Chapter 1

THE WORLD OF ROCKS

Introduction

The Earth's crust on which we are living is a mosaic of different types of rocks. Knowledge of the rocks is much essential in civil engineering, mining and hydrogeology. The study of rocks-petrology forms the basis for the study of plate tectonics. Through this chapter, the learner is expected to get awareness on the formation and classification of the three basic types of rock. The learner shall able to identify some of the common rocks found on the Earth's crust.

Rocks reveal a record of their origin and development which in turn helps to reconstruct the story of past climates and landscape. The nature of rocks which occur in an area might influence to a great extent the topography, agriculture, industrial development and the habitat of an area.

It takes millions of years for rocks to be formed and transformed in nature. Rocks are highly consumed in civil engineering construction fields nowadays. A sense of conservation of the rocks as well as the mineral resources enclosed in rocks must be cultivated in the learners. The learner should become bothered about the uncontrolled quarrying of rocks from ecologically sensitive areas in different parts of our country.

Values and attitudes

Cultivating a positive attitude towards the natural landscape

Realising the cultural, historical and economic growth that human kind have acquired through generations by making use of rocks

Unit Frame

Concepts/Ideas and Process skills.	**Learning Processes and activity with kind of assessment**	**Learning Outcome**
Rocks- definition and types of rocks-igneous, sedimentary and metamorphic rocks ✓ Observation skill ✓ Skill to of comprehension	Group discussion based on previous knowledge and demonstration of rock specimens (*process assessment*)	Distinguishes between the three basic types of rock found on the Earth's crust
Igneous rocks-magma and lava, formation of igneous rocks ✓ Skill of presentation	Video on volcanic eruption/animation , Classroom presentation on crystallization of magma, Small group discussion, General discussion	States the mode of formation of igneous rocks
Classification of igneous rocks-plutonic, volcanic and hypabyssal rocks, Textures of igneous rocks- granularity and crystallinity, glassy and frothy texture ✓ Recognition skill	Demonstration, general discussion, chart preparation	Explains the textural and compositional differences exhibited by igneous rocks
Megascopic identification of igneous rocks ✓ Skill to observe and identify things	Practical work (*to process and portfolio assessment*).	Identifies common igneous rocks in hand specimens
Formation of sedimentary rocks, Classification-clastic, chemical and organic sedimentary rocks	Doing an inquiry based learning activity on the modes of formation of sedimentary rocks, conducting experiments (*to process and portfolio*	Explains the formation and classification of sedimentary rocks

✓ Comprehension skill ✓ Illustration skill ✓ Skill of presentation	*assessment*).	
Identification of common sedimentary rocks ✓ Skill of identifying things	Practical activity, conducting experiment(*to process and portfolio*)	Identifies the common sedimentary rocks megascopically
Metamorphism-agents and types ✓ Observation ✓ Communication	Table preparation, Demonstration, Group discussion through jig-saw method, Citing of real life examples.	Describes the agents and types of metamorphism
Identification of common metamorphic rocks ✓ Skill of identifying things	Practical work (*to process and portfolio assessment*).	Identifies the common types of metamorphic rocks
Rock cycle ✓ Skill of analyzing things	Analysis of diagram	Illustrates diagrammatically the concept of rock cycle

Unit Analysis

The learners have a previous knowledge on minerals by which the rocks are composed. Recall their previous knowledge by asking some questions,

Where do you find minerals on the earth's crust?

What is the basic building unit of the earth's crust?

Convince them that, rocks are aggregates of any combination of minerals, elements, solid organic material (coal), and/or other rocks. Geologists place rocks into three groups according to how they form: igneous, sedimentary and metamorphic.

Demonstrate specimens of three different types of rocks- granite (igneous), sandstone (sedimentary) and gneiss (metamorphic). If possible, trays containing typical igneous,

sedimentary and metamorphic rocks can be given to the groups of learners having 5 to 6 members.

They can also observe the features in the given three different rock specimens. Let them discuss each other the features that make those three rocks different.

You can exhibit specimens of visible minerals together with rock specimens. Rocks containing single dominant mineral such as pure marble and polly- mineralic rocks such as granite can also be demonstrated.

The Earth's crust is made up of rocks. Rocks are aggregates of minerals. Most rocks are made up of minerals, but a few a few are made of only a single mineral.

1. Igneous rocks

Learners are asked to look at a piece of granite closely and see that it is made of little bits of material, of different colours, firmly fixed together. Ask them, some of these little bits shine in the light. It consists of tiny pieces called crystals with definite arrangement of atoms in it.

Granite is a solid mass of several kinds of crystals. The white/pink crystals are minerals called feldspar. Thus they see some smaller crystals which shine very brightly in the light. The rest of the granite is made of a very hard glass like material called quartz. Flat pearly crystals may be white/brown/black coloured mica.

Tell them once again that rocks are aggregates of minerals. Granite is a rock composed of feldspar, quartz and mica.

Ask them rock like granite have been formed from melted rocks or magma. We call them igneous (fire-formed) rock. As molten rock cools, the minerals form crystals and interlock with each other. The liquid melt from which granite comes cools so slowly that the different minerals in it separate from one another and form crystals. Feldspar crystals are first to crystallize and may be larger and more perfect in shape than the other minerals, which crystallize later.

