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# 

# CHAPTER – 1: GEOLOGICAL MAPPING (TOPOSHEET WISE/GEOLOGICAL EXPEDITION) IN 1:50,000 SCALE

The geological mapping not only generates geological information such as geology and mineral resources of the nation but it also help in understanding geological hazards. The geological maps produced through this process help delineate fragile habitat and ecosystems and protect against natural geological hazards. Further, the geological maps form vital tool in providing information for intelligent land-use planning and growth. Today, the geological mapping coverage of Bhutan stands to be around 39%. Recognizing the importance of carrying out geological mapping and having geological map, the Geological Survey of Bhutan with its limited number of geologists will strive to carry out geological mapping through adoption of the standards or procedures and guidelines given below.

### 1.1 EQUIPMENTS, TOOLS & MATERIALS NEEDED

1. Handheld GPS
2. Geological Compass
3. Geological Hammer
4. Hand lens
5. Altimeter
6. Stereoscope
7. Meter tape
8. Digital Camera
9. Copies of geological maps of Bhutan (1:500,000)
10. Topomaps of the region or area (1:25,000 and 1: 1:50000 scales)
11. Hard copies of remote sensing image/s covering the map area in 1:100,000 scale
12. Chisel
13. Masking tapes and sample bags
14. Field notebooks
15. Pencils, sharpener, erasers, pens, colour pencils, marker pens
16. Diluted HCL
17. Pocket magnet
18. Streak plate
19. Pen knife

The following work process will be followed to carry out geological mapping or geological expedition in 1:50000 scale:

### PRE-FIELD ACTIVITIES

#### 1.2.1 Literature Survey and Desktop Study

1. Collect geological information from existing /available map of the region.
2. Gather all the available literature such as geological reports, research papers, journals etc. of the region or area concerned and go through all these available information.
3. Gather all the available remote sensing data such as Landsat, ALOS and Google earth imageries and do a desktop study of these images.
4. Prepare base map of the region or area by overlaying these satellite image/s on topomap (1:25,000 and 1:50,000). The base map must have geographic coordinate grids with 1 minute spacing.
5. Make consultations with geologists or researchers who have worked in the region or area or in similar projects. Have thorough discussions with supervisory officers and get proper guidance from them.
6. Locate camp sites, markets, and communication facilities; and familiarize with approachability, local places, settlements, land-use, outcrop availability etc. using the available information and prepare a traverses plan and its scheduling.

### FIELD ACTIVITIES

#### 1.3.1 Preliminary (reconnaissance) Field Work

1. Familarize with the stratigraphy in the area by making geological traverses in the easily accessible area such as along the road or trail in the first few days of the field work. Take short notes of the geological observations made.
2. Plan the main traverses ahead, based on the acquired actual information and pre-planned purposes identified during desktop study.
3. Prepare the updated version of traverse plan. Based on the accessibility of the area, traverse line should be fixed at least at the spacing of 500m and 250 m apart in the direction normal to the regional strike of rock formation for 1:50000 and 1:250000 base map respectively.

#### 1.3.2 Main Field Work

##### 1.3.2.1 Outcrop Analysis and Record

1. Start of each day should contain the information such as a) Date and Time b) Name of Traverse and intended purpose c) Name/s of professional partner (if any) on the new page of the field notebook.
2. Keeping in the mind that the main objective of geological mapping being mapping every litho-unit, and identifying and locating the economic minerals, every outcrop has to be assessed thoroughly and recorded with adequate spacing.
3. Record the station number or way point number and GPS location (geographic coordinate unit) of each geological observation in the field book. Save the same in the GPS as well.
4. Note the morphology of the outcrop: hill, flat, river, creek, road, cliff, saddle, etc.
5. Note the nature of exposure; continuous, partly covered, blocky, massive, fragmental
6. Note the heterogeneity and homogeneity of exposed rocks
7. Inspect for colour, textural and mineralogical variations occurring in a relatively homogeneous outcrops
8. Closely examine the lithostratigraphic relationships among different type of rocks in heterogeneous outcrops
9. Describe each identified rock type: colour, degree of weathering, texture/grain size, mineralogy, etc.
10. Describe the type of contact in adjacent litho-units: sharp, graditional
11. Note the nature of structural features on the outcrop: simple, complex, etc
12. Identify structures in each of litho-units: primary (formational), secondary (deformational)
13. Describe the identified structures: type, attitude, geometry, age
14. Make sketches/photographs of outcrops with significant information on the geologic history. The sketched or photographed features must show appropriate scale and compass orientation. Note the number of the photograph, direction of view, etc in the field notebook.
15. Conclude the outcrop analysis with interpretation remarks on the genesis, lithostratigraphy, structural history and/or problems of interpretation
16. Take rock samples for comparisons with other similar outcrops, further microscope characterization of litho-units and/or solving particular problems noted on the outcrop.
17. Transfer observation points on the 1:25000 scale base map in the field and colour mark sample locations.
18. Delineate contacts of lithologies on the base map
19. Summarize acquired field data and identify problems to be worked out
20. Transfer the data on the 1:50000 scale fair base map in the evening at the field camp.

##### 1.3.2.2 Sampling

1. Based on the outcrop analysis, decide what to sample (rock, fossil or mineral) and its purpose
2. Collect only unweathered samples from the outcrop. Weathered material if any are trimmed off.
3. Mark the position of sectioning of specimens for simple petrographic study
4. Samples for specific petrographic/polished thin section studies (ex. Structural study) should have compass orientation marks and attitude of geological feature to be studied
5. Give the number to each sample with reference to locality name and station number. Give the same number on the masking tape and sample bag as well.
6. Record samples collected and reasons for further study on the note book

Note/Remark:

1. The observed and written records at each observation point need to be comprehensive and legible to be of use to any other geologist
2. Cross sections should also be made at a point, where geology is complex
3. It is desirable to make as much observations on good outcrops
4. The weekly field data has to be evaluated and summarized at the field camp.
5. During the course of regional mapping, if encountered with traces of some important mineralization, locate and record it in the map and give more importance in the area by collecting more geological data, samples and if time permits, carry out tape and compass survey on large scale. If you are unable to identify the mineral, bring the sample to the Head office for group discussion.
6. Make log for samples collected towards the last pages of field book.
7. At the month end, the officer In-charge needs to summarize and submit the progress report along with base map, findings, problems etc., to the Heads of Division and Section. He/she may submit samples for chemical analysis and carry out miscellaneous office works. Discuss with Heads about their field visit plan and further planning of work.
8. The heads will make field visit every month to supervise and quality check the work and suggest any changes required with a note of observations.

### POST-FIELD ACTIVITIES

#### 1.4.1 Data analysis, Map Preparation and Interpretation, Report Writing, and Presentation

1. Submit all the samples to the Geosciences Laboratory of the Department for analysis.
2. Download all the GPS data on the computer and overlay it on the topographic base map using GIS
3. Plot all the structural attitudes on the map and delineate the litho-unit contacts using V-rules and make interpretations of any geologic features.
4. Construct cross-section/s and make scientific and logic interpretations on it. It is very vital to maintain the proper direction and amount of dip while drawing the geologic contacts on the topographic profile.
5. Download all the photographs.
6. Once the entire required information is ready, the team shall write a geological report. The geological report of geological mapping should have contents outlined in the table:

