Experiment No.-1

OBJECT: To Study the physical properties of minerals.

Theory:

A **mineral** is a naturally occurring inorganic solid substance that is characterized with a definite chemical composition and very often with a definite atomic structure. **Mineralogy** is that branch of geology which deals with various aspects related to minerals such as their individual properties, their mode of formation and mode of occurrence.

Minerals can be described by various physical properties which relate to their chemical structure and composition. Common distinguishing characteristics include crystal structure and habit, hardness, lustre, diaphaneity, colour, streak, tenacity, cleavage, fracture, parting, and specific gravity. More specific tests for minerals include reaction to acid, magnetism, taste or smell, and radioactivity.

Minerals are classified by key chemical constituents; the two dominant systems are the Dana classification and the Strunz classification. The silicate class of minerals is subdivided into six subclasses by the degree of polymerization in the chemical structure. All silicate minerals have a base unit of a $[SiO_4]^{4-}$ silica tetrahedra—that is, a silicon cation coordinated by four oxygen anions, which gives the shape of a tetrahedron. These tetrahedra can be polymerized to give the subclasses: orthosilicates (no polymerization, thus single tetrahedra), disilicates (two tetrahedra bonded together), cyclosilicates (rings of tetrahedra), inosilicates (chains of tetrahedra), phyllosilicates (sheets of tetrahedra), and tectosilicates (three-dimensional network of tetrahedra). Other important mineral groups include the native elements, sulfides, oxides, halides, carbonates, sulfates, and phosphates.

Physical Properties of Minerals:

Minerals can be only identified absolutely by x-ray analysis and chemical tests. The x-ray analysis determines the structure of the mineral and the chemical tests determine the composition of the mineral. Structure and composition are the defining marks of a mineral.

Unfortunately for the average collector, these tests require expensive equipment, expert know-how and often destroy the specimen. Fortunately, both structure and composition affect certain physical properties. It is through the proper use of these properties that minerals can reliably be identified.

The best physical property is one that will give a unique result for a mineral and will always give the same result, again and again, for any and every specimen of that mineral. This is of course idealized. Mineralogists are usually happy to have a property that simply is consistent in providing the same result for every specimen of a certain mineral. Hopefully, this property also has a good range of possible results so that two similar minerals might stand a good chance of having different results. It would be nice if every mineral had their own special test that we could name after them such as the "Fluorite Test" for example. But they usually don't, so we must catalog all the results of several known physical property tests and hope that a collector can find enough positive (or diagnostically negative) results out of these to identify an unknown mineral.

Crystal Habit

In nature perfect crystals are rare. The faces that develop on a crystal depend on the space available for the crystals to grow. If crystals grow into one another or in a restricted environment, it is possible that no well-formed crystal faces will be developed. However, crystals sometimes develop certain forms more commonly than others, although the symmetry may not be readily apparent from these common forms. The term used to describe general shape of a crystal is ***habit.***

Some common crystal habits are as follows (discussed previously):

Individual Crystals

- *Cubic* - cube shapes
- *Octahedral* - shaped like octahedrons, as described above.
- *Tabular* - rectangular shapes.
- *Equant* - a term used to describe minerals that have all of their boundaries of approximately equal length.
- *Acicular* - long, slender crystals.
- *Prismatic* - abundance of prism faces.
- *Bladed* - like a wedge or knife blade.

Groups of Distinct Crystals

- *Dendritic* - tree-like growths.
- *Reticulated* - lattice-like groups of slender crystals.
- *Radiated* - radiating groups of crystals.
- *Fibrous* - elongated clusters of fibers.
- *Botryoidal* - smooth bulbous or globular shapes.
- *Globular* - radiating individual crystals that form spherical groups.

- *Drusy* - small crystals that cover a surface.
- *Stellated* - radiating individuals that form a star-like shape.

Some minerals characteristically show one or more of these habits, so habit can sometimes be a powerful diagnostic tool.

Cleavage, Parting, and Fracture

Cleavage

Crystals often contain planes of atoms along which the bonding between the atoms is weaker than along other planes. In such a case, if the mineral is struck with a hard object, it will tend to break along these planes. This property of breaking along specific planes is termed cleavage. Because cleavage occurs along planes in the crystal lattice, it can be described in the same manner that crystal forms are described. For example if a mineral has cleavage along {100} it will break easily along planes parallel to the (100) crystal face, and any other planes that are related to it by symmetry. Thus, if the mineral belongs to the tetragonal crystal system it should also cleave along faces parallel to (010), because (100) and (010) are symmetrically related by the 4-fold rotation axis. The mineral will be said to have two directions of cleavage. [Note that in the tetragonal system, the form {100} has four faces: (100), $(\bar{1}00)$, (010), and $(0\bar{1}0)$. But if we are referring to cleavage directions, the mineral only has two, because the cleavage planes $(0\bar{1}0)$ and $(\bar{1}00)$ are parallel to, and thus in the same direction as (010) and (100).]

The cleavage can also be described in terms of its quality, i.e., if it cleaves along perfect planes it is said to be perfect, and if it cleaves along poorly defined planes it is said to be poor.

Note: *Please do not attempt to cleave the minerals in the laboratory. Many of the specimens you examine cannot be readily replaced. Cleavage is usually induced in the mineral when it is extracted from the rock when it is found, and can usually be seen as planes running through the mineral. Therefore, you do not have to break the mineral in order to see its cleavage.*

Cleavage can also be described by general forms names, for example if the mineral breaks into rectangular shaped pieces it is said to have cubic cleavage (3 cleavage directions), if it breaks into prismatic shapes, it is said to have prismatic cleavage (2 cleavage directions), or if it breaks along basal pinacoids(1 cleavage direction) it is said to have pinacoidal cleavage. For examples, see figure2.12 on page 29 of your text.