1.1 Classifying igneous rocks

Igneous rocks are classified according to their composition and texture. Composition refers to the minerals of which rocks are formed. Texture means the shape, size, arrangement and distribution of the minerals that make up rocks. Both are evident in a rock's appearance.

Materials needed: - Igneous rock specimens such as basalt, dolerite, obsidian, pumice, gabbro and granite.

Show the learners specimens of the different igneous rocks. The rocks can be labelled properly. Give the learners an idea about the texture of igneous rocks and its significance in their identification. Make them convince of the grain size and crystallinity. Learners shall work in groups having 5-6 members to examine the rocks closely. A magnifying glass may

also be provided for each group. The learners are asked to note down their findings about each rock. The findings can be summarised by asking some questions as follows,

Which rocks have minerals large enough to be seen with the naked eye?

Which rocks have minerals so small that they can only be observed with the aid of microscope?

Why is pumice full of holes and very light in weight?

Whether basalt is cooled slowly or rapidly?

Focus attention on differences in texture. Tell them that the rate of cooling is an important characteristic that affect the type of rock. The rocks having same mineral composition may appear very different because of the textural difference. The grain size or texture of igneous rocks is associated with the rate of cooling.

A coarse texture results from slow cooling and a fine texture results from rapid cooling of molten rock material. The holes in the pumice were caused by the gases present within the liquid magma from which it is solidified. Making of glass can be explained to get an idea of glass texture. The learners are then asked to make a chart showing the textural characteristics of plutonic, volcanic and hypabyssal igneous rocks. A model is given for an example,

Plutonic- Coarse grained/visible minerals- Granite

Volcanic- Fine grained but not glassy- Basalt

Hypabyssal- Medium grained- Dolerite

Glassy- Obsidian

Frothy/ full of holes- pumice

Learners are allowed to note down the following points-

A glassy texture occurs when rock freezes instantly. There are no crystals (obsidian).
A porphyritic texture is a rock with large crystals surrounded by fine-grained crystals (rhyolite).
A vesicular texture is a rock that has many holes in it (pumice).
Vesicular - rock containing vesicles (gas holes). Always have light in weight. Example;- pumice.
Glassy - not composed of minerals at all but a true glass. Glasses are not crystalline

Then they are asked to fill the blank space in the given table.

Rock	Rate of cooling	Extrusive/intrusive	Crystal size	Texture
Basalt	Fast	Extrusive	Small	Fine grained

Dolerite				Medium grained
Gabbro	Slow			
Granite			Large	
Rhyolite				Glassy
Obsidian	Very fast			
Pegmatite	Very slow			
Pumice			No crystals	

Intrusive igneous rocks cool slowly, producing a coarse texture with mineral grains visible to the naked eye. The minerals that form are determined by the chemistry of the magma and the way that it cools (relatively slowly or quickly, steadily or variably). The process of observation, involvement in groups and the results obtained in the activity shall be considered for *process* and *portfolio assessment*.

1.2 Igneous rocks- compositional consideration

An introductory discussion is conducted on the mineralogical composition of igneous rocks. The following aspects are highlighted.

There are two types of magma

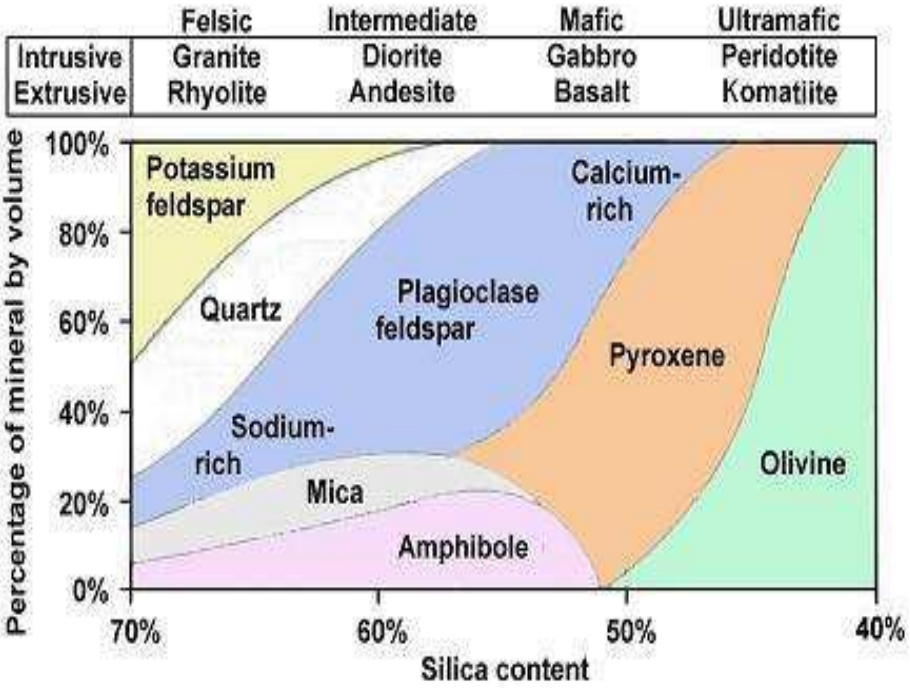
Felsic = Light colour, high in silica, viscous (thick and slow), low in iron, calcium or magnesium

Felsic = Feldspar + Silica

Mafic = Dark colour, low in silica, not viscous (thin and watery), high in iron, calcium and magnesium

Mafic = Magnesium + Iron (Fe)

Learners are then guided to analyse the figure (Fig.1.7) given in the text book.



