Hashemite University
College of Engineering
Civil Engineering Department

Engineering Geology Lab Notes
110401436

Engineering Geology is backbone of Civil Engineering

By:

Eng. Iqbal Marie

1. Mineral Properties and Identification

For minerals identification you need the following:

- A copper penny
- A pocket knife
- Mohs scale
- A "streak plate" (unglazed porcelain tile)
- A cigarette lighter.
- A small pair of tweezers.
- A needle in a wooden dowel (for generating cleavage, etc.)
- A small magnet
- A plastic dropper bottle for dilute (10%) HCl acid solution Sheets when
- A 10x hand lens
- Pens or pencils.

Mohs scale of hardness

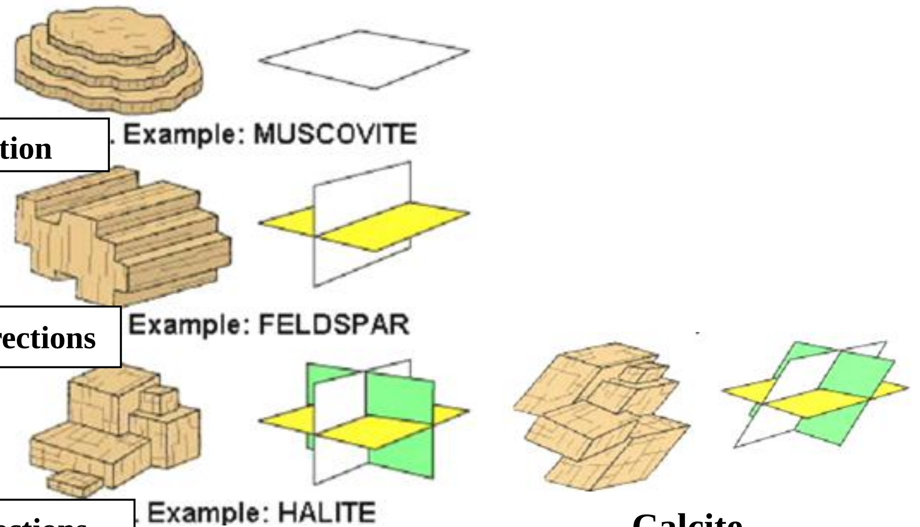
Hardness	Mineral	Common materials
1	Talc	
2	Gypsum	
2.2	**Fingernail**	
3	Calcite	
3.2	**Copper penny**	
4	Fluorite	
5	Apatite	
5	Steel nail	
5.5	**Glass plate**	
6	Feldspar	
6.5	**Steel file**	
7	Quartz	
7	Streak plate	
8	Topaz	
9	Corundum	
10	Diamond	

Some of the cleavage forms:

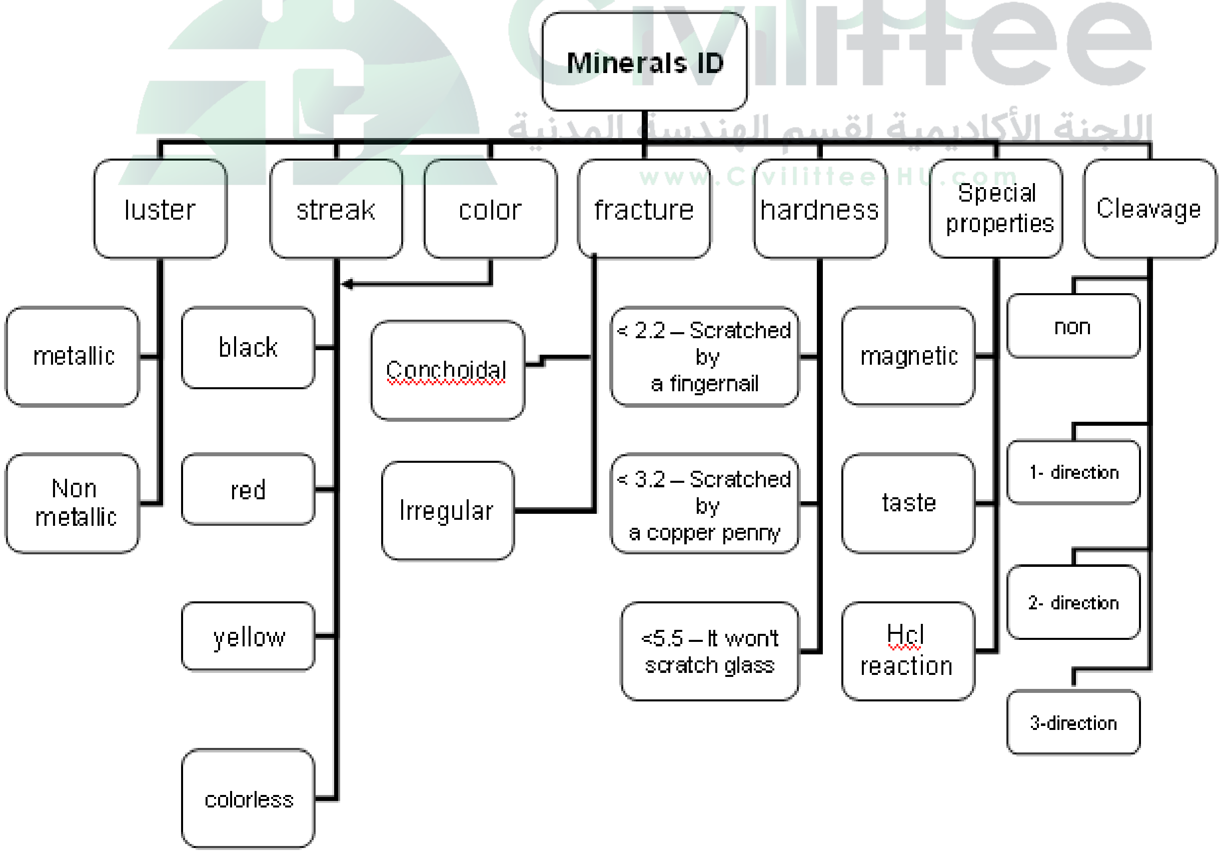
Cleavage in 1- direction

Cleavage in 2 directions

Cleavage in 3 directions



Calcite



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observe important mineral characteristics and Identify the given specimens according to the following table

#	Color	Streak	Hardness	Cleavage or fracture	Other properties	Main uses
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Comments:

Mineral Physical Properties Chart		
PHYSICAL PROPERTY	**Definition***	**Testing Method**
Cleavage	Breakage of a mineral along planes of weakness in the crystal structure.	Examine the mineral for areas where the mineral is broken.
Color	Visible light spectrum radiation reflected from a mineral.	Look at the sample and determine its color - white, black, green, clear, etc.
Crystal Form	Geometric shape of a crystal or mineral.	Examine and describe the geometric shape of the mineral - cubic, hexagonal, etc. Not commonly seen in most introductory lab samples.
Fracture	Breakage of a mineral, not along planes of weakness in the crystral structure.	Examine the mineral for areas where the mineral is broken. Describe the breakage as either irregular or conchoidal (has the appearance of broken glass)
Hardness	Resistance to scratching or abrasion.	Use minerals of known hardness from the Mohs Hardness Kits. Scratch the unknown mineral with a known hardness to determine which mineral is harder. Continue doing this with harder or softer minerals from the kit until the hardness is determined.
Luster	Character of the light reflected by a mineral.	Look at the sample to determine if the mineral is metallic in appearance (looks like a chunk of metal) or non-metallic (doesn't look like a chunk of metal).
Magnetism	Electromagnetic force generated by an object or electrical field.	Use a magnet to determine if the magnet is attracted to the sample.
Reaction to HCl	Chemical interaction of hydrochloric acid and calcium carbonate ($CaCO_3$).	Place one small drop of HCl on a sample, and watch for a reaction - effervesces (bubbles).
Specific Gravity	Ratio of the mass of a mineral to the mass of an equal volume of water.	Generally not determined in an introductory lab. Look this information up in your lab manual once the mineral has been identified.
Streak	Color of the mineral when it is powdered.	Grind a small amount of a mineral into a powder on a porcelain streak plate and determine the color of the powder.
Taste	Nerve ending reaction in the tongue to different chemicals.	Lick the mineral. (not recommended in an introductory lab - you don't know who has handled or licked the sample before you).
Other Properties	Fluorescence, Radioactivity	Requires special equipment such as a UV lamp and geiger counter. These are not commonly tested for in an introductory lab.