Parting

Parting is also a plane of weakness in the crystal structure, but it is along planes that are weakened by some applied force. It therefore may not be apparent in all specimens of the same mineral, but may appear if the mineral has been subjected to the right stress conditions.

Fracture

If the mineral contains no planes of weakness, it will break along random directions called fracture. Several different kinds of fracture patterns are observed.

- Conchoidal fracture - breaks along smooth curved surfaces.
- Fibrous and splintery - similar to the way wood breaks.
- Hackly - jagged fractures with sharp edges.
- Uneven or Irregular - rough irregular surfaces.

Hardness

Hardness is determined by scratching the mineral with a mineral or substance of known hardness. Hardness is a relative scale, thus to determine a mineral's hardness, you must determine that a substance with a hardness greater than the mineral does indeed scratch the unknown mineral, and that the unknown mineral scratches a known mineral of lesser hardness.

Hardness is determined on the basis of Moh's relative scale of hardness exhibited by some common minerals. These minerals are listed below, along with the hardness of some common objects.

Hardness	Mineral	Common Objects
1	Talc	
2	Gypsum	Fingernail (2+)
3	Calcite	Copper Penny (3+)
4	Fluorite	
5	Apatite	Steel knife blade (5+), Window glass (5.5)
6	Orthoclase	Steel file
7	Quartz	
8	Topaz	
9	Corundum	
10	Diamond	

Several precautions are necessary for performing the hardness test.

- If you attempt to scratch a soft mineral on the surface of a harder mineral some of the softer substance may leave a mark of fine powder on the harder mineral. This should not be mistaken for a scratch on the harder mineral. A powder will easily rub off, but a scratch will occur as a permanent indentation on the scratched mineral.

- Some minerals have surfaces that are altered to a different substance that may be softer than the original mineral. A scratch in this softer alteration product will not reflect the true hardness of the mineral. Always use a fresh surface to perform the hardness test.
- Sometimes the habit of the mineral will make a difference. For example aggregates of minerals may break apart leaving the impression that the mineral is soft. Or, minerals that show fibrous or splintery habit may break easily into fibers or splinters. It is therefore wise to always perform the hardness test in reverse. If one mineral appears to scratch another mineral, make sure that the other mineral does not scratch the apparently harder mineral before you declare which of the minerals is harder.
- In some minerals hardness is very dependant on direction, since hardness is a vectorial property. When there is significant difference in hardness in different directions, it can be a very diagnostic property of the mineral. It is thus wise to perform the hardness test by attempting to scratch the mineral in different directions. Two minerals of note have differences in hardness depending on direction:
    - Kyanite has a hardness of 5 parallel to the length of the crystal, and a hardness of 7 when scratched along a direction perpendicular to the length.
    - Calcite has a hardness of 3 for all surfaces except the {0001} plane. On {0001} it has a hardness of 2.

Tenacity

Tenacity is the resistance of a mineral to breaking, crushing, or bending. Tenacity can be described by the following terms.

- *Brittle* - Breaks or powders easily.
- *Malleable* - can be hammered into thin sheets.
- *Sectile* - can be cut into thin shavings with a knife.
- *Ductile* - bends easily and does not return to its original shape.
- *Flexible* - bends somewhat and does not return to its original shape.

- *Elastic* - bends but does return to its original shape.

Density (Specific Gravity)

Density refers to the mass per unit volume. Specific Gravity is the relative density, (weight of substance divided by the weight of an equal volume of water). In cgs units density is grams per cm^3, and since water has a density of 1 g/cm^3, specific gravity would have the same numerical value has density, but no units (units would cancel). Specific gravity is often a very diagnostic property for those minerals that have high specific gravities. In general, if a mineral has higher atomic number cations it has a higher specific gravity. For example, in the carbonate minerals the following is observed:

Mineral	Composition	Atomic # of Cation	Specific Gravity
Aragonite	$CaCO_3$	40.08	2.94
Strontianite	$SrCO_3$	87.82	3.78
Witherite	$BaCO_3$	137.34	4.31
Cerussite	$PbCO_3$	207.19	6.58

Specific gravity can usually be qualitatively measured by the heft of a mineral, in other words those with high specific gravities usually feel heavier. Most common silicate minerals have a specific gravity between about 2.5 and 3.0. These would feel light compared to minerals with high specific gravities.

For comparison, examine the following table:

Mineral	Composition	Specific Gravity
Graphite	C	2.23
Quartz	SiO_2	2.65
Feldspars	$(K,Na)AlSi_3O_8$	2.6 - 2.75
Fluorite	CaF_2	3.18
Topaz	$Al_2SiO_4(F,OH)_2$	3.53
Corundum	Al_2O_3	4.02
Barite	$BaSO_4$	4.45
Pyrite	FeS_2	5.02

Galena	PbS	7.5
Cinnabar	HgS	8.1
Copper	Cu	8.9
Silver	Ag	10.5

Color

Color is sometimes an extremely diagnostic property of a mineral, for example olivine and epidote are almost always green in color. But, for some minerals it is not at all diagnostic because minerals can take on a variety of colors. These minerals are said to be allochromatic. For example quartz can be clear, white, black, pink, blue, or purple. Read in your textbook, pp. 234-241, about what causes minerals to have color.

Streak

Streak is the color produced by a fine powder of the mineral when scratched on a streak plate. Often it is different than the color of the mineral in non- powdered form

Luster

Luster refers to the general appearance of a mineral surface to reflected light. Two general types of luster are designated as follows:

1. ***Metallic*** - looks shiny like a metal. Usually opaque and gives black or dark colored streak.