The chart given is very simple to analyze. At the top, many igneous rocks are listed, separated by the size of the crystals (up and down) and the mineralogical composition from left to right. For example, gabbro and basalt have same mineral composition in the same proportions, but they differ from each other in the size of crystals.

Let them place the pointer/finger in the centre of the word *basalt* and drag it straight down. Their pointer will pass through basalt's minerals: plagioclase feldspar and pyroxene. They can tell also the relative percentage of each mineral in the rock from the chart.

Learners are asked to take a pointer and point it at the name of rock shown in the chart and drag it straight down into the bottom half of the chart. The pointer drags through the minerals present in the rock. The relative percentage of each mineral in the rock can also be determined from the chart.

Now let them tell if the following rock samples are:

1. Felsic or Mafic

2. Fine grained or Coarse grained

3. Intrusive or Extrusive

(Basalt, diorite, gabbro, pumice, scoria, dolerite, granite, pegmatite and rhyolite)

Let the learners be made according to the given chart, a brief descriptions of igneous rocks as shown here,

Basalt = fine grained extrusive/volcanic rock

Granite= Coarse grained intrusive rock

Dolerite= Medium grained intrusive rock

Rhyolite: Light coloured (felsic), fine grained (volcanic) igneous rock

Pumice: Fine grained, felsic, vesicular volcanic igneous rock

Scoria: Fine grained, mafic, vesicular volcanic igneous rock

Tell them that magma and lava are mixtures, so the amount of each mineral in a rock can vary. As a result, the granite, diorite and the rocks belong to mafic and ultramafic groups may blend each other at their edges. There can be a variation in cooling rates resulting in the formation of overlapping textures.

1.3. Crystallization of magma

Class room presentation

In this method, everyone in the designated group gives a small presentation on the topic-crystallization of magma. Learners can made their presentations either in the form of giving a summary of the topic, or arguing against the ideas presented by other learners or relating the personal experience of the learners to the content material. Here the teacher can adopt an active learning method.

The active learning *process* includes the presentations and discussions occurring between learners and the whole class. It includes the interactions between the teacher and the learners; and between the learner and peer learners. Both content and process must be considered when attempting to engage learners in meaningful discussion.

A short presentation on the learning material can be made by each learner to the whole class. It may be as short as half to two minutes depending on the size and period of the class. The whole class can be broken into small groups and the learners can do daily presentations within their small groups also.

In order to generate the discussion process, the content area including the text book, reference materials and information using multimedia and questions regarding the content area must be taken into consideration. Learners are encouraged to ask questions about the learning material and express their level of understanding of the material. Teacher shall develop questions that may help initiate discussions rather than the questions intended to meet the curriculum achievement.

Everyone takes notes during presentations. Comment and questions about presentations may be noted. Questions from the group may be asked after all the presentations are completed.

Presentation may be done based on the various topics on a daily basis in the form daily presentations.

1.4. Practical activity-Lab work

Megascopic identification of igneous rocks

Learners examine the rock specimens (igneous rocks) that are provided in groups and let them prepare a record of their texture and mineralogy. Remind them about the features that are helpful to recognize the different rock specimens.

They are asked to discuss these ideas and compare those features with the information listed in appendix II given at the end of the text book.

Based on the texture and mineralogy, learners can try to identify each sample by the rock name given in the appendix. The process and product of practical work shall be evaluated and kept a record for *process* and *portfolio assessment*.

1.5. Formation and classification of sedimentary rocks

Inquiry based learning

Teacher brings a piece of chalk, a specimen of rock salt and sample of shale into the class. Questions are posed to the whole class in a casual situation.

Do you know what these samples of rocks are?

Learners respond by telling their names such as chalk, salt, etc.

Can you tell where these kinds of rocks are formed?

Answers such as sea, desert, estuaries, wetlands, etc. may be expected.

Teacher then explains that these rocks belong to the class of sedimentary rocks. Teacher poses some more questions such as

Do you expect the formation of these kinds of rocks at the Earth’s surface or deep in the earth?

What processes were responsible for the formation of this group of rocks?

How are the sediments hardened to become rocks?

Through discussions, the teacher tries to find out the problem. What kind of geological processes were responsible to the formation of sedimentary group of rocks. Temporary conclusions can be drawn during the discussion session such as,

Sediments carried by streams may be deposited and become rocks.

Salts dissolved in sea water may get evaporated.

Can you prepare a report on the formation of sedimentary rocks by doing a project?

Learners raise questions related to content goals. They can plan and carry out their investigations based on their questions. Learners are self-directed to carry out the learning process with some predetermined parameters. They can unfold the processes involved in the formation of different sedimentary rocks.