|  |  |  |
| --- | --- | --- |
| **Contents of Geological Mapping (Toposheet-wise/Geological Expedition in 1:50,000 scale)** | | |
| **Sl. No** | **Component name/Content** | **Remark** |
|  | **Cover/title page**  Containing the following information in chronological order:   1. DGM logo 2. Ministry 3. Department 4. Division 5. Report Title 6. Photograph (most appropriate picture taken from the area) 7. Author name/s 8. Editor name/s 9. Field Season Period |  |
|  | **Abstract**  A very brief account on:-   1. Location 2. Objectives 3. Methods/techniques used 4. Lithologies 5. Structure 6. Highlights of finding and conclusion 7. Mineral resources in the area 8. Suggestion for further study | The abstract is concise summary of the report. It should attract the reader in terms of findings and should spell out the results of the study not what the report is about.  It is condensation and concentration of essential information. It does not include undiscussed information and references to text, tables and other works.  Avoid the use of terms such as discussed, concluded or investigated. |
|  | **Table of contents**   1. Headings and subheadings ordered according to rank 2. Page column showing page number from which a chapter starts 3. List of Figures 4. Figure number 5. Figure caption 6. Page number 7. List of Tables 8. Table number 9. Table caption 10. Page number 11. List of Plates 12. Plate number 13. Title of plate | Use appropriate indentation to separate heading/sub-headings. Include page numbers for list of figures, tables, plates etc.  Do not include page number for the title page and contents page.  The list of figures, tables and plates should be descriptive. |
|  | **Introduction**  Objective and Scope   1. Statement on the objective/purpose 2. Summary of method and approach 3. Scope of the work/state briefly contents of report 4. Statement on new findings |  |
|  | **Location and Accessibility**   1. Location with respect to the known place/s 2. Boundary limits of the area in geographic coordinates and toposheet number 3. Size of the area in sq.km 4. Main and branch access route, its type and distance etc. to the study area with reference to popular place/s or known place/s | This section is should be accompanied by location map of the area in Google earth image or topomap, showing some well-known places, roads and rivers. |
|  | **Physiography/Geomorphology/Topography and Drainage**   1. Major landforms and its characteristics 2. Statement on drainage basin and drainage patterns 3. Relation of drainage to physiographic features/geology/structure | This should not be mere explanation of topographic division using elevation ranges. It should be a brief summary of geomorphological features in the mapped area, from both field observations and analysis of Google earth DEM data or topomap.  Include appropriate photographs. |
|  | **Climate, Vegetation and Wildlife**   1. General climatic condition with respect to regional perspective 2. Statement of dry and rainy seasons (local scale) 3. Statement of temperature variation (local scale) 4. Notes on precipitation, humidity etc. (local) 5. Description on types of vegetation 6. Statement on types of wildlife and condition | Information includes both field observation and other sources. |
|  | **Previous Geological Studies**   1. Statement about relevant geological studies, that has been made within the limits area 2. Statement on earlier geological studies close to study area 3. Notes on the purpose and results of previous studies 4. Statement on significant geological opinions forwarded as compared to earlier or current investigation:  * Survey of what has been done * What they have written and said | This is short summary to indicate references to earliest and most recent works. The question is who has worked previously, what method was applied and what was the finding (result).  Include year of work, purpose and important conclusion. |
|  | **Methods and Techniques Applied**   1. Note on pre-field preparation, material, method and techniques employed 2. Summary of field geological activities:  * Nature and density of traverse including duration of field work * Type and number of rock samples collected, specifying kind of analysis to be made * Statement on field data base and map preparation  1. Notes on geochemical analysis (if any)  * Purpose and type of analysis made * Procedures and methods of analysis * Number of samples analyzed  1. Data acquisition analysis and interpretation  * Type of data analyzed and kind of method (software) used * Techniques of interpretation  1. Final report and map preparation  * Format and software used for final metadata base, report writing, map and illustration | This is an explanation to what has been done. It should be clear, concise and detailed statement of current work process and techniques employed in a sequential order. |
|  | **Regional Geology** | Regional geological map showing major lithologies may be included. |
|  | **Geology of the Mapped Area** | This section should include detailed description on lithology, metamorphism and structures in the mapped area.  Stratigraphic table (if more than two lithology) is required.  Include field photographs.  Structures described must be clear representation of factual data and interpretation based on supporting references such as cross-section, stererographic projection etc. |
|  | **Economic Geology**   1. Overview on the kinds of mineral resources and construction materials occurring in the study area, including brief information on social & environmental aspects, and existing/abandoned mining/quarrying site. 2. List of mineral and construction material resources with geographical location (GPS), extent, geological attributes of each resources 3. Note on previous/current mining/quarrying activities (if any) | Map showing the location of the resources can be added. |
|  | **Conclusions and Recommendations**   1. Summarized remarks on tectono-stratigraphy, significant natural resources 2. Notes on the findings of the study and interpretation 3. Suggestions for further investigation or research |  |
|  | **Acknowledgements**   1. Courtesy to anyone or institutions that have contributed/shared ideas in the course of study 2. Acknowledgements to sources of figures or tables incorporated (if provided by anyone and not published) 3. Appreciation to anyone or organization who provided non-technical help towards the accomplishment of the field work |  |
|  | **References**   1. List of articles used or referred in the report 2. References alphabetically order by author and year 3. Sequence of referencing and typography according to standard conventions |  |
|  | **Appendix/Appendices**  Additional supporting information that is not main part of the report. It includes:   1. List of places in the mapped area referred in the report with location coordinate 2. List of rock/mineral samples collected with location coordinate, brief description and purpose 3. List and location of structural data measured in the field 4. Mineralogical & textural attributes of petrographically studied rocks |  |

1. In order to maintain the standards of geological report, all the reports shall be reviewed and endorsed for publication by editorial board of the department as per office order no. DGM/2011-2012/32/1441 dated 03/04/2012. To do so, concerned geologist will submit the draft report to the board for review within ***three months*** from the date of the completion of field work. The board shall review and endorse the report within ***two weeks*** from the date of its receipt. The quorum of the board will consist of minimum three members.
2. The endorsed report (three hard & one soft) must be submitted to the library and one hard copy to the Mining Division within two weeks.
3. The field team must make overall presentation within 15 days from the submission of the report to inform the department on the project. The officer in-charge should organize the presentation. The presentation will outline the following:
4. Title
5. Location and Accessibility (with map)
6. Geomorphology
7. Objectives
8. Methodology/Techniques Applied
9. Regional Geology
10. Geology of the Mapped Area
11. Economic Geology
12. Findings/Results
13. Recommendations
14. The MLTC of the department shall assess the report if it indicates some potential mineral reserves in the study area. The assessment shall be in terms of socio-economic viability, environmental considerations and the existing policies of the government. The committee based on the assessment may recommend for detailed exploration of the intended mineral to the Mineral Exploration Section.
15. The Head of Geological Mapping & Mineral Exploration Section will update the information generated from the project in the Database of the Section and also do the same in the National Geosciences Database System of the Department.

# 

# CHAPTER – 2: MINERAL EXPLORATION

Mineral is a hidden treasure of a nation that lies below the earth surface. Geological mapping, remote sensing & geophysical techniques will be used for generating mineral exploration targets. This targets generated will be assessed both qualitatively and quantitatively through three stages of exploration in order to assess its economic potentiality or viability for development.

## STAGE-I – PRELIMINARY (RECCONNAISSANCE) EXPLORATION

### 2.1.1 EQUIPMENTS, TOOLS AND MATERIALS NEEDED

1. Handheld GPS
2. Geological Compass
3. Geological Hammer
4. Hand lens
5. Altimeter
6. Stereoscope
7. Meter tape
8. Digital Camera
9. Copies of geological maps of Bhutan (1:500,000)
10. Regional geological map (1:50,000 scale)
11. Topomap of the area (1:25,000 scales)
12. Chisel
13. Masking tapes and sample bags
14. Field notebooks
15. Pencils, sharpener, erasers, pens, colour pencils, marker pens
16. Diluted HCL
17. Pocket magnet
18. Streak plate
19. Pen knife

The following work process will be followed for carrying out stage –I exploration:

### PRE-FIELD ACTIVITIES

#### 2.1.2.1 Literature Survey and Desktop Study

1. Collect geological information from existing /available map of the area.
2. Gather all the available literature such as geological reports, research papers, journals etc. of the area concerned and go through all these available information.
3. Gather all the available remote sensing data such as Landsat, ALOS and google earth imageries and do a desktop study of these images.
4. Prepare base map of the region or area by overlaying these satellite image/s on topomap (1:25,000). The base map must have geophraphic coordinate grids with 30 minute spacing.
5. Make consultations with geologists or researchers who have worked in the region or area or in similar projects. Have thorough discussions with supervisory officers and get proper guidance from them.
6. Locate camp sites, markets, and communication facilities; and familiarize with approachability, local places, settlements, land-use, outcrop availability etc. using the available information and prepare a traverses plan and its scheduling.

### FIELD ACTIVITIES

#### 2.1.3.1 Preliminary (reconnaissance) Field Work

1. Familiarize with the stratigraphy in the area by making geological traverses in the easily accessible part of the target area in the first few days of the field work. Take short notes of the observations made on the mineral band or Ore.
2. Plan the main traverses ahead, based on the acquired actual information and pre-planned purposes identified during desktop study.
3. Prepare the updated version of traverse plan. Based on the accessibility of the area, traverse line should be fixed at least at the spacing of 250 m apart in the direction normal to the regional strike of rock formation.

