. older than calcite vein.
    b. younger than calcite vein.
    c. same age as calcite vein.
    d. younger than quartz vein.

22. When the earthquake strikes, _____ cause the loss of lives and properties.
    a. primary waves or push-pull waves
    b. secondary waves or shear waves
    c. long waves or surface waves
    d. body waves

23. Sandstone is a typical example of
    a. aquitard
    b. aquiclude
    c. aquifuge
    d. aquifer

24. Which rock is used as main raw material in Ferro-Silicon industry?
    a. dolomite
    b. talc
    c. marble
    d. quartzite

25. A ductile deformation of rocks tends to occur in
    a. low pressure-temperature environment.
    b. high pressure-temperature environment.
    c. mantle.
    d. uppermost part of the crust or near earth's surface.

26. Which mineral occur only in metamorphic rocks?
    a. quartz
    b. muscovite
    c. kyanite
    d. garnet

27. Trace elements in rocks and minerals occur in concentration

    a. <1000 ppm
    b. > 1000 ppm
    c. < 1 weight percent
    d. > 1 weight percent

28. The place that lies vertically above the origin of earthquake is known as

    a. focus
    b. hypocenter
    c. epicenter
    d. seismic shield area

29. Breccias and/or linear arrangement of spring water are indication of

    a. foliation
    b. fold
    c. bedding
    d. fault

30. Industrial minerals have been defined as

    a. minerals which are used as raw materials in mineral-based industry.
    b. rocks which are used as raw materials in mineral-based industry.
    c. any rock or mineral of economic value, exclusive of metallic ores, mineral fuels and gemstones.
    d. any rock or minerals of economic value, inclusive of metallic ores and gemstones but exclusive of mineral fuels.

PART II – Short Answer Questions (20 marks).

This part has 4 Short Answer Questions. Answer ALL the questions. Each question carries 5 marks.

1. During geological mapping, depending on the purpose, the scale of mapping will differ. Explain the differences between large-scale and small-scale mapping in terms of area coverage and data details that need to be collected. Give an example each for these two mapping scales.

2. What key elements are required for constructing a geological cross-section? Describe the procedures in sequence for its construction. Why geological cross-section is important? Provide one example where cross-section is used.

3. Describe the four main types of faults with respect to the regional stress regime. Which one is the dominant major structure in Bhutan?

4. Explain the term ore, gangue, and tenor and provide one example each. Write down the differences between mineral reserve and resource. What are the three types of reserve?

SECTION B

Case Study

Choose either Case 1 or 2 from this section. Each case study carries 50 marks.

Case 1

The ongoing collision between Indian plate and Eurasian since ca. 55 Ma has resulted in development of Himalayan fold-thrust belt and different mineralization across the belt. The geology is quite homogenous along the entire Himalaya with four major tectonostragraphic zones: Tethyn Zone, Sub-Himalayan Zone, Greater Himalayan Section (GHS), and Lesser Himalayan Section (LHS), bounded by continental-scale structures of varying ages such as Main Central Thrust (MCT), Main Boundary Thrust (MBT), Main Frontal Thrust (MFT), Kakhtang Thrust (KT) and South Tibetan Detachment (STD). Paro Formation is interpreted as a tectonic window comprising of metasedimentary rocks that are equivalent to LHS rocks.

In general, the Himalayas are not hosts to significant mineral deposits. However, the Bhutan Himalaya perhaps is an exception to other parts of Himalayas. The country is endowed with several industrial minerals and a fuel mineral. Most of these minerals are currently mined and form an important supply chain to mineral-based industry in Bhutan that produce *calcium carbide, cement, ferrosilicon, chicken feeds* and *plaster of Paris (POP)*. Few minerals are exported to India and Bangladesh. Bhutan also has huge potential for exporting construction materials. Occurrence of significant metallic mineralization are also known in the country. Considering the rock types, their age and stratigraphy of Gondwana succession within LHS in the south east, Bhutan perhaps is also potential for hosting petroleum deposits.

Write a report on geological setting and mineral resources of Bhutan. The report should include but not limited to the following:

- origin 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.
- details on the non-metallic and metallic mineral resources of Bhutan. The details should contain the 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.