The class is now ready to execute the project. Groups are formed for gathering information and the data gathered is to be analysed. By analysing the information collected, the learners are arrived into conclusions. Now let them go through the following steps to solve the problem.

1. *Stating the goal/ problem*
   I want to understand how sedimentary rocks are formed.
2. *Posing real questions*
   What are the processes involved in the formation of sedimentary rocks?
   How were sedimentary rocks formed?
   What are the different types of sedimentary rocks?
3. *Listing the sources of information they will use*
   Library books and text book, internet, Geology teacher
4. *Describing the steps that they will take to achieve their goal*
   Arranges a talk with the Geology teacher and other experts about sedimentary process of rock formation.
   Looks up internet, library books and reading the text materials
   Conducts a field visits to nearby area
   Carries out experiments
5. *Listing the main concepts that they want to investigate*
   What are sedimentary rocks?
   How are the sediments formed?
   What are the stages involved in the consolidation of loose sediments into a hard rock?
   Can I classify sedimentary rocks into different classes?
   Can I make a model of sedimentary rock?
   What are the common types of sedimentary rocks?
   How can I identify sedimentary rocks?
6. *Listing the methods that they will use to present their project*
   Explains what sedimentary rocks are.
   Describes the processes involved in sedimentary rock formation.
   Makes a classification chart of sedimentary rocks
   Makes a video presentation of common sedimentary rocks.
   Exhibits some of the common sedimentary rocks in the class.
7. *Organizing the project into a timeline*

Day 1: Collects sources of information
Day 2: Collects sources of information
Day 3: Interviews experts
Day 4: Looks at specimens of sedimentary rocks available in the geology laboratory
Day 5: Carrying out experiments
Day 6: Carrying out a field visit in the neighbourhood areas/ Collecting samples
Day 7: Makes diagrams, charts, handouts/slides and notes
Day 8: Practices presentation
Day 9: Presents in the class

8. *Deciding the evaluation strategies of the project*
   Practices in front of my peer *X* and *Y*
   Asks the class for a feedback on my presentation and project work
   Fills out self-evaluation Performa
   Collects the teacher's evaluation

In this method, the learners explore materials and make observations related to the formation of sedimentary rocks. After completion of the investigation, learners prepare a report on the investigation done. Finally they share investigation results with each other and with the whole class which lead to further understanding of the concepts.

The teacher shall provoke interest and curiosity and provide a reason for investigation and learning. He/she shall help students discover what they do and what they do not know thereby ensuring that the learners reach beyond what they know.

Both the process and product of the project are evaluated by the learners and teacher.

Self evaluation tool for the learner:-

Evaluation items	**Yes**	**No**
I have understood the objective of the project clearly		
I have gathered information from all possible sources		
I have analyzed the data collected and consolidated my findings		
I have prepared a report on all the activities done right from the planning of the project to the presentation of the report in the class		
I have prepared for sharing the ideas with others and presenting the report in the whole class		

Peer evaluation

Evaluation questions	**Learner's response**	**Peer learners' response**
What did you felt about the need of executing this project?		
What hypothesis did you draw about the problem?		
What were the methods of study that you have used?		
What conclusion did you arrive after executing the task?		
Do you provide any suggestions as part of the activity done?		

Teacher evaluation

Teacher can evaluate the learning *process* considering the given *process skills*

- Ability to formulate questions and form hypotheses
- Ability to collect, observe and record data accurately
- Ability to work in groups in an organized and productive manner
- Ability to talk and share ideas with others
- Ability to verify their findings and thinking through personal experiences

Check list for teacher evaluation

Evaluation items	**Yes**	**No**
Does the work comes from a need for solve a real problem?		
Will the task allows learners to better understand their learning needs?		
Can the learners understand, organize and systematically use data?		
Do the learners comprehend the facts, concepts and solutions to the problem?		
Have I prepared a record showing the performance and differences in the ways of learners presenting their conclusions		

Portfolio assessment:-

Project report

Evaluation items	Missing	Limited degree	Good	Very good	Excellent
Title					
Introduction					
Statement of the objectives					
Rational of the problem					
Data collected					
Tools used for study					
Data analysis & interpretation					
Conclusion					
Appendices					

1.6. Classifying sedimentary rocks

Learners are allowed to work in groups. Each group is given a sample of sandstone, conglomerate and shale. Learners observe the samples and give their ideas about how they might have been formed. They are asked to go through the table1.2 of the text material.

The teacher asks the following questions

Can you classify the given three rocks according to the size of grain particles?

In what ways do they differ?

Which rock has the largest grains?

Which rock consists of smallest particles?

What can you discover about sandstone?

Learners can recognize that,

Shale has the finest particles and it is probably composed of clay particles.

Sandstone consists of sand sized grains and the mineral will be usually sand.

Conglomerate has the largest grain particles (pebbles and rock fragments).

Teacher can also demonstrate settling of sand and clay in water.

Teacher concludes that, sedimentary rocks are formed of deposited grains of clay, sand, gravel particles pressed together by subsequent layers and then cemented together. Shale formed from very fine particles being compacted together; sandstone resulted from cemented sand grains and conglomerate is the result of cementation of various large sized particles.

