Rajiv Gandhi University of Knowledge Technologies Basar

LABORATORY MANUAL

GEO SCIENCE LAB

DEPARTMENT OF CIVIL ENGINEERING

RGUKT BASAR

TELANGANA. -504107

MINERALS

Mineralsarenaturally occurring homogenous solid, inorganically formed, having a definite chemicalcomposition and an orderly atomic arrangement. Most minerals have fairly definite physicalproperties such as crystal form, color, luster, hardness, specific gravity, and solubility.Minerals are classified as to their origin and chemical composition Based on origin, mineralsmay be primary and secondary minerals Rocks are simply aggregates of two or moreminerals.

Primary Minerals:

Are formed by the cooling and solidification of original moltenmaterial.

1.Quartz: SiO2

• Most common soil forming mineral
• Make up 13% of earth's crust and from 30 to 40% of the average soil
• Commonly a translucent milky-white color
• Hard enough to scratch glass
• Resistant to weathering
• Present in granite; absent from basalt
• Present in almost all sandstone
• Does not contribute plant nutrients to the soil

2. Feldspar - *alumino-silicates with bases of K, Na, and Ca*

• Account for 60% of the earth's crust

A. Orthoclase Feldspar---KA1Si3O8

• Slightly harder than glass
• Commonly white, orange, or pink in color
• Fine wavy lines may occur within crystals
• Flat surfaces are common (intersecting at 88-90° angles)
• The most abundant mineral in granite
• Is an important source of potassium

B. Plagioclase feldspar--Na AlSi308↔Ca Al2Si2O8

• Slightly harder than glass
• Common gray color (from almost white to dark bluish gray)
• Commonly has striations (flat faces within crystals seen as straight lines on surface)
• Flat surfaces are common (interesting at 87-89° angles)
• Weathers more readily than orthoclase

3. Horneblende --- NaCa2 (Mg, Fe, Al)5 (Si, Al)8 O22 (OH)2

• Slightly harder than glass
• Black, dark brown, or dark green in color
• One of the dark-colored minerals in granite
• Weathers more rapidly than feldspar, but persist in soils as dark coloredgravel

4. Micas- *alumino-silicates with K, Mg, and Fe basic components*

• Easily spilt into thin flexible elastic plates
• Has shiny surface
• Present in granite, basalt, loess, and glacial till
• ***Muscovite (white Mica) KAl3Si3O10(OH)2* : is Al mica and is colorless**
Contains more Potassium than Biotite
• ***Biotite (black mica) KA1(MgFe)3Si3O10(OH)2***: is Mg, Fe mica and is black
Has more Iron and Magnesium

Secondary minerals: are formed by the weathering of primary minerals

1. Gypsum - $CaSO_4\ 2H_2Q$
• Forms from evaporating calcium sulfate-bearing waters
• Very soft and weathers fairly readily
• Accumulate in large quantities in semi-arid regions
• Can be both a Primary and Secondary mineral
2. Calcite - $CaCO_3$(carbonates)
• Commonly found in limestone and Marble
• Much softer than glass; harder than fingernails
• White or colored by impurities
• Slightly soluble in water
• Effervesces in dilute HCI (release bubbles of CO_2)
3. Dolomite - $CaCO_3\ MgCO_3$
• Most common liming material in NC
• Similar to calcite
• Contains Mg
4. Iron oxides
• Formed through chemical weathering
• *Geothite (FeOOH):* gives yellow color in soils
• *Hematite (Fe_2O_3):* responsible for red coloration in soils
5. Clay Minerals (kaolinite)
• Highly colloidal
• Formed primarily form chemical weathering of primary minerals
• Ability to adsorb or hold nutrient ions on their surfaces
ROCKS
Rocks are composed of combinations of two or more minerals.
Three major groups of rocks:
1. igneous
2. sedimentary
3. metamorphic
Igneous rocks
• Formed when molten rock cools and solidifies
• This is the most abundant group of rocks within the earth's crust
• Classified on the basis of their chemical composition
Acidic (Felsic) - Usually light colored
Basic (Mafic) - Igneous rocks that have less than 50% SiO_2
Neutral - Igneous rocks that have between 50 and 65% SiO_2
• Mode of occurrence refers to the location of igneous rock at time of formation
1. Rocks deep within the earth's crust were formed by

• relatively slow cooling process
• Have coarse-grained (pea size) texture
• Intrusive mode of occurrence
2. At or near the earth's surface the igneous rocks developed by

• Rapid to very rapid cooling processes
• Fine grained (size of sugar crystals)
• Or glassy textures
• These are termed as extrusive in mode occurrence
Examples of Igneous Rock

1. Granite
• Are coarse-grained and light colored
• has quartz and orthoclase feldspar as principal minerals
• Acidic in chemical composition and intrusive in mode of occurrence
2. Syenite
• Relatively coarse-grained
• Contains large amounts of feldspar and hornblende
• Classified as neutral and intrusive
3. Rhyolite
• Mineralogical and chemical composition are similar to granite
• Fine grained in texture
• It is acidic in chemical composition
• Extrusive in mode of occurrence
4. Gabbro
• Dark colored
• Has a predominance of plagioclase feldspar, hornblende, and augite
• Basic
• Intrusive
• Coarse-grained
5. Basalt
• Same chemical and mineralogical composition as gabbro
• Fine-grained
• Basic in chemical composition
• Extrusive in mode of occurrence
Sedimentary rocks
• Result from the erosion and deposition of sediments
• Have two classifications

1. **Clastics (fragmental)**

• Are sedimentary rocks which have been formed through physical or mechanical means.
• Vary in size
• Cementing agents may be Clay, Iron oxide, Silica, or calcium carbonate.

2. **Precipitates**

• Types of sedimentary rocks have been produced by chemical or biochemical precipitation of ions from solution (biochemical precipitates usually involve marine animals and may be fossiliferous)
Examples of Sedimentary Rocks
1. Conglomerates
• Formed from rounded pebbles or boulders (>2mm in diameter)
• Cemented together with finer-grained material
• Weather to a very coarse material-which-may forma gravelly soft
2. Sandstone
• Consists of sand grains (0.5 to 2mm in diameter)
• Gives rise to sandy or sandy loam soil
3. Shale
• Composed of minute particles (<0.005mm diameter) which are consolidated
• Predominant mineral is clay which is deposited in slowly moving water

• Soils derived by shales are clayey

4. Limestone

• Usually fine-grained chemical precipitates.
• Principal minerals are Calcite and dolomite
• Dunng weathering the carbonate minerals dissolve and leach away
• Remaining impurities determine the nature of the developed soil

Metamorphic rocks

• Form from igneous and sedimentary rocks exposed to extreme heat and/or pressure
• These are classified according to their structure and parent material

1. **Banded (foliated):**

• Metamorphic rocks that have more or less parallel layers of different minerals.
• Usually uniformed in color or they alternate light and dark-colored layers

2. **Non-banded**

• Metamorphic rocks that have a random pattern of mineral crystals
• Any pre-existing rock may be the parent of metamorphic rock
• Both igneous and sedimentary rocks are parent rocks

Examples of Metamorphic rocks

1. Gneiss

• Banded (alternates light and dark bands)
• Derived primarily from acidic igneous rocks.
• Contains an abundance of feldspar

2. Schists

• Layered
• Fairly uniform in color
• These are metamorphosed shale, gneiss, or basic igneous rock.
• Newly formed minerals like mica, chlorite, and hornblende tend to predominate

3. Slate

• Layered
• Derived from shale
• Mineral grains are invisible
• Is more dense and compact than shale and cleaves into sheet

4. Quartzite

• Non-layered metamorphosed sandstone
• Very hard
• Weathers extremely slowly
• The rock fractures through sand grains which are mainly quartz

5. Marble

• Is a recrystallized limestone with a random array of mineral grains
• Coarser-grained than parent limestone
• Weather more slowly than limestone
• The impurities determine the kind of soil.

ROCKS

What is a Rock?

Rocks are aggregates of mineral grains. Most rocks are **polymineralic** and contain several different minerals. For example, granite contains the following minerals:

- -quartz
- -2 types of the mineral feldspar: plagioclase and orthoclase
- -2 types of the mineral mica: muscovite and biotite

Some rocks contain grains of only one kind of mineral and are called **monomineralic**.

There are three types of rocks: **igneous rocks, sedimentary rocks,** and **metamorphic rocks.** After this lab, you will be familiar with some igneous rocks. We'll learn about sedimentary and metamorphic rocks in the weeks to come.

What is an Igneous Rock?

Igneous rocks form by cooling and solidification of molten Earth material (magma). Let's break that definition down. Igneous rocks come from magma. **Magma** is hot, liquid (molten) rock below the surface of the Earth. When magma flows upward toward Earth's surface, one of two things will happen to the magma. The fate of the magma determines which kind of igneous rock will form.

What happens to magma as it rises?

Some magma never makes it to the surface of the Earth. Instead, it [illegible]d solidifies beneath Earth's surface very slowly and forms **plutons** like sills, dikes, laccoliths**,** and batholiths (Figure 2.1).

intrusive igneous rocks
(plutonic rocks)

Some magma is erupted out of volcanoes and onto the surface of the Earth. Hot liquid rock above Earth's surface is called **lava**. Erupted lava cools and solidifies very quickly. (Figure 2.1—composite volcano, lava plateau, caldera)

extrusive igneous rocks
(volcanic rocks)

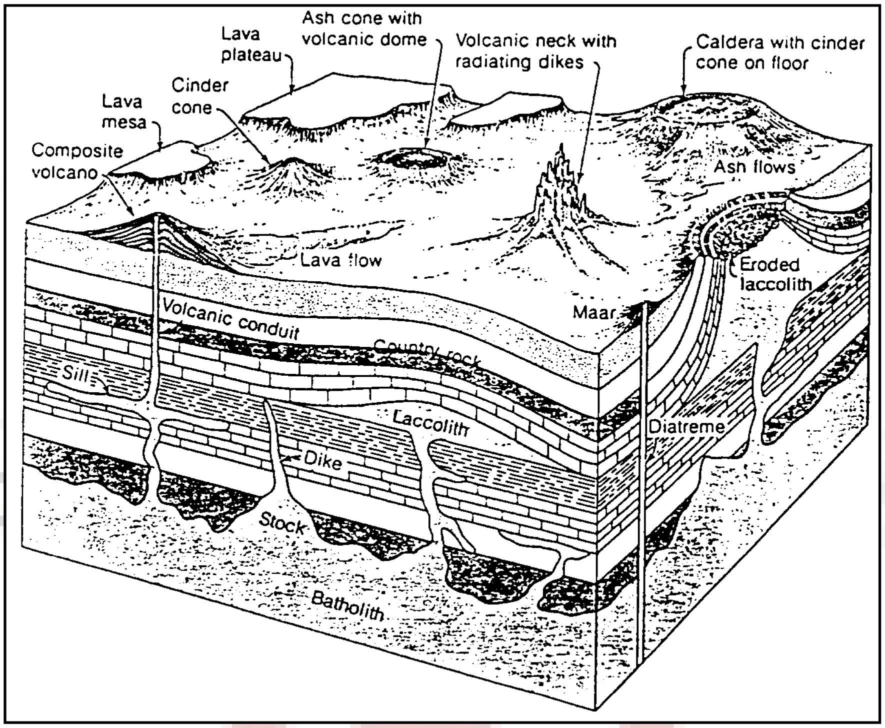


Figure 2.1. Plutonic and volcanic structures (after Schmidt and Shaw, U.S.G.S.).

How do geologists identify igneous rocks?

Igneous rocks are identified using a classification system based on:

(1) **composition** (which minerals make up the rock)
(2) **texture** (a description of what the rock looks like)

Composition:

Remember in lab 1 when we divided the minerals into **felsic** and **mafic** groups? We did that for a reason:
-it represents the chemical difference between light-colored and dark-colored minerals. Igneous rocks contain varying proportions of light-colored, low-density minerals (**felsic**) and dark-colored, denser (**mafic**) minerals.

Felsic: light colored minerals and the igneous rocks abundant in these minerals. Felsic minerals include feldspars — orthoclase (potassium feldspar, or K-Spar) and plagioclase (sodium/calcium feldspar), quartz, and muscovite.

Mafic: dark-colored minerals and the igneous rocks abundant in these minerals. Mafic minerals are chiefly composed of magnesium and iron and include olivine, augite [pyroxene], hornblende [amphibole], and biotite.

****Important!!** Only igneous rocks and the minerals that compose igneous rocks can be referred to as mafic or felsic. This is because igneous rocks are directly created from cooled magma and magma is compositionally differentiated as felsic or mafic. Geologists do not use these terms for metamorphic or sedimentary rocks.

The most common minerals in igneous rocks are:

Chemical Group	Mineral Name
Feldspars	Plagioclase and orthoclase
Micas	Muscovite and biotite

Oxides	Quartz
Amphiboles	Hornblende
Pyroxenes	Augite
Olivines	Olivine

The chemical group is how these minerals are classified on the basis of their chemical composition. Descriptions of the forms these minerals often take in igneous rocks can be found in the References Section at the end of this lab.

**The mineral names above should sound familiar to you after lab 1. Could you identify each of those minerals in hand sample? ? Ask your T.A. if you have any questions.

Exercise 1: Composition—Bowen's Reaction Series

Figures 2.2 and 2.3 illustrate **Bowen's Reaction Series.**

Why is Bowen's Reaction Series important?

Remember our definition: igneous rocks form by cooling and solidification of molten Earth material. But if all igneous rocks come from molten Earth material, why do different magmas have different compositions (in other words, different mineral assemblages)? Bowen's Reaction Series is a principle that attempts to answer that question.

Bowen's Reaction Series explains that different minerals in a magma crystallize at different temperature conditions. Bowen's Reaction Series includes the discontinuous reaction series and continuous reaction series.

*Important note! Bowen's Reaction Series operates under the assumption of a closed system. It is a generalization that accurately explains mineral crystallization in a melt in many, but not all, scenarios.

Discontinuous reaction series.

- Look at the left-hand side of Figure 2.2 at the series of mineral names enclosed in bubbles and linked by arrows from top to bottom. This portion of the diagram represents the discontinuous reaction series.
- Picture starting out with a pool of very high temperature magma (hot, liquid rock) in Earth's crust with atoms of iron, silica, magnesium, and all the other elements that create minerals, swimming around in the melt. The pool of magma is a **closed system**, which means that no ingredients can be added to the melt, and no ingredients can be lost from the melt.
- As the melt starts to cool, minerals will **crystallize** and become solid crystals swimming around in the melt. The first crystals to form will be olivine because olivine is very stable as a solid in high temperatures. If the melt instantaneously cooled to a solid at this point, you would have olivine crystals in a rock mass.
- However, if the melt with olivine crystals continued to cool, the olivine crystals would slowly **destabilize** within the melt and pyroxene (augite) crystals would begin to form. This occurs because pyroxenes are the more stable mineral at this slightly lower temperature. Eventually, all of the olivine crystals would be **reabsorbed** back into the magma.
- This process of destabilization, reabsorption, and formation of new, lower-temperature minerals will continue to occur until biotite, the last mafic mineral in the discontinuous reaction series, is crystallized out of the magma. The felsic minerals, potassium feldspar (orthoclase), muscovite, and finally, quartz, will crystallize out of the remaining magma in the last stages of cooling. The remaining magma will be concentrated in those elements that create the felsic minerals.

<u>Continuous reaction series.</u>

- As depicted on the right-hand side of Figure 2.2, the felsic mineral plagioclase feldspar forms in a continuous reaction series with calcium-rich plagioclase crystallizing at high temperatures, and sodium-rich plagioclase crystallizing at low temperatures.
- It is very important to understand that felsic minerals generally are stable (in equilibrium) at lower temperatures and mafic minerals generally are stable (in equilibrium) at higher temperatures. For example, olivine is not commonly seen at the Earth's surface because olivine is not stable in these low temperature conditions — olivine will easily weather and quickly be broken down. Plagioclase feldspar is the exception to this general rule.