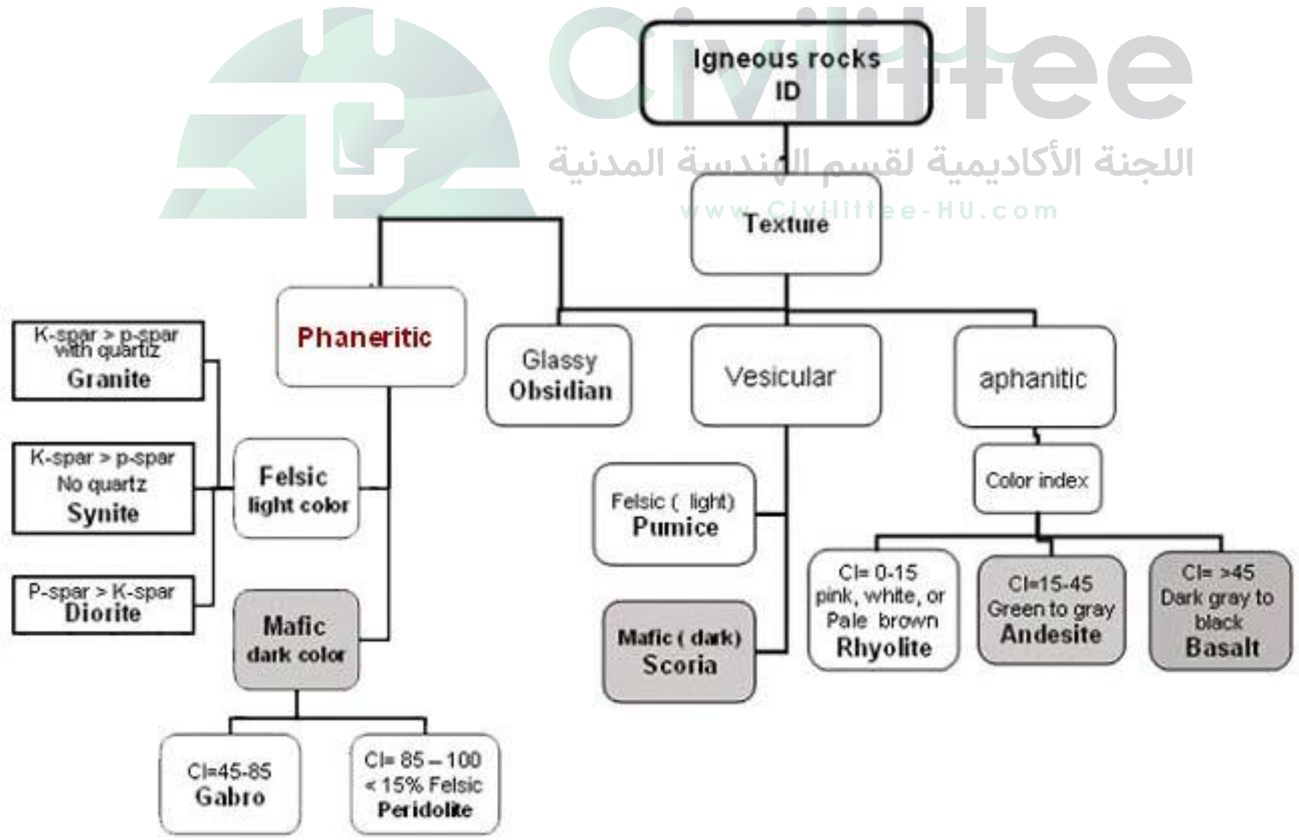
* http://facweb.bhc.edu/academics/science/harwoodr/Geol101/Labs/Minerals/

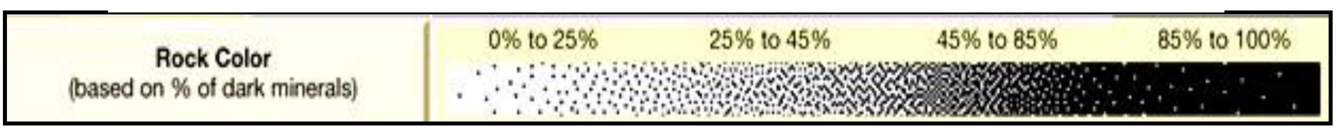
Mineral Identification - Diagnostic Physical Properties	
Apatite	Green color, H=5, may show hexagonal crystal form
Augite	Dark or dull green color, 2 cleavages at ~90 degrees, similar properties to Hornblende
Biotite	Black color, one perfect direction of cleavage resulting in the mineral pealing into thin, flexible sheets, similar properties to Muscovite
Calcite	H=3, reacts with HCl, 3 directions of cleavage (rhombic cleavage)
orundum	H=9, often shows hexagonal crystal form
Dolomite	Reacts to HCL in its powdered form, similar properties to calcite
Fluorite	H=4, 4 directions of cleavage, often purple in color (can be white, clear, yellow, green)
Galena	Gray, metallic mineral, 3 directions of cleavage (cubic)
Garnet	Typically reddish brown color, no cleavage, commonly found in twelve-sided crystals (dodecahedrons)
Graphite	"Pencil lead", soft metallic mineral, gray streak
Gypsum	H=2, can be scratched with a fingernail
Halite	"Salt", H=2.5, cannot be scratched with a fingernail, 3 directions of cleavage (cubic), salty taste
Hematite	Reddish brown streak, "rust"
Hornblende	Black to dk. green color, 2 directions of cleavage at 120 or 60 degrees, similar properties to Augite
Magnetite	Magnetic, metallic mineral
Muscovite	Clear or translucent color, one perfect direction of cleavage resulting in the mineral pealing into thin, flexible sheets, similar properties to Biotite
Olivine	Apple green or yellowish green color, H=7 (often difficult to determine), conchoidal fracture, no cleavage
Orthoclase	H=6, salmon pink color is typical, perthitic intergrowths are common, 2 directions of cleavage at 90 degrees, similar properties to plagioclase
Plagioclase	H=6, white or gray color, striations may be seen on cleavage surface, 2 directions of cleavage at 90 degrees, similar properties to orthoclase
Pyrite	"Fool's Gold", gold metallic color
Quartz	H=7, conchoidal fracture, no cleavage, color is typically white or clear but can be pink, red, purple, black
Sulfur	Yellow color, "rotten egg" smell if burned
Talc	H=1, very soft, easily scratched by fingernail

2. Identification of Igneous Rocks

The object of the lab is to be able to identify the various types of igneous rocks based upon their color, mineral composition, and texture.

1. Determine which minerals are present.
2. Determine the grain size.
3. Determine what color the rock is (light, dark, gray, pink, etc.).
4. Does the rock have any textures, (vesicles, phenocrysts, etc.?
5. Use the chart below to determine the name of the rock, and whether the rock is extrusive or intrusive.





Aphanitic texture is a fine grained texture but the crystals are too small to see