#### 2.1.3.2 Main Field Work

##### 2.1.3.2.1 Mineralized band or Ore Analysis and Record

1. Start of each day should contain the information such as a) Date and Time b) Name of Traverse and intended purpose c) Name/s of professional partner (if any) on the new page of the field notebook.
2. Keeping in the mind that the main objective of Preliminary Exploration being verifying the type and nature of the targeted mineral deposit, and deducing its possible reserve and grade, every exposure with mineral occurrences/ ore has to be assessed thoroughly and recorded with adequate spacing.
3. Record the station number or way point number and GPS location (geographic coordinate unit) of each observation in the field book. Save the same in the GPS as well.
4. Note the morphology of the exposure: hill, flat, river, creek, road, cliff, saddle, etc.
5. Note the nature of exposure; continuous, partly covered, blocky, massive, fragmental
6. Describe the mineral band or ore: colour, degree of weathering, texture/grain size, mode of occurrence, type of deposit, size, extend (strike length), thickness etc.
7. Describe and measure the identified structures: type, attitude, geometry
8. Conclude the mineralized band or ore analysis with interpretation remarks on the genesis, structural interpretation and/or problems of interpretation
9. Collect fresh grab samples for chemical analysis to determine its quality.
10. Transfer observation points on the 1:25000 scale base map in the field and colour mark sample locations.
11. Delineate contacts of mineralized band or ore band on the base map
12. Summarize acquired field data and identify problems to be worked out
13. Transfer the data on the fair base map in the evening at the field camp.

##### 2.1.3.2.2 Sampling

1. Collect only unweathered or fresh samples from the mineralized band or ore. Weathered material if any are trimmed off.
2. Give the number to each sample with reference to locality name and station number. Give the same number on the masking tape and sample bag as well.
3. Record samples collected and its purpose on the note book

Note/Remark:

1. The observed and written records at each observation point need to be comprehensive and legible to be of use to any other geologist
2. Cross sections should also be made at a point, where geology is complex
3. It is desirable to make as much observations on good outcrops
4. The weekly field data has to be evaluated and summarized at the field camp.
5. Make log for samples collected towards the last pages of field book.
6. At the month end, the officer-incharge needs to summarize and submit the progress report along with base map, findings, problems etc., to the Heads of Division and Section. He/she may submit samples for chemical analysis and carry out miscellaneous office works. Discuss with Heads about their field visit plan and further planning of work.
7. The heads will make field visit every month to supervise and quality check the work and suggest any changes required with a note of observations.

### POST-FIELD ACTIVITIES

#### 2.1.4.1 Data analysis, Map Preparation and Interpretation, and Report Writing

1. Submit all the samples to the Geosciences Laboratory of the Department for analysis.
2. Download all the GPS data on the computer and overlay it on the topographic base map using GIS.
3. Plot all the structural attitudes on the map and delineate the mineralized band or ore band contacts on the host rock or with reference to host rock.
4. Construct cross-section/s and make scientific and logical interpretations on it. It is very vital to maintain the proper direction and amount of dip while drawing the contacts on the topographic profile.
5. Download all the photographs.
6. Once the entire required information is ready, the team shall write a preliminary (reconnaissance) mineral exploration report. The report should have the contents outlined in the table:

|  |  |  |
| --- | --- | --- |
| **Contents of Stage – I : Preliminary (reconnaissance) Mineral Exploration** | | |
| **Sl. No** | **Component name/Content** | **Remark** |
|  | **Cover/title page** | Refer to Sl. No. 1 under Section 1.4.1. vi, Chapter -1 |
|  | **Abstract** | Refer to Sl. No. 2 under Section 1.4.1. vi, Chapter -1 (Need not write on the Mineral Resources in the Area) |
|  | **Table of contents** | Refer to Sl. No. 3 under Section 1.4.1. vi, Chapter -1 |
|  | **Introduction** | Refer to Sl. No. 4 under Section 1.4.1. vi, Chapter -1 |
|  | **Location and Accessibility** | Refer to Sl. No. 5 under Section 1.4.1. vi, Chapter -1.  The size of study area must be in acres. |
|  | **Physiography/Geomorphology/Topography and Drainage** | Refer to Sl. No. 6 under Section 1.4.1. vi, Chapter -1 |
|  | **Climate, Vegetation and Wildlife** | Refer to Sl. No. 7 under Section 1.4.1. vi, Chapter -1 |
|  | **Previous Exploration Studies** | Refer to Sl. No. 8 under Section 1.4.1. vi, Chapter -1 |
|  | **Methods and Techniques Applied**   1. Note on pre-field preparation, material, method and techniques employed 2. Summary of field exploration activities:  * Nature and density of traverse including duration of field work * Type and number of mineralized band or ore samples collected, specifying kind of analysis to be made * Statement on field data base and map preparation  1. Notes on geochemical analysis  * Purpose and type of analysis made * Procedures and methods of analysis * Number of samples analyzed  1. Data acquisition analysis and interpretation  * Type of data analyzed and kind of method (software) used * Techniques of interpretation  1. Final report and map preparation  * Format and software used for final metadata base, report writing, map and illustration | This is an explanation to what has been done. It should be clear, concise and detailed statement of current work process and techniques employed in a sequential order. |
|  | **Regional Geology** | Regional geological map showing major lithologies may be included. |
|  | **Geology of the Study Area** | Refer to Sl. No. 11 under Section 1.4.1. vi, Chapter -1 |
|  | **Economic Geology**   1. Detailed description on the mineral deposit: such as mode of occurrence, type of deposit, size, extend, thickness, etc. 2. Possible Reserve and Grade of the mineralized band or Ore | The reserve must be calculated based on either of the following (whichever is convenient or necessary for the type and nature of mineralized band or ore):   1. Cross-sectional method 2. Polygonal Method 3. Triangle method |
|  | **Conclusions and Recommendations**   1. Summarized remarks on mineralized band or ore 2. Notes on the findings of the study and interpretation 3. Recommendation to either proceed with next stage of exploration (Stage –II) or abandon the exploration target with strong justifications. |  |
|  | **Acknowledgements** | Refer to Sl. No. 14 under Section 1.4.1. vi, Chapter -1 |
|  | **References** | Refer to Sl. No. 15 under Section 1.4.1. vi, Chapter -1 |
|  | **Appendix/Appendices**  Additional supporting information that is not main part of the report. It includes:   1. List of places in the study area referred in the report with location coordinate 2. List of mineralized band or ore samples collected with location coordinate, brief description and purpose 3. List and location of structural data measured in the field |  |

1. In order to maintain the standards of geological report, all the reports shall be reviewed and endorsed for publication by editorial board of the department as per office order no. DGM/2011-2012/32/1441 dated 03/04/2012. To do so, concerned geologist will submit the draft report to the board for review within ***three months*** from the date of the completion of field work. The board shall review and endorse the report within ***two weeks*** from the date of its receipt. The quorum of the board will consist of minimum three members.
2. The endorsed report (three hard & one soft) must be submitted to the library and one hard copy to the Mining Division within two weeks.
3. The field team must make overall presentation within 15 days from the submission of the report to inform the department on the project. The officer in-charge should organize the presentation. The presentation will outline the following:
4. Title (also include stage of the investigation and team members)
5. Location and Accessibility (with map)
6. Geomorphology
7. Objectives
8. Methodology/Techniques Applied
9. Regional Geology
10. Geology of the Mapped Area
11. Economic Geology
12. Findings/Results
13. Recommendations
14. The MLTC of the department shall make assessment of the report in terms of socio-economic viability, environmental considerations and the existing policies of the government. The committee based on the assessment may recommend for stage –II exploration of the mineral to the Mineral Exploration Section.
15. The Head of Geological Mapping & Mineral Exploration Section will update the information generated from the project in the Database of the Section and also do the same in the National Geosciences Database System of the Department.

## STAGE-II – DETAILED SURFACE EXPLORATION

The stage –II mineral exploration will be carried out based on the recommendation of the stage –I exploration. During this stage detailed exploration including topographical survey on 1:1000 or 1:2000 scales, trenching, pitting and grove or channel sampling will be involved.