2. ***Non-metallic*** - Non metallic lusters are referred to as

    a. ***vitreous*** - looks glassy - examples: clear quartz, tourmaline

    b. ***resinous*** - looks resinous - examples: sphalerite, sulfur.

    c. **pearly** - iridescent pearl-like - example: apophyllite.

    d. ***greasy*** - appears to be covered with a thin layer of oil - example: nepheline.

    e. ***silky*** - looks fibrous. - examples - some gypsum, serpentine, malachite.

    f. ***adamantine*** - brilliant luster like diamond.

Play of Colors

Interference of light reflected from the surface or from within a mineral may cause the color of the mineral to change as the angle of incident light changes. This sometimes gives the mineral an iridescent quality. Minerals that show this include: bornite (Cu_5FeS_4) , hematite (Fe_2O_3), sphalerite (ZnS), and some specimens of labradorite (plagioclase).

Fluorescence and Phosphorescence

Minerals that light up when exposed to ultraviolet light, x-rays, or cathode rays are called fluorescent. If the emission of light continues after the light is cut off, they are said to be phosphorescent.

Some specimens of the same mineral show fluorescence while other don't. For example some crystals of fluorite (CaF_2) show fluorescence and others do not. Other minerals show fluorescence frequently, but not always. These include - scheelite ($CaWO_4$), willemite (Zn_2SiO_4), calcite ($CaCO_3$), scapolite ($3NaAlSi_3O8 \cdot (NaCl - CaCO_3)$), and diamond (C).

Magnetism

Magnetic minerals result from properties that are specific to a number of elements. Minerals that do not have these elements, and thus have no magnetism are called ***diamagnetic***. Examples of diamagnetic minerals are quartz, plagioclase, calcite, and apatite. Elements like Ti, Cr, V, Mn, Fe, Co, Ni, and Cu can sometimes result in magnetism. Minerals that contain these elements may be weakly magnetic and can be separated from each other by their various degrees of magnetic susceptibility. These are called ***paramagnetic*** minerals. Paramagnetic minerals only show magnetic properties when subjected to an external magnetic field. When the magnetic field is removed, the minerals have no magnetism.

Ferromagnetic minerals have permanent magnetism if the temperature is below the ***Curie Temperature***. These materials will become magnetized when placed in a magnetic field, and will remain magnetic after the external field is removed. Examples of such minerals are magnetite, hematite-ilmenite solid solutions (Fe_2O_3 - $FeTiO_3$), and pyrrhotite ($Fe_{1-x}S$).

Experiment No.-2

OBJECT: To Study various rock forming minerals.

THEORY: Minerals are the fundamental components of rocks. They are naturally occurring inorganic substances with a specific chemical composition and an orderly repeating atomic structure that defines a crystal structure.

Silicate minerals are the most abundant components of rocks on the Earth's surface, making up over 90% by mass of the Earth's crust. The fundamental chemical building block of silicate minerals is the chemical compound silicon tetroxide, SiO_4 (Figure 1).

The common non-silicate minerals, which constitute less than 10% of the Earth's crust, include carbonates, oxides, sulphides, phosphates and salts. A few elements may occur in pure form. These include gold, silver, copper, bismuth, arsenic, lead, tellurium and carbon.

Although 92 naturally occurring elements exist in nature, only eight of these are common in the rocks of the Earth's crust. Together, these eight elements make up more than 98% of the crust (Table 1).

Oxygen (O)	46.6%
Silicon (Si)	27.7%
Aluminium (Al)	8.1%
Iron (Fe)	5.0%
Calcium (Ca)	3.6%
Sodium (Na)	2.8%
Potassium (K)	2.6%
Magnesium (Mg)	2.1%

Table 1. The eight most common elements in the Earth's crust (by mass).

Quartz

- Quartz (Figure 2), which is usually called silica, is one of the most common minerals in the Earth's crust.
- Quartz is made up of silicon dioxide (SiO_2)
- Quartz crystals are usually hexagonal and prismatic in shape.
- Pure quartz is colourless, although the presence of impurities may give a range of colours, such as violet, pink and orange.
- Quartz is the raw material for making glass.

Figure 2: Quartz.

Plagioclase feldspar

- Plagioclase feldspar (Figure 3) is a sodium- or calcium-rich feldspar. The chemical composition ranges from sodium aluminium silicate, $NaAlSi_3O_8$to calcium aluminium silicate, $CaAl_2Si_2O_8$.
- Plagioclase feldspar crystals usually occur as stubby prisms.
- Plagioclase feldspar is generally white to grey and has a vitreous lustre.
- Plagioclase feldspar is an important industrial mineral used in ceramics.

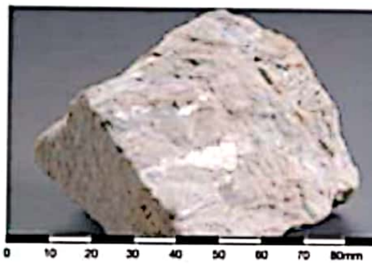


Figure 3: Plagioclase feldspar

Alkali Feldspar

- Alkali feldspar (Figure 4) is another member of the family of feldspar minerals.
- Alkali feldspar (Potassium aluminium silicate $(K,Na)AlSi_3O_8$) are rich in alkali metal ions.
- Alkali feldspar crystals usually occur as stubby prisms.
- Alkali feldspar is commonly pink to white.
- Alkali feldspar is used as raw material to make porcelain.