Phaneritic texture is composed of crystals which are large enough to see

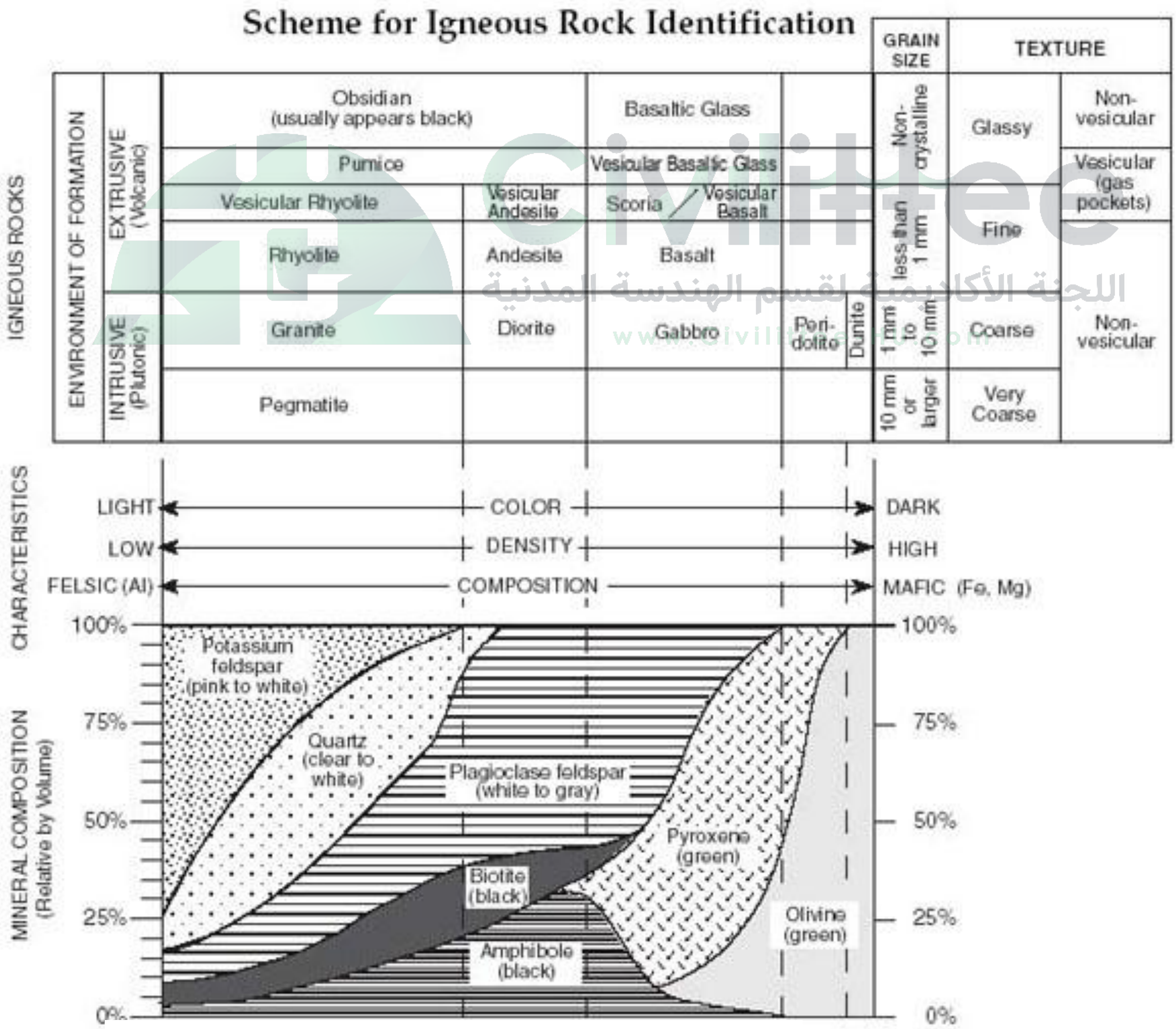
Porphyritic texture is composed of crystals of two different sizes. Typically the large crystals (phenocrysts) are visible while the smaller crystal are not (referred to as groundmass

Color Index : % Dark Minerals

Materials Needed

1. Rocks Set

2. Hand lens



http://depthome.brooklyn.cuny.edu/geology/core332/geofield.htm

Example of some igneous rocks

#	Grain Size	Color	Other properties	Composition	Rock Type
1	fine	dark	glassy appearance	lava glass	Obsidian
2	fine	Light	many small bubbles (viscular)	lava froth from sticky lava	Pumice
3	fine	Dark	many large bubbles. (viscular)	lava froth from fluid lava	Scoria
4	fine or mixed	light	contains quartz	high-silica lava	Felsite
5	fine or mixed	medium	between felsite and basalt	medium-silica lava	Andesite
6	fine	dark	has no quartz	low-silica lava	Basalt
7	mixed	any color	large grains in fine-grained matrix	large grains of feldspar, quartz, pyroxene or olivine	Porphyry
8	coarse	light	wide range of color and grain size	feldspar and quartz with minor mica, amphibole or pyroxene	Granite
9	coarse	medium to dark	little or no quartz	low-calcium plagioclase and dark minerals	Diorite
10	coarse	medium to dark	no quartz; may have olivine	high-calcium plagioclase and dark minerals	Gabbro
11	very coarse	any color	usually in small intrusive bodies	typically granitic	Pegmatite

http://geology.about.com/library/bl/blrockident_tables.htm


1


2

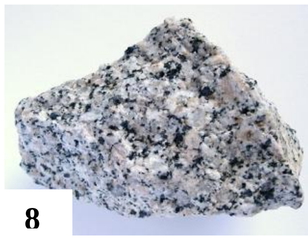

3


4


5


6


7


8


9


10


11

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Igneous Rocks Identification Work Sheet

Observe important Rocks characteristics and identify the given specimens according to the following table

Sample #	**Color**	**Composition** mafic, intermediate, felsic)	**Texture:** Aphanitic, phaneritic, vesicular, glassy, porphyritic	*** Major Minerals**	Sketch the texture	Rock Name
1						
2						
3						
4						

*

a. Mafic: plagioclase, pyroxene, olivine
b. Intermediate: plagioclase, amphibole, biotite
c. Felsic: potassium feldspar, quartz, biotite, muscovite

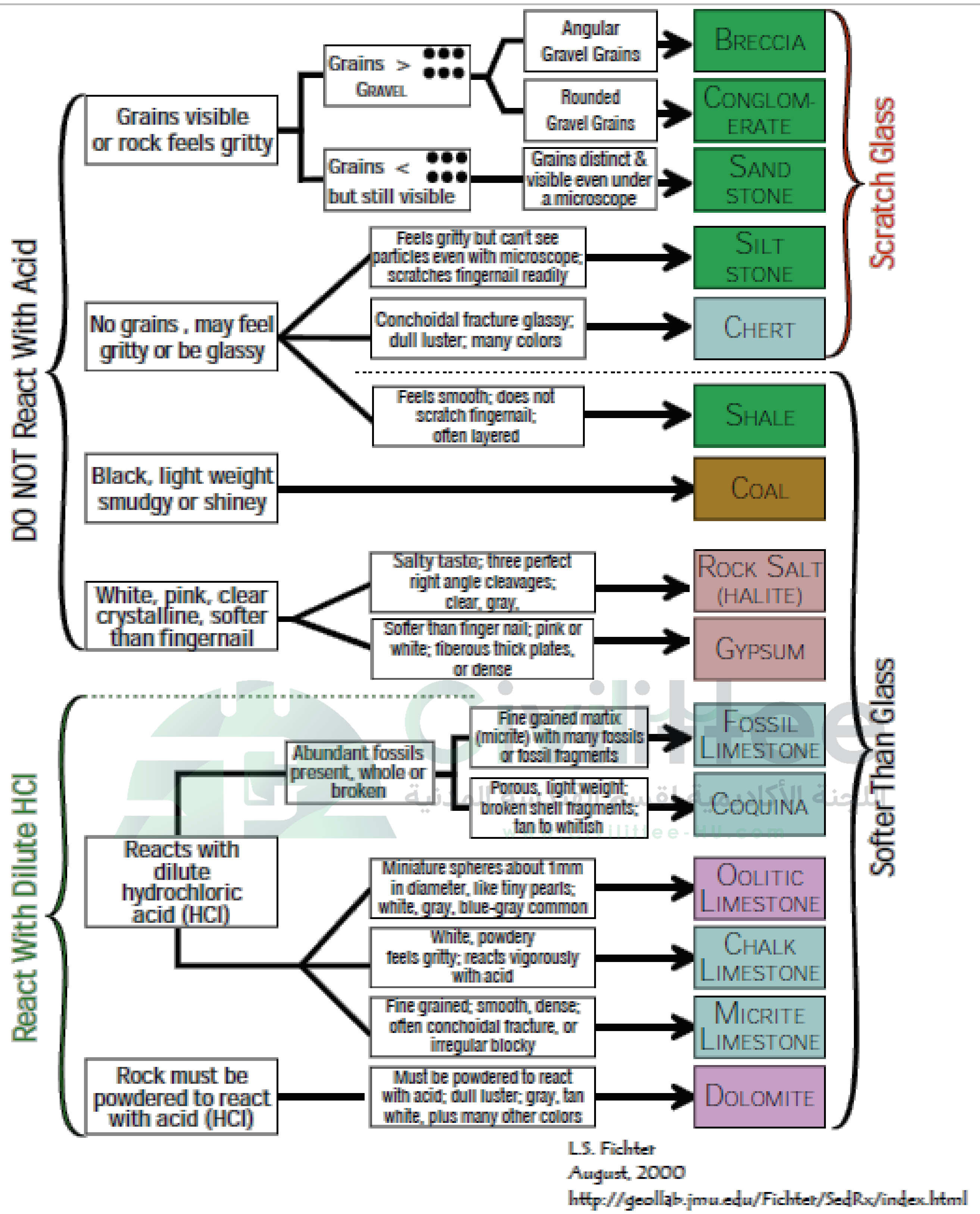
3. Identification of Sedimentary rocks

The object of the lab is to be able to identify the various types of sedimentary rocks based upon their composition and texture.