### EQUIPMENTS, TOOLS AND MATERIALS NEEDED

1. Handheld GPS
2. Geological Compass
3. Geological Hammer
4. Hand lens
5. Altimeter
6. Stereoscope
7. Meter tape
8. Digital Camera
9. Copies of mineralized band or Ore map of stage –I exploration (1:25,000 scale)
10. Chisel
11. Masking tapes and sample bags
12. Field notebooks
13. Pencils, sharpener, erasers, pens, colour pencils, marker pens
14. Diluted HCL
15. Pocket magnet
16. Streak plate
17. Pen knife
18. Spade
19. Crowbar
20. Surveying equipments and tools

The following work process will be followed:

### PRE-FIELD ACTIVITIES

#### Desktop Study

1. Go through the report, map and cross sections of stage –I exploration in detail
2. Prepare a base map (stage-I map) and make a work plan.

### FIELD ACTIVITIES

The main objective of Stage-II exploration is to determine the probable reserve and grade of the mineralized band or ore. Therefore following fieldwork process will be followed:

#### 2.2.3.1 Main work

1. Dig trenches to expose the concealed part of the mineralized band or ore. Pitting may be required to confirm the continuity of the band or ore.
2. Describe the mineral band or ore : colour, degree of weathering, texture/grain size, size, extend, thickness etc
3. Describe and measure the identified structures: type, attitude, geometry
4. Note down the GPS location and give location number on each observation made. A clear and prominent location mark (eg. Peg with location number) should be erected at a place were observation is made.
5. Topographical surveying at 1:000 or 1:2000 scales with 5 m contour interval has to be carried out using total station to prepare mineralized band or ore map. The topographical map should have the details of surface features such as drainage, escarpment, slides, footpath, roads, dwellings, vegetation etc. apart from the detail geology in it. Topographical surveying procedures and guidelines are given separately.
6. Each and every observations made will be located by total station during the surveying process.
7. Collect fresh groove or channel samples for chemical analysis to determine the grade of mineralized band or ore.
8. Transfer observation points on the base map in the field and colour mark sample locations.
9. Delineate contacts of mineralized band or ore band on the base map.
10. Summarize acquired field data and identify problems to be worked out.
11. Transfer the data on the fair base map in the evening at the field camp.

##### 2.2.3.1.1 Sampling

1. Cut groove or channel lines across the entire mineralized bands and collect meter age unweathered groove or channel samples in order to determine the grade persistency.
2. The groove or channel sampling should be carried out at a predetermined distance of about 100m along the strike of the non-metallic bands, in order to determine the grade persistency along the strike.
3. Give the number to each sample with reference to locality name and station number. Give the same number on the masking tape and sample bag as well.
4. Record samples collected and its purpose on the field note book

Note/Remark:

1. The observed and written records at each observation point need to be comprehensive and legible to be of use to any other geologist
2. Cross sections should also be made at a point, where geology is complex
3. It is desirable to make as much observations on good outcrops
4. The weekly field data has to be evaluated and summarized at the field camp.
5. Make log for samples collected towards the last pages of field book.
6. At the month end, the officer-incharge needs to summarize and submit the progress report along with base map, findings, problems etc., to the Heads of Division and Section. He/she may submit samples for chemical analysis and carry out miscellaneous office works. Discuss with Heads about their field visit plan and further planning of work.
7. The heads will make field visit every month to supervise and quality check the work and suggest any changes required with a note of observations.

### POST-FIELD ACTIVITIES

#### 2.2.4.1 Data analysis, Map Preparation and Interpretation, and Report Writing

1. Submit all the samples to the Geosciences Laboratory of the Department for analysis.
2. Download all the surveying data on the computer and prepare contour map with geological observation points.
3. Plot all the structural attitudes on the map and delineate the mineralized band or ore band contacts on the host rock or with reference to host rock.
4. Construct a series of cross-section/s and make scientific and logical interpretations on it. It is very vital to maintain the proper direction and amount of dip while drawing the contacts on the topographic profile.
5. Download all the photographs.
6. Once the entire required information is ready, the team shall write a Stage-II mineral exploration report. The report should have the contents outlined in the table:

|  |  |  |
| --- | --- | --- |
| **Contents of Stage – II : Detailed Surface Mineral Exploration** | | |
| **Sl. No** | **Component name/Content** | **Remark** |
|  | **Cover/title page** | Refer to Sl. No. 1 under Section 1.4.1. vi, Chapter -1 |
|  | **Abstract** | Refer to Sl. No. 2 under Section 1.4.1. vi, Chapter -1 (Need not write on the Mineral Resources in the Area) |
|  | **Table of contents** | Refer to Sl. No. 3 under Section 1.4.1. vi, Chapter -1 |
|  | **Introduction** | Refer to Sl. No. 4 under Section 1.4.1. vi, Chapter -1 |
|  | **Location and Accessibility** | Refer to Sl. No. 5 under Section 1.4.1. vi, Chapter -1.  The size of study area must be in acres. |
|  | **Physiography/Geomorphology/Topography and Drainage** | Refer to Sl. No. 6 under Section 1.4.1. vi, Chapter -1. |
|  | **Climate, Vegetation and Wildlife** | Refer to Sl. No. 7 under Section 1.4.1. vi, Chapter -1. |
|  | **Previous Exploration Studies** | This is short summary to indicate references to stage – I exploration work. The question is who has worked, what method was applied and what was the finding (result).  Include year of work, purpose and important conclusion. |
|  | **Methods and Techniques Applied** | Refer to Sl. 9 under Section 2.1.4.1.vi, Chapter - 2 |
|  | **Regional Geology** | Regional geological map showing major lithologies may be included. |
|  | **Geology of the Study Area** | Refer to Sl. No. 11 under Section 1.4.1. vi, Chapter -1. |
|  | **Economic Geology**   1. Detailed description on the mineral deposit: such size, extend, thickness etc. 2. Probable Reserve and Grade of the mineralized band or Ore | Refer to Sl. 12 under Section 2.1.4.1.vi, Chapter - 2 |
|  | **Conclusions and Recommendations**   1. Summarized remarks on mineralized band or ore 2. Notes on the findings of the study and interpretation 3. Recommendation to either proceed with next stage of exploration (Stage –III) or abandon the study area with strong justifications. |  |
|  | **Acknowledgements** | Refer to Sl. No. 14 under Section 1.4.1. vi, Chapter -1 |
|  | **References** | Refer to Sl. No. 15 under Section 1.4.1. vi, Chapter -1 |
|  | **Appendix/Appendices** | Refer to Sl. 16 under Section 2.1.4.1.vi, Chapter – 2 (Need not list the places) |

1. In order to maintain the standards of geological report, all the reports shall be reviewed and endorsed for publication by editorial board of the department as per office order no. DGM/2011-2012/32/1441 dated 03/04/2012. To do so, concerned geologist will submit the draft report to the board for review within ***three months*** from the date of the completion of field work. The board shall review and endorse the report within ***two weeks*** from the date of its receipt. The quorum of the board will consist of minimum three members.
2. The endorsed report (three hard & one soft) must be submitted to the library and one hard copy to the Mining Division within two weeks.
3. The field team must make overall presentation within 15 days from the submission of the report to inform the department on the project. The officer in-charge should organize the presentation. The presentation will outline the following:
4. Title (also include stage of the investigation and team members)
5. Location and Accessibility (with map)
6. Geomorphology
7. Objectives
8. Methodology/Techniques Applied
9. Regional Geology
10. Geology of the Mapped Area
11. Economic Geology
12. Findings/Results
13. Recommendations
14. The MLTC of the department shall make assessment of the report in terms of socio-economic viability, environmental considerations and the existing policies of the government. The committee based on the assessment may recommend for stage –III exploration of the mineral to the Mineral Exploration Section.
15. The Head of Geological Mapping & Mineral Exploration Section will update the information generated from the project in the Database of the Section and also do the same in the National Geosciences Database System of the Department.

## STAGE – III: DETAILED MINERAL EXPLORATION BY SUB-SURFACE METHOD –DRILLING

The stage –III mineral exploration will be carried out based on the recommendation of the stage –II exploration. During this stage, detailed exploration including peg geology, topographical survey on 1:500 or larger scale (depending on the nature and type of deposit), borehole drilling, core logging and core sampling will be involved.