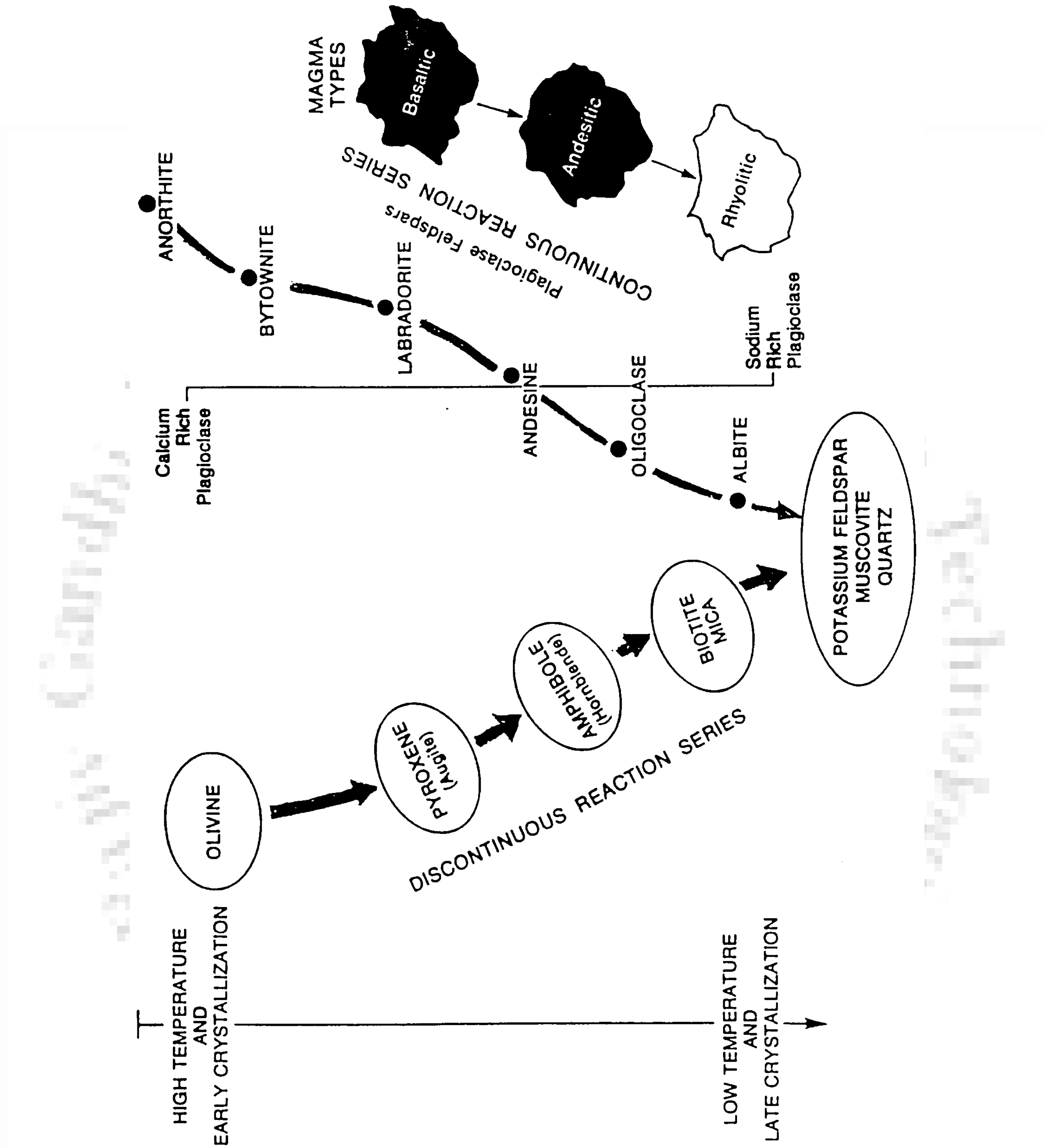


Figure 2.2. Bowens Reaction Series

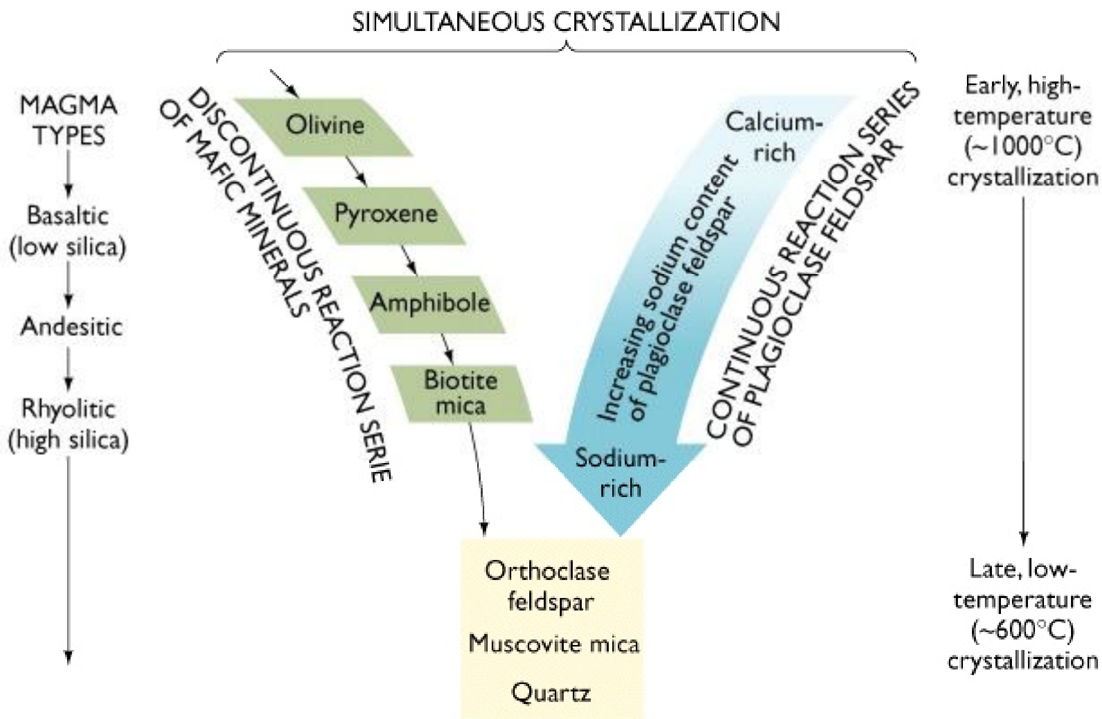


Figure 2.3. Another depiction of Bowen's Reaction Series.

1. What is the difference between the discontinuous reaction series and the continuous reaction series? (.2)

2. Felsic and mafic minerals are chemically different. Felsic minerals are rich in silica (Si), while mafic minerals are dominated by iron (Fe) and magnesium (Mg). (.1 each)

   (a) In lab #1, how did you tell the difference between the felsic and mafic minerals?

   (b) Name two mafic minerals that you identified in lab #1.

   (c) Name two felsic minerals that you identified in lab #1.

3. Study figure 2.3. (.1 each)

   (a) Are mafic minerals *generally* more stable at high temperature conditions or low temperature conditions?

   (b) Are felsic minerals *generally* more stable at high temperature conditions or low temperature conditions?

4. Are there any exceptions to this generalization from question #3? If yes, which mineral(s)? (.2)

5. Based on Bowen's reaction series:

(a) Name two minerals that you would NOT expect to find in the same rock. (.1)

(b) Explain why you picked these two minerals. (.2)

6. Classify the following samples as mafic or felsic. (.1 each)

(a) Sample I-4 ____________ (b) Sample I-6 ______________ (c) Sample I-8 _____________ (d) Sample I-10 ______________

7. (a) Name two minerals from lab #1 that you would expect to find in felsic rocks. (.1)

(b) Name two minerals from lab #1 that you would expect to find in mafic rocks. (.1)

Exercise 2: Texture

The texture of an igneous rock depends directly on of the cooling history of that rock (in other words, how fast the magma cooled and solidified). How fast magma will cool is depends on the igneous environment (where the rock formed).

Intrusive igneous environments are characterized by slow cooling of the magma.
Extrusive igneous rocks are produced by rapid cooling of the magma.

Answer the following texture-related questions. Use the reference section at the end of the lab for help.

8. Would magma cool more rapidly above or below Earth's surface? Why? (.2)

9. Based on your answers to question 8 and your knowledge of intrusive vs. extrusive rocks, complete the following sentences: (.1 each)

(above or below) *(fast or slow)*

(a) Intrusive igneous rocks cool ___________ Earth's surface at relatively _________ rates.

(b) Extrusive igneous rocks cool ___________ Earth's surface at relatively _________ rates.

10. Pick out two intrusive samples from the igneous rock tray. (.2)

Sample ____________________ and ____________________

11. Your samples should have visible mineral crystals interlocking with one another. Identify two different minerals present in each sample (from question 10). (.2)

Sample	Minerals	
__________	____________________	____________________
__________	____________________	____________________

12. Pick out two extrusive samples from the igneous rock tray. (.2)

Sample ____________________ and ____________________

13. Which sample exhibits a pyroclastic texture? (.1) ___________

(b) Explain why you picked this sample. (.1)

14. Compare samples I-5 and I-6. Which sample exhibits a porphyritic texture? (.1)

Sample __________

(b) Explain why you picked this sample and not the other. (.1)

Exercise 3: Igneous Rock Identification Profiles

The composition and texture of an igneous rock tell the story of how the rock formed. Did the rock form above or below Earth's surface? At relatively high or low temperatures? On land or underwater? From a lava flow or an explosive volcanic eruption?

Complete identification profiles for the ten igneous rock samples. Along the way, you will be reading about different environments of formation for igneous rocks and answering questions. When it comes to identifying the rocks, it is as important to understand how the rock formed as it is to correctly identify it.

Use the references section to describe the rocks and identify them by name.

Intrusive Environments of Formation

Plutons:
Felsic magmas can form at subduction zones where oceanic crust is being dragged underneath continental crust (see Figure 2.4). Melt from the subducting oceanic plate and/or the mantle causes continental crust to melt, which produces a felsic magma. If the magma crystallizes slowly within the crust, it is called a **pluton**. The only way these bodies become exposed at the Earth's surface is through **uplift** and/or **erosion**. Plutons include laccoliths, lopoliths, stocks, and batholiths (see Figure 2.1). **Batholiths** are the largest of these igneous bodies and a spectacular example is the Sierra Nevada Range in California, containing the Yosemite Valley.

Plutons are created underground by very slow cooling of the pooled magma, insulated by the surrounding rock. Because cooling is so slow, individual mineral crystals have time to grow and interlock together. Individual minerals **(phenocrysts)** are visible without a hand lens, and this coarse grain size is called **phaneritic**.

15. (a) If someone brought you a phaneritic rock, what could you tell him/her about where the rock formed relative to Earth's surface? (.1 each)

    (b) How would you explain to him/her why the phenocrysts were relatively large?

Complete the igneous rock identification profile for samples I-1 and I-10 now.

Ocean crust:
The formation of ocean crust is a direct result of the geologic phenomenon known as **sea-floor spreading** (see Figure 2.5). The mid-ocean ridge is essentially a crack in the ocean crust through which magma can be pushed out. The newly extruded magma will quickly harden onto the ridge walls, creating new crust material. Due to convection, the ocean crust on either side of the mid-ocean ridge will move away from the ridge in opposite directions. By this process, new ocean crust is being continuously created. The rocks that form below the surface of the ocean floor are considered intrusive because they never reach the Earth's surface. **Fractures** in the **rift zone** allow seawater to cool the top of the magma chamber, causing the magma to crystallize out and plate to the bottom of the ocean crust as a coarse-grained mafic rock. The composition of these rocks is mafic because the mantle

composition is mafic to ultramafic.

16. Complete the igneous rock identification profile for sample I-2 now.

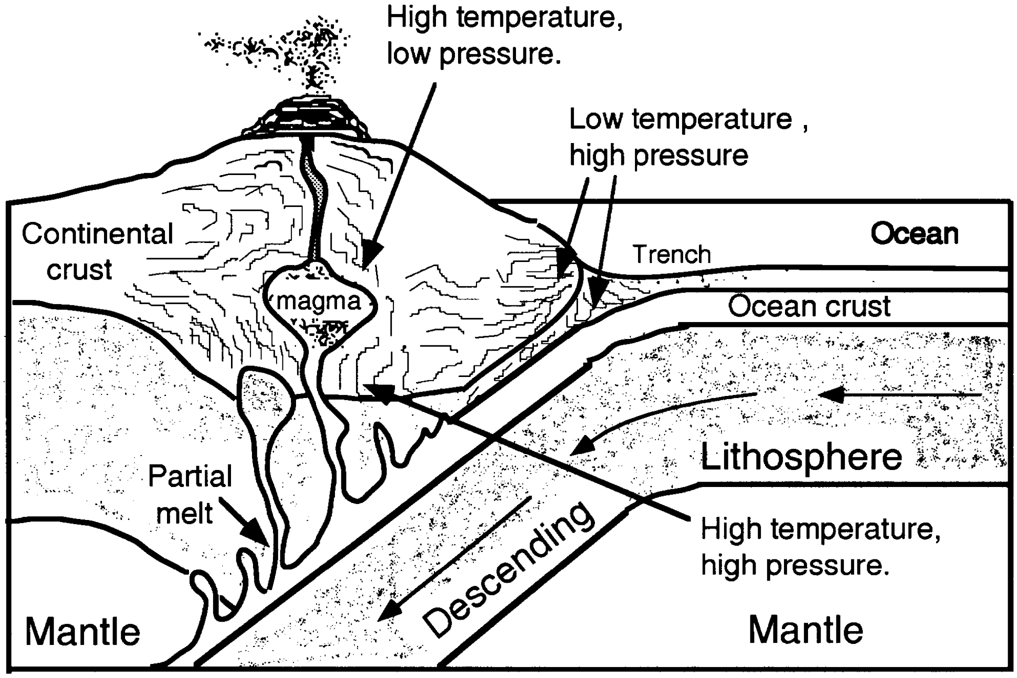


Figure 2.4. Igneous and metamorphic environments according to the plate tectonics model.

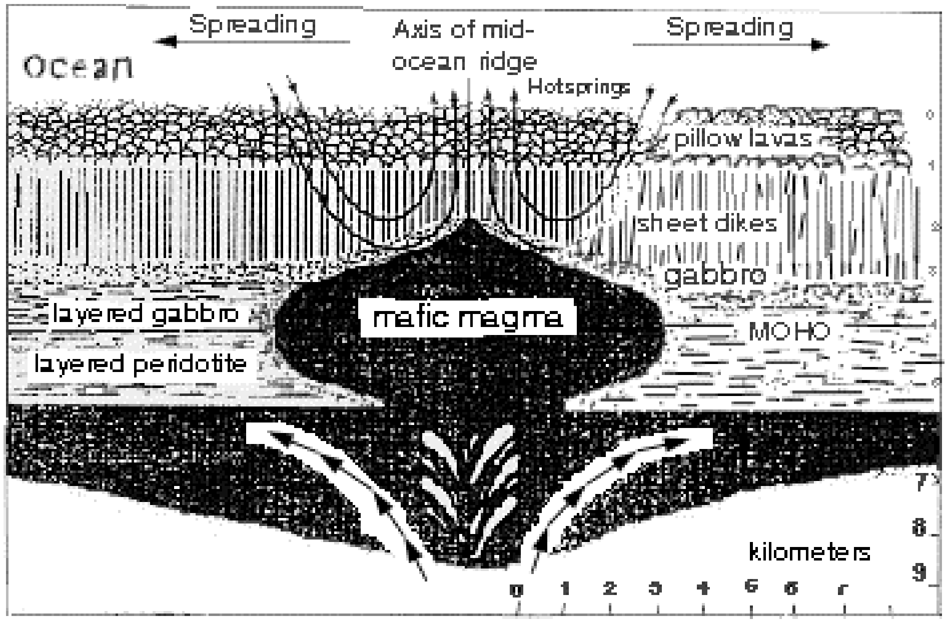


Figure 2.5. Ocean crust formation at a Mid-Ocean Ridge.

Extrusive Environments of Formation

Composite volcanoes:

Composite volcanoes are created by the eruption of magma from a central vent, or pipe, and give rise to the most familiar of all volcanic features — the **cone**. When a volcano erupts lava as well as **pyroclasts** (bits of rock fragments, glass and ash shot high up into the air), a **composite cone** (or **stratovolcano**) is built of alternating lava flows and beds of pyroclasts. A single eruption will result in one layer of felsic to intermediate lava flows overlain by a layer of pyroclasts, the airborne materials that eventually rain back down onto the surrounding landscape. Spectacular examples of composite volcanoes include Mt. Fuji, Vesuvius and Mt. St. Helens. Composite volcanic rocks are typically felsic to intermediate in composition because the rising magma melts the more felsic continental rocks as it travels through them, and incorporates these materials into the melt. Overall, the magma becomes more felsic. Sample I-8 is a classic example of material from a composite volcano.

Of the volcanically ejected, airborne rocks, Sample I-4 is one of the most commonly known forms. This sample formed from a volcanic explosion expelling magma high into the air, cooling quickly to glass. The bubbles were formed by gas escaping from the melt. Bubbles are a direct clue when determining the rock texture.

Another very typical form of explosive volcanic rocks is Sample I-8. This sample was created when all of the varieties of material ejected from the volcano (including pumice fragments, rock fragments and ash) are hardened into a rock. Sample I-5 can often be seen incorporated in this rock. The fine-grained matrix for the fragments is probably composed largely of ash welded together from the volcanic heat.

Sample I-5 is the result of two different rates of cooling. The larger crystals, surrounded by the fine-grained matrix, were formed as the magma in the chamber of the volcano cooled at a very slow rate. Then, when the volcano exploded, the magma, including the phenocrysts, was extruded and quickly cooled on the surface of the Earth, cementing the phenocrysts in the finer-grained matrix.

17. If someone brought you a pyroclastic rock, what could you tell him/her about where the rock formed relative to Earth's surface (above or below)? (.1)

(b) How would you explain to him/her why the rock contained ash, glass, and rock fragments? (.2)

(c) Complete the igneous rock identification profile for samples I-2, I-3, I-4, I-5, I-6, I-8, and I-9.

Shield volcanoes, fissures, rifts, ocean crust, cinder cones:
Sample I-10 is formed in all of these environments, where the distance between the mantle and the surface of the Earth is very small. The magma maintains its original mafic mantle composition because very little felsic continental crust has a chance to be incorporated into the magma. The high temperature, mafic mineral olivine is often found associated with this sample (especially in ocean crust) for the same reason.

On the Earth's surface, this type of rock is extruded as lava which can flow great distances, often forming sheets over the landscape. Many of the mesas and plateaus so evident in the Southwest were created by ancient flows. Once the flow cools into rock, it becomes very resistant to weathering compared to the surrounding rocks, and therefore acts as caps for the less resistant rocks beneath them. Refer to your textbook for more complete descriptions of these assorted environments. **Cinder cones** commonly eject lava short distances creating **vesicular**, mafic rocks. Vesicular rocks are essentially a framework of **vesicles** (bubbles). It is also possible to have an aphanitic (fine-grained) rock with vesicles ; the vesicles in this case are less frequent and do not create a framework.