Identify the type of sediment the rock is composed of. (sand, pebbles, or shells)	→	Is the rock clastic, chemical or bioclastic.	→	feature or physical property that is unique to Rock type.	→	Affected by HCL Any fossils?

The major characteristics of sedimentary rocks:

- Classified by texture and composition
- Often contains fossils
- May react with acid
- Often has layers, flat or curved
- Usually composed of pieces cemented or pressed together
- Has great color variety
- Particle size may be the same or vary
- porous
- May have cross-bedding, mud cracks, ripples


DO NOT React With Acid
Grains visible or rock feels gritty
Grains > GRAVEL
Grains < but still visible
Angular Gravel Grains
Rounded Gravel Grains
Grains distinct & visible even under a microscope
BRECCIA
CONGLOM-ERATE
SAND STONE
No grains , may feel gritty or be glassy
Feels gritty but can't see particles even with microscope; scratches fingernail readily
SILT STONE
Conchoidal fracture glassy; dull luster; many colors
CHERT
Scratch Glass
Feels smooth; does not scratch fingernail; often layered
SHALE
Black, light weight smudgy or shiney
COAL
White, pink, clear crystalline, softer than fingernail
Salty taste; three perfect right angle cleavages; clear, gray,
ROCK SALT (HALITE)
Softer than finger nail; pink or white; fiberous thick plates, or dense
GYPSUM
React With Dilute HCl
Abundant fossils present, whole or broken
Fine grained matrix (micrite) with many fossils or fossil fragments
FOSSIL LIMESTONE
Porous, light weight; broken shell fragments; tan to whitish
COQUINA
Reacts with dilute hydrochloric acid (HCl)
Miniature spheres about 1mm in diameter, like tiny pearls; white, gray, blue-gray common
OOLITIC LIMESTONE
White, powdery feels gritty; reacts vigorously with acid
CHALK LIMESTONE
Fine grained; smooth, dense; often conchoidal fracture, or irregular blocky
MICRITE LIMESTONE
Rock must be powdered to react with acid (HCl)
Must be powdered to react with acid; dull luster; gray, tan white, plus many other colors
DOLOMITE
Softer Than Glass
L.S. Fichter
August, 2000
http://geollab.jmu.edu/Fichter/SedRx/index.html

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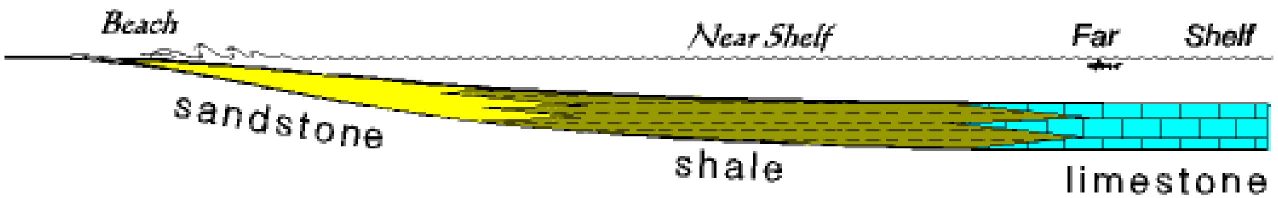
Sedimentary Rocks Identification Work Sheet

Observe important sedimentary Rocks characteristics and identify the given specimens according to the following table

Sample #	Colour	Texture	Sediment Name	Reaction with HCL	Sketch the texture	Rock Name
1						
2						
3						
4						
5						

Sediments: Small pieces of rocks, shells, or the remains of plants and animals that have been carried along and deposited by wind, water, or ice.



4. Identification of Metamorphic rocks

Metamorphic rocks are rocks that have undergone a change from their original form due to changes in temperature, pressure or chemical alteration. The classification of metamorphic rocks is based on the minerals that are present and the temperature and pressure at which these minerals form

The object of the lab is to be able to identify the variety of commonly occurring metamorphic rocks, and to use grain size and foliation to name metamorphic rocks.

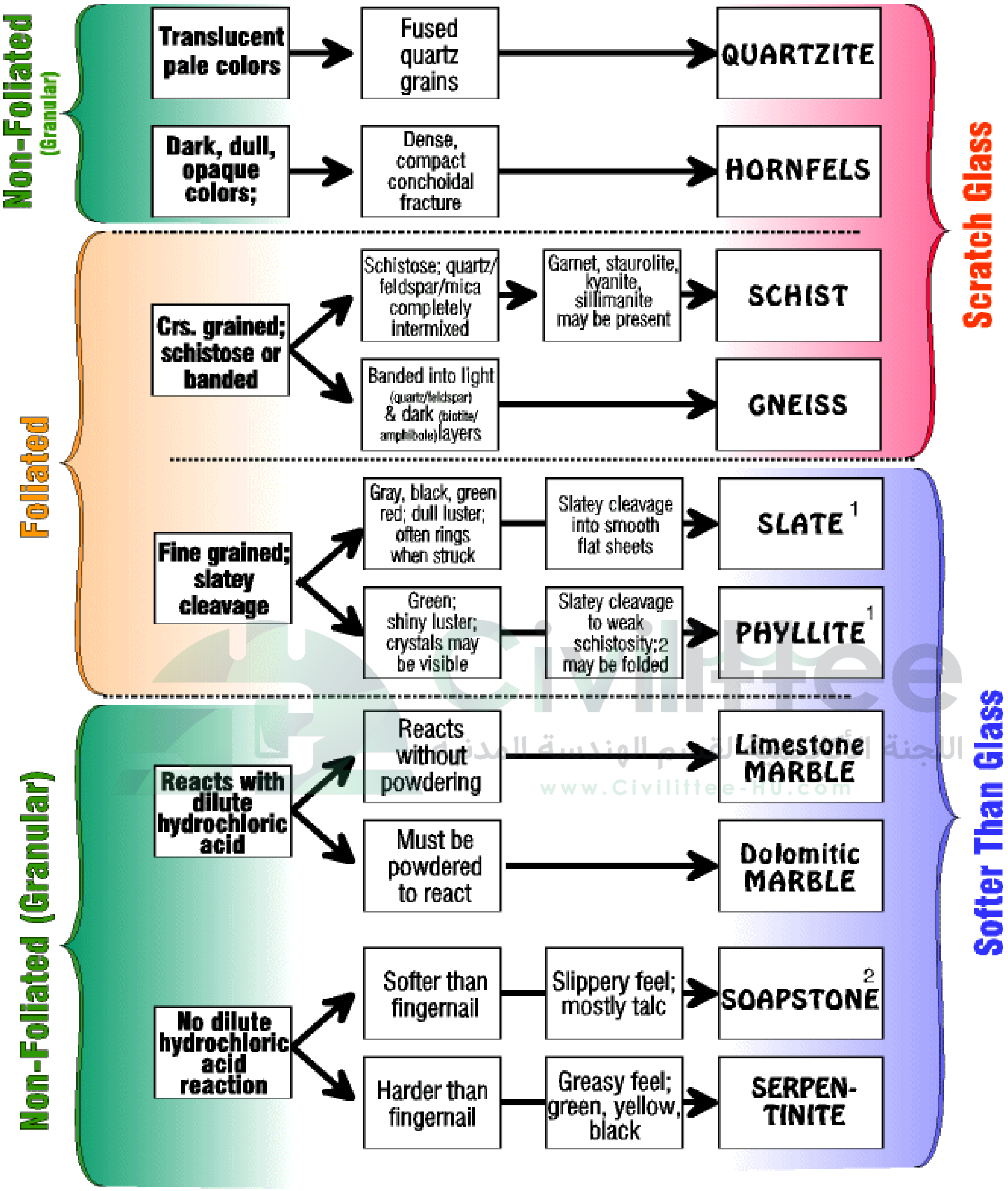
Is the rock foliated or non-foliated → What type of texture → fine grained, coarse grained or granoblastic texture → React with HCl? Any fossils?

Use the attached charts to help you in identifying the rocks.