The teacher, learner and peers shall evaluate all the stages involved learning process and each one can prepare an evaluation report. The item can be taken for *process assessment* also.

1.7. Chemical sedimentary rocks- formation

Conducting experiment

Learners are asked to dissolve as much as salt as they can in a cupful of water and make a saturated solution of salt. Pour the water into a shallow pan and let it stand until the water evaporates. The solution can be allows to evaporate for several days.

What is left behind?

Let them examine the resulting salt formation.

Tell them that precipitated sedimentary rocks are formed in the same way from the evaporation of saline water. The crystals were not visible in the saturated solution because the salt was dissolved in the water. Particles in precipitated sedimentary rocks were once

dissolved in water and lat precipitated out of solution. Learners can compare the salt with chemically precipitated rocks like gypsum, limestone, rock salt, etc.

Sedimentary rocks-points to be highlighted

The following key points may be reminded once again.

Clastic (also called Detrital)—made of broken pieces of other rocks

Examples:- sandstone, shale

Organic—remains of plants and animals are deposited in thick layers

Examples:- Fossiliferous limestone

Chemical—minerals dissolved in lakes, seas, or underground water

Examples: - Rock salt and Chalk. Limestone forms when calcite mineral precipitates from sea water.

Sedimentary rocks are rocks formed from the consolidation of loose sediment (sandstone) or from chemical precipitation (limestone) at or near the earth's surface. Sedimentary rocks are formed by the weathering, (physical and chemical) of igneous, metamorphic and other sedimentary rocks. The weathered fragments are transported via water, air or ice before they are deposited and transformed. Sediments are transformed into rocks by: **cementation**, usually calcite, silica or iron oxides that glue the fragments together and compaction **(**fragments being squashed together).

1.8. Practical work

Megascopic identification of sedimentary rocks

Sedimentary rocks are mostly identified by their characteristic textures. Their textures range from very fine grained, to very coarse. Colours include red, brown, gray, yellow, pink, black, green and purple. Specimens of sandstone, shale, conglomerate and limestone are given as part of practical evaluation.

Learners are advised to go through the table 1.3(Kinds of clastic sedimentary rocks) given in the text book.

Detrital particle	**Size range**	**Term applied for loose sediments**	**Name of the consolidated sedimentary rock**
Boulder	>256 mm	Gravel	Conglomerate or Breccia (depends on rounding)
Cobble	64 - 256 mm	Gravel	
Pebble	2 - 64 mm	Gravel	
Sand	1/16 - 2mm	Sand	Sandstone
Silt	1/256-1/16 mm	Silt	Siltstone
Clay	<1/256 mm	Clay	Claystone, mudstone and shale

They are directed to study the individual grains that make up the rock.

Are they very coarse grained/ composed of larger, rounded gravels and pebbles?
It might be conglomerate.
Are the grains that make up the rock are composed of sand grade particles/ the rock feels gritty by touching with the hand?
The rock may be identified as sandstone.
Are the grains composing the rock are very fine grained clay and silt/too small to be identified by naked eye/have bedding or lamination?
The rock can be designated as shale.

Limestone can be identified by doing the experiment given below.

Identification of limestone

Materials: Specimens of limestone weak hydrochloric acid (HCl), lemon juice (or vinegar).
Procedure:
(1) Pour dilute HCl or lemon juice over the rocks.
(2) Observe and discuss.

Learners can identify samples of limestone by this method. With a medicine dropper, they are asked to put a few drops of weak hydrochloric acid on the piece of limestone. They can notice the bubbles that are formed. The acid/lemon juice will "bubble" or effervesce on the surfaces of the rock.

Limestone contains calcium carbonate which is an alkaline substance. When the hydrochloric acid or acidic lemon juice react with the alkaline limestone it produces carbon dioxide, which results in the appearance of bubbles. Rocks composed of calcium carbonate such as chalk and marble will also give similar results.

1.9. Types of metamorphic rocks

Group activity-Jigsaw method

The information that needs to transact to the learners can be communicated by the co-operative learning method called jigsaw (Aronson 1978)

The content area can be organized into 7 topics numbering each section as 1, 2, 3,4,5,6 and 7.

i) Slate ii) Phyllite iii) Schist iv) Gneiss

v) Marble vi) Quartzite vii) Charnockite

Divide the whole class into 7 basic/master groups comprising of 7 members each. Provide each group with the complete set of learning material (common metamorphic rocks) divided into seven parts. Explain that learners must teach their peers about the part of content area that they each have received.

To teach their peers, learners must first master their content. Expert groups /sub-groups are then formed incorporating one member each from the already formed basic groups. That is, organize learners so that all ones are together in a group, all the twos are together in a group, and so on. Thus seven expert groups are formed. The expert groups develop strategies to teach their content.

Distribute the key ideas regarding the structure/texture and mineralogy of the above mentioned rocks are discussed in sub groups in a way that details regarding the rock slate are learnt by the first subgroup, phyllite by the second subgroup, schist by the third, and so on.