OR

Case 2

Bhutan has huge limestone resource of ~181 million metric tonnes along the foothills. Limestone composes of more than 50% calcium carbonate ($CaCO_3$). Based on the grade, limestone can be broadly categorized into two: *(1) chemical grade limestone* and *(2) cement grade limestone*. Those limestones that contain > *50% of CaO* and < *1% of MgO* are classified as chemical grade limestone. It is mainly used in the calcium carbide industry. The limestones that contain > *46% of CaO* and *1-4% of MgO* are classified as cement grade and used for cement production.

A team from Department of Geology & Mines (DGM) during the course of regional geological mapping in the 12th Five Year Plan has identified/located a limestone band in Bagala and Idi area under Zhemgang Dzongkhag. Assay value from the chemical analysis of two random grab samples carried out by Geochemical Laboratory of DGM indicated that the limestone is of chemical grade. DGM therefore intends to undertake the reconnaissance geological mapping first and then detailed exploration (if the results of reconnaissance mapping are found promising). You are assigned as a principal investigator for this project. Write a report outlining and describing various exploration stages (stage I, II, and III). A geological report is a scientific report and therefore its key components in chronological manner are: (1) Introduction, (2) Geological Setting, (3) Materials and Methods, (4) Results and Discussions, (5) Conclusions and Recommendations, and (6) References. Other important components are table of content, acknowledgement, appendices, figures, maps, photos, tables etc.

The report should follow the outline provided below and describe them in detail (do not forget to describe the materials and methods, results, conclusions and recommendations in Stage I, II and III; but no need to repeat the introduction and geological setting in these stages):

1. Introduction

    - demonstrate or justify why need the exploration? – gap or problem. Clear link between problem and solution.
    - state clearly the objectives, aim and scope
    - study area (location, accessibility, vegetation, climatic conditions, topography, drainage, flora and fauna etc.)

Note: The prospect area falls within sub-tropical zone and the nearest road head is about 2.5 hour walk.

2. Geological setting (as from regional mapping)

    - Regional Geology:

        - LHS: Daling-Shumar Group, Baxa Group; low-grade to un-metamorphosed metasedimentary rocks
        - Daling-Shumar Group emplaced on top of Baxa Group by Shumar Thrust (ST)
        - Baxa Group emplaced on top of Siwalik Group by Main Boundary Thrust (MBT)
        - Baxa Group: Phuntsholing Formation, Manas Formation, Pangsari Formation.

- Siwalik Group: Syn-orogenic sediments and un-metamorphosed sedimentary rocks

- Local Geology:
  - limestone within Manas formation
  - major rock types from footwall (bottom) to hanging wall (top) section: phyllite, dolomitic limestone, limestone, phyllite and quartzite
  - average regional strike and dip of bedding and foliation is N20°W/15° NE

3. Stage I: Reconnaissance mapping
   - preliminary mapping using existing topographic maps. Decide the scale yourself. Your traverse spacing and area coverage will depend on the mapping scale.
   - grab sampling (representative samples from bottom, middle and top section).
   - sketch of a geological map containing structural data, delineation of rock types and location of samples. Include all the mandatory elements of map (for e.g. legend).

   Note: Making decision for undertaking next stage (Stage II) will depend on the results of Stage I. Information such as grade, thickness, strike length, possible reserve, feasibility to mine in terms social and environment impacts, and economic viability would form critical in this stage.

4. Stage II: Detailed mapping
   - mapping in large scale of top, middle and bottom section with surveying. Decide the scale yourself. Your traverse spacing and area coverage will depend on the mapping scale.
   - accurate tracing of both concealed and unconcealed limestone contacts
   - widely-spaced boreholes (diamond drilling)
   - geochemical analyses
   - construction of geological cross-sections
   - calculation of reserve (probable)
   - sketch of a geological map containing structural data, delineation of rock types, location of boreholes, borehole samples and cross-section lines. Include all the mandatory elements of map (for e.g. legend).

5. Stage III: Detailed exploration
   - closely spaced boreholes
   - improved geological cross-sections
   - calculation of reserve (proven)
   - sketch of a geological map containing structural data, delineation of rock types, location of boreholes, borehole samples and cross-section lines. Include all the mandatory elements of map (for e.g. legend).

   Note: The geological map will be same as the map of Stage II, except that this map will contain more location of boreholes and samples. The number and location of section lines on this map may also differ.