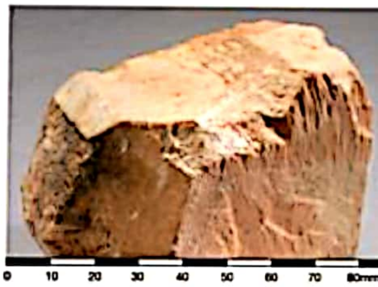


Figure 4: Alkali feldspar.

Micas

- Micas are a family of silicate minerals.
- Micas are made up of varying amounts of potassium, magnesium, iron, as well as aluminium, silicon and water.
- Micas form flat, book-like crystals that split into individual sheets, separating into smooth flakes along the cleavage planes.
- They are common minerals in intrusive igneous rocks, and can also be found in sedimentary and metamorphic rocks.
- Biotite (Figure 5) is a dark, black or brown mica; muscovite (Figure 6) is a light-coloured or clear mica.

Figure 5: Biotite.

Amphiboles

- Amphiboles are a family of silicate minerals.
- Amphibole minerals generally contain iron, magnesium, calcium and aluminium as well as silicon, oxygen, and water.
- Amphiboles form prismatic or needle-like crystals.
- Amphibole is a component of many igneous and metamorphic rocks.
- Hornblende (Figure 7) is a common member of the amphibole group of rock-forming minerals.

Figure 7: Hornblende.

Pyroxene

- Pyroxenes (Figure 8) are a family of silicate minerals.
- Pyroxene minerals generally contain magnesium, iron, calcium and aluminium as well as silicon and oxygen.
- Pyroxenes form short or columnar prismatic crystals.
- Pyroxene is a component in many igneous and metamorphic rocks.
- Pyroxene crystals are commonly faceted as gemstones. For instance, precious jade (jadeite) is a pyroxene.

Figure 8: Pyroxene.

Olivine

- Olivine (Figure 9) is a silicate mineral.
- Olivine ($(Mg,Fe)_2SiO_4$) contains iron and magnesium.
- Olivine is a green, glassy mineral.
- Olivine is common in mafic and ultramafic rocks, but has not been found in Hong Kong.
- Clear and transparent olivine crystals are commonly faceted as gemstones.

Figure 9: Olivine.

Calcite

- Calcite (Figure 10) is a carbonate mineral.
- Calcite is made up of calcium carbonate ($CaCO_3$).
- Calcite is generally white to clear, and is easily scratched with knife.
- Calcite is a common sedimentary mineral that is the major component of calcareous sedimentary rocks such as limestone. Metamorphism of limestone produces marble.

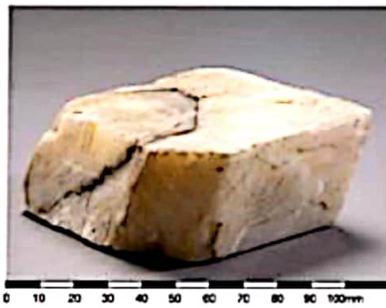


Figure 10: Calcite.

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

Experiment No.-3

OBJECT: To Study the measurement procedure of dip and strike of formation using Brunton compass.

Theory: A **Brunton compass**, properly known as the **Brunton Pocket Transit**, is a type of precision compass made by Brunton, Inc. of Riverton,Wyoming. The instrument was patented in 1894 by a Canadian-born Colorado geologist named David W. Brunton. Unlike most modern compasses, the Brunton Pocket Transit utilizes magnetic induction damping rather than fluid to damp needle oscillation. Although Brunton Inc. makes many other types of magnetic compasses, the Brunton Pocket Transit is a specialized instrument used widely by those needing to make accurate degree and angle measurements in the field. These people are primarily geologists, but archaeologists, environmental engineers, and surveyors also make use of the Brunton's capabilities. The United States Army has adopted the Pocket Transit as the M2 Compass for use by crew-served artillery.

The Pocket Transit may be adjusted for declination angle according to one's location on the Earth. It is used to get directional degree measurements (azimuth) through use of the Earth's magnetic field. Holding the compass at waist-height, the user looks down into the mirror and lines up the target, needle, and guide line that is on the mirror. Once all three are lined up and the compass is level, the reading for that azimuth can be made. Arguably the most frequent use for the Brunton in the field is the calculation of the strike and dip ofgeological features (faults, contacts, foliation, sedimentary strata, etc.). If next to the feature, the strike is measured by leveling (with thebull's eye level) the compass along the plane being measured. Dip is taken by laying the side of the compass perpendicular to the strike measurement and rotating horizontal level until the bubble is stable and the reading has been made. If properly used and if field conditions allow, additional features of the compass allow users to measure such geological attributes from a distance.

As with most traditional compasses, directional measurements are made in reference to the Earth's magnetic field and will thus run into difficulties if in a region of locally abnormal magnetism. For example, if the user is near an outcrop that contains magnetite or some other iron-bearing material, compass readings can be affected anywhere from several inches from the outcrop to tens of yards away (depending on the strength of the magnetic field). Since they are measured only using a rotating level, dip measurements are unaffected by magnetic fields.

There are numerous other compasses used by geologists, for example a Breithaupt compass. This is commonly used by structural geologists because it readily allows accurate measurement of the orientation of planes (foliations) and of lines on those planes (lineations). With the advent of portable electronic devices such as the iPhone, a new generation of compasses has emerged, some again of specific interest to geologists The *listerCompass* (designed by structural geologist Professor Gordon Lister) allows a single measurement that simultaneously records strike, dip, as well as the rake of a lineation on a foliation plane. Alternatively with the focus on lineations, an option that allows measurement of yaw, pitch, and roll (the same as involved in the motion of an aircraft) may achieve the same objective. Unlike analogue compasses, a digital compass relies on an accelerometer and a teslameter, and may provide much information as to the reliability of a measurement (e.g. by repeating the same measurement and performing statistical analysis).