18. (a) Explain why extrusive rocks are aphanitic. (.1)

(b) Some extrusive rocks have vesicles. How do vesicles form? (.1)

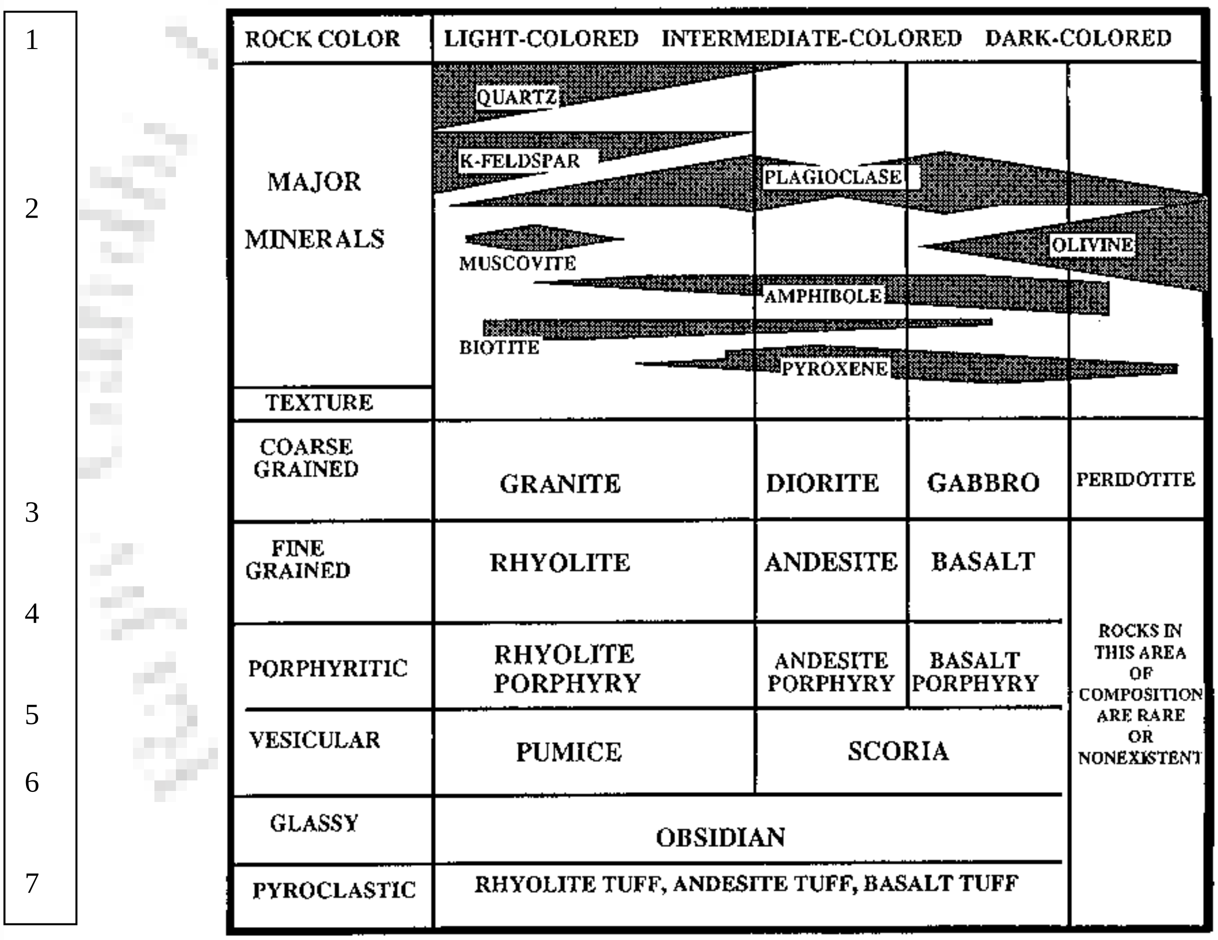
(c) Complete the igneous rock identification profile for samples I-7 and I-10 now.

Exercise 4: Igneous Rock Identification Chart.

The columns represent composition. Rows 3-8 represent texture. By determining a rock's composition and texture, you can identify the rock.

Example: You are holding a dark-colored, coarse-grained rock. First go to the mafic column of the chart and scan that column. You should be seeing gabbro, basalt, basalt porphyry, etc. These are all mafic rocks, but they differ in texture. Your sample is a rock in the mafic column. To narrow down which one, go to the left-hand side of the chart and determine which row (or texture) applies to your sample. Since it is coarse-grained, it will be in the phaneritic row. Therefore, find the rock from the phaneritic row and mafic column. Your rock is a gabbro.

IGNEOUS ROCK IDENTIFICATION CHART



felsic

intermediate mafic ultramafic

19. What would you call a rock that is aphanitic (fine-grained) and contains crystals of plagioclase, amphibole, and pyroxene, but not quartz? (.1)

20. What would you call a rock with olivine crystals suspended in a mafic matrix? (.1)

21. Name an igneous rock whose composition may range from felsic to mafic with a glassy texture. (.1)

22. Draw and label a picture of a sill and a dike and explain the difference between a sill and a dike. (.4)

23. Complete the igneous rock identification profile for sample I-9 now.

Lab 2 References

I. Igneous rock identification chart based on composition and grain size.

light-colored---dark-colored

	felsic	intermediate	mafic	ultramafic
Intrusive (coarse-grained)	**Granite**	**Diorite**	**Gabbro**	**Peridotite**

extrusive (fine-grained)	**Rhyolite**	**Andesite**	**Basalt**	**Komatiite** (very rare)

II. Identifying Minerals in Igneous Rocks (tip: use hand lens to identify minerals!)

Mineral	Diagnostic Physical Properties
Orthoclase	1. Generally **equidimensional** grains 2. Usually white, pink, or gray 3. Two directions of cleavage nearly at right angles 4. Cleavage planes flash light when specimen is rotated
Plagioclase feldspar	1. **Lath-**shaped grains (rectangular) 2. Usually white or gray in granite, may be slightly green 3. Dark bluish color in gabbro 4. Two directions of cleavage nearly at right angles 5. Parallel markings on cleavage faces
Quartz	1. Usually poorly defined grains 2. Colorless to smoky in color and glassy appearance 3. No cleavage
Olivine	1. Small, round-shaped grains 2. Pale green and glassy in appearance 3. No cleavage
Hornblende (amphibole)	1. Lath-shaped grains 2. Black or dark green 3. Two directions of cleavage not at right angles 4. Usually in a light-colored matrix
Augite (pyroxene)	1. Blocky or lath-shaped grains 2. Black or dark green 3. Two directions of cleavage nearly at right angles 4. Usually in darker rocks
Biotite	1. Flat, flaky grains 2. Black or dark brown 3. One perfect direction of cleavage 4. Reflects light
Muscovite	1. Flat, flaky grains 2. Light green of silvery white 3. One perfect direction of cleavage 4. Usually associated with quartz and orthoclase

III. Igneous Rocks — An Overview

Identification of igneous rocks is based on:

1. Composition (chemistry)
    - Which minerals that compose the rock? (Mineral assemblage)
    - Composition influences the color of the rock.
        -Mafic (olivine, pyroxene, amphibole) minerals are typically dark in color.
        -Felsic (quartz, feldspar) minerals are typically light in color.

2. Texture (consequence of cooling rate)

- Extrusive — cools quickly on the Earth's surface
  - -lava flows
  - -pyroclastics
- Intrusive — cools slowly within the Earth
  - -Intrusive rock bodies
    - -dikes: intrusions discordant with country rock
    - sill: intrusions concordant with country rock
  - -Plutons
    - -laccolith: domed the overlying rock and looks like a mushroom
    - -stock: often used to describe a cylindrical pluton
    - -batholith: large body of discordant plutonic rock that has an area of more than 40 square miles and is often formed from a series of plutons

<u>Texture Definitions</u>: words to describe igneous rock textures.

Phaneritic: an intrusive texture. Coarse-grained, visible interlocking mineral crystals. Can typically see individual minerals without using a hand lens.

Aphanitic: an extrusive texture. So fine-grained that you typically cannot see the individual grains without a hand lens.

Porphyritic: two distinct grain sizes. Usually minerals in a fine-grained matrix (extrusive porphyry), but can also have large crystals in a matrix of smaller crystals (intrusive porphyry such as a dike rock). Indicates two distinct stages (rates) in the cooling history of the rock body.

Glassy: no grains visible, even under a microscope. Shiny. Implies very quick cooling.

Vesicular: an extrusive texture. Aphanitic, glassy, or porphyritic rock containing abundant vesicles (gas bubbles.)

Pyroclastic: an extrusive texture. Rock, glass, and mineral fragments (phenocrysts) in a fine-grained, ashy matrix. The rock often feels relatively light for its size because it is composed of heat-welded ash. Pumice fragments are often incorporated and sometimes flattened. Pyroclastic material has been aerially ejected, or exploded, from a volcanic vent.

Metamorphic Rocks

Introduction

The word **metamorphic** means "of changed form." Metamorphic rocks are rocks that have been changed from one form, such as igneous or sedimentary, to another. This can occur when a given rock is exposed to intense heat, pressure, or hot fluids.

Recalling igneous rocks, the specific rock that forms from a given magma depends on the components of the magma, the temperature at which the magma cools, how quickly the magma cools and also the pressure at which the rock forms. As materials crystallize, the atoms form a structure that is most stable at the temperature and pressure of the environment.

Imagine a group of people filling a small room. If only a few people are in the room there is plenty of space for people to spread out and move around while they talk. However, as more and more people enter the room, those same people no longer have the same space and may have to adjust their bodies to become more comfortable.

Although, rocks differ significantly from people, pressure and temperature will have the same effect on the atoms that make up the rock. As pressure or temperature increases, the atoms that make up the original rock must rearrange themselves in order to form a more stable or "comfortable" structure, just as people in a room. However, since rocks are made of minerals and each mineral has a specific chemical structure and form, changing the structure and or form will then change the mineral.

The type of metamorphic rock that can form depends on the rock that is being metamorphosed as well as the amount of pressure and heat to which the rock is exposed. Since varied temperature and pressures will produce different minerals, the exact type of metamorphic rock produced depends on the ***grade***(intensity) ofmetamorphism. The grade of metamorphism can most often be determined by the minerals present within the metamorphic rock and the type of rock formed. Some of the more common metamorphic minerals include quartz, feldspar, biotite, muscovite, chlorite, garnet, tourmaline, calcite, and amphibole. The rock that has undergone change is called the ***parent rock***. Parent rocks can be any of the three types of rocks: igneous, sedimentary, or even metamorphic rocks which can be metamorphosed again.

Metamorphic Processes

Metamorphism often occurs on two scales: contact and regional. **Contact metamorphism** occurs relatively locally, in areas adjacent to igneous intrusions or in areas that are in contact with hot water known as **hydrothermal fluids**.

Typically this kind of metamorphism is caused by moderate pressure and extreme heat that may last for a period of days to thousands of years. In cases of contact metamorphism, the most extreme metamorphism occurs at the contact point between the parent rock and the intrusive magma or hydrothermal fluid. The degree of metamorphism then decreases rapidly as distance from the heat source increases. Depending on the source, zones of contact metamorphism may range from a few millimeters to tens of meters.

In contrast to contact metamorphism, **regional metamorphism** occurs over much larger areas. In areas such as rising mountain ranges, large igneous intrusions can form and warp overlying strata increasing the pressures above the intrusion. Also the extreme heat and pressures caused by tectonic forces or deep burial will cause widespread metamorphism.

In order to identify a metamorphic rock and understand the history of the rock, it is necessary to describe the mineralogical composition of the rock. Mineral composition of metamorphic rocks is often described in terms of relative abundance. The most abundant mineral will most often be used in naming the rock and, more importantly, will be helpful in determining the environment from which the rock formed.

Recrystallization, Neometamorphism, and Metasomatism

Foliated Textures	Examples
Slaty Rock Cleavage ▪ very flat foliation that resembles mineral cleavage. ▪ develops in clay or mica rich rocks- ▪ indicative of low grade metamorphism	

The most common process in the formation of metamorphic rocks is recrystallization. In this process, small crystals of one mineral in contact with one another slowly come together to form fewer larger crystals. For example, the sedimentary rock, limestone. Limestone is composed of microscopic crystals of calcite that once formed the shells of marine creatures. When metamorphosed, those tiny crystals are slowly forced together under high pressure and begin to form larger, more visible crystals of calcite found in the metamorphic rock marble.

In other situations, mineral crystals may completely rearrange to form completely new minerals that are more stable under increased pressure and/or temperatures. This process is known as **neometamorphism**. This is most often observed with the sedimentary rock shale, which is composed of fine grained quartz, feldspars, and other clay minerals. When metamorphosed, these minerals grains will change to muscovite mica and garnet.

The process of **metasomatism** results in the loss or addition of chemicals. This can best be seen in the production of anthracite coal, which is almost pure carbon. The parent rock bituminous coal is produced from the aggregation of dead plant material, and anthracite is produced by the loss of the more volatile materials such as nitrogen, oxygen, and methane.

Classification of Metamorphic rocks

Texture

In order to identify any metamorphic rock, it is first necessary to determine its texture. The texture of a metamorphic rock is a description of its constituent minerals along with their arrangement and shape. Typically this will be initially described as foliated or non foliated. Non foliated textures have no obvious features and are classified mainly on the basis of crystal size.

Foliationis the existence or appearance of layers. Foliated textures result from a parallel arrangement of flat, platy minerals such as muscovite. This is usually a result of mineral recrystallization in the presence of a directed pressure. Under this condition, the mineral grains will grow in an orientation that best distributes the force of the pressure. Typically, mineral grains will grow perpendicular to the force being enacted on them.

Phyllite ▪ wavy wrinkled foliation made up of small platy minerals such as muscovite and chlorite. ▪ usually gives rock a somewhat metallic look ▪ indicative of an intermediate grade metamorphism	
Schistosity ▪ a scaly layering of large (visible) crystals of platy minerals such as amphibole, micas, and chlorite ▪ product of intermediate to high grade metamorphism	
Gneissic ▪ Alternating layers of dark and light medium to coarse grained mineral crystals ▪ Indicative of high grade metamorphism	

Metamorphic rocks are classified based on their texture and mineralogical composition. This information will also be useful in determining the conditions under which the rock has formed, which can give valuable insight into the geologic past.

Using the following chart and the information supplied in this lab answer the questions and complete the table at the end of this lab using metamorphic rock samples supplied by your instructor.

Texture			Mineralogical composition	Name	Parent Rock
Foliated	Fine Grained	Slaty Rock Cleavage	Dull luster, breaks into flat sheets	**Slate** Modify by describing color	Mudstone or Shale

		More Wavy foliation than rock cleavage	Shiny luster, wrinkled or wavy surface	**Phyllite** Modify by naming other minerals by order of abundance	
	Coarse Grained	Schistosity	Visible crystals of platy minerals such as chlorite, muscovite, biotite, amphibole	**Schist** Modify by naming other minerals by order of abundance	
		Gneissic	Visible crystals of two or more minerals in alternating bands	**Gneiss** Modify by naming other minerals by order of abundance	
Nonfoliated	Fine grained	Glassy Texture	Black glossy rock, conchoidal fracture	**Anthracite**	Peat, lignite, bituminous
		Microcrystalline	Dark dull color	**Hornfels**	Any type of rock
		Microcrystalline-may have smooth cleavage surface	Dull or glossy shades of green	**Serpentinite**	Basalt, Gabbro, or ultra maffic rock
	Coarse grained	Sandy or crystalline texture	Quarts sand grains fused together	**Quartzite** Modify by naming quartz	Sandstone
			Calcite-reacts with acid	**Marble**	Limestone
		Conglomerate but breaks across grains	Stretched pebbles	**Meta-conglomerate**	Conglomerate

ENGINEERING GEOLOGY LAB

List of Experiments

1. Study of Physical properties ofminerals
2. Identification of rocks forming silicate and oreminerals
3. Recognition ofrocks
4. Use of clinometers compass and Burton compass for measurement dip and strike of formations.
5. Geological cross sections and study of geologicalmaps.
6. Study of models of geological structures and out crops patterns of different types of rocks and landforms

Objective of Engineering Geology Lab

- To understand the role of geology in the design and construction process of underground openings inrock.
- To apply geologic concepts and approaches on rock engineeringprojects.
- To identify and classify rock using basic geologic classificationsystems.
- To use the geologic literature to establish the geotechnical framework needed to properly design and construct heavy civil works rockprojects.
- To identify and characterize intact rock/rock massproperties.

Experiment :- 1

Objective:- Study of Physical properties of minerals

Theory:- Earth is made up of minerals that are the constituents of rocks. Mineral specimens are usually identified by determining their physical properties.

Colour : Although the colour of some minerals, such as azurite, is quite distinctive, other minerals, such as quartz, occur in a variety of colours. Also there are many white minerals. Hence colour is frequently NOT a useful diagnostic property.

Streak: Streak is the colour of the powdered mineral. It is a useful diagnostic property for many coloured minerals — especially those with a metallic lustre. It is found by rubbing the specimen on a piece of unglazed tile, or streakplate.