Members of each subgroup are assigned the cooperative task of learning the same section of material and thus become experts on the material to be learnt and taught. They plan also how to teach the content areas to the other members of the basic groups. The best ideas from each group member can be incorporated into each member's presentation. The experts return to the master groups and teach their content. They meet their peers and share the ideas they learnt from the seven different subgroups.

Teacher shall assess the learners' degree of mastery of all the material. The groups whose members all perform excellence can be rewarded. Thus the group members are responsible for mastering their information, teaching it to the rest of the group, and learning the information presented by other group members.

Demonstration and laboratory works can be followed by the group activity. Learners can work singly or pairs pr in small groups. They should observe specimens of gneiss, schist, slate, marble, quartzite, hornfels and charnockite.

Group activity-comparison of rocks

Provide specimens of shale and slate. Let them observe the contrasts of foliation in metamorphic rocks with the beddings exhibited by sedimentary rocks.

Have them examine a piece of limestone and a piece of marble. Let them to scratch one with another and try to find out which one is harder. Learners also examine both the specimens with a magnifying glass and observe the close packing of particles together in marble.

Place a drop of dilute hydrochloric acid on each rock with a dropper. Since both are made of calcium carbonate, bubbles of a gas evolve from both. They can observe that both limestone and marble consist of same mineralogical composition.

Next, have them compare the sandstone and quartzite. Remind them that, sandstone is a sedimentary rock composed of sand grade particles cemented together. Ask them if they observe any difference and why quartzite is much harder than sandstone.

Make the learners convince that during the process of metamorphism, great heat and pressure caused the grains of quartz melt and become welded together. Metamorphism alters the appearance of their protoliths and makes them more compact.

Emphasis shall be given to prepare tables showing relationship of metamorphic rocks to sedimentary and igneous rocks. A comparison chart can be prepared as given below.

Table-1

Rocks	**Minerals found**	**Characteristics**	**Type of rock**

Quartzite			
Limestone			
Marble			
Shale			
Slate			

1.10. Types of metamorphic rocks

Remind them the fact that metamorphic rocks are derived from pre-existing igneous and sedimentary rocks. The original rock has been changed in form by the earth's temperature, pressure and chemical fluids to form a new metamorphic rock. Examples would include areas where an igneous intrusion forces its way through the earth's crust resulting in pressure and temperature changes due conducted heat, force and friction.

The contact with extreme heat is similar to the food we cook-food comes into contact with the hot pan changes in its properties. Learners can remind of what happens when raw rice is put in boiling water to understand the effect of fluids during metamorphism. The effect of pressure can be exemplified by the process of making beaten rice.

Tell them that metamorphism can occur in areas of stress such as faulting and folding of rock or in areas of plate tectonics such as the oceanic crust colliding into the continental crust. The principal characteristic of metamorphic changes is that they occur while the rock is solid.

Texture/structure characteristics are very important in classifying metamorphic rocks. They range from very fine grained to coarse grained minerals. Metamorphic rocks can be divided into two textural groups, foliated (layered) and non-foliated (not layered). **Foliation:** Parallel layers of minerals, sometimes of different composition, giving the rock a distinctive planar to platy feature (Schist, Gneiss).

Non-foliated: No preferred orientation of minerals. The rock has no preferred orientation of breakage (Quartzite and Marble).

Learners are asked to go through the text book and analyse the basis of classifying metamorphic rocks into foliated and non-foliated rocks. Metamorphic rocks and their corresponding protoliths can be displayed in the whole class and the learners are asked to complete the table given below.

Table-2

Metamorphic rock	**Parent rock/protolith**	**Foliated/non-foliated**
Slate		Foliated
Phyllite	Slate	
Schist		
Gneiss	schist	
Quartzite		
Marble		
Hornfels	Varying rocks	Non-foliated

The tasks completed are discussed in the class. Teacher can assess the reports which shall be taken for *portfolio assessment*.

1.11. Practical activity- Megascopic identification of metamorphic rocks

The structures exhibited by metamorphic rocks are very helpful in identifying the rocks. As mentioned above metamorphic rocks belong to two major classes- foliated and non-foliated. As part of practical work learners are asked to identify the following rock specimens.

Schist, Gneiss, Slate and Charnockite

Foliated—mineral grains are flattened and line up in parallel bands. Rocks belong to this class include mostly schist, gneiss and slate. **Non-foliated** metamorphic rocks show a characteristic granular/granulose texture. Examples include pure marble, quartzite and charnockite.

Distribute specimens of the foresaid rocks to the learners

Does the rock is composed of flaky or platy minerals arranged in parallel layers/shows a schistose structure?

The rock can be termed as Schist.

Are the minerals forming the rock show a gneissose structure in which the platy minerals and granular minerals are segregated in to bands having contrasting colours?

The rock might be a metamorphic rock called Gneiss.

Does the rock shows a slaty cleavage /can be split into separable layers/have a marked fissility?

The rock shall be identified as Slate.