### EQUIPMENTS, TOOLS AND MATERIALS NEEDED

1. Handheld GPS
2. Geological Compass
3. Geological Hammer
4. Hand lens
5. Altimeter
6. Stereoscope
7. Meter tape
8. Digital Camera
9. Copies of mineralized band or Ore map of stage –II exploration (1:1000 0r 1: 2000 scale)
10. Chisel
11. Masking tapes and sample bags
12. Field notebooks
13. Pencils, sharpener, erasers, pens, colour pencils, marker pens
14. Diluted HCL
15. Pocket magnet
16. Streak plate
17. Pen knife
18. Spade
19. Crowbar
20. Surveying equipments and tools
21. Drilling equipments and tools

The following work process will be followed:

### PRE-FIELD ACTIVITIES

#### Desktop Study

1. Go through the report, maps and cross-sections of stage –II exploration in detail
2. Prepare a base map (stage-II map) and make a work plan including tentative borehole plans.

### FIELD ACTIVITIES

The main objective of Stage-III exploration is to prove the reserve and grade of the mineralized band or ore. Therefore following fieldwork process will be followed:

#### 2.3.3.1Main Work

1. Carry out peg geology or profiling on the mineralized area maintaining spacing
2. Depending upon the nature of deposit, accessibility and topography, propose series of borehole points along and across the strike of the mineralized band or ore or host rock.
3. Update the tentative borehole plan and submit the updated and final version to the Drilling Section of the department.
4. Describe and measure the identified structures: type, attitude, geometry , during the process of carrying out peg geology or profiling
5. Give location number on each observation made. A clear and prominent location mark (eg. Peg with location number) should be erected at a place were observation is made.
6. Topographical surveying at 1:500 or larger scale with 5 m contour interval has to be carried out using total station to prepare mineralized band or ore map. The topographical map should have the details of surface features such as drainage, escarpment, slides, footpath, roads, dwellings, vegetation etc. apart from the detail geology in it. Topographical surveying procedures and guidelines are given separately.
7. Each and every observations made on the proposed profiles will be located by total station during the surveying process.
8. Diamond drilling of the proposed boreholes will be carried out by Drilling Section. The drilling officials will maintain the detailed drilling logs and submit it to the Geologist In-charge at the end of every day.
9. Core logging and Core sampling will be carried out the concern geologist.
10. Core samples will be submitted to Geochemical Laboratory of the department from time to time for analysis.
11. Transfer observation points on the base map in the field and colour mark sample locations.
12. Delineate contacts of mineralized band or ore band on the base map.
13. Summarize acquired field data including the litho-log of drilled cores and identify problems to be worked out.
14. Transfer the data on the fair base map in the evening at the field camp.

##### 2.3.3.1.1 Sampling

1. Core samples will be collected from every borehole maintaining the adequate spacing that will be representative of entire depth of borehole, in order to determine the precise grade.
2. Give the number to each sample with reference to borehole number and locality name. Give the same number on the masking tape and sample bag as well.
3. Record samples collected and its purpose on the field note book.

Note/Remark:

1. The observed and written records at each observation point need to be comprehensive and legible to be of use to any other geologist
2. Cross sections should also be made at a point, where geology is complex
3. It is desirable to make as much observations on good outcrops
4. The weekly field data has to be evaluated and summarized at the field camp.
5. Make log for samples collected towards the last pages of field book.
6. At the month end, the officer-incharge needs to summarize and submit the progress report along with base map, findings, problems etc., to the Heads of Division and Section. He/she may submit samples for chemical analysis and carry out miscellaneous office works. Discuss with Heads about their field visit plan and further planning of work.
7. The heads will make field visit every month to supervise and quality check the work and suggest any changes required with a note of observations.

### POST-FIELD ACTIVITIES

#### 2.3.4.1 Data analysis, Map Preparation and Interpretation, and Report Writing

1. Submit all the samples to the Geosciences Laboratory of the Department for analysis.
2. Download all the surveying data on the computer and prepare contour map and profile with geological observation points.
3. Plot all the structural attitudes on the map and delineate the mineralized band or ore band contacts on the host rock or with reference to host rock.
4. Prepare detailed sub-surface geological/mineralized band/ore map with the help of borehole data or stratum contour.
5. Construct transverse sections along the profile lines and make scientific and logical interpretations on it. It is very vital to maintain the proper direction and amount of dip while drawing the contacts on the topographic profile.
6. Prepare graphic litho-log of the boreholes.
7. Download all the photographs.
8. Once the entire required information is ready, write a Stage-III mineral exploration report. The report should have the contents outlined in the table:

|  |  |  |
| --- | --- | --- |
| **Contents of Stage – III : Detailed Mineral Exploration by Sub-Surface Method - Drilling** | | |
| **Sl. No** | **Component name/Content** | **Remark** |
|  | **Cover/title page** | Refer to Sl. No. 1 under Section 1.4.1. vi, Chapter -1 |
|  | **Abstract** | Refer to Sl. No. 2 under Section 1.4.1. vi, Chapter -1 (Need not write on the Mineral Resources in the Area) |
|  | **Table of contents** | Refer to Sl. No. 3 under Section 1.4.1. vi, Chapter -1 |
|  | **Introduction** | Refer to Sl. No. 4 under Section 1.4.1. vi, Chapter -1 |
|  | **Location and Accessibility** | Refer to Sl. No. 5 under Section 1.4.1. vi, Chapter -1  The size of the study area must be in acres. |
|  | **Physiography/Geomorphology/Topography and Drainage** | Refer to Sl. No. 6 under Section 1.4.1. vi, Chapter -1 |
|  | **Climate, Vegetation and Wildlife** | Refer to Sl. No. 7 under Section 1.4.1. vi, Chapter -1 |
|  | **Previous Exploration Studies** | This is short summary to indicate references to stage – II exploration work. The question is who has worked, what method was applied and what was the finding (result).  Include year of work, purpose and important conclusion. |
|  | **Methods and Techniques Applied** | Refer to Sl. 9 under Section 2.1.4.1.vi, Chapter – 2.  In addition, include note on Drilling Activities:  - Drilling methods  -No. of bore holes carried out  -Total depth of boreholes |
|  | **Regional Geology** | Regional geological map showing major lithologies may be included. |
|  | **Geology of the Study Area** | Refer to Sl. No. 11 under Section 1.4.1. vi, Chapter -1 |
|  | **Economic Geology**   1. Detailed description on the mineral deposit: such size, extend, thickness etc. 2. Proved Reserve and Grade of the mineralized band or Ore | Refer to Sl. 12 under Section 2.1.4.1.vi, Chapter - 2 |
|  | **Conclusions and Recommendations**   1. Summarized remarks on mineralized band or ore 2. Notes on the findings of the study and interpretation |  |
|  | **Acknowledgements** | Refer to Sl. No. 14 under Section 1.4.1. vi, Chapter -1 |
|  | **References** | Refer to Sl. No. 15 under Section 1.4.1. vi, Chapter -1 |
|  | **Appendix/Appendices**  Additional supporting information that is not main part of the report. It includes:   1. List of core samples collected with location coordinate, brief description and purpose 2. List and location of structural data measured in the field |  |

1. In order to maintain the standards of geological report, all the reports shall be reviewed and endorsed for publication by editorial board of the department as per office order no. DGM/2011-2012/32/1441 dated 03/04/2012. To do so, concerned geologist will submit the draft report to the board for review within ***three months*** from the date of the completion of field work. The board shall review and endorse the report within ***two weeks*** from the date of its receipt. The quorum of the board will consist of minimum three members.
2. The endorsed report (three hard & one soft) must be submitted to the library and one hard copy to the Mining Division within two weeks.
3. The field team must make overall presentation within 15 days from the submission of the report to inform the department on the project. The officer in-charge should organize the presentation. The presentation will outline the following:
4. Title (also include stage of the investigation and team members)
5. Location and Accessibility (with map)
6. Geomorphology
7. Objectives
8. Methodology/Techniques Applied
9. Regional Geology
10. Geology of the Mapped Area
11. Economic Geology
12. Findings/Results
13. Recommendations
14. The MLTC of the department shall make assessment of the report in terms of socio-economic viability, environmental considerations and the existing policies of the government. The committee based on the assessment may recommend for auction of the mineral reserve.
15. The Head of Geological Mapping & Mineral Exploration Section will update the information generated from the project in the Database of the Section and also do the same in the National Geosciences Database System of the Department.

# CHAPTER – 3: CONSTRUCTION MATERIAL STUDY (PLANNED ACTIVITY)

Bhutan’s development has accelerated rapidly over the last five years, due to which, the demand for construction materials (building stones, gravels, aggregates, chips, slabs) from the construction sector has manifold by many times. Beside geological mapping and mineral exploration, GSB is also being mandated to locate prospective quarry sites and assess them both qualitatively and quantitatively throughout the country. The geologists will follow the procedures and guidelines given below to prospect and study the construction material deposits.