Lustre: The lustre of a mineral is the way its surface shines when held up to the light. Lustre is a property distinct from colour. There are many ways of classifying and describing lustre, but the following system isadequate:

Vitreous — the mineral shines like glass — e.g. quartz, diamond
Metallic — the mineral shines like the surface of a metal — e.g. pyrite, galena
Earthy (dull) – the mineral does not shine at all — e.g. kaolinite

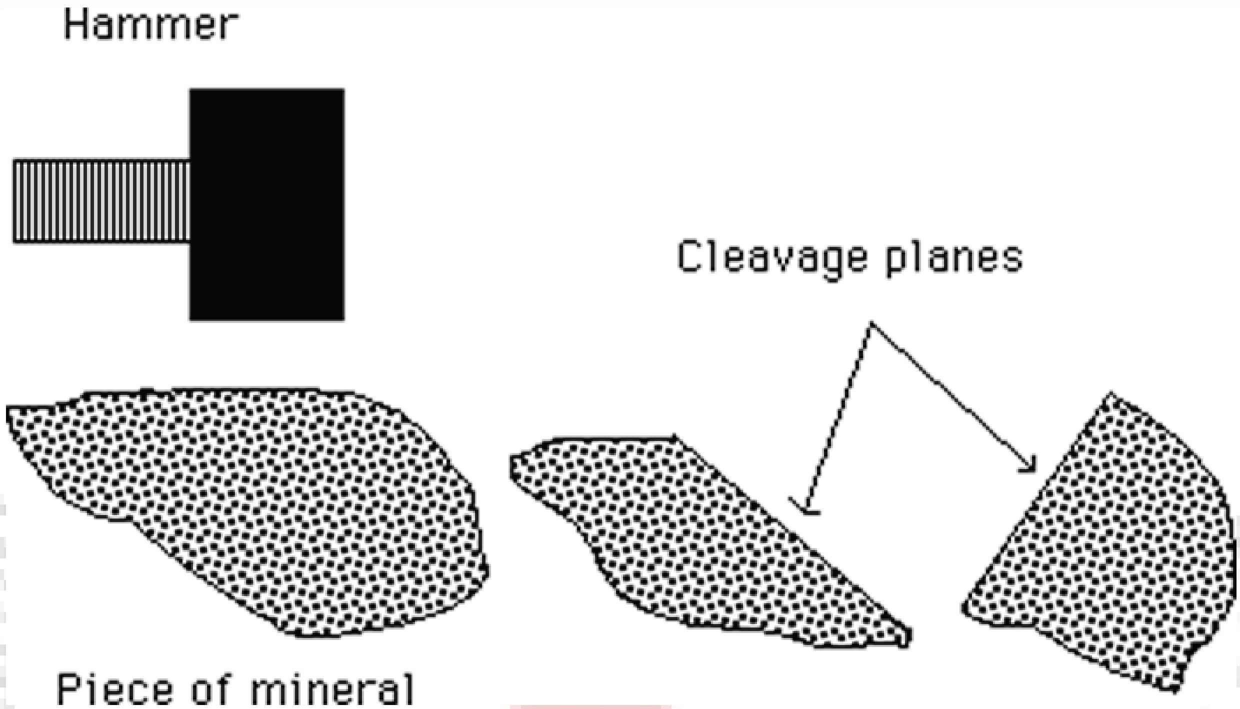
Hardness: The hardness of any mineral can be assigned a number between 1 and 10, on Moh's Scale of Hardness. The instruments used to determine the hardness of a mineral specimen are (in order of increasing hardness) a finger-nail, copper coin, knife blade and a quartz crystal.

The table below lists the minerals that define **Moh's Scale of Hardness**, and gives the relative hardnesses of the test items named above.

	Defining Mineral	Test Item
1	Talc	
2	Gypsum	
3	Calcite	Finger nail ~2.5
4	Fluorite	Copper coin ~3.5
5	Apatite	Knife blade ~5.5
6	Orthoclase	
7	Quartz	Quartz crystal 7
8	Topaz	
9	Corundum	
10	Diamond	

Density: It is not usual to measure the actual densities (relative to water = 1) of specimens; however, minerals should be classified according to whether they are light, medium or

heavy. This can be done by holding similar-sized specimens of two different minerals in your hands, and comparing their weights.
Cleavage: When a piece of a mineral is dropped or struck, it may tend to break so that flat, shiny surfaces are formed.



Minerals, or individual surfaces, that do not cleave to form flat faces are said to show fracture.
Cleavage is a diagnostic property for identification of minerals, but the cleavage of an actual specimen is not always easy to determine. Many specimens do not show the expected cleavage characteristics.
Magnetism: Some minerals that contain iron are magnetic. Magnetite is strongly magnetic, and will be attracted by a magnet. Other iron-bearing minerals such as ilmenite sand size particles.
Reaction to dilute Hydrochloric Acid: Some minerals especially carbonates, effervesce when a drop of dilute hydrochloric acid is placed on them. This is useful diagnostic test for calcite and a white mineral which is not easily distinguished.

Viva Questions

1. Differentiate between Rock andMineral
2. What is streak?
3. What instrument is used to find thestreak?
4. Explain Clevage andMagetism.
5. Why study of minerals is important inGeology?

EXPERIMENT :-2

Objective :- Identification of rocks forming silicate and ore minerals

Theory:- Although about 4000 minerals are known to exist, only about 8 of them are common. These common rock forming minerals are the major constituents of igneous, sedimentary and metamorphic rocks. They constitute more that 99% of Earth's crust. You must be able to identify these 8 minerals, and you must know the mineral group to which each onebelongs.

The following table lists the common rock-forming minerals…

Mineral	Group	SIGNIFICANT DIAGNOSTIC PROPERTIES				
		H	Colour	Lustre	Cleavage	Other properties
Quartz	Silicate	7	Clear when pure. Impurities cause many colour variations.	Vitreous	None	Hexagonal crystals
Feldspar group: Orthoclase Plagioclase	Silicate	6	Orthoclase: pink, cream Plagioclase: white, grey	Vitreous	2 at ~90°	
Biotite	Silicate	2.5	Black	Vitreous: sometimes appears metallic	1	Thin sheets are flexible and elastic
Muscovite	Silicate	2.5	White or clear		1	
Amphibole (*e.g.* Hornblende)	Silicate	5.5	Black	Vitreous	2 at 120°	Often confused with Pyroxene
Olivine	Silicate	6.5	Green	Vitreous	none	Small green crystals. Often enclosed in a basalt volcanic 'bomb'.
Pyroxene (*e.g.* Augite)	Silicate	5.5	Black	Vitreous	2 at 87° & 93°	Often confused with Amphibole
Calcite	Carbonate	3	White or clear	Vitreous	3 **not** at 90°	Effervesces with acid
Clays (*e.g.* Kaolinite)	Silicate	2.5	White	Dull	None	Very powdery

Properties:- Properties Such as Hardness, Density and cleavage are often impossible to determine in these specimens. However, colour, lustre and streak are usually sufficient for identification of common ore minerals

Mineral	Composition	SIGNIFICANT DIAGNOSTIC PROPERTIES				
		H	Colour	Lustre	Streak	Other properties
Galena	Lead sulphide (PbS)	2.5	Grey	Metallic	Lead-grey	Very high density, 3 cleavage planes at 90°
Chalcopyrite	Copper iron sulphide ($CuFeS_2$)	3.5	Greenish-gold or many colours (iridescent)	Metallic	Greenish black	Iridescent specimens are known as 'peacock ore'.
Malachite	Copper carbonate [$Cu_2CO_3(OH)_2$]	3.5	Green	Vitreous or dull	Green	Green colour is diagnostic.
Sphalerite	Zinc sulphide (ZnS)	3.5	Brown/black	Metallic	Brown	Dodecahedral cleavage (6 planes of cleavage)
Bauxite	Mixture of aluminium hydroxides	2	Brown	Dull	Brown	Consists of round nodules (*i.e.* pisolitic). Easily recognised.
Haematite	Iron oxide (Fe_2O_3)	6	Reddish brown to black	Usually dull	Reddish brown	Appearance of mineral varies. Streak is diagnostic.
Magnetite	Iron oxide (Fe_3O_4)	6	Black	Metallic	Black	Strongly magnetic.

Rock-forming minerals:-

Minerals are the building blocks of rocks. Geologists define a mineral as:

A naturally occurring, inorganic, solid, crystalline substance which has a fixed structure and a chemical composition which is either fixed or which may vary within certain defined limits.

Some minerals have a definite fixed composition, e.g. quartzis always SiO_2, and calciteis always $CaCO_3$. However, other minerals exhibit a range of compositions between two or more compounds called end-members. For example, plagioclasefeldspar has a composition that ranges between end-members anorthite ($CaAl_2Si_2O_8$) and albite ($NaAlSi_3O_8$), so its chemical formula is written as $(Ca, Na)(Al, Si)AlSi_2O_8$.

There are also minerals which form both by inorganic and organic processes. For example, calcite($CaCO_3$) is a common vein mineral in rocks, and also a shell-forming material in many life forms. Calcite of organic origin conforms to the above definition except for the requirement that it be inorganic. This is an inconsistency in the definition of a mineral that is generally overlooked.

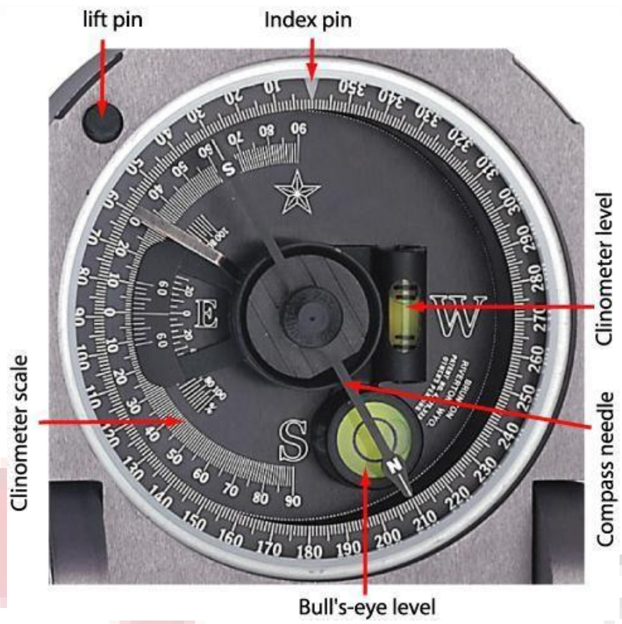
How can a mineral be identified?

A particular mineral can be identified by its unique crystal structure and chemistry. Geologists working in the field, however, don't usually have access to the sophisticated laboratory techniques needed to determine these properties. More commonly, they use Propertieswhich can be observed with the naked eye (or with a hand lens) or determined with simple tools (e.g. a pocketknife).

Useful physical properties for identifying a mineral include its cleavage / fracture, colour, crystalhabit / mode of occurrence, hardness, lustre, specific gravity, streak and transparency

<u>EXPERIMENT No. </u>:- 3

<u>Objective</u>:- Use of Brunton Compass for measurement dip and strike of formations.

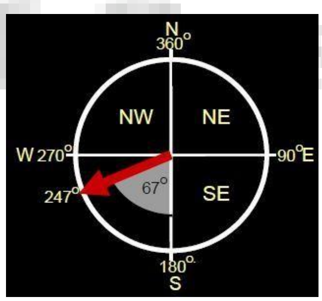


<u>**Theory**</u>:- **The brunton compass are used for measurement of dip and strike of formations.**

<u>Compass Mastery:-</u>

•Locate North, Set local declination
•Measure Bearings*=
•Measure Strike and Dip of planes
•Measure Trend and Plunge of lines
•Measure Vertical Angles
  omeasuring height / thickness of a feature

<u>Recording a Bearing:-</u>
<u>Bearing</u>: direction from one point to another
<u>Recording notation</u>:
•Azimuth: “247°”



Strike: *Direction of the line of intersection between a tilted plane and a horizontal plane*

•Compass must be horizontal (bull’s eye bubble centered), with compass edge flush to the tilted plane

Dip: *The maximum slope of a plane, measured from horizontal. The dip direction is always perpendicular to strike.*
The dip direction is:
•The “fall line” in skiing
•The direction water runs down a sloping surface
•The direction a pebble rolls down a sloping surface

Viva Quations :-

1. What is bruntoncompass?
2. What is the use of bruntoncompass?
3. What is deep andstrike?
4. What is the working procedure of bruntoncompass?

EXPERIMENT No.:- 4

OBJECTIVES :-

- Recognizing rockcharacteristics.
- Classifying different rocktypes.

VOCABULARY:

i. Conglomerate
ii. Gneiss
iii. Granite
iv. Marble
v. Obsidian
vi. Sandstone
vii. Schist
viii. Scoria
ix. Shale

MATERIALS:

i. Identification sheets made in prelab
ii. Rocks
iii. 10% HCL Solution(Optional)

Theory:-

Rocks record the earth's history when those rocks where formed. When students get a piece of rock in lab they need to associate different environments of sedimentary, igneous, and metamorphic. Although sedimentary is the most common rock found on the surface of earth, students can most of the groups very easily. It is very common for building and see the different types of rocks, even if they did not form in thatcity.

Discuss with the students that rocks have key characteristics, just like minerals, but that identifying rocks is much more difficult, in this lab they will become familiar with the key characteristics of small group of sedimentary, igneous and metamorphic,

PROCEDURE:-

1. Review the rocks on the pre lab identification sheets. You may want to go over some of the characteristics describedbelow.

BLACK, GLASSY - black-the color; glassy - have students imagine broken glass
RED, HOLES - red-the color; holes, - like Swiss cheese
LARGE MINERALS - visible, obvious minerals
WHITE, FLAT, LIGHT - white-the color; flat - as a pancake; _ like a balloon
PEBBLES, GLUED - sand size; sand grains look like they are pasted together **FLAT, LAYERS** - pancakes stacked on top of each other
SHINY - like a new car
WHITE AND GRAY MINERALS - the minerals are large enough to see and are white and gray; fizz - if you have dilute HCl(can be bought in a hardware store as Muriatic Acid -

Cement Cleaner) pour just a drop on a specimen so students can see it fizz (DO NOT LET CHILDREN PLAY WITH HCl).

2. See if the students can match the rocks in their packets with the characteristics on the identification sheet. Frequently check on their process. as they decide which rock belongswhere.

3. Discuss with students which rocks belong to which group as groupedbelow:
   IGNEOUS - granite, scoria, obsidian

   SEDIMENTARY - sandstone, conglomerate, shale

   METAMORPHIC - marble, schist, gneiss

Physical Properties of rocks:-

i) **Hardness** :- A scratch test developed by a German mineralogist FredriechMohs in 1822 is used to determine mineral hardness. He developed a hardness scale that helps to identify mineralproperties.

ii) **Color** :- Color can sometimes be helpful when identifying minerals. However, some minerals have more than one color, like quartz. Quartz can be blue, brown, pink, red, purple, and almost any other color, or it can be totally colorless. Therefore, geologists have developed a better way of using color as an identifying property. This property is called astreak.

iii) **Streak** :- Streak is the name given to the colored residue left by scratching a mineral across an abrasive surface, such as a tile of unglazed porcelain. The streak may not always be the same color you see in the hand specimen. A mineral with more than one color will always leave a certain color of streak. Hematite is a mineral that can be red, brown, or black, but it will always leave a characteristic reddish brownstreak.

iv) **Luster** :- Another mineral property that geologists use to identify minerals is luster. Luster is the way in which the surface of a mineral reflects light. There are two main types of luster: metallic and nonmetallic. A metallic luster is shiny and similar to the reflection from a metal object, such as a faucet. A mineral that does not shine like metal has a nonmetallic luster. For example, the wall has a nonmetallicluster.

v) **Cleavage** :- Cleavage is another property used to distinguish minerals. Cleavage is the tendency for minerals to break along flat planar surfaces. Cleavage is rated as good, fair and poor depending on the quality of the flat surface produced. Mica, for example, is a mineral that has goodcleavage.

vi) **Chemical Reaction** :- A weak acid is used to tell if rocks or minerals contain calcium carbonate (CaCO3). If the specimen fizzes (giving off CO2) when it comes in contact with acid, it is considered carbonate rich. If it does not contain calcium carbonate, it will not fizz. Calcite and aragonite are two minerals that will always fizz.