Texture	Grain Size	Comments	Parent Rock	Rock Name
Foliated	Very fine	Excellent rock cleavage, smooth dull surfaces	Shale, mudstone, or siltstone	Slate
Foliated	Fine	Breaks along wavey surfaces, glossy sheen	Slate	Phyllite
Foliated	Medium to Coarse	Micaceous minerals dominate, scaly foliation	Phyllite	Schist
Foliated	Medium to Coarse	Compositional banding due to segregation of minerals	Schist, granite, or volcanic rocks	Gneiss
Foliated	Medium to Coarse	Banded rock with zones of light-colored crystalline minerals	Gneiss, schist	Migmatite
Weakly Foliated	Fine	When very fine-grained, resembles chert, often breaks into slabs	Any rock type	Mylonite
Weakly Foliated	Coarse-grained	Stretched pebbles with preferred orientation	Quartz-rich conglomerate	Metaconglomerate
Nonfoliated	Medium to coarse	Interlocking calcite or dolomite grains	Limestone, dolostone	Marble
Nonfoliated	Medium to coarse	Fused quartz grains, massive, very hard	Quartz sandstone	Quartzite
Nonfoliated	Fine	Usually, dark massive rock with dull luster	Any rock type	Hornfels
Nonfoliated	Fine	Shiny black rock that may exhibit conchoidal fracture	Bituminous coal	Anthracite
Nonfoliated	Medium to very coarse	Broken fragments in a haphazard arrangement	Any rock type	Fault breccia

Increasing Metamorphism

Key to Common Metamorphic Rocks



1 (Shale), slate, and phyllite complete intergrade with each other. Distinctions may be difficult.

2 Soapstone may be weakly foliated.

Metamorphic Rocks Identification Work Sheet

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Observe important Metamorphic Rocks characteristics and Identify the given specimens according to the following table

Sample #	Foliation	Texture:	Certain characteristics	Reaction with HCL	Sketch the texture	Rock Name
1						
2						
3						
4						

Comments:
………..
……….
……
…….…….
……….

5. Slake- Durability Index

Slake durability index test has long been used to identify the durability and water sensitivity of rocks as subject to engineering requirements under in-situ conditions. (ASTM D4644),
Franklin and Chandra (1972) developed the slake durability test to evaluate the influence of alteration on rock by measuring its resistance to deterioration and breakdown when subjected to wetting and drying cycles. Slaking occurs from the swelling of rocks containing clay minerals when in contact with water. The slake durability index (ID_2) provides a measure of durability.

Slake durability is a simulated weathering test to determine abrasion resistance during wetting and drying cycles of shale and similar soft rocks as used in embankments and other construction-related applications. Samples are alternately tumbled in mesh drums through a water medium and oven-dried for two cycles. The percent loss of mass is referred to as the slake durability index. The primary objectives of the slake durability index test are to predict long-term durability of the rock specimens, to establish weathering and degradation characteristics of each rock type, and to assess the impact of water on the rock degradation

The apparatus consists of a base-mounted, double-ended motor drive unit which rotates two sturdy wire mesh drums at **twenty revolutions per minute** in included water tanks

Procedure:

- Sample of 10 rock pieces, each weighing between 40 and 60 g, providing a total sample weight ranging from 450 to 550 g.
- The sample is placed in a screen drum and both the drum and the sample are oven-dried at a temperature of 110° ± 5° C to a constant weight.
- After the sample cools to room temperature, the drum is coupled to a motor and rotated immersed in distilled water at a speed of 20 rpm for 10 min.
- The sample is again oven-dried at a temperature of 110° ± 5° C to a constant weight.
- The sample is subjected to a second wetting and drying cycle.

$$ID_2 = \frac{W_A - W_D}{W_B - W_D} \times 100$$

Where:

ID_2 = slake durability index (second cycle), (%)

W (weight of sample before drying + drum)

W_B = mass of drum plus oven-dried sample before the first cycle, (g)

W_A = mass of drum plus oven-dried sample retained after the second cycle, (g)

W_D = mass of drum, (g).

Use the given lab sheet to record your data

A visual and an index classification are established according to the appearance of the remaining rock pieces and the range of the ID_2 as shown in the following tables.

Table 1. Visual description of the rock samples retained in the test drum after the second cycle (after Franklin and Chandra. 1972).

Type	Description
I	Pieces remain virtually unchanged
II	Consist of large and small pieces
III	Exclusively small fragments

Table 2. Slake durability index classification (after Franklin and Chandra. 1972).

ID_2 (%)	Durability classification
0 – 25	Very Low
26 – 50	Low
51 – 75	Medium
76 - 90	High
91 – 95	Very High
96 - 100	Extremely High

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Slake- Durability test

Description of material and origin : ……………………………………………

……………………………………………………………………………………..

……………………………………………………………………………………

W_D = mass of drum, (g).= ………………………………..

% Natural water content : (W - W_B / W_B) % = ……………………

Sample #	**W**	**W_B**	**W_A**	Visual description of the of rock sample after second cycle remaining in the drum. (table 1)	**Slake Durability** $ID_2 = \frac{W_A - W_D}{W_B - W_D} \times 100$ **ID_2**	**Durability classification (table 2)**
1						
2						

Second cycle slake durability index to nearest 0.1%: sample 1.

……………………………………………………………………………………..

…………………………………………………………………………………….

Second cycle slake durability index to nearest 0.1%: sample 2.

……………………………………………………………………………………..

…………………………………………………………………………………….

Description of appearance of fragments remaining in drum after second cycle for sample 1 and 2. :

……………………………………………………………………………………..

……………………………………………………………………………………

Comments: ……………………………………………………………………

6. Unconfined Compressive Strength
UCS (*ASTM D2938*.)

Scope

Determining unconfined compressive strength of intact rock core specimens, using the direct compression test and compare it with the one obtained by Schmidt hammer.

Sampling

- The specimen should be selected from the cores to represent a valid average of the type of rock under consideration. This can be achieved by visual observations of mineral constituents, grain sizes and shape, partings and defects such as pores and fissures.
- Test specimens shall be cut as carefully as possible to right cylinders. The cuts shall be parallel to each other and at right angles to the longitudinal axis.
- Determine the diameter of the test specimen to the nearest. (0.1 mm) by averaging two diameters measured at right angles to each other at about mid-height of the specimen. Then calculate the cross –sectional area
- Determine the length of the test specimen to the nearest (0.1 mm) The specimen shall have a length-to-diameter ratio (L/D) of 2.0 to 2.5 and a diameter of not less than 47 m).
- When cores of diameter smaller than the specified minimum must be tested because of the unavailability of larger diameter core, suitable notation of this fact shall be made in the report.
- Determine the mass of the specimen to the nearest 0.01 kg
- The rock cores shall be capped with a neoprene cap conforming to the requirements of ASTM C 1231.

Procedure

- Apply axial load continuously and without shock until the load becomes constant. Apply the load in such a manner as to produce either a stress rate or a strain rate as constant as feasible throughout the test, so that failure in a test time between 2 and 15 minutes.

- Record the maximum load sustained by the specimen.

Calculations

Calculate the cross-sectional area (A) of the specimen to the nearest 0.01 m^2

$A = \pi d^2 / 4$ mm^2 d = average specimen diameter, (mm)

Calculate the volume of the specimen (V) to the nearest 0.001 m^3 :

$V = A * L$ m^3 L = specimen length, m

Calculate the specimen unit weight to the nearest 1.0 kg/m^3:

$\gamma = M * 9.81 / V$ N/m^3 M = specimen mass, kg

Calculate the compressive strength (σ_C)

$\sigma_C = P / A$ kN/m^2 P = maximum load, kN

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Unconfined Compressive Strength work sheet

Sample #: ……………………………………….
Sample description: ……………………………………………………………………
……………………………………………………………………………………….
………………………………………………………………………………………
Sample measurements:

	1	2	Avg.
Diameter (d) mm			
Length (L) mm			
Mass (kg)			

L/d: …………………………………………
$A = \pi(d^2) / 4$ = …………………………..mm^2
$V = A (L)$ = ………………………… m^3

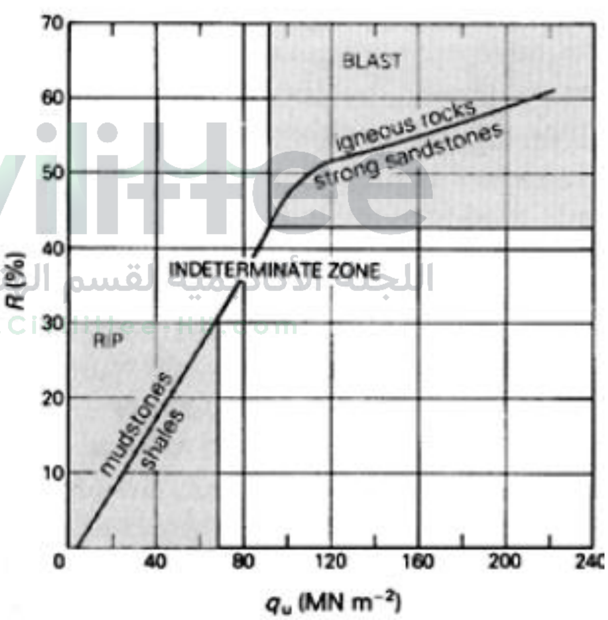
$\gamma = M * 9.81 / V$ = …………………………………… N/m^3

Sample #	**Shape of failure**	**A (mm^2)**	**P $_{ultimate}$ (kN)**	**UCS σ_C = P /A kN/m^2**
1				
2				

Comments: ……………………………………………………………………………
……………………………………………………………………………………..
……………………………………………………………………………………..