### 3.1 EQUIPMENTS, TOOLS & MATERIALS NEEDED

1. Handheld GPS
2. Geological Compass
3. Geological Hammer
4. Hand lens
5. Altimeter
6. Stereoscope
7. Meter tape
8. Digital Camera
9. Copies of geological maps of Bhutan (1:500,000)
10. Copies of geological map in 1:50000 scale of the region (if available)
11. Topomaps of the region or area (1:25,000 and 1: 1:50000 scales)
12. Hard copies of remote sensing image/s covering the map area in 1:100,000 scale
13. Chisel
14. Masking tapes and sample bags
15. Field notebooks
16. Pencils, sharpener, erasers, pens, colour pencils, marker pens
17. Diluted HCL
18. Pocket magnet
19. Streak plate
20. Pen knife

The following work process will be followed to carry out construction material study:

### PRE-FIELD ACTIVITIES

#### 3.2.1 Literature Survey and Desktop Study

1. Collect geological information from existing /available map of the region.
2. Gather all the available literature such as geological reports of the region or area concerned and go through all these available information.
3. Gather all the available remote sensing data such as Landsat, ALOS and Google earth imageries and do a desktop study of these images to locate the prospective quarry sites.
4. Prepare base map of the region or area by overlaying these satellite image/s with located prospective sites on topomap (1:25,000 and 1:50,000). The base map must have geographic coordinate grids with 1 minute spacing.
5. Make consultations with geologists or researchers who have worked in the region or area or in similar projects. Have thorough discussions with supervisory officers and get proper guidance from them.
6. Locate camp sites, markets, and communication facilities; and familiarize with approachability, local places, settlements, and land-use using the available information and prepare a work plan with scheduling.

### FIELD ACTIVITIES

#### 3.3.1 Preliminary (reconnaissance) Field Work

1. Plan the work ahead, based on the acquired actual information and pre-planned purposes identified during desktop study.
2. Prepare the updated version of work plan.

#### 3.3.2 Main Field Work

##### 3.3.2.1 Prospective Quarry Site Analysis and Record

1. Start of each day should contain the information such as a) Date and Time b) Name of the site and intended purpose c) Name/s of professional partner (if any) on the new page of the field notebook.
2. Keeping in the mind that the main objective of construction materials study being locating the prospective quarry sites and assessing their feasibility to quarry and assessing economic viability, every site has to be assessed thoroughly and recorded.
3. The following information must be collected from every located prospective site:
4. *Location:*
5. *place name, village, gewog, dzongkhag*
6. *GPS coordinates*

1. *Land Type: Government Reserved Forest (GRF)/ Private*
2. *Accessibility: Access and distance from the highway/feeder/farm road*
3. *Field characteristics:*
4. *Topography: land features, slope, etc.*
5. *Vegetation: Thickly/Sparsely*
6. *Weathering Intensity: High/Moderate/Slight*
7. *Rock Type*
8. *Name of rock*
9. *Mode of occurrence*
10. *Mineralogical composition*
11. *Attitudes :*
12. *Foliation/ Bedding with measurements, mention whether dipping along or against the slope direction of the topography*
13. *Joints*
14. *Joint spacing*
15. *Other geological structures*
16. *Quality of rock or Engineering Properties of Rock:*
17. *Textural description: Granularity, Grain size and shape*
18. *Impurities*
19. *Defects: Fractures/partings/intrusions/intercalations etc.*
20. *Strength: Strong/Moderate/Soft*
21. *Durability*
22. *Appearance*
23. *Quantity of rocks (Reserves):*

*a) Length in meters*

*b) Width in meters*

*c) Depth in meters*

*d) Specific gravity*

*e) Recovery percentage*

*f) Probable in-situ Geological Reserve*

*g) Probable Quarriable Reserve*

1. *Quarrying:*

*a) Amenability to obtaining blocks*

*b) Number of faces available for mining*

*c) Method of mining*

*d) Average size of blocks*

*e) Over burden*

1. Note the heterogeneity and homogeneity of exposed rocks
2. Inspect for colour, textural and mineralogical variations occurring in a relatively homogeneous outcrops
3. Closely examine the lithostratigraphic relationships among different type of rocks in heterogeneous outcrops
4. Describe each identified rock type: colour, degree of weathering, texture/grain size, mineralogy, etc.
5. Describe the type of contact in adjacent litho-units: sharp, graditional
6. Note the nature of structural features on the outcrop: simple, complex, etc
7. Identify structures in each of litho-units: primary (formational), secondary (deformational)
8. Describe the identified structures: type, attitude, geometry, age
9. Make sketches/photographs of outcrops with significant information on the geologic history. The sketched or photographed features must show appropriate scale and compass orientation. Note the number of the photograph, direction of view, etc in the field notebook.
10. Collect appropriate number of samples from every located site for geotechnical laboratory tests to examine comprehensive strength, aggregate impact value, porosity percentage etc.
11. Transfer observation points on the 1:25000 scale base map in the field and colour mark sample locations.
12. Delineate contacts of lithologies on the base map
13. Summarize acquired field data and identify problems to be worked out (if any)
14. Transfer the data on the 1:50000 scale fair base map in the evening at the field camp.

##### 3.3.2.2 Sampling

1. Collect appropriate sizes and number of samples for different geotechnical tests from the site representative of whole section of the material deposit.
2. Collect only unweathered samples from the outcrop. Weathered material if any are trimmed off.
3. Give the number to each sample with reference to locality name and station number. Give the same number on the masking tape and sample bag as well.
4. Record samples collected and its purpose on the note book

Note/Remark:

1. The observed and written records at each prospective site need to be comprehensive and legible to be of use to any other geologist
2. Cross sections should also be made at a point, where geology is complex
3. It is desirable to make as much observations on good outcrops
4. The weekly field data has to be evaluated and summarized at the field camp.
5. During the course of prospecting prospective quarry sites, if encountered with traces of some important mineralization, locate and record it in the map and give more importance in the area by collecting more geological data, samples and if time permits, carry out tape and compass survey on large scale. If you are unable to identify the mineral, bring the sample to the Head office for group discussion.
6. Make log for samples collected towards the last pages of field book.
7. At the month end, the officer In-charge needs to summarize and submit the progress report along with base map, findings, problems etc., to the Heads of Division and Section. He/she may submit samples for chemical analysis and carry out miscellaneous office works. Discuss with Heads about their field visit plan and further planning of work.
8. The heads will make field visit every month to supervise and quality check the work and suggest any changes required with a note of observations.

### POST-FIELD ACTIVITIES

#### 3.4.1 Data analysis, Map Preparation and Interpretation, and Report Writing

1. Submit all the samples to the Geosciences Laboratory of the Department for analysis.
2. Download all the GPS data on the computer and overlay it on the topographic base map using GIS.
3. Plot all the structural attitudes on the map and delineate the litho-unit contacts using V-rules and make interpretations of any geologic features.
4. Construct cross-section/s and make scientific and logic interpretations on it. It is very vital to maintain the proper direction and amount of dip while drawing the geologic contacts on the topographic profile.
5. Download all the photographs.
6. Once the entire required information is ready, the team shall write a geological report. The geological report of geological mapping should have the contents outlined in the table:

|  |  |  |
| --- | --- | --- |
| **Contents of Construction Materials Study (Planned Activity) Report** | | |
| **Sl. No** | **Component name/Content** | **Remark** |
|  | **Cover/title page** | Refer to Sl. No. 1 under Section 1.4.1. vi, Chapter -1 |
|  | **Abstract** | Refer to Sl. No. 2 under Section 1.4.1. vi, Chapter -1 |
|  | **Table of contents** | Refer to Sl. No. 3 under Section 1.4.1. vi, Chapter -1 |
|  | **Introduction** | Refer to Sl. No. 4 under Section 1.4.1. vi, Chapter -1 |
|  | **Location and Accessibility** | Refer to Sl. No. 5 under Section 1.4.1. vi, Chapter -1 |
|  | **Physiography/Geomorphology/Topography and Drainage** | Refer to Sl. No. 6 under Section 1.4.1. vi, Chapter -1 |
|  | **Climate, Vegetation and Wildlife** | Refer to Sl. No. 7 under Section 1.4.1. vi, Chapter -1 |
|  | **Previous Geological Studies** | Refer to Sl. No. 8 under Section 1.4.1. vi, Chapter -1 |
|  | **Methods and Techniques Applied**   1. Notes on geotechnical analysis | Refer to Sl. No. 9 under Section 1.4.1. vi, Chapter -1 (In this case, include notes on geotechnical analysis:  -Purpose and type of analysis made  -Procedures and methods of analysis  -Number of samples analyzed |
|  | **Regional Geology** | Regional geological map showing major lithologies may be included. |
|  | **Geology of the Study Area** | Refer to Sl. No. 11 under Section 1.4.1. vi, Chapter -1 |
|  | **Detailed Assessment of Prospective Quarry Sites**  The information collected under Section 3.3.2.1. iii must be included both in table and brief report form including explanation on the geotechnical tests result. | Map showing the location of the prospective site must be included.  Photographs of every site must be included. |
|  | **Conclusions and Recommendations**   1. Notes on the findings of the study and interpretation 2. Suggestions for further investigation or research |  |
|  | **Acknowledgements** | Refer to Sl. No. 14 under Section 1.4.1. vi, Chapter -1 |
|  | **References** | Refer to Sl. No. 15 under Section 1.4.1. vi, Chapter -1 |
|  | **Appendix/Appendices** | Refer to Sl. No. 16 under Section 1.4.1. vi, Chapter -1 |

1. In order to maintain the standards of geological report, all the reports shall be reviewed and endorsed for publication by editorial board of the department as per office order no. DGM/2011-2012/32/1441 dated 03/04/2012. To do so, concerned geologist will submit the draft report to the board for review within ***three months*** from the date of the completion of field work. The board shall review and endorse the report within ***two weeks*** from the date of its receipt. The quorum of the board will consist of minimum three members.
2. The endorsed report (three hard & one soft) must be submitted to the library and one hard copy to the Mining Division within two weeks.
3. The field team must make overall presentation within 15 days from the submission of the report to inform the department on the project. The officer in-charge should organize the presentation. The presentation will outline the following:
4. Title
5. Location and Accessibility (with map)
6. Geomorphology
7. Objectives
8. Methodology/Techniques Applied
9. Regional Geology
10. Geology of the Study Area
11. Prospective Quarry Sites
12. Findings/Results
13. Recommendations
14. The MLTC of the department shall assess the report if it indicates some potential construction material reserves in the study area. The assessment shall be in terms of socio-economic viability, environmental considerations and the existing policies of the government. The committee based on the assessment may recommend for detailed study of the intended construction material to the Mineral Exploration Section.
15. The Head of Geological Mapping & Mineral Exploration Section will update the information generated from the project in the Database of the Section and also do the same in the National Geosciences Database System of the Department.

# CHAPTER – 4: MAPPING AND EXPLORATION SERVICES (ON DEPOSIT WORK BASIS)

The Geological Survey of Bhutan under the Department of Geology & Mines, Ministry of Economic Affairs besides being mandated to carry out planned programs like geological mapping, mineral exploration, construction materials study, and engineering geological studies throughout the country, the Division is also responsible for chartering the geological services (mapping, exploration, engineering geological) needs of different government agencies, corporations, private companies and individual proponents in the country at present on deposit work basis as there are no full-fledged consultancy firms in the market to provide such services. Therefore, the Division is often pressured to fulfill this additional responsibility with the implementing agencies making a mandatory requirement to carry out the geotechnical or geological studies of the project sites of the projects funded by the donor agencies such as GOI, DANIDA, NORAD, ADB and World Bank.

Without any other options, the department has been entertaining such request on case by case basis without hampering the department’s planned programs. This practice has been going on since early 1990s.

In most cases, the geological service requirements consist of carrying out of the followings works:

1. Geotechnical and engineering geological studies, surveying and drilling services for foundation study of infrastructural development sites such as hydropower construction sites, bridges, mega governmental offices, schools, colleges, etc.
2. Geotechnical and engineering studies for road/highway construction
3. Mapping & exploration services (including drilling and surveying services) in assessing mineral deposits and construction materials.
4. Geological services for ground water exploration

As the department thought that these geological services being rendered are for the overall benefit of the nation, only the actual cost incurred for carrying out the works were levied to the applicants until 2004. However, as per the RAA audit recommendation of 2004 for levying nominal service charge, a 10 % service charge on the total cost of the service was levied since then.

The procedures being followed for carrying out the deposit works so far is outlined below:

1. An application is submitted to the Department of Geology & Mines (DGM) by the applicant, articulating the need of the professional services from DGM.
2. The department after reviewing the application and depending upon the availability of the technical manpower at that very period accepts the application and prepares the budget estimate of the requested service. Any charges required for testing of the samples from the department’s Laboratory is required to be borne by the client as per the existing approved charges.
3. The client accordingly deposits the estimated amount in the **“Refundable Deposit Account, Administration and Finance Division, Ministry of Economic Affairs, Thimphu”** with intimation to the DGM.
4. The release of the budget comes like the normal planned programs of the department.
5. After the work is completed, a geological/geotechnical report is prepared and submitted to the client.
6. A Project Completion report along with financial status is also submitted by the Officer In-charge to the Administration and Finance Division (AFD) of the Ministry for necessary adjustment and refund (if any) to the client. A copy of this completion report is also being given to the client for their necessary follow-up.
7. Balance amount (if any) is being refunded to the client or proponent.

However, in the last audit exercise of the department during the FY 2012-2013, the audit team pointed out that even the salary of the officials involved in the deposit work should be included in the budget estimate. Accordingly, in compliance to the audit observation made, the department proposes to include even the salary of the officials involved in carrying out the deposit works.

## 4.1 DETAILED MINERAL EXPLORATION AND CONSTRUCTION MATERIALS STUDY (ON DEPOSIT WORK BASIS)

The Department after receiving application from the application for request of exploration services for the identified or located exploration target, the department depending on the availability of resources will assign the work.

## 4.1.1 Mineral Exploration

The assigned team for carrying out the exploration project will follow the stages of mineral exploration as outlined in detail under the Chapter – 2 on Mineral Exploration.

## 4.1.2 Construction Materials Study

The construction materials study will include detailed geological mapping and topographical survey in 1:500 to 1:2000 scale. The geologist will follow the following procedures and guidelines to carryout detailed assessment of construction materials.

### 4.1.2.1 EQUIPMENTS, TOOLS & MATERIALS NEEDED

1. Handheld GPS
2. Geological Compass
3. Geological Hammer
4. Hand lens
5. Altimeter
6. Stereoscope
7. Meter tape
8. Digital Camera
9. Copies of geological maps of Bhutan (1:500,000)
10. Copies of geological map in 1:50000 scale of the region (if available)
11. Topomaps of the study area (1:25,000 and 1: 1:50000 scales)
12. Hard copies of remote sensing image/s covering the map area in 1:100,000 scale
13. Chisel
14. Masking tapes and sample bags
15. Field notebooks
16. Pencils, sharpener, erasers, pens, colour pencils, marker pens
17. Diluted HCL
18. Pocket magnet
19. Streak plate
20. Pen knife

### 4.1.2.2 PRE-FIELD ACTIVITIES

#### 4.1.2.2.1 Literature Survey and Desktop Study

1. Collect geological information from existing /available map of the region.
2. Gather all the available literature such as geological reports of the area concerned and go through all these available information.
3. Gather all the available remote sensing data such as Landsat, ALOS and Google earth imageries and do a desktop study
4. Make consultations with geologists who have worked in the area or in similar projects. Have thorough discussions with supervisory officers and get proper guidance from them.
5. Familiarize with approachability, local places, settlements, and land-use using the available information and prepare a work plan with traverses and scheduling.

### 4.1.2.3 FIELD ACTIVITIES

#### 4.1.2.3.1 Preliminary (reconnaissance) Field Work

1. To know the lithostratigraphy or geological setting of the area, preliminary reconnaissance should be made by walking a well-exposed section. Walk across the strike to get different rock types to establish the stratigraphy.
2. Plan the work ahead, based on the acquired actual information and pre-planned purposes identified during desktop study.
3. Prepare the updated version of work plan.