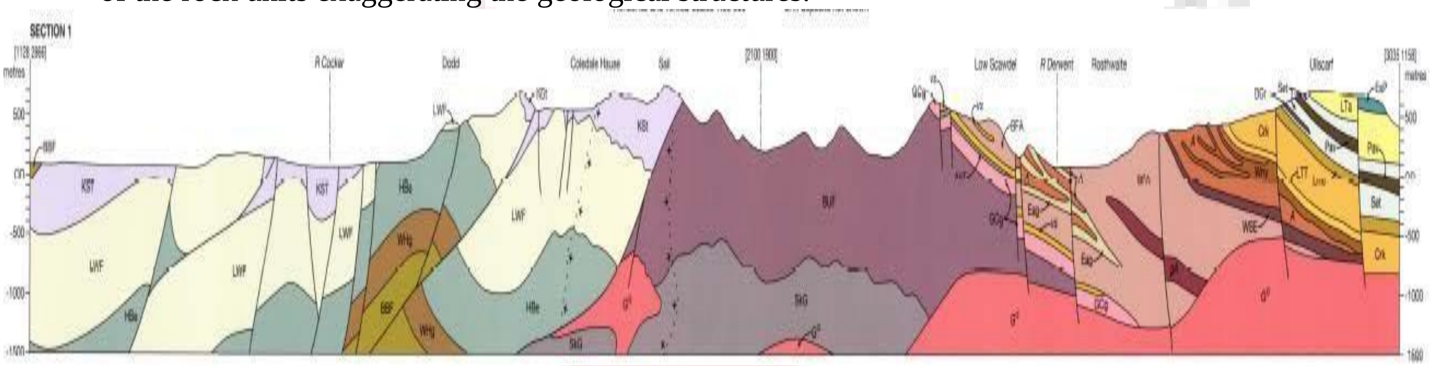
Viva Quations :-

1. What isRock.?
2. Properties ofRocks.
3. What is the Classification ofRocks?.

EXPERIMENT No.:-5

Objective:- Geological cross section and study of Geological map

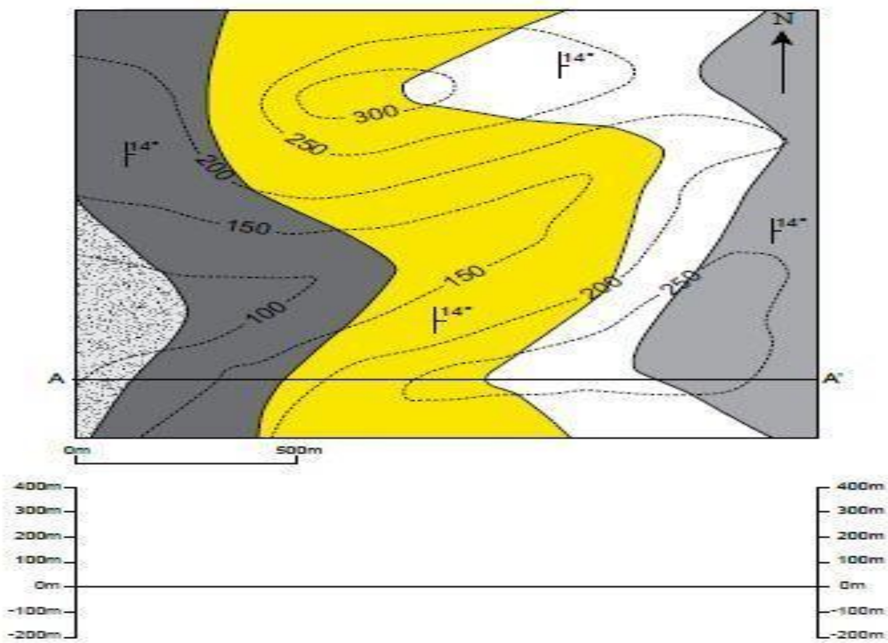
Theory:-A cross section should be consistent with all the available data, although there are often several viable interpretations of the same data. Most cross sections are drawn to true scale, that is, where the horizontal scale is the same as the vertical scale. This means the true dip of the rock units are shown. Vertical exaggeration, where the vertical scale is increased relative to the horizontal, is sometimes used to make a cross section clearer. However, it also increases the dips of the rock units exaggerating the geological structures.



Procedure:-

Step 1:

Determine the line along which to draw the section.The line of section should berepresentative ofthe study area, be perpendicular to the majorstructural feature of the area (e.g. large scalefolds or faults), cross as many structural featuresas possible and run through areas with the mostdata readings.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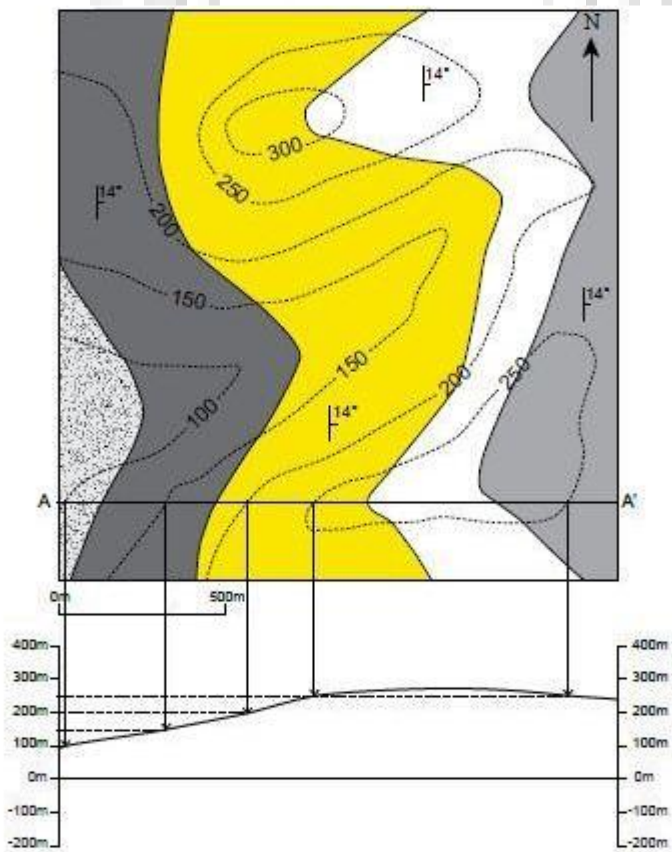
400m
300m
200m
100m
0m
-100m
-200m

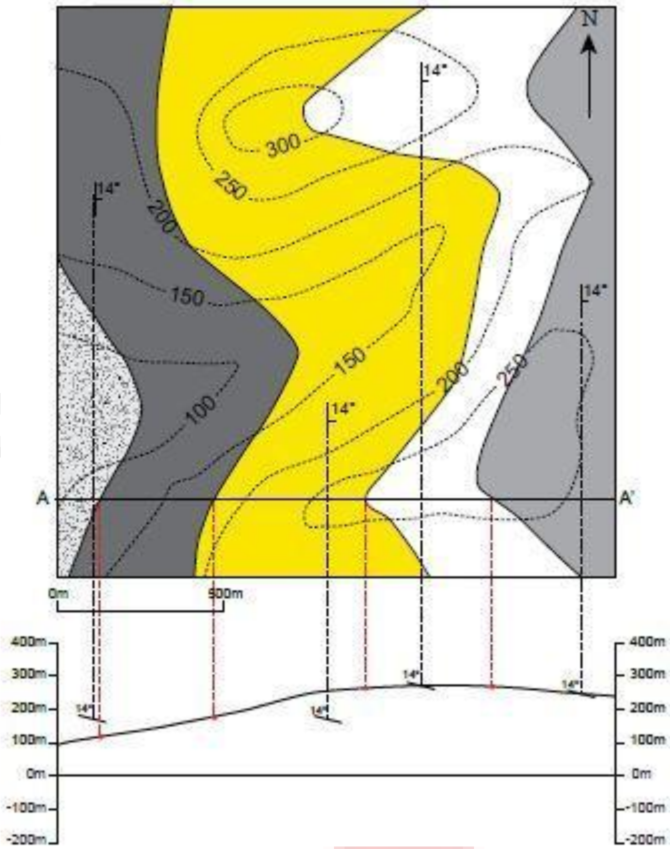
Step 2:
Draw axes of an appropriate scale with theopographic values. Unless there is a reason todo otherwise, draw a true-scale section.

Step 3:
Transfer the topographic information from themap to the section. Project the height of eachtopographic contour, where it crosses the lineof section, on to the section and draw in thetopography.



Step 4:
Transfer the lithological boundaries, faults etc onto the cross section in the same way.

Step 5:
Transfer bedding readings on to the section,correcting for apparent dip if necessary (see figure). Plot the readings at the height at which theyoccur, so where a reading is extrapolated froma greater or lesser height than the topographyof the cross section plot it above or below thetopography as appropriate.



Step 6:
Using the bedding readings as a guide, drawin the lithological boundaries both above andbelow the surface. Geology extended abovethe topography is shown by dashed lines. Whendrawing the section always consider what isgeologically reasonable behavior for the layerse.g. sudden changes in a unit's thickness or dipshould be justifiable.
Step 7:- Stand back and admire your work.

Viva Questions :-

Q1. What do you mean by Geological Map?

Q2. What are lithological boundaries?

Q3. What do you mean by Scale?

<u>EXPERIMENT No.:-</u> 6

<u>Objective</u>:-Outcrop patterns on geological maps

Theory:-If the Earth’s surface was flat, if there was notopography, then geological maps would besimple. They would be a direct reflection ofthe underlying geology. However, topographyinteracts with the geology to produce morecomplex but predictable patterns.

Horizontal and vertical strata:

Horizontal and vertical strata are the moststraightforward to interpret on a map. Horizontaloutcrops will always follow the topographiccontours (figure 2a), whilst vertical layers willalways form straight lines (figure 2b).

Dipping strata

Dipping layers interact with the topography inpredictable ways. In valleys, beds will appear to‘vee’ either up or down the valley in the directionof dip (figure 2c and 2d). This is because thevalley side acts as an approximate cross section–not always helpful on small scale maps but onlarge scale maps and in the field this is a usefulaid in interpretation.

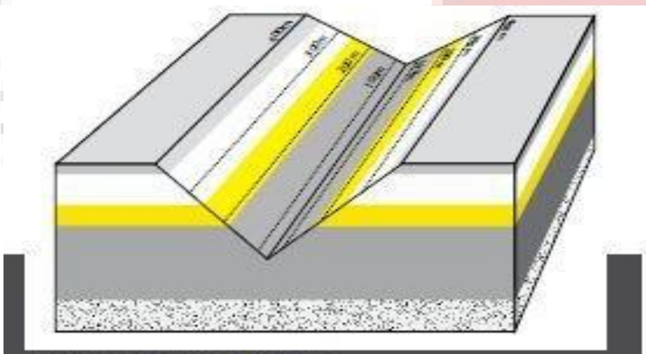


Figure 2a: Horizontal beds

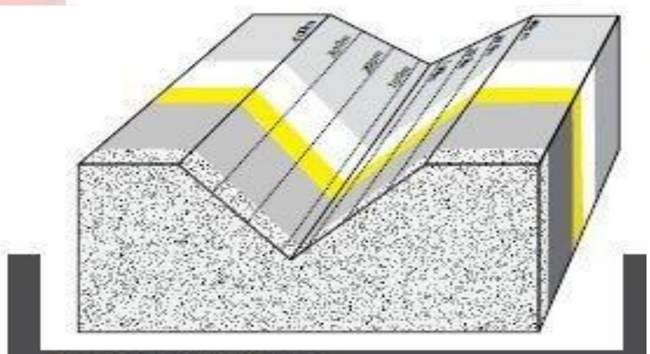


Figure 2b: Vertical beds

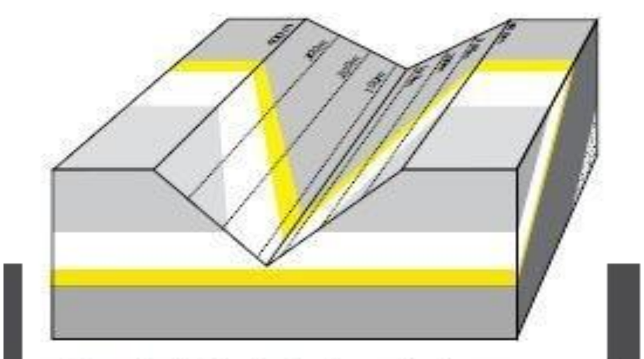


Figure 2c: Beds dipping towards viewer

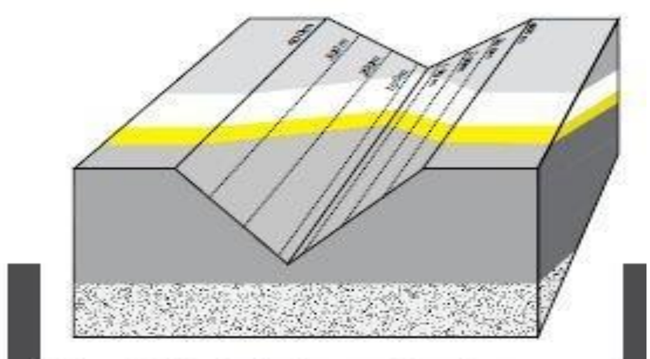


Figure 2d: Beds dipping away from viewer

- Outcrop, structure and agerelationships

A. Folding of rocks

a. Layer cakerelations

(1) oldest on bottom, youngest ontop

b. FoldTypes

(1) Anticlines-upfolded forms, results in older rocks becoming enclosed within youngerstrata

(2) synclines-downfolded forms, results in younger rocks becoming enclosed within olderstrata.

(3) symmetrical folds- both limbs of the fold dipping at same angle away from fold axis

(4) asymmetrical folds- both limbs of the fold not dipping at same angle away from foldaxis

(5) overturned folds- condition in which one limb of fold has been tilted beyond vertical

(6) plunging folds- axis of fold istilted

(7) Domes- more or less circular equivalent of anticline, oldest rocks exposed in center ofdome

(8) Structural Basin- more or less circular equivalent of syncline, youngest rocks exposed in center of dome (not to be confused with depositionalbasin)

c. Outcrops Patterns Associated with FoldedRocks

(1) As rocks are folded, and subsequently subjected to erosion, regular patterns become evident in relation to type of rock that outcrops and age of the rock that outcropsin an area of folded strata. In essence, erosion exposes the interiors of the folds

(2) Non-plunging Folds- axis of fold is horizontal, results in parallel bands of dipping strata about the foldaxis

(a) anticlines- oldest strata exposed along foldaxis

(b) synclines- youngest strata exposed along foldaxis

(3) Plunging Folds-axis of fold is tilted, results in alternating V-shaped bands of dipping strata oriented about the foldaxis.

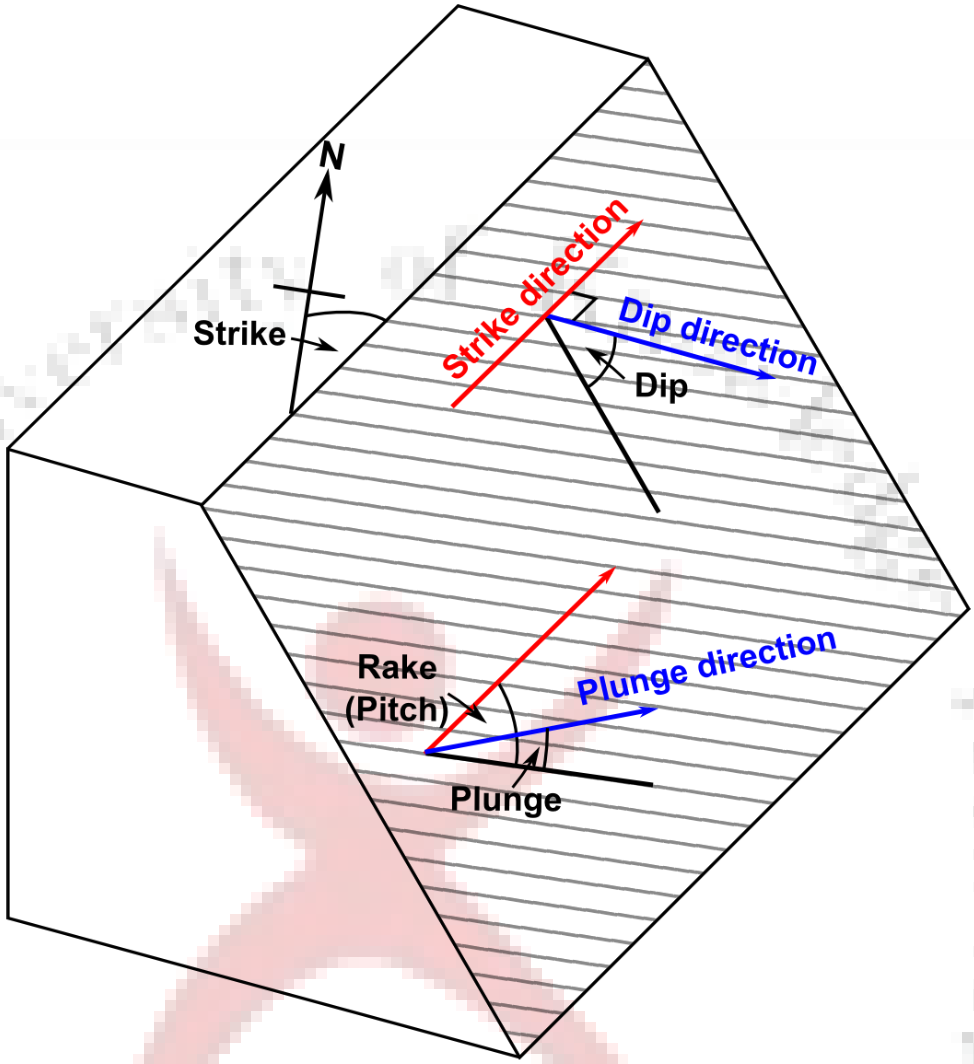
(a) anticlines- oldest strata exposed in the center of the V, V points in direction of plunge of foldaxis

(b) syncline- youngest strata exposed in the center of the V, V points in opposite direction of plunge of foldaxis.

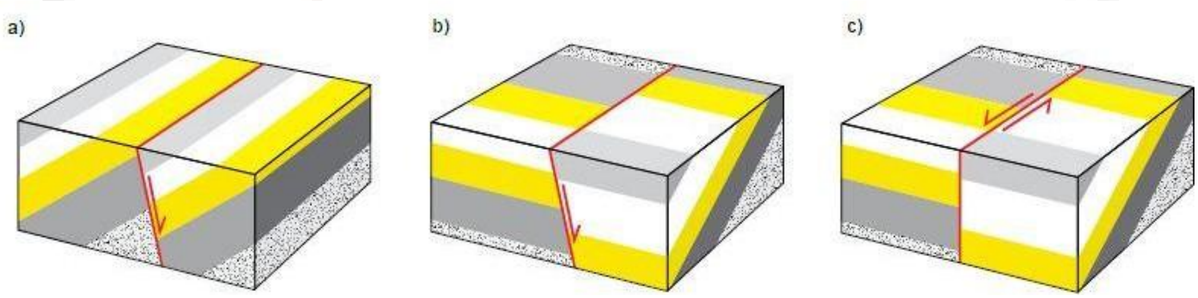
(4) Doubly Plunging Folds- fold axis is plunging in two opposite directions, results in a flattened oval pattern, or a double V-shaped pattern<<<>>>.