7. Schmidt Hammer Test (ASTM D5873)

- A rebound hammer may be used was to assess the relative hardness characteristics of select rock core samples.
- Prior to testing, each core sample should be visually inspected for surface defects resulting from sampling irregularities and rock fabric/structure to avoid testing near fractures.
- The test surfaces of all specimens were smooth over the area as a result of coring. Samples were visually observed to be free of apparent joints, fractures, or other incipient breaks.
- The Schmidt hammer hits the rock with a spring-driven pin, and then measures the rebound number
- Measure the rebound for each rock (at least 10 trials on each rock).
- Note that the Schmidt hammer does not work well for small samples and will make marks.
- These values usually are considered reliable when at least 10 of the 15 readings deviate no more than 2 to 3½ on the impact scale.
- The compressive strength is then determined by using the best 10 out of the 15 readings using correlation charts.



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ID:…………….
Lab section : ………

Inst. Iqbal Marie

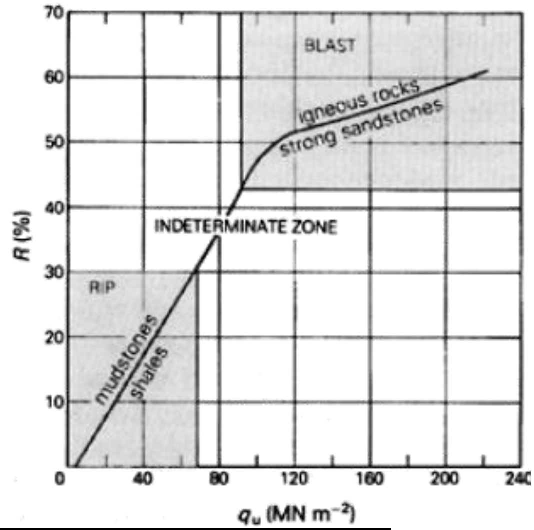
Schmidt hammer test work sheet

Sample measurements:

Sample #	Diameter (D) mm	Length (L) m	Mass (M) kg
1			
2			

Calculations

Sample #	L/D	A (mm^2) π□$D^2/4$	V (m^3) $A\times L$	**γ (N/m^3) ($M\times 9.81$)/V**
1				
2				



Sample #	Shape of Failure	P ultimate N	UCS MPa (N/mm^2) P /A	Schmidt Hammer Number	% error	Correlated Compressive Strength MPa
				1		
				2-		
				3-		
				4-		
				5-		
				6-		
				7-		
				8-		
				9-		
				10-		
				Avg. =		
2				1-		
				2-		
				3-		
				4-		
				5-		
				6-		
				7-		
				8-		
				9-		
				10-		
				Avg. =		

Comments: ……………………………………………………………………

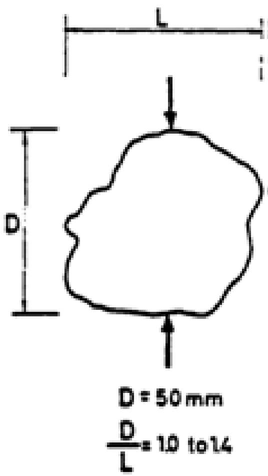
8. Point load Index
Indirect Compressive Strength of Rocks

The point load strength test is used as an index test for strength **classification of rock materials**. The test results should not be used for design or analytical purposes.
The test is typically used in the field because the testing machine is portable, little or minimal specimen preparation is required
Specimens in the form of either rock core or of irregular lumps are broken by application of a concentrated load using a pair of conical platens.
A Point Load Strength Index $\mathbf{I_{s(50)}}$ is obtained and may be used for rock strength classification.

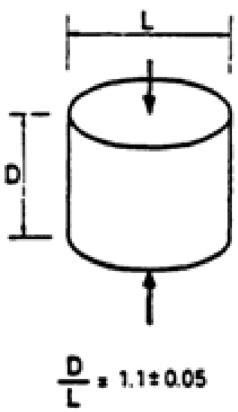
Sample Preparation:

Little or no specimen preparation is required and can therefore be tested shortly after being obtained and any influence of moisture condition on the test data minimized. However, the results can be highly influenced by how the specimen is treated from the time it is obtained until the time it is tested. Therefore, it may be necessary to handle specimens in accordance with Practice D 5079 and to document moisture conditions in some manner in the data collection.

Specimens in the form of **rock cores, blocks, or irregular lumps** with a test diameter from 30 to 85 mm can be tested by this test method.

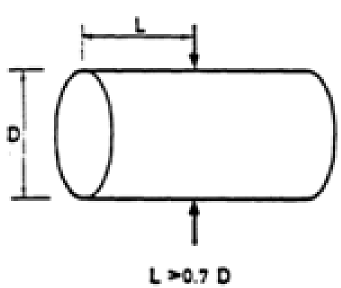


Irregular lump test



$$D_e^2 = 4A/\pi = 4DL/\pi$$

Axial test



$$D_e^2 = D^2$$

Diametral test

Preferably **ten or more tests per sample** are required depending on the available quantity of core and on the uniformity of rock in the sample.

Calculations:

Using Point Load Tester supplied, The distance (**D)** between the point loads is recorded and the load increased to failure. The failure load **P** is recorded.

Compute values of:

- Point Load Index, Is = P/D^2
- Is $_{(50),}$ corresponding to a specimen of 0.05 m in diameter $=(P / D^2_e) * F$:
  F is the size correction factor $\mathbf{=(D_e / .05)^{0.45}}$
- Indirect Compressive Strength $\boldsymbol{\sigma}$ **u = 24 Is** $_{\mathbf{(50)}}$

Advantages of the point load test:

- the specimen fails at much lower loads than in compression, needing a machine load capacity less than one-tenth of that usually required for compression:
- core can be tested direct from the core box without previous machining-even weak or broken rock can thus be tested; and
- As fracture initiates in the specimen interior, platen contact conditions are of little importance.

Point load strength index classification (Broch and Franklin, 1972).

Is50 (MPa)	Strength classification
< 0.03	Extremely low
0.03 – 0.1	Very low
0.1 – 0.3	Low
0.3 – 1.0	Medium
1.0 – 3.0	High
3.0 – 10	Very high
> 10	Extremely high

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Point load Index work sheet

Sample #	**Sample (Axial, Lump Diametral)**	**D (m)**	**D/L**	**D_e**	**P (kN)**	**Correction Factor (F)**	**I_s = P/D^2**	**σ_u = 24 $I_{s\,(50)}$**	**Strength classification**
1									
2									
3									

Calculations:

Comments: ……………………………………………………………………………….
………………………………………………………………………………………..
………………………………………………………………………………………..
……………………………………………………………………………………….
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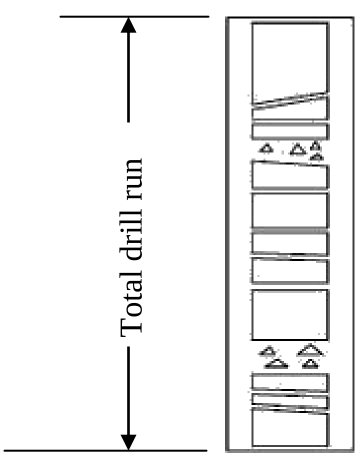
8- Rock Quality Designation (RQD)

Rock Quality Designation, **RQD**, is based on a modified core recovery procedure which, in turn, is based indirectly on the number of fractures and amount of softening or alteration in the rock mass as observed in the rock cores from a drill hole > 50mm diameter.

RQD is a measure of the spacing of the discontinuities (bedding, fractures, faults, joints, shear zones, etc.) in the rock mass.