#### 4.1.2.3.2 Main Field Work

##### 4.1.2.3.2.1 The proposed Site Analysis and Record

1. Start of each day should contain the information such as a) Date and Time b) Name and number of the traverses c) Name/s of professional partner (if any) on the new page of the field notebook.
2. Keeping in the mind that the main objective of construction materials study being assessing the quality and quantity of the materials of the proposed site for determining the economic viability, the site has to be assessed thoroughly and recorded.
3. Dig trenches to expose the concealed part of the band or ore. Pitting may be required to confirm the continuity of the band.
4. Describe the outcrop : colour, degree of weathering, texture/grain size, size, extend, thickness etc
5. Describe and measure the identified structures: type, attitude, geometry
6. See the nature of outcrops whether it is a dip slope or dipping in to the hill.
7. Examine carefully the thickness of the bed and measure it.
8. See the degree of fracture, measure each fracture system and its spacing, this will determine the size of the gravel in its natural form.
9. Record the attitude of all joint sets and measure the joint spacing as well.
10. Always see the unwanted intercalations as these may affect your reserve calculation.

1. Collect appropriate number of samples from every located site for geotechnical laboratory tests to examine comprehensive strength, aggregate impact value, porosity percentage etc.
2. Determine the portion that is fractured and weathered and the portion that is massive for construction materials.
3. Determine also the level of overburden at each point.
4. Give location number on each observation made. A clear and prominent location mark (eg. Peg with location number) should be erected at a place were observation is made.
5. Topographical surveying at 1:500 to 1:2000 scales with 5 m contour interval has to be carried out using total station to prepare the geological map. The topographical map should have the details of surface features such as drainage, escarpment, slides, footpath, roads, dwellings, vegetation etc. apart from the detail geology in it. Topographical surveying procedures and guidelines are given separately.
6. Each and every observations made will be located by total station during the surveying process.
7. Take enough time to examine the rock while in field and if you suspect any occurrences of mineral where you are unable to make judgment bring the sample to the Head office for group discussion.
8. Decide where you will place your Cross-section (s) before you finish your field work. Choose a line (s) normal to the strike of the main structure (s).This should reveal geology that is representative of the structure and should be well exposed.
9. Walk the line of section and record as much structural data as possible along the line.
10. Collect fresh grab samples for geotechnical tests to determine the quality of the construction material. The samples may also be examined whether the rock type is of any economic significance to avoid misjudging it for mere low value mineral. E.g. High grade marble or quartzite is more economic to be used for industry rather than construction materials.
11. Transfer observation points on the base map in the field and colour mark sample locations.
12. Delineate contacts of construction material band on the base map.
13. Summarize acquired field data and identify problems to be worked out.
14. Transfer the data on the fair base map in the evening at the field camp.

##### 4.1.2.3.2.2 Sampling

1. Collect appropriate sizes and number of samples for different geotechnical tests from the site representative of whole section of the material deposit.
2. Collect only unweathered samples from the outcrop. Weathered material if any are trimmed off.
3. Give the number to each sample with reference to locality name and station number. Give the same number on the masking tape and sample bag as well.
4. Record samples collected and its purpose on the note book

Note/Remark:

1. The observed and written records at each observation point need to be comprehensive and legible to be of use to any other geologist
2. Cross sections should also be made at a point, where geology is complex
3. It is desirable to make as much observations on good outcrops
4. The weekly field data has to be evaluated and summarized at the field camp.
5. Make log for samples collected towards the last pages of field book.

### POST-FIELD ACTIVITIES

#### 4.1.2.4.1 Data analysis, Map Preparation and Interpretation, and Report Writing

1. Submit all the samples to the Geosciences Laboratory of the Department for analysis.
2. Download all the surveying data on the computer and prepare contour map with geological observation points.
3. Plot all the structural attitudes on the map and delineate the construction material band using the V-rule.
4. Construct a series of cross-section/s and make scientific and logical interpretations on it. It is very vital to maintain the proper direction and amount of dip while drawing the contacts on the topographic profile.
5. Download all the photographs.
6. Once the entire required information is ready, the team shall write a report. The report should have the contents outlined in the table:

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| **Contents of Stage – II : Detailed Surface Mineral Exploration** | | |
| **Sl. No** | **Component name/Content** | **Remark** |
|  | **Cover/title page** | Refer to Sl. No. 1 under Section 1.4.1. vi, Chapter -1 |
|  | **Abstract** | Refer to Sl. No. 2 under Section 1.4.1. vi, Chapter -1 (Need not write on the Mineral Resources in the Area) |
|  | **Table of contents** | Refer to Sl. No. 3 under Section 1.4.1. vi, Chapter -1 |
|  | **Introduction** | Refer to Sl. No. 4 under Section 1.4.1. vi, Chapter -1 |
|  | **Location and Accessibility** | Refer to Sl. No. 5 under Section 1.4.1. vi, Chapter -1  The size of the study area must be in acres. |
|  | **Physiography/Geomorphology/Topography and Drainage** | Refer to Sl. No. 6 under Section 1.4.1. vi, Chapter -1 |
|  | **Climate, Vegetation and Wildlife** | Information includes both field observation and other sources. |
|  | **Previous Exploration Studies** | Refer to Sl. No. 7 under Section 1.4.1. vi, Chapter -1 |
|  | **Methods and Techniques Applied** | Refer to Sl. No. 9 under Section 1.4.1. vi, Chapter -1. In addition, include  a) Notes on geotechnical analysis  -purpose and type of analysis made  -procedures and method of analysis  -number of samples analyzed  b)Notes on geochemical analysis  -Purpose and type of analysis made  -Procedures and methods of analysis  -Number of samples analyzed |
|  | **Regional Geology** | Regional geological map showing major lithologies may be included. |
|  | **Geology of the Prospect**   1. Detailed descripition of the lithologies, structures, the construction material (size, extend, thickness etc.) 2. Reserve and Quality of the material | Refer to Sl. No. 11 under Section 1.4.1. vi, Chapter -1 |
|  | **Conclusions and Recommendations**   1. Summarized remarks on construction material deposit. 2. Notes on the findings of the study and interpretation 3. Any recommendations. |  |
|  | **Acknowledgements** | Refer to Sl. No. 14 under Section 1.4.1. vi, Chapter -1 |
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2. The endorsed report (three hard & one soft) must be submitted to the library and one hard copy to the Mining Division within two weeks.
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4. Balance amount (if any) must be refunded to the client or proponent.

# Annexure – 1: PROCEDURES & GUIDELINES FOR SURVEYING & MAPPING

1. **Desktop Preparation/Pre-field preparation.**

Before visiting the actual field, the need for desktop preparation is vital for further proceedings and field duration approximation. The surveyor should find the approximate location of the site and the site information as to choose ideal tool for particular job. And more importantly the items required in the field should be listed, checked and pack with care.

1. **Reconnaissance.**

Reconnaissance is prerequisite to any field survey. Basically after reaching the field it is a firsthand look at how to go about and most importantly for the smooth flow of work. During recii, the surveyor should look for ideal site to launch, primary control points, how and where to run traverse to densify the secondary control points, enhancing visibility by clearing obstructions and so on. The surveyor should keep in mind that the secondary control points are provided from the place where the visibility is maximum.

1. **Control Points.**

The primary control Points used should be provided by either through GPS observation in a standard coordinate system or extended from if there are existing ones . Alternatively there are dense network of control points throughout the country provided by the National Land Commission Secretariat in Druk\_Ref Coordinate system which is highly recommended.

1. **Traverse**

Traverse should be run to densify the control points. We can either use GPS traversing or by using total station. While doing traverse adjustment, the minimum required accuracy should be maintained both horizontally and vertically (accuracy defers base on data requirement).

1. **Data Collection/Detail survey.**

Data/feature should be collected by using total station. Each and every features position should be collected and its standard code and description should be also provided to ease the map preparation work either by the same surveyor or other. For the accurate generation of contours, the elevation data should be acquired at the minimum horizontal/slope distance of the required contour interval.

\*Note- at the end of every day, the surveyor should download the data and check the possibility of any occurrence of error, If found, the same data should be recollected the next day.

1. **Data Downloading and Preparation of Maps.**

Data should be downloaded in the standard software being provided with the total station. For Leica Total Station user, Liscad is used to download the data. After downloading the data, maps are prepared either in Liscad itself or in ArcMap. The title of the map, Scale and Contour interval of the map, and the Map Legends and the season should be accurately and specifically provided on the map. The names of the person who were present during data collection should be mentioned on the map corner against his/her profession.