(a) anticlines- oldest strata exposed in center of flattenedoval

(b) synclines-youngest strata exposed in center of flattenedoval.



Faults on maps:-Faults can occur at any angle with respect to bedding and so the outcrop patterns produced are not unique to any one fault type. Figure **a** and **b** show two potential outcrop patterns for anormal fault.



Fold on maps:- Figure shows the different outcrop patterns for folds. The limbs of the folds form a repeating pattern on either side of the axial plane. For anticlines, the oldest rocks are in core of the fold and the rocks get younger away from the axial trace (figure a).
For synclines, the youngest rocks are in the core and the rocks getolder away from the axial trace (figureb).

Plunging folds form the same repeating pattern as non-plunging folds, except their limbs converge around the axial traces. The limbs of synclines open in the direction they plunge (figure c); whilst the limbs of anticlines close in the direction they plunge (figure d).

Viva Questions:-

1. What is Fault?.
2. What is Fold?.
3. What do you mean by Syncline andanticyline?
4. What are types offolds?

Identifying Minerals

- Many rock properties can be assessed very easily in a classroom
  - Color
  - Streak
  - Hardness
  - Specific Gravity
  - Magnetism
  - Luster
  - Cleavage

Mineral Properties: Color

- Color comes from the chemical composition of a mineral
- Easy to identify, but ***not always reliable***
  - Some minerals have an inherent color and are always the same
  - But some minerals come in a variety of colors based on presence of trace elements

Exhibit A: All fluorite! ←

Mineral Properties: Streak

- Streak is the color a mineral produces when ground to a fine powder
- ***Much more reliable than mineral color*** because each mineral has a diagnostic streak color, no matter the color of the mineral itself
- Note: ***many minerals do not produce a streak***
- Test streak by marking the mineral on a white porcelain streak plate – ***press firmly!***

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Mineral Properties: Hardness

- The hardness of a mineral is a factor of the strength of the chemical bonds within the mineral
- Hardness is shown by a mineral's ability to resist or inflict abrasion (a scratch) on or by another mineral
- Hardness is measured from ***1 (softest) through 10 (hardest)*** on the **Moh's Hardness Scale**
- Hardness is tested by scratching a mineral against various reference materials

Mineral	Mohs Hardness	Image
Talc	1	
Gypsum	2	
Calcite	3	
Fluorite	4	
Apatite	5	
Feldspar	6	
Quartz	7	
Topaz	8	
Corundum	9	
Diamond	10	

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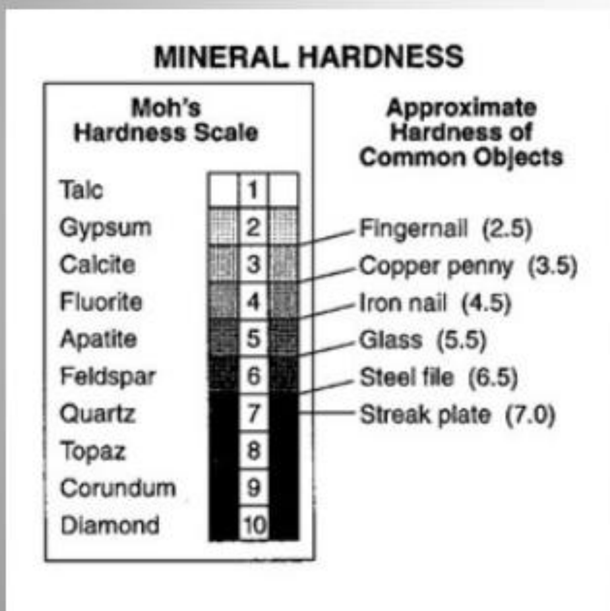
Hardness Test

- Use common classroom materials to test the hardness of minerals



- If a mineral can be scratched by your fingernail, its hardness is: ____________
- If a mineral scratches a streak plate, its hardness is: ________________
- If a mineral can scratch glass but can be scratched by a steel file, its hardness must be: __________________

Mineral Properties: Specific Gravity

- Specific gravity of a mineral is its density (*ρ)* relative to water
  - Specific gravity = $\frac{\rho_{mineral}}{\rho_{water}}$
- In a classroom, you can measure specific gravity by doing a density test or by a more subjective "heft test"
  - "**Heft test**": Does the mineral feel heavier, lighter, or about what you'd expect based on its size?
    - Heavier = high specific gravity
    - Lighter = low specific gravity
    - About what you'd expect = medium specific gravity

Mineral Properties: Magnetism

- Magnetism is the ability of some minerals to behave like magnets
- Magnetism is strongly related to iron content

Assess magnetism by holding a magnet up to a sample and feeling if there is a “pull” when you move the mineral farther away.

Mineral Properties: Luster

- Luster refers to how a mineral reflects light
- Mineral luster is classified generally as "metallic" or "non-metallic"
  - ***Metallic***: looks like a metal
  - ***Non-metallic***: does **NOT** look like a metal
    - ***Caution: can still be shiny!***
    - Glassy, shiny, greasy, waxy, dull, earthy


Luster (continued)
• Metallic
• Non-metallic
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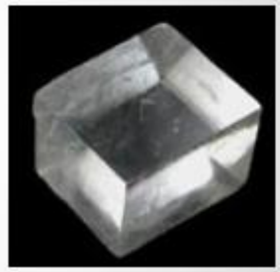
Mineral Properties: Cleavage

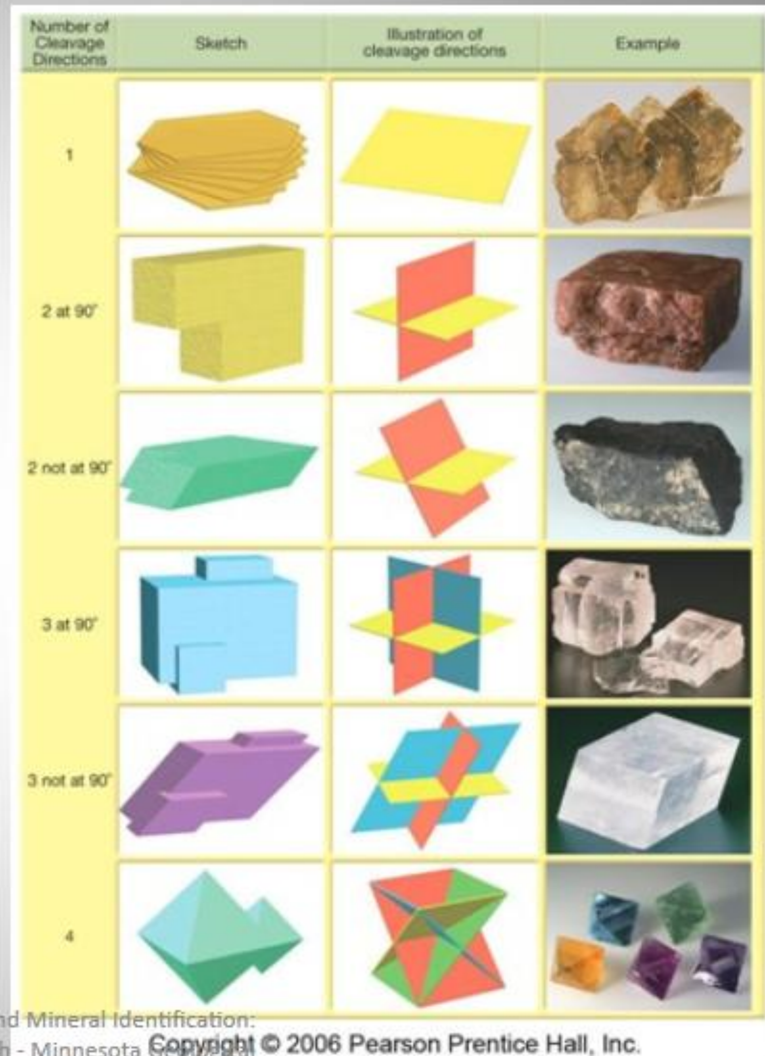
- Cleavage describes **the way a mineral breaks (cleaves) along planes of weakness in its atomic structure**
- ***Caution: Not all minerals have cleavage.*** Some minerals break or fracture in irregular ways
- Cleavage <u>does</u> form:
  - Flat, reflective surfaces
  - Angular corners
  - Defined edges

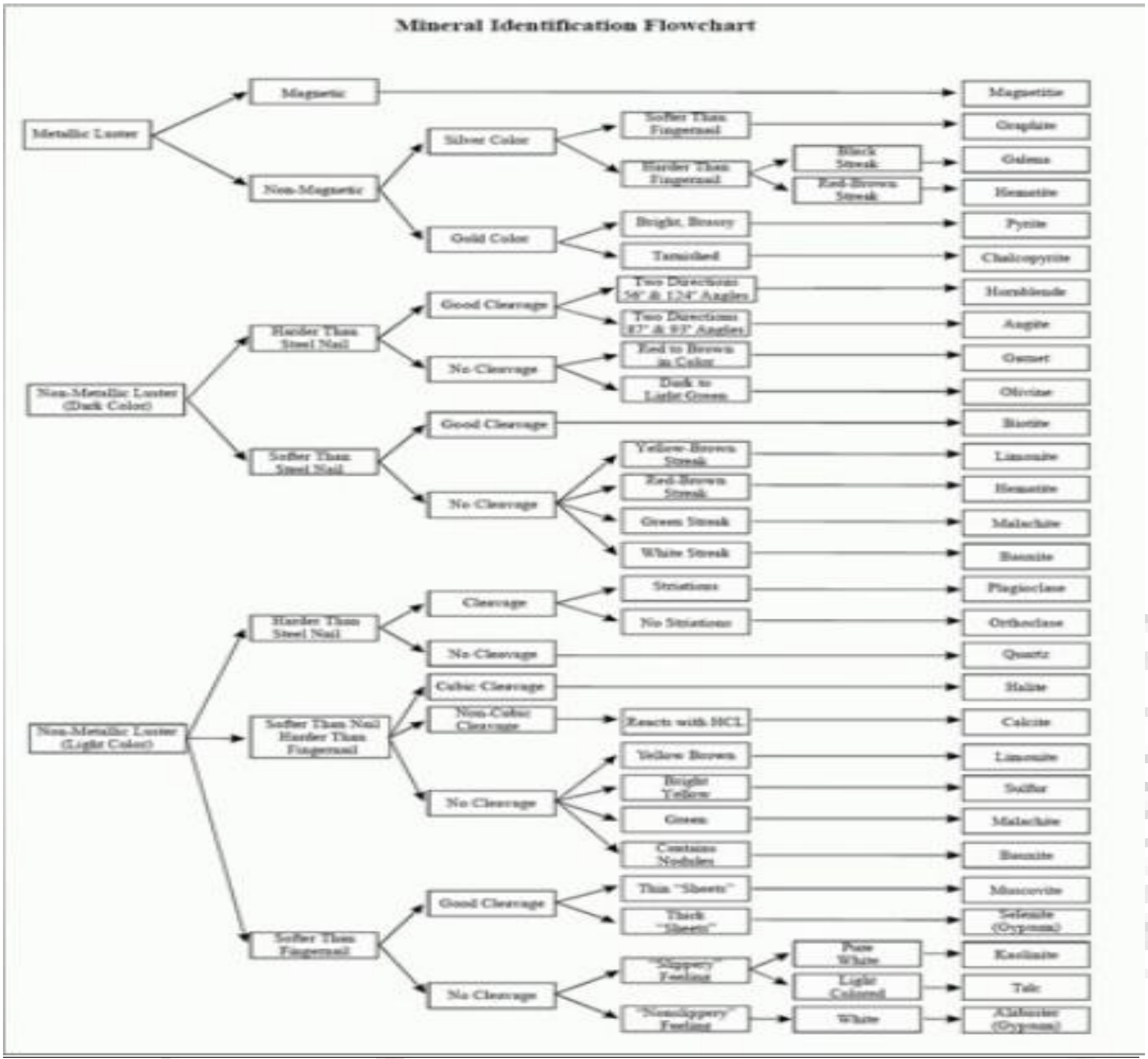


- Cleavage <u>does NOT</u> form:
  - Lumps & bumps
  - Irregular surfaces
  - Conchoidal fracture

Cleavage (continued)

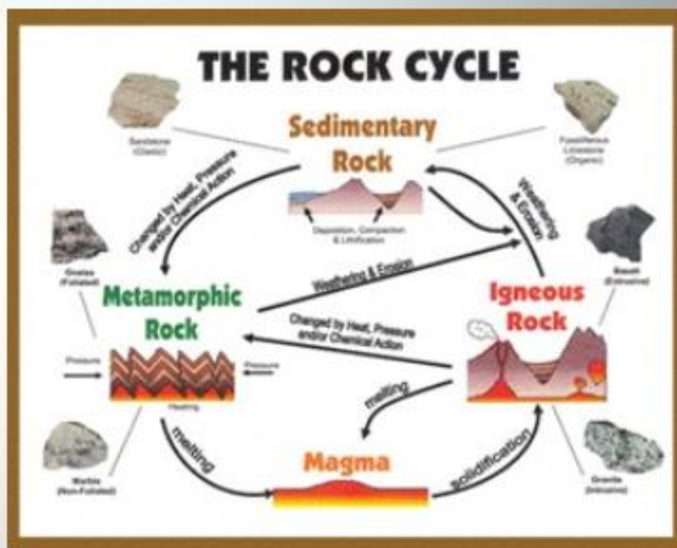
- Minerals can have one, two, three, or even four different directions of cleavage depending on the strength or weakness of a mineral's atomic bonds.
- Multiple cleavage faces intersect each other at specific and predictable angles in certain minerals




Mineral Identification Flowchart
Metallic Luster
Magnetic
Magnetite
Non-Magnetic
Silver Color
Softer Than Fingernail
Graphite
Harder Than Fingernail
Black Streak
Galena
Red-Brown Streak
Hematite
Gold Color
Bright, Brassy
Pyrite
Tarnished
Chalcopyrite
Non-Metallic Luster (Dark Color)
Harder Than Steel Nail
Good Cleavage
Two Directions 56° & 124° Angles
Hornblende
Two Directions 87° & 93° Angles
Augite
No Cleavage
Red to Brown in Color
Garnet
Dark to Light Green
Olivine
Softer Than Steel Nail
Good Cleavage
Biotite
No Cleavage
Yellow-Brown Streak
Limonite
Red-Brown Streak
Hematite
Green Streak
Malachite
White Streak
Bauxite
Non-Metallic Luster (Light Color)
Harder Than Steel Nail
Cleavage
Striations
Plagioclase
No Striations
Orthoclase
No Cleavage
Quartz
Softer Than Nail Harder Than Fingernail
Cubic Cleavage
Halite
Non-Cubic Cleavage
Reacts with HCL
Calcite
No Cleavage
Yellow Brown
Limonite
Bright Yellow
Sulfur
Green
Malachite
Contains Nodules
Bauxite
Softer Than Fingernail
Good Cleavage
Thin "Sheets"
Muscovite
Thick "Sheets"
Selenite (Gypsum)
No Cleavage
"Slippery" Feeling
Pure White
Kaolinite
Light Colored
Talc
"Nonslippery" Feeling
White
Alabaster (Gypsum)

Minerals to Rocks

- ***All rocks are made up of minerals***
- ***Most rocks are composed of numerous minerals***
- Three types of rocks
  - Sedimentary
  - Igneous
  - Metamorphic
- These three rock types are interconnected through the rock cycle. Erosion & weathering, heat, and pressure can transform any rock types into another, given enough time



Sedimentary Rocks

Sedimentary rocks form by deposition of sediment or precipitation of minerals at or near Earth's surface.