RQD obtained by summing up the total length of core recovered but counting only those pieces of core which are ≥ 10 cm in length, and which are hard and sound. If the core is broken by handling or by the drilling process (i.e., the fracture surfaces are fresh irregular breaks rather than natural joint surfaces), the fresh broken pieces are fitted together and counted as one piece, provided that they form the requisite length of 10cm. Some judgement is necessary in the case of sedimentary rocks and the foliated metamorphic rocks, and the limestone, sandstone, etc. However, the system has been applied successfully even for shale although it was necessary to log the cores immediately upon removing them from the core barrel before air-slaking and cracking began.



$$RQD = \frac{\text{Sum of core pieces} \geq 10\text{ cm}}{\text{Total drill run}} \times 100$$

RQD %	Description
0- 25	Very poor
25-50	Poor
50-75	Fair
75-90	Good
90-100	Excellent

* The type of support (rock bolts, steel ribs) which can be used for rock masses with RQD values ranging between 25 and 75
No supports are needed for formation with RQD values exceeding 75

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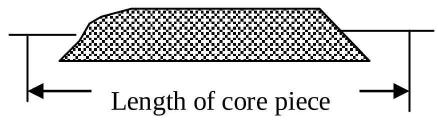
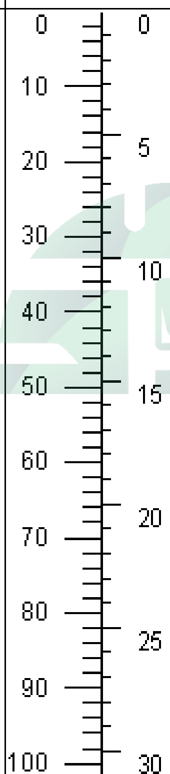
Rock Quality Designation (RQD)

Core #: ………………………………………..
Total Drill Length = ……………………..
Time of bore: …………………..
Time of test: …………………………



<table>
<tr><th>Core #</th><th>Core plot and pieces measurements</th><th>RQD % $\frac{\text{Sum of core pieces} \geq 10\text{ cm}}{\text{Total drill run}} \times 100$</th><th>LR% length recovery</th><th>Description</th></tr>
<tr><td>1</td><td>

mm - in</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Σ</td><td></td><td></td><td></td></tr>
</table>

LR% length recovery $= \dfrac{\textbf{total length of all pieces}}{\textbf{Total length or Drill}} \textbf{*100}$

10. Estimation of Intact Rock Strength

Rock Classification:
Rock classification for engineering purposes consists of two basic assessments; one based on:

the ***intact*** properties of the rock, and the other based on the ***in situ*** (engineering) features of the rock mass.

• **Intact properties** - This assessment is based on the character of the intact rock (hand specimens and rock core) in terms of its genetic origin, mineralogical make-up, texture, and degree of chemical alteration and/or physical weathering.

• **In situ properties -** This assessment is based on the engineering characteristics (orientation, spacing, etc.) of the bounding discontinuities (bedding, joints, foliation planes, shear zones, faults etc.) within the rock mass.

Both assessments are essential engineering characterization of the rock mass, and are the basis for rock slope design and excavation, foundation design on rock, rock anchorage, and characterizing rock quarries.

Relative Rock Strength

Rock strength is controlled by many factors including degree of indurations, cementation, crystal bonding, degree of weathering or alteration, etc.

Determination of relative rock strength can be estimated by simple field tests, which can be refined, if required, through laboratory testing. The relative rock strength should be determined based on the Simple means' field tests that make use of hand pressure, geological hammer, etc. (Burnett, 1975), are used to determine intact rock strength classes in the British Standard (BS 5930, 1981)

Field Tools :

Geological Hammer

Lens

Knife edge

Table.1 Estimation of intact rock strength.

intact rock strength	'simple means' test (standard geological hammer of about 1 kg)
< 1.25 MPa	Crumbles in hand
1.25 – 5 MPa	Thin slabs break easily in hand
5 - 12.5 MPa	Thin slabs break by heavy hand pressure
12.5 - 50 MPa	Lumps broken by light hammer blows
50 – 100 MPa	Lumps broken by heavy hammer blows
100 - 200 MPa	Lumps only chip by heavy hammer blows
> 200 MPa	Rocks ring on hammer blows. Sparks fly.

Table. 2 Unconfined compressive strengths of the main rock types.

Descriptive term	Compressive strength ($MN\ m^{-2}$)	Indicative rock types
very weak	<1.25	some weakly compacted sedimentary rocks, some very highly weathered igneous or metamorphic rocks boulder clays
weak	1.25–5	
moderately weak	5–12.5	
moderately strong	12.5–50	some sedimentary rocks, some foliated metamorphic rocks, highly weathered igneous and metamorphic rocks
strong	50–100	some low-grade metamorphic rocks, marbles, some strongly cemented sedimentary rocks, some weathered and metamorphic igneous rocks
very strong	100–200	mainly plutonic, hypabyssal and extrusive igneous rocks (medium to coarse grained), sedimentary quartzites, strong slates, gneisses
extremely strong	>200	fine-grained igneous rocks; metamorphic quartzites, some hornfelses

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Estimation of Intact Rock Strength

Use the samples in the lab to estimate their strength depending on the simple means using table 1 and indicate the rock type using table 2

Sample No.	Method of simple Testing (table 1)	Estimated intact rock strength (table 1)	Indicative rock type (table 2)
1			
2			
3			

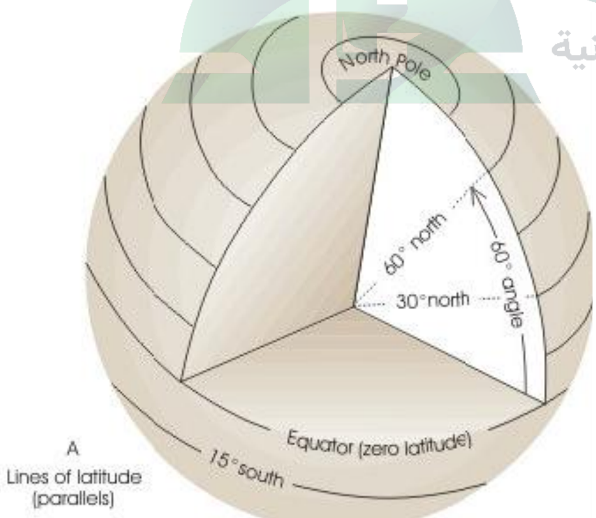
10. Topographic maps using Surfer 8.

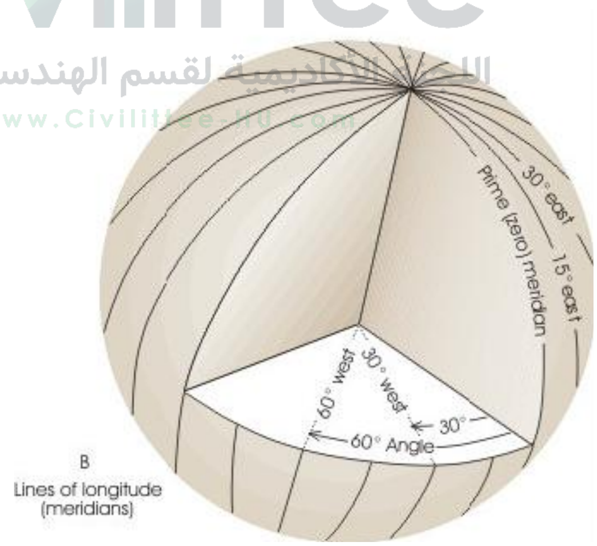
While maps may vary in content, scale, and size, they all have several things in common: publishing information (title, the author of the map, year printed), the contour interval, the scale of the map, a North indicator, and a legend stating what each of the symbols and lines on the map represent. Each of these features are important and will be able to guide the user in finding the desired information contained in the map.

Map Contours

Topographic maps indicate the three dimensional shape of the Earth's surface on a flat piece of paper. The most precise method of indicating the shape of the Earth's surface along with the elevation of different areas above sea level is by means of **contour lines**.