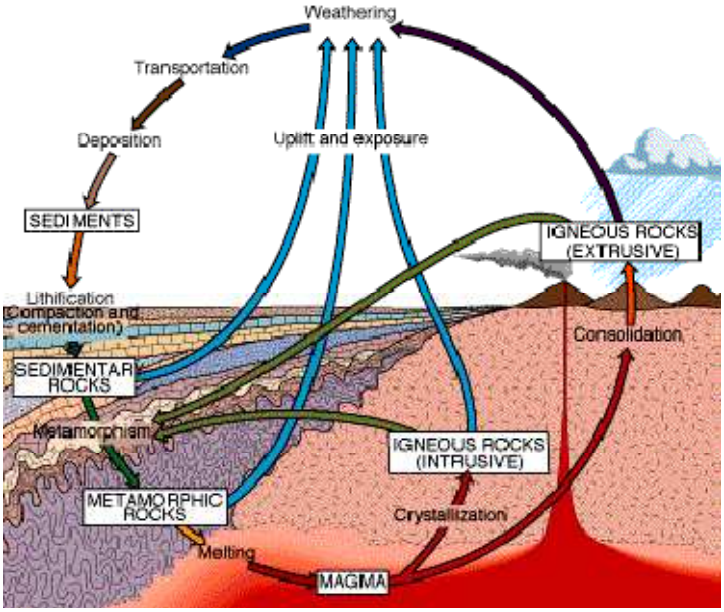
Since granular rocks such a Marble, Quartzite and Charnockite are composed of mineral grains without having a well defined banded arrangement or foliation, they can be identified particularly on the basis of the mineralogical composition. The minerals in the rocks show signs of recrystallisation associated with metamorphic process.

Presence of dark coloured mineral called hypersthenes can be visualised in Charnockite. Re-crystallized grains of calcite can be seen in Marble while Quartzite is composed dominantly with interwoven grains of quartz.

1.12. The rock cycle

Analysis of diagram

Introduce the topic giving an idea of the cyclic changes taking place on the rocks of the Earth's crust. The continuous changing of rocks from one kind to another over long periods of time is called the rock cycle. Learners are directed to use the diagram of the rock cycle (Fig.1.34), given in the text book and answer the questions given below.



1. As magma cools, it forms -------- rocks by the process of crystallization.
2. Igneous rocks can form from ----------, -------- and ------- rocks.
3. ------- forms from the process of weathering of rocks.
4. Sediments form -------- rocks by the process of lithification, compaction and cementation.
5. Sedimentary rocks can form from -------, --------- and -------- rocks.
6. Metamorphism under extreme heat and pressure transforms pre-existing rocks into ---------- rocks.
7. Melting of rocks produces magma and solidification of the molten rocks forms ------ rocks.

The return of rocks to molten state completes the cycle and the rocks can move through the rock cycle.

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Conducting field visits

A field visit may be arranged to the following areas of interest

1. Bedrock overlies with the regolith
2. Road cuts with visible layers of rocks
3. General characteristics of igneous rocks, plutons and extrusive bodies
4. Stages involved in the formation of sedimentary rocks, sedimentary structures and types of sediments
5. Observing specimens of different rock types
6. Processes involved in cyclic changes taking place on the rocks of the earth's crust

7. Social, economic and environmental aspects related with utilization of rocks as a resource

Learners can be encouraged to collect samples of different rocks by conducting local field visits. They have to make their own collections and try to identify them by the use of keys given in the text book and referring other books. They can watch any new buildings being built near the school and try to find out what kind of stone there are used.

ICT-based activities

Learners can make use of information and communication technology in a variety of ways. You can also assign to the learners some simple activities such as-

1. Download photographs of various rock types from internet found in different parts of the world
2. Using internet make a list of ten monuments that are built entirely using rocks in different parts of the country as well as the world.
3. Collect web articles related with the use and abuse of rocks and display its printouts in the class bulletin board.
4. Make a documentary illustrating the formation, texture, identification and utilization of rocks in various realms of life.
5. Prepare and arrange a slide show on rocks and rocky landscapes of the world.
6. Draw a multimedia cartoon showing the environmental problem associated with unscientific mining of charnockite and laterite from ecologically sensitive areas of the state.

Evaluation items- samples

Self assessment tool for the learner

Sl. No	Evaluation Item	Complete idea	Vague idea	No idea
1	Can I differentiate among plutonic, hypabyssal and volcanic igneous rocks?			
2	Can I explain the difference between felsic, mafic and intermediate igneous rocks?			
3	Am I distinguishing between			

	clastic and non-clastic sedimentary rocks?			
4	Have I acquired an idea of identifying sedimentary rocks on the basis of particles composed the rock?			
5	Can I differentiate foliated rocks from non-foliated ones?			
6	Have I acquired the ability to identify the common metamorphic rocks?			

Complete the given table (to be done by the learner)

No.	**Rocks**	**Texture/ Structure**	**Essential minerals**	**Accessory minerals**	**Type of rock**
1	Granite				
2	Quartzite				
3	Sandstone				
4	Limestone				
5	Marble				
6	Basalt				
7	Dolerite				
8	Charnockite				
9	Dunite				
10	Shale				

Peer group evaluation

(To be performed by the learner's peer groups)

Sl. No	**Evaluation Item**	**Response of learner**	**Remarks of peer learner**
1	Do you know the difference between rock and mineral?		
2	Have you understood the basis of the threefold division of rocks?		
3	How can you distinguish igneous rocks from sedimentary rocks?		