- Two types of sedimentary rocks
  - **Clastic:** form by cementing together fragments or grains of pre-existing rocks
  - **Chemical:** form when minerals precipitate out of water solutions at the earth's surface

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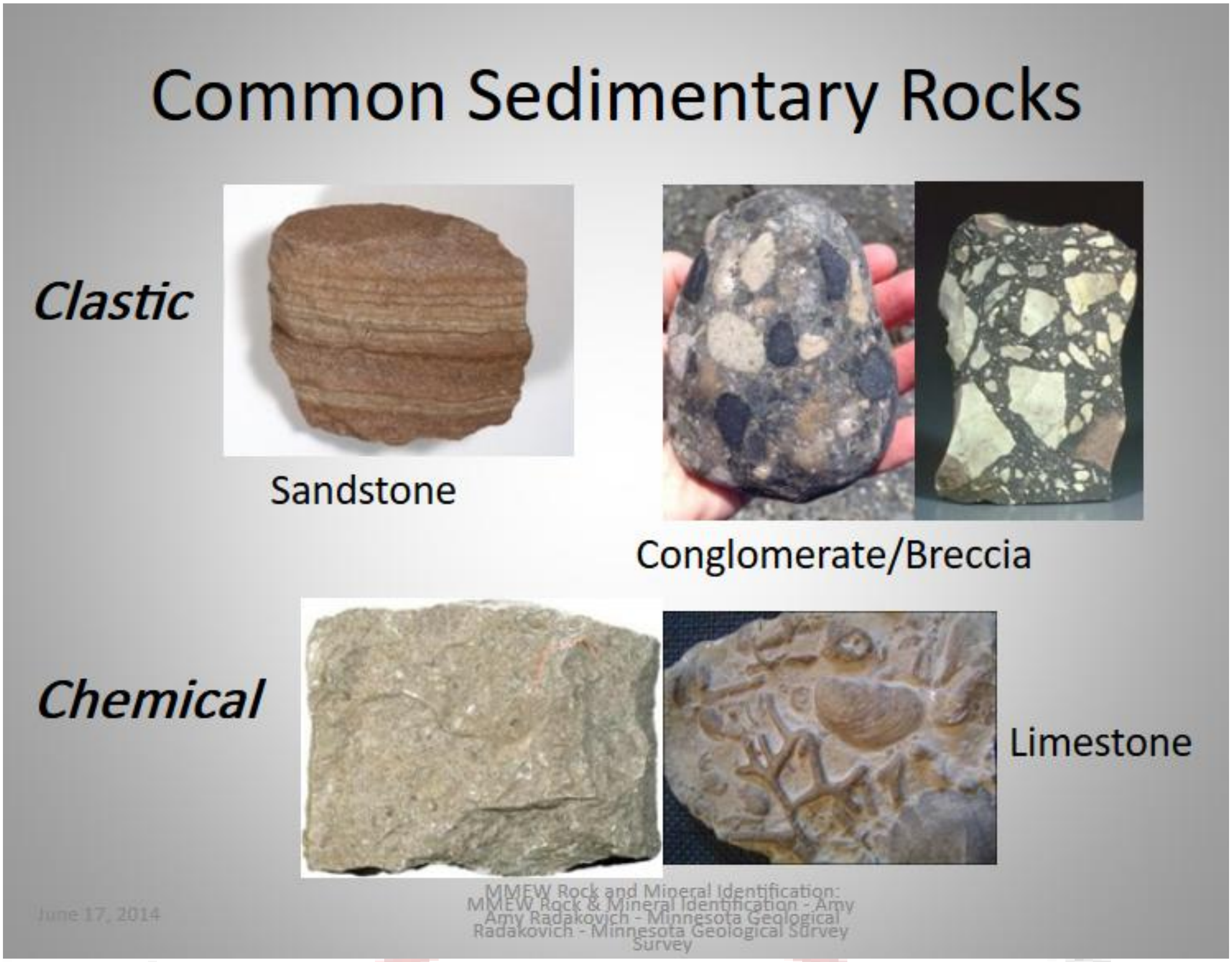
Common Sedimentary Rocks
Clastic
Sandstone
Conglomerate/Breccia
Chemical
Limestone
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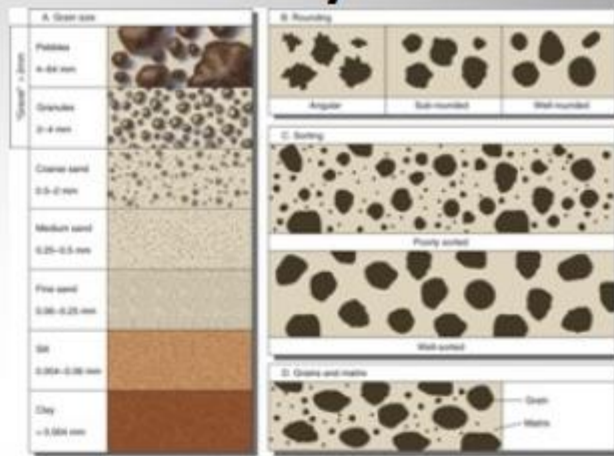
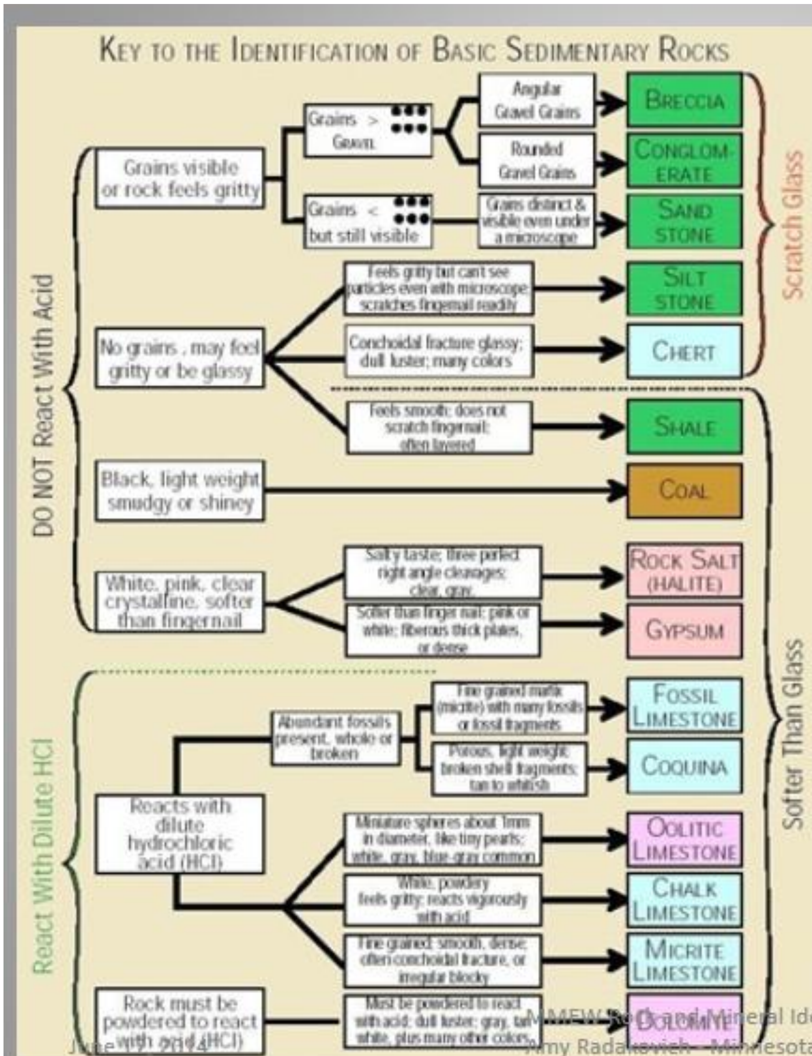
Identifying Sedimentary Rocks



- Grain Size
  - Fine, medium, or coarse-grained
- Grain Sorting
  - Well or poorly sorted
- Grain shape
  - Rounded or angular

- Reaction with dilute HCl (Hydrochloric acid)
  - Fizzes readily, fizzes after being powdered, or does not fizz

- Other "dead-giveaway" characteristics
  - Fossils
  - Layering



Flow Chart for Sedimentary Rock Identification

- This is a very comprehensive chart, but is probably a bit to detailed for elementary and middle school Earth science
- The next slide is a much more simplified chart I made that might be a bit more appropriate with rock ID at this grade level

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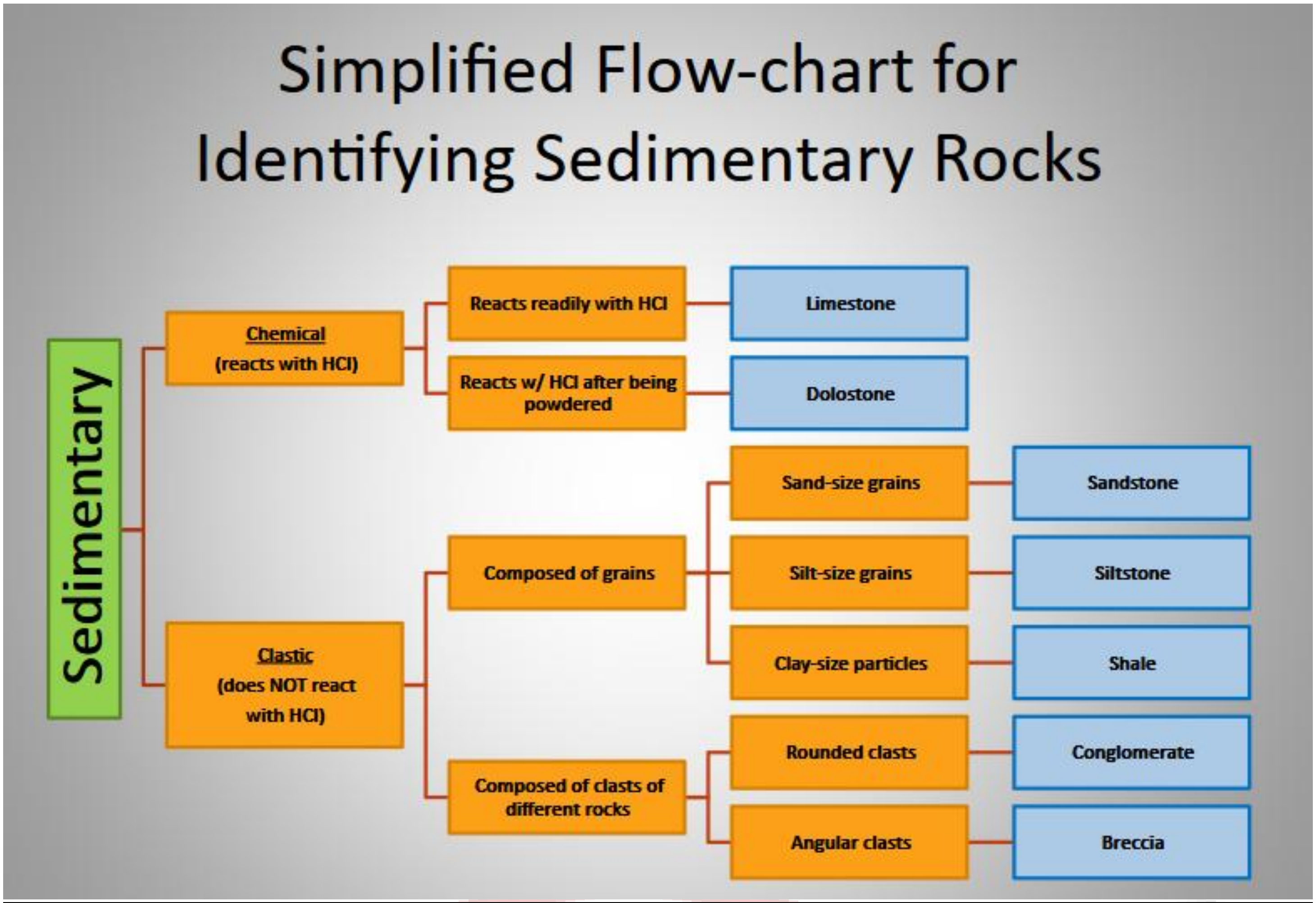
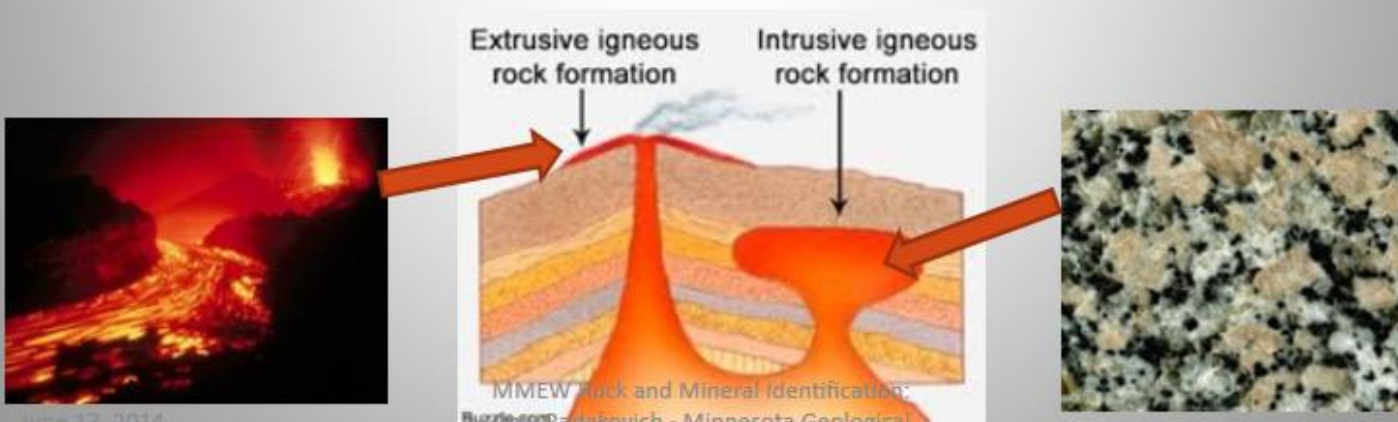

Simplified Flow-chart for Identifying Sedimentary Rocks
Sedimentary
Chemical
(reacts with HCl)
Reacts readily with HCl
Limestone
Reacts w/ HCl after being powdered
Dolostone
Clastic
(does NOT react with HCl)
Composed of grains
Sand-size grains
Sandstone
Silt-size grains
Siltstone
Clay-size particles
Shale
Composed of clasts of different rocks
Rounded clasts
Conglomerate
Angular clasts
Breccia

Igneous Rocks

- Rocks that solidified from a molten (or partially molten) material (magma or lava)
- 2 kinds of igneous rocks
  - **Intrusive** (form below the earth's surface)
  - **Extrusive** (form above the earth's surface)



Igneous Rock Formation

- How does magma/lava turn into a rock?
- Think about ice forming from water

Minerals in Igneous Rocks

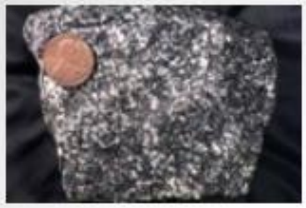
- Mineral size is a factor of TIME
  - The more time a rock has to crystallize, the bigger the minerals can grow!
    - Extrusive (Volcanic) = quick cooling, fine-grained
      - ***No visible crystals - aphanitic***
    - Intrusive (Plutonic) = slow cooling, coarse-grained
      - ***Crystals visible with the naked eye – phaneritic***

Fine-grained

Identifying Igneous Rocks

- **Grain size:** Fine-, medium-, coarse-grained, or a combination

fine



medium

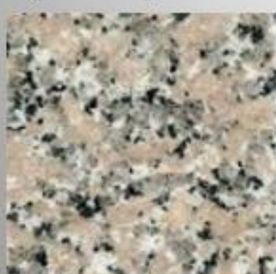
coarse

combination – porphyritic)

- **Color & Composition:** determined by minerals present
  - **Light** (felsic)

  medium (intermediate)

  dark (mafic)



Identifying Igneous Rocks (continued)

- Other features
  - Vesicles/Amygdules

  - Glassiness

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Identifying Igneous Rocks (continued)

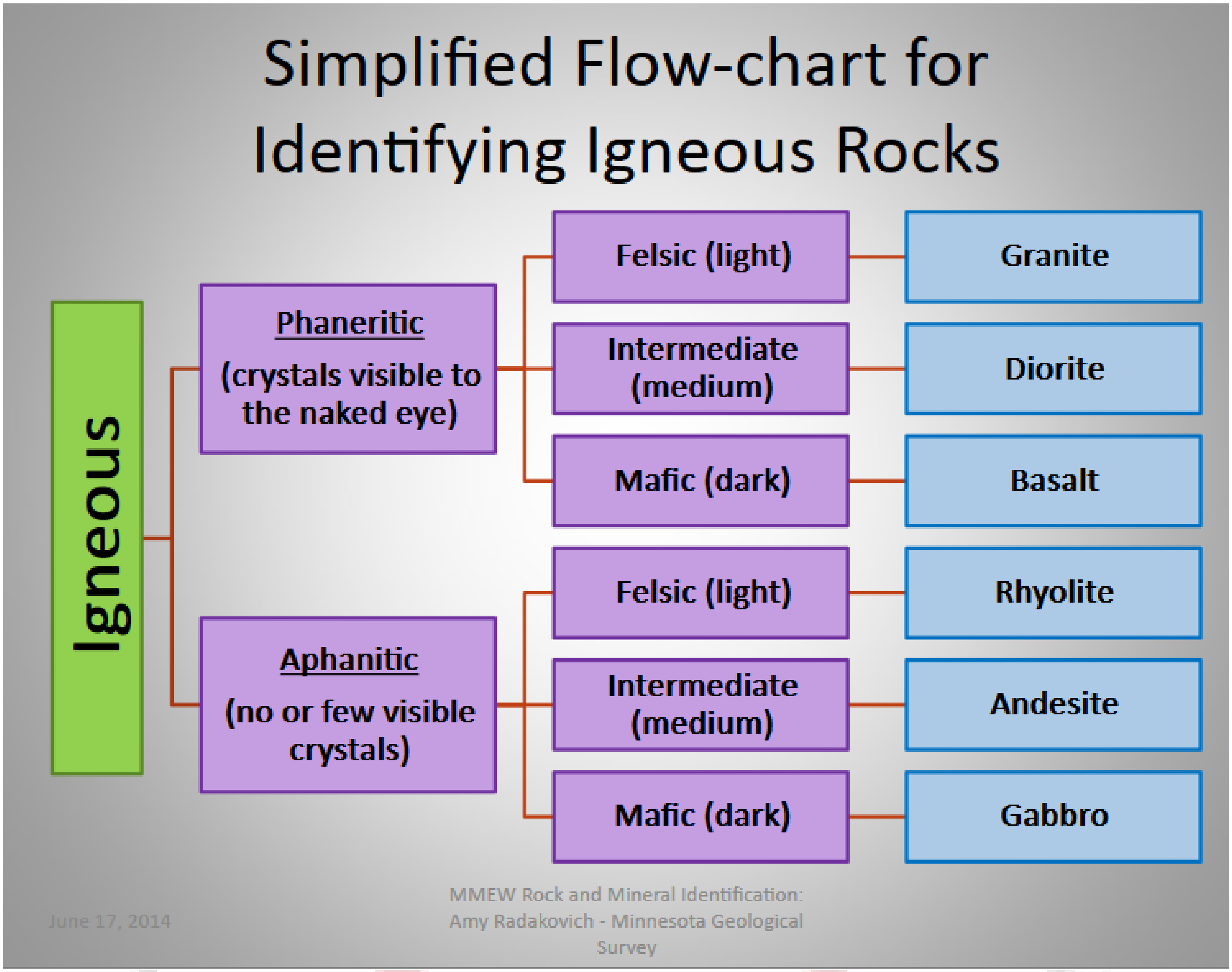
Increasing Fe and Mg →

← Increasing silica content

Igneous Rock Classification		Felsic/ Silicic light colored high in SiO_2	intermediate	Mafic dark colored low in SiO_2
Phaneritic (coarse grained)	Plutonic (magma) Intrusive	Granite	Diorite	Gabbro
Aphanitic (fine grained)	Volcanic (lava) Extrusive	Rhyolite	Andesite	Basalt

This table can be VERY useful to help understand the similarities and differences of igneous rocks.