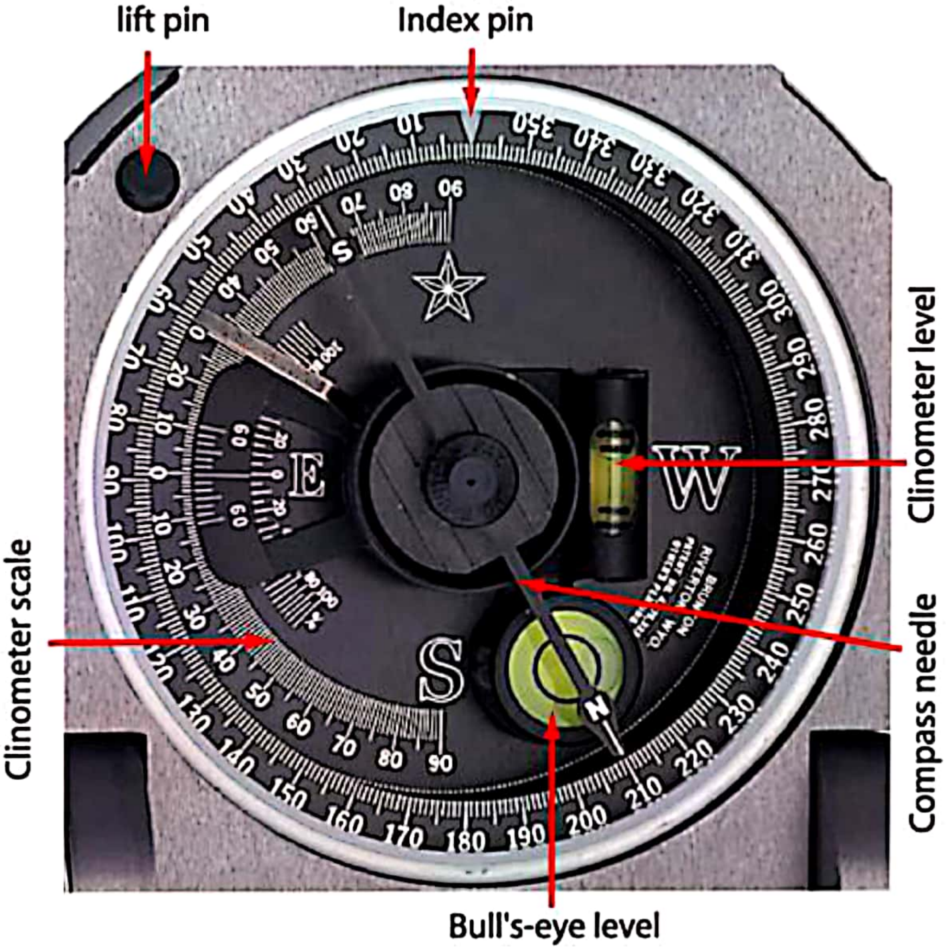


Fig: Parts of Brunton Compass

Procedure:

1. Measurement of strike:

We will begin by taking the strike of a bedding plane. For these measurements we will use a Brunton compass like the one you see in the pictures above. In order to measure the strike, place the side or edge of the compass against the plane of the outcrop. Sometimes it is easier to put your field book against the outcrop and then the compass against the book to get a smoother and/or a larger surface. Now, rotate the compass keeping the lower side edge of the compass fixed, until the bulls-eye level bubble is centered (the round tube; not the long narrow one). When the bubble is centered, the compass is horizontal against the plane and parallel to the line of strike. Now, with the bulls-eye bubble centered, record the number that either end of the compass needle is showing.

In other words:

1. Place the bottom EDGE of the compass flat against the plane of interest.
2. Adjust the compass orientation, making sure the bottom edge is always flat against the plane, until the air bubble in the "Bull's eye level" is centered.
3. Read either end of the compass needle to obtain the value of strike.

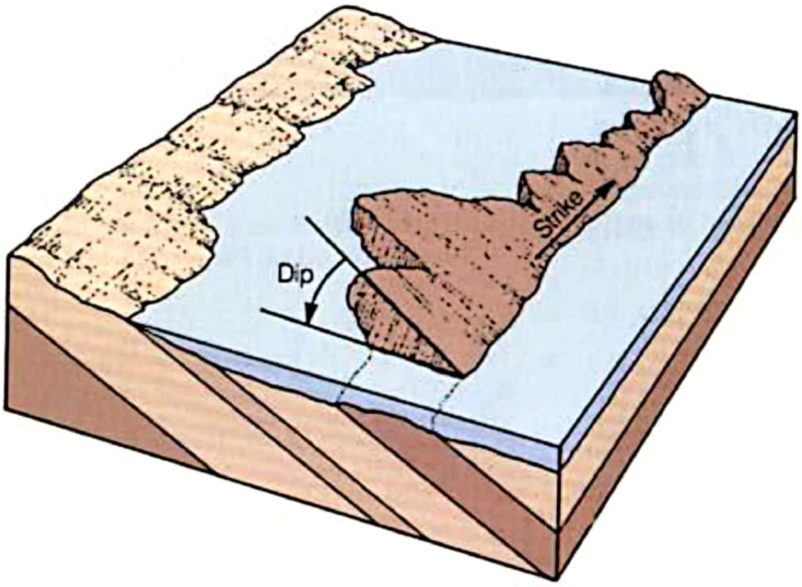


Fig: Dip & Strike

2. Measurement of Dip:

To measure the dip of the bedding plane, take your compass and put its side against the rock so that it points in the same direction as the line of dip (The dip line is perpendicular to the strike line). Move the clinometer until the clinometer level bubble is centered. As we did when we found the strike, record where the white tipped end of the clinometer needle is pointing. Note the degrees and the direction. Recall that the dip direction MUST always be perpendicular to the strike direction (e.g., a strike of 40° could only dip to the SE or NW, never NE or SW)

In other words:

1. AFTER you determine strike, rotate the compass 90°.
2. Place the SIDE of the compass flat against the plane.
3. Adjust the lever on the back of the compass until the air bubble in the "Clinometer level" is centered.
4. Read the dip directly from the scale in the compass.