4	Can you identify rocks on the basis of their texture and mineralogy?		
5	Could you distinguish between the metamorphic rocks and their corresponding protoliths?		
6	Do you have an idea of different textures exhibited by igneous rocks?		
7	How can sedimentary rocks be classified?		
8	Can you explain the different types of igneous rocks?		
9	Do you know the agents that are responsible for metamorphism?		
10	Could you illustrate the story of movement of rocks through the rock cycle?		

Teacher evaluation

Sl. No	**Evaluation Item**	**Yes**	**No**
1	The learners have achieved the specific learning outcomes intended by the unit		
2	The learners have actively participated in the collaborative learning activities performed in the class		
3	The learners are able to identify different rock types		
4	The learners have got an idea of the subdivisions of rocks within the major groups		
5	The learners are aware of the significance of rocks in their daily life		
6	The learners can evaluate the roles played by		

	rocks in the economic development of the country		
7	The learners have realized that rocks serve an important non-renewable resource that should be conserved for their coming generation.		

CONTINUOUS EVALUATION ITEMS

1. **Process assessment**
   A. Skill for analyzing diagrams and charts given in the text book.
   B. Procedures of conducting the investigative learning activity assigned on the formation of sedimentary rocks.
   C. Involvement in the group activities given at various stages during the transaction of the content.
   D. Ability to present and share ideas among the learners in the class.
   E. Collection and identification of local rock samples.
   F. Performance of learner's identification skill during laboratory work.
2. **Portfolio assessment**
   A. Preparation of an observation diary on rocks collected and identified.
   B. Rocks collected from local areas and through field visits.
   C. Chart showing classification and subdivision of igneous, sedimentary and metamorphic rocks.
   D. Making a report after visiting the websites of ten major Geological organizations that are functioning in our country and find out the fields and areas of investigations, projects done and services contributed related to rocks, such as mining, prospecting, landscape protecting, conservation of natural habitat, regulation of unscientific activities, construction etc.
   E. Preparation of observation notes in the process of megascopic identification of rocks.

3. Unit Assessment:

A. Conducting a quiz based on formation and classification of rocks.

B. Oral test related with the texture and mineralogy of the major rocks that they have learnt.

C. An open book assessment incorporating open-ended, life related and application level questions related with the unit.

Quiz- a few sample items

1. What is the name given for the molten rock material occurring below the Earth's surface?

A. Magma B. Lava C. Igneous rock D. Asthenosphre

2. What type of rock is formed when weathering and erosion cause sediments to press together in layers?

A. Igneous B. Volcanic C. Sedimentary D. Metamorphic

3. What type of rock is formed when magma cools and solidifies?

A. Plutonic B. Volcanic C. Sedimentary D. Metamorphic

4. What type of rock is formed when change occurs from heat and pressure in the Earth?

A. Igneous B. Plutonic C. Sedimentary D. Metamorphic

PRACTICAL EVALUATION (P E)

Megascopic identification of the following rocks

A. Igneous rocks:- Granite, Pegmatite, Basalt, Dolerite, Gabbro, Dunite

B. Sedimentary rocks:- Shale, Sand stone, Conglomerate, Lime stone

C. Metamorphic rocks:- Gneiss, Schist, Slate, Marble, Charnockite

TERM-END EVALUATION- T E

1. Which one of the following is not true about basalt?

(a). It is composed mostly of mafic minerals

(b). It is the volcanic equivalent of gabbro

(c). It is a fine-grained extrusive rock

(d). It is a coarse grained extrusive rock

2. What geologic processes transform a sedimentary rock into an igneous rock?

(a). Melting and solidification

(b). Weathering and erosion

(c). Cementation and compaction

(d). Diagenesis and lithificaion

3. How can you identify granites from pegmatites?

4. Describe the geologic process by which an igneous rock is transformed into a metamorphic rock and then exposed to erosion.

5. How would you be certain that a given rock is quartzite and not sandstone?

6. Why are intrusive igneous rocks coarsely crystalline and extrusive igneous rocks finely crystalline?

7. What kinds of igneous rocks contain quartz?

8. Name two intrusive igneous rocks with higher silica content than that of gabbro.

9. How would you compare rhyolite with granite?

10. What is the difference between a foliated metamorphic rock and a non-foliated one?

Scoring indicators

1. It is a coarse grained extrusive rock
2. Melting and solidification
3. Granites are coarse grained while pegmatites are extremely coarse grained
4. Description of rock cycle
5. Sand grains composing quartzite might become hard and bigger in size because of recrystallization during metamorphism
6. Intrusive rocks are cooled slowly and hence the crystals become larger in size. The fine crystal size of extrusive rocks is attributed to the faster rate of cooling lava at the earth's surface.
7. Felsic/Silicic rocks
8. Granite and diorite
9. Both are felsic /contains same mineral composition/ composed dominantly of quartz and feldspar
10. Foliated rocks have flat thin layers that may be split easily. Non-foliated rocks lack such layers and flakes.

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Petrology activities and examples