However, a simplified flow chart like I created on the next slide often proves MUCH more helpful in the process of identifying igneous rocks.


Simplified Flow-chart for Identifying Igneous Rocks
Igneous
Phaneritic
(crystals visible to the naked eye)
Aphanitic
(no or few visible crystals)
Felsic (light)
Intermediate (medium)
Mafic (dark)
Felsic (light)
Intermediate (medium)
Mafic (dark)
Granite
Diorite
Basalt
Rhyolite
Andesite
Gabbro
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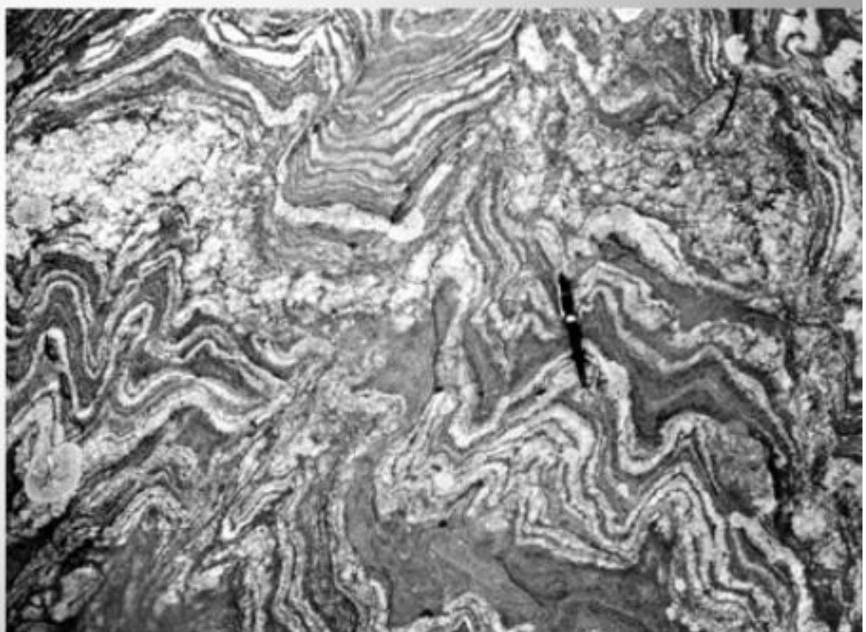
Metamorphic Rocks

- Metamorphic rocks form when a rock is exposed to elevated temperature and pressure
  - Involves a change in texture or mineralogy in the solid state (***in other words, the rock can't re-melt***)
  - Can form from an igneous rock, a sedimentary rock, or another metamorphic rock



Common metamorphic rocks

- The more heat and pressure you add, the more the rock changes
- The most common structure developed in metamorphic rocks is ***foliaton***, when minerals are aligned parallel to one another by deformation

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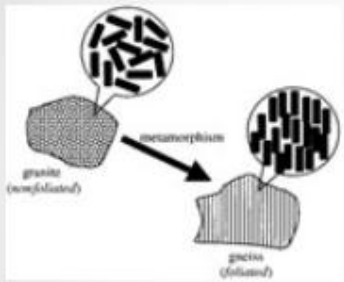
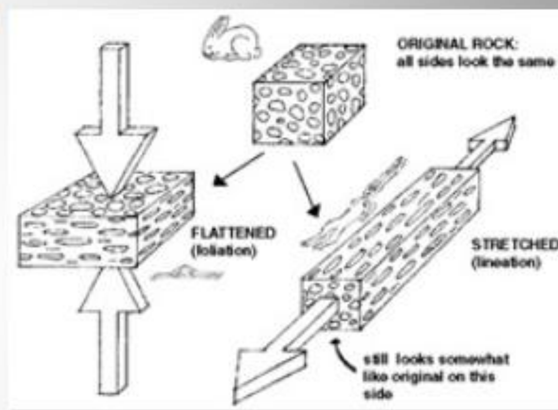
Identifying Metamorphic Rocks

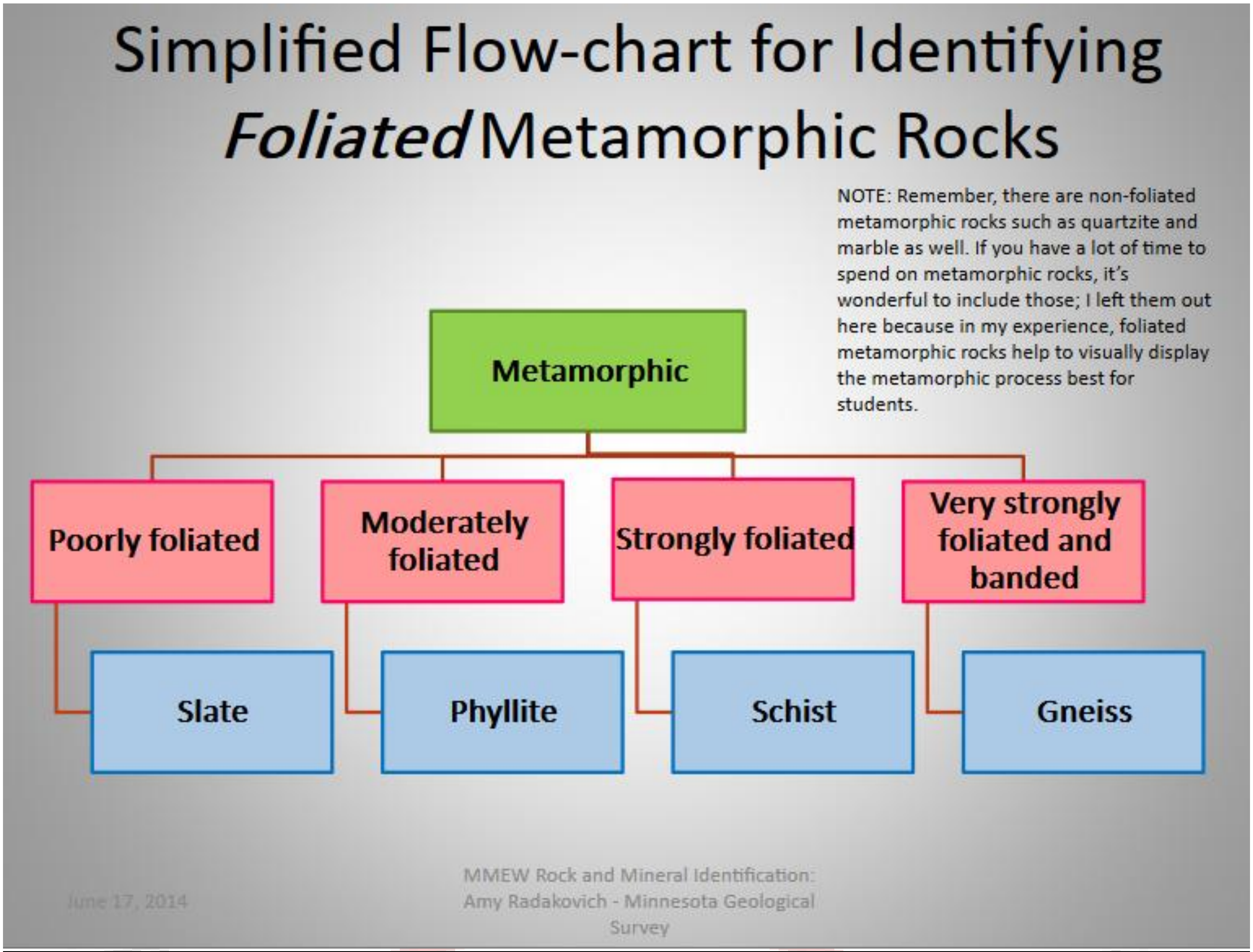
- Grain size (grain size usually increases with increasing metamorphism)
- Foliation





- Other features
  - Folding

"Squished" appearance


Simplified Flow-chart for Identifying *Foliated* Metamorphic Rocks
NOTE: Remember, there are non-foliated metamorphic rocks such as quartzite and marble as well. If you have a lot of time to spend on metamorphic rocks, it's wonderful to include those; I left them out here because in my experience, foliated metamorphic rocks help to visually display the metamorphic process best for students.
Metamorphic
Poorly foliated
Moderately foliated
Strongly foliated
Very strongly foliated and banded
Slate
Phyllite
Schist
Gneiss
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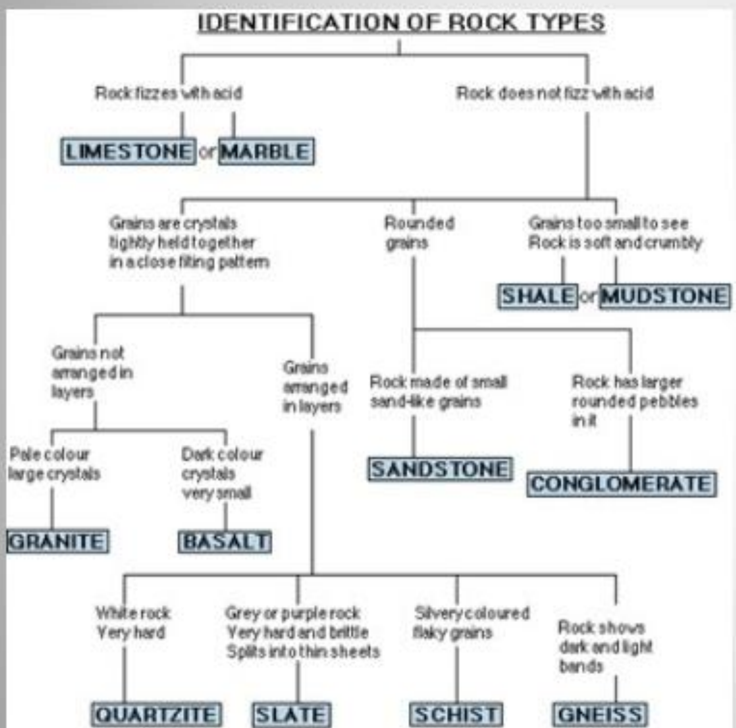
General Rock Identification



Many rock identification charts like this are available on the Internet, but I found it most helpful to create my own chart that helps students arrive at a rock name by eliminating possibilities in manageable steps (see next slide) ...Hopefully this will help you in your classroom as well!

This rock ID chart is a combination of the three shown previously for the three different rock types.

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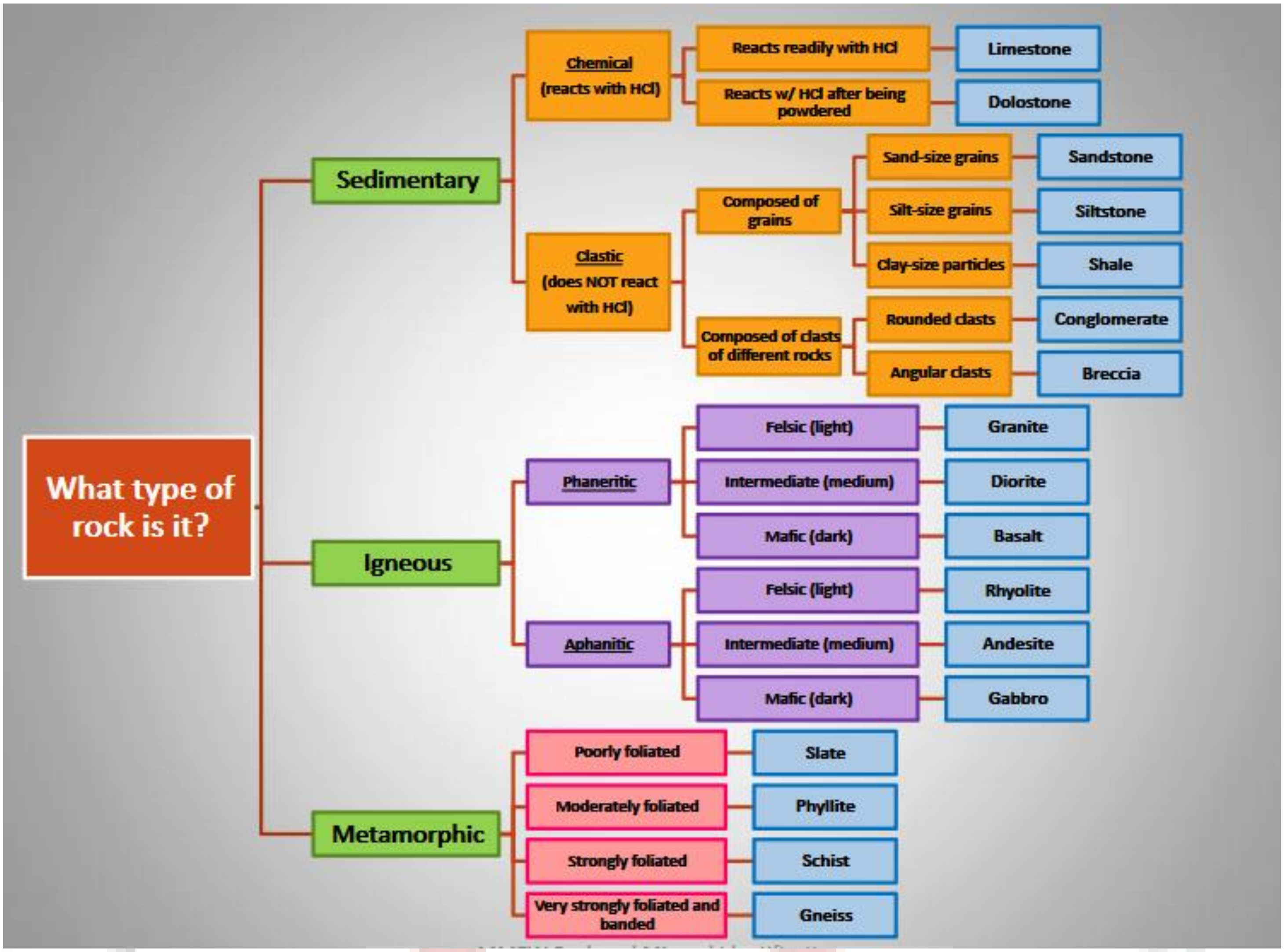
What type of rock is it?
Sedimentary
Chemical
(reacts with HCl)
Reacts readily with HCl
Limestone
Reacts w/ HCl after being powdered
Dolostone
Clastic
(does NOT react with HCl)
Composed of grains
Sand-size grains
Sandstone
Silt-size grains
Siltstone
Clay-size particles
Shale
Composed of clasts of different rocks
Rounded clasts
Conglomerate
Angular clasts
Breccia
Igneous
Phaneritic
Felsic (light)
Granite
Intermediate (medium)
Diorite
Mafic (dark)
Basalt
Aphanitic
Felsic (light)
Rhyolite
Intermediate (medium)
Andesite
Mafic (dark)
Gabbro
Metamorphic
Poorly foliated
Slate
Moderately foliated
Phyllite
Strongly foliated
Schist
Very strongly foliated and banded
Gneiss

#	Color	Streak	Hardness	Specific Gravity	Mag	Luster	Cleavage	Mineral Name
0	Grey	Grey	1-1.5	Low	N	Non-metallic	1	graphite
1	Silver	Dk. Grey	2.5-2.75	high		metallic	Cubic (3 @ 90)	Galena
2	Gold	Black/grey	6-6.5	High	weak	Metallic	Cubic (3 @ 90)	Pyrite
3	Dk grey/silver	Dk grey	5.5-6.5	High	y	Metallic	none	Magnetite
4	Red or silver	Red to dk brown	4.5	High	weak	Metallic to non-metallic	none	Hematite
5	Orange to yellow	Orange to yellow	4-5.5	Med-high	N	Non-metallic	none	limonite
6	Clear	white	2-2.5	med	N	Vitreous	2 @ 90	Halite
7	Clear to white	white	1.5-2	High	N	Vitreous, pearly	2 @ 90	Gypsum
8	Clear to yellow	white	3	med	N	Vitreous to pearly	3 not @ 90	Calcite
9	Green	none	6.5-7	high	N	vitreous	none	Olivine
10	Dk green to black	White	5-6	Med	N	Vitreous/shiny to dull	2 @ 90	Pyroxene
11	Dk green to black	white	5-6	Med	N	Vitreous/shiny to dull	2 @60	Hornblende
12	black	White/none	2.5-3	Low	N	shiny	1	Biotite
13	Clear/tan	White/none	2.5-3	Low	N	shiny	1	Muscovite
14	White, tan, grey	None	6	med	N	Non-metallic	2 @ 90	Plagioclase
15	Pink to white	None	6	Med	N	Non-metallic	2 @ 90	Orthoclase