Experiment No.-4

OBJECT: To Study the measurement procedure of dip and strike of formation using Clinometer compass.

THEORY:

An inclinometer or clinometer is an instrument for measuring angles of slope (or tilt), elevation or depression of an object with respect to gravity. It is also known as a tilt meter, tilt indicator, slope alert, slope gauge, gradient meter, gradiometer, level gauge, level meter, declinometer, and pitch & roll indicator. Clinometers measure both inclines (positive slopes, as seen by an observer looking upwards) and declines (negative slopes, as seen by an observer looking downward) using three different units of measure: degrees, percent, and topo. Astrolabes are inclinometers that were used for navigation and locating astronomical objects from ancient times to the Renaissance.

Procedure of measuring dip and strike

1. Set the clinometer so that 90 and 270 on the dial are lined up with the markers on the clinometer and the inner scale reads 0 when the instrument is horizontal.
2. Place the clinometer on the bedding plane and move it around until a reading of 0 is obtained.
3. Draw a soft pencil line on the bedding plane to mark where the base of the clinometer rests on the rock. Since this line is horizontal, it will show the direction of strike.
4. Draw another line on the rock so that it is at right angles to the direction of strike and points directly down the sloping bedding plane. This line marks the direction of dip.
5. Using the clinometer, measure the angle of dip by placing the clinometer along the line which shows the direction of dip.
6. Using a compass measure the direction of strike and the direction of dip, as shown by the lines drawn on the rock.
7. Record the Grid Reference of the location, the strike direction in degrees and the dip direction in degrees.

Experiment No.-5

OBJECT: To Study the various geological cross-sections.

Theory:

Geological Cross-sections- A geological cross-section is a graphic representation of the intersection of the geological bodies in the subsurface with a vertical plane of a certain orientation. It is a section of the terrain where the different types of rocks, their constitution and internal structure and the geometric relationship between them are represented. It is an approximate model of the real distribution of the rocks in depth, consistent with the information available on the surface and the subsurface. It can also represent the extension of the materials of the structures that have been eroded above the topographic surface.

The cross-sections are an indispensable complement of the geological maps; maps and cross-sections are fruit of the interpretation of the arrangement of the rocks using diverse types of data, normally incomplete and with different degrees of uncertainty. Both are bi-dimensional representations of the geological reality and jointly allow us to understand the tri-dimensional structure of the rocky volumes and, in consequence, the geological history of a zone.

The geological cross-sections have a very relevant economic and social importance. They are the basis for planning engineering works, fundamentally the lineal works that affect the surface and the subsurface (roads, tunnels, utilities) and for the exploration and production of geological resources: water, stones, minerals and energy.

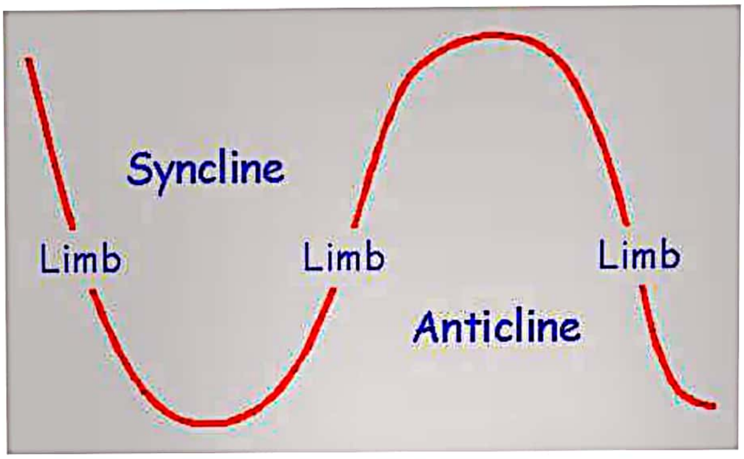
The various geological cross-sections are as follows-

1. Folds
2. Faults
3. Joints
4. Unconformities

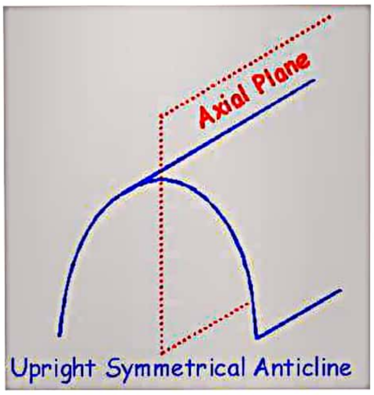
Folds:

There are two principle mechanisms by which rocks deform: plastically to form folds, and brittly to form faults. When exposed to compressional stress, rock can either fold or fault. However, rocks lack the ability to experience significant plastic deformation under conditions of tensional or transform stress. As such, folds are nearly always the products of compressional force. When applied to sedimentary rocks, compression results in the formation of sets of folds that are oriented perpendicular to the stress direction.