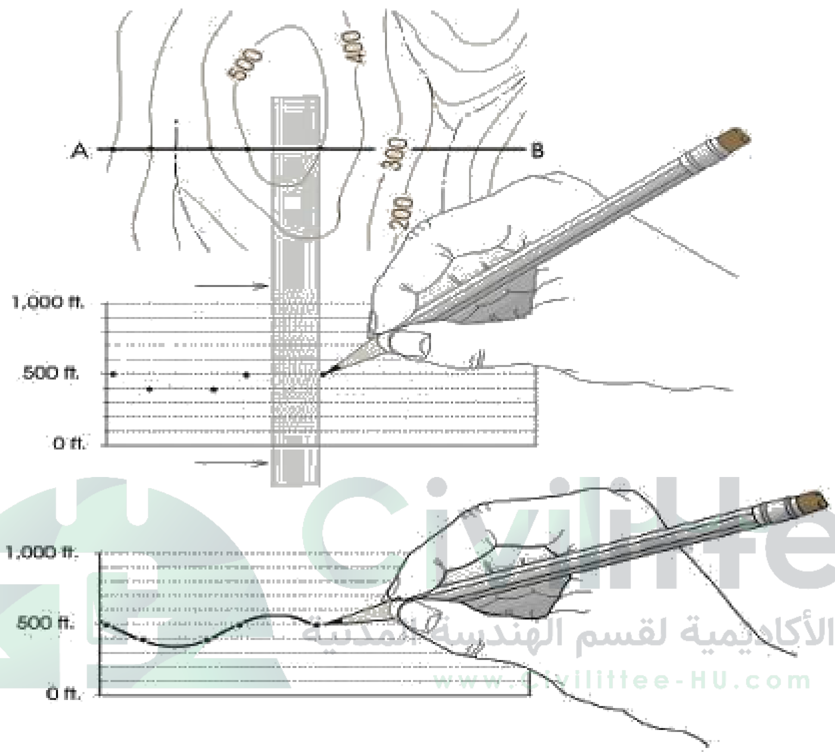
Latitude and Longitude





Surface Profile

A topographic profile shows the intersection of the land surface with a vertical plane. Such views of the land surface can be seen in road-cuts, quarries, and canyon walls. A profile can be constructed from a topographic map along any straight line by the method shown in the figure to the below.



For the data shown , Use the surfer software to:

1. Draw a contour map that represents the topography of the land, Use suitable gridding and post the data on it
2. Draw a surface topographic map with stacked with the contour map.
3. Draw surface profile along line of [0.0, 3.0 and 9.0, 5.0]

Easting	Northing	Elevation
3.5	0	45
6	0	40
7	0	55
9	0	25
9	5	55
9	3	48
9	7	45
6.5	7	75
4.5	7	50
1	7	52
0	7	70
0	4.1	90
0	2.1	105
2.5	3.6	60
4.6	1.6	70
4.5	2.5	80
4.6	3.6	94
4.5	4.2	80
4.3	5.1	70
7.1	5	104
7	3.5	90
6.9	2.7	80
6.9	1.9	70
7	0.6	60
6.3	4.8	70
3	6	75
4	4.5	75
5	4.5	75
0.6	5	80
1.8	2	70

11. Earthquake

Using an Online Interactive Simulation

Students will learn how to read seismograms and plot earthquake locations and magnitudes. They participate by estimating measurements on screen and imputing data. From their measurements and estimations they will be able to see how earthquake locations and magnitudes are determined. If students make mistakes they are allowed to go back and try again. After completing the simulation a personalized "certificate of completion" can be printed out and kept in the students notebook or turned in for a grade as proof that they successfully completed the assignment.

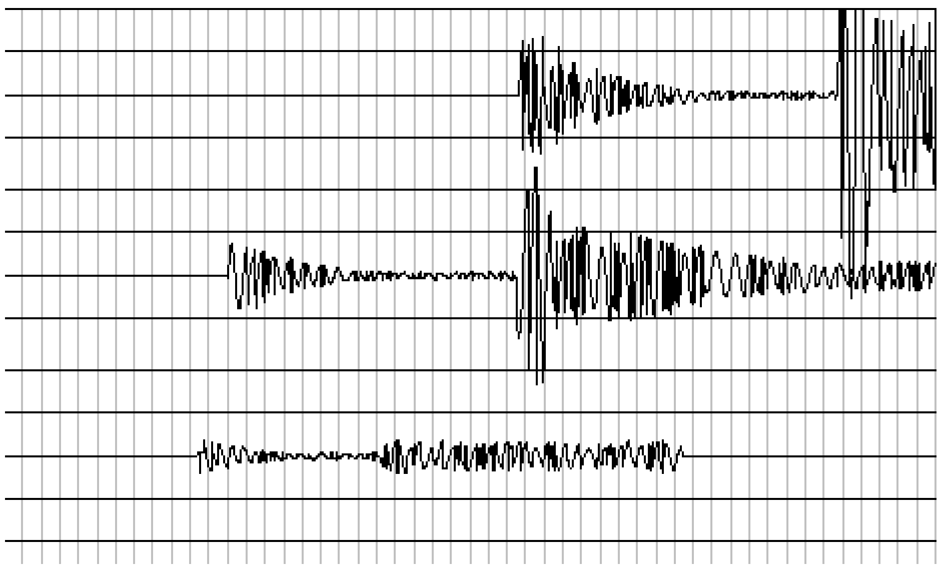
You are to locate the **epicentre** of an earthquake by making simple measurements on three seismograms

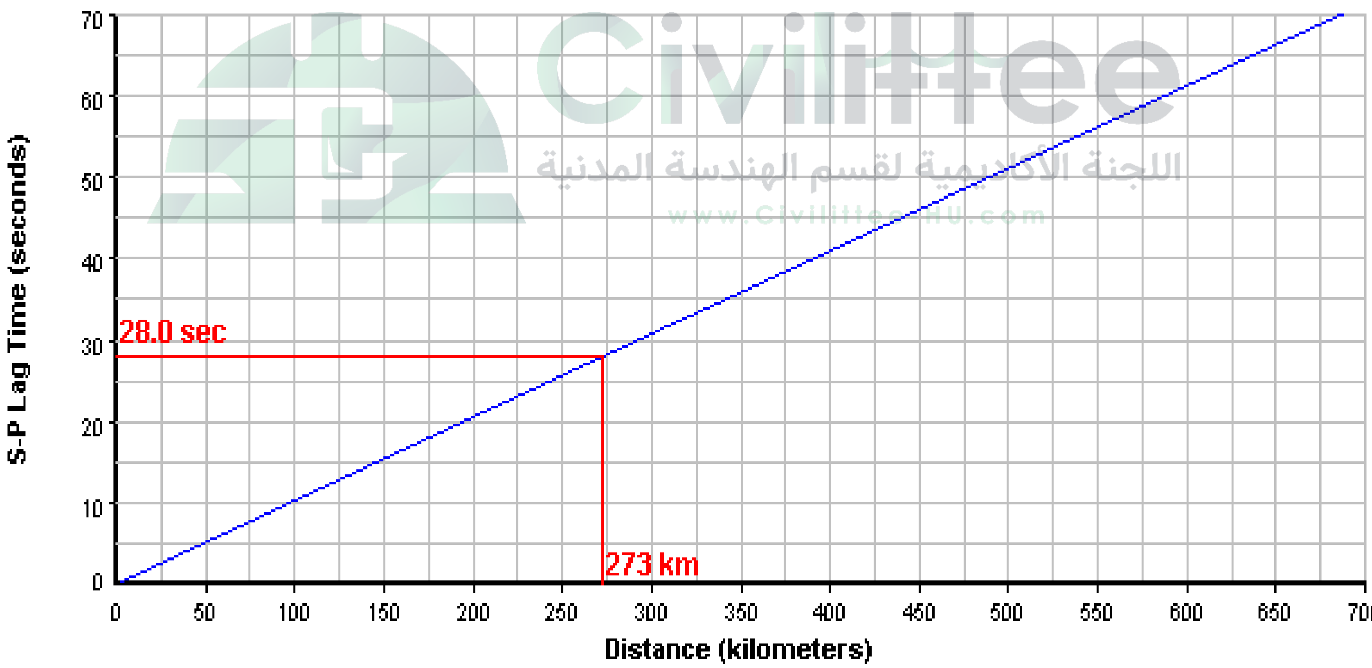
You will be required to determine the **Richter Magnitude** of that quake from the same recordings. **Richter Magnitude** is an estimate of the amount of energy released during and earthquake.

http://www.laep.org/target/technology/secondary/earthquakes/

http://www.sciencecourseware.org/eec/Earthquake/EpicenterMagnitude/

1. measure the S-P lag times for 3 stations
2. find the distances from the epicentre
3. measure the maximum S-wave amplitude
4. draw circles on the map to triangulate to the epicentre
5. locate the epicentre on the map
6. Estimate the latitude and longitude of your earthquake's epicentre
7. Estimate your earthquake's magnitude





S-P Lag Time (seconds)
70
60
50
40
30
20
10
0
28.0 sec
273 km
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
Distance (kilometers)

Richter's Nomogram