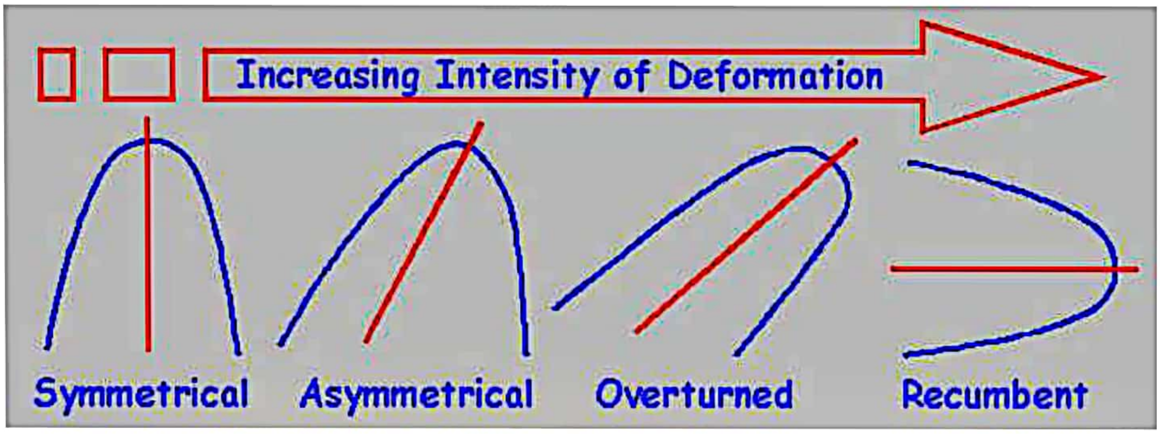
When viewed in cross-section, folds can be recognized as either concave up or concave down. The concave up (or U-shaped) folds are termed synclines while the concave down (or A-shaped) folds are known as anticlines. Commonly, these two fold types occur as linked structures. Each fold consists of two sides, or limbs, that are separated by an imaginary axial plane that divides the fold.



Fold geometries are categorized by the angular relationships between the fold limbs, the axial plane, and an imaginary horizontal plane. Symmetrical folds are recognized by the angular symmetry of the limbs on either side of the axial plane. A special case is the upright symmetrical fold, wherein the axial plane is vertical and the dip angles of beds in both limbs are equal. Conversely, the limbs of asymmetrical folds have dip angles that are unequal. Thus, an asymmetrical fold has a steeply dipping limb and a shallowly dipping limb. Importantly, asymmetrical folds are also characterized by a dipping axial plane wherein the axial plane dips in the same direction as the shallowly dipping limb of the fold.



As the dip angle of the axial plane decreases, the steeply dipping limb reaches a vertical orientation. Continued deformation past this point produces an overturned fold. Structures of this type are recognized by the "turned-over" nature of the steeply dipping limb. In this case, both limbs and the axial plane dip in the same direction. If deformation is sufficiently intense, the axial plane of the fold will be pushed over to a horizontal position. In this extreme situation, both limbs of the fold and the axial plane are parallel. These very tightly folded structures are common in intensely deformed mountain ranges such as the Alps and are known as recumbent.

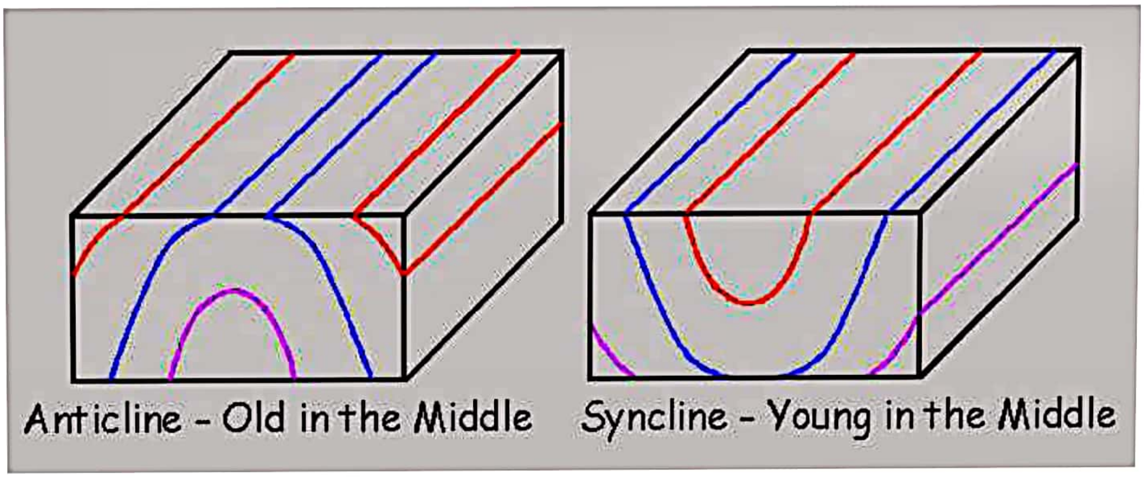


Plunging Folds

So far, folds have been described in terms of their two-dimensional cross-sections. However, many folds are more complex. In order to understand such three-dimensional complexity consider the case of a simple, upright, symmetrical anticline. The axial plane intersects the fold along a line at the top of the structure. This line of intersection is known as the trace of the axial plane because the line can be "traced" or "drawn" on the folded bed. On a simple upright fold, the trace of the axial plane is a horizontal line. However, in many folds this line is inclined to the horizontal. When this occurs the entire fold is tilted in a direction that is perpendicular to the dip direction of the limbs – it is a plunging fold. To more completely visualize this three-dimensional geometry take a sheet of paper and draw a line length-wise down its center. Fold the paper so that a symmetrical upright anticline is formed with the line at the top of the fold. Orient the paper so the trace of the axial plane is pointing towards you. Now, tilt the paper so the fold plunges towards you. Reverse the plunge direction so the fold is tilted away.

Age Relations

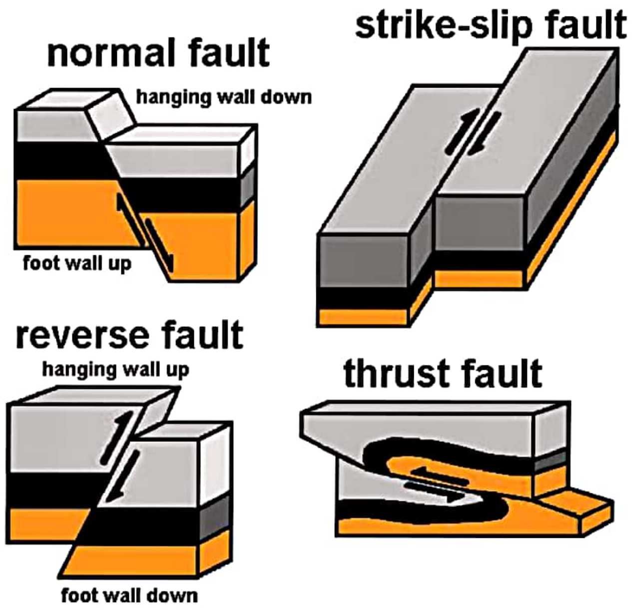
Prior to deformation, sedimentary rocks exist as horizontal beds, the oldest of which are on the bottom (first formed) and the youngest of which are on top (last formed). When folded, this simple sequential age relationship produces patterns on the eroded landscape. The presence of these patterns allows for rapid determination of the geometry of folding. Anticlines are characterized by the presence of the oldest rocks in the center of their structure while synclines have their youngest beds in the central position. When folds are plunging the rocks of different ages exhibit curving patters but retain the basic age relationships of synclines and anticlines. In order to fully grasp the relationship between fold geometry and age, draw a few examples in cross-section and map-view.



Fold:

The folding of rock most commonly occurs under conditions of compressional stress. However, the brittle failure of rocks to produce faults occurs in a wide-range of complex ways. Generally, faults occur under conditions of low lithostatic pressure in the upper regions of the crust. Additionally, faults are associated with all three forms of force: compression, tension, and transform stress. In each case, a specific geometry of faulting is associated with each stress type.

Technically, a fault is a break in rock along which some movement, or displacement, has occurred; breaks in rock that do not have any measurable displacement are known as fractures or joints. Faults are classified by the nature of the displacement. That is, by how one side of the fault moved relative to the other. The reason movement occurs along faults is because such motion is the mechanism by which stress is transformed into strain during brittle deformation. There are two general types of motion on faults: dip-slip and strike-slip. A fault plane can be thought of in the same way as any other plane in space – such as a bed of sedimentary rock – it has a dip angle and a strike angle that are measured in the same way as they are for sedimentary beds. However, in this case, the significance of these angles is that they can be used to describe displacement along the fault. In the case of dip-slip movement, one side of the fault moves up or down along the dip of the fault plane. Conversely, in strike-slip motion, one side of the fault moves laterally past the other along the fault's surface. Dip-slip displacement occurs during the application of compressional and tensional stresses while strike-slip motion occurs by transform stress.



Dip-slip Faults

Description of dip-slip motion begins with an understanding of the two sides of a fault plane. Consider a fault that is dipping at a uniform angle to the right. The right hand side of the fault is not only to the right of the fault plane, it is also everywhere above the fault. The left hand side is likewise everywhere under the fault plane. Importantly, the upper and lower sides of the fault plane are defined independently of the right or left hand sides. The side of the fault that is above the fault plane is always known as the hanging wall of the fault while the underside of the fault is known as the foot wall. These names were derived from early miners who tunneled along the fault surface in search of mineral deposits.

Within the general class of dip-slip faults, there are two important divisions. In those faults that are formed by tensional stresses there must be a net lengthening of the total area being deformed. That is, tension tries to stretch rocks. When that stress is taken up by brittle deformation the hanging wall (upper side) of the fault moves downward along the fault plane. This form of displacement – hanging wall down – produces a dip-slip fault known as a normal fault.

The second form of dip-slip fault is produced by compressional deformation. In this case, the compressional forces act to shorten the rocks. This is accomplished by motion of the hanging wall upward along the dip of the fault. Thus, hanging wall up motion is driven by compressional force and the resultant structure is termed a reverse fault.

A special case of reverse faults occurs when thick sequences of sedimentary rocks are put under compressional stress. In these cases the reverse faulting occurs in a series of steeply dipping ramps and bedding parallel flats to produce a thrust fault. The significance of this style of faulting is that a great deal of compressional displacement can be accomplished and, as such, thrust faulting provides an important style of deformation in compressional settings.

Strike-slip Faults

The second major class of faults are those that experience strike-slip motion. Transform forces produce a sheering stress in rock. Importantly, however, rocks are very weak in sheering and tend to only deform brittly. When rocks break due to transform stress, the dip angle of the fault plane is less important than the strike angle. The sense of motion along the fault is in the direction of the strike of the fault plane. That is, one side of the fault slips past the other. Importantly, the graphical description of motion along a strike-slip fault is done by map-view illustrations rather than cross-sections.

Strike-slip faults are broken into two different geometries based upon the sense of sheer that occurs along the fault. In this case the sides of the fault plane are not given special names. However, the direction of motion does define the specific type of strike-slip fault. Imagine looking down on a strike-slip fault, the trace of the fault is trending north-south. Thus, there is an eastern side of the fault and a western side of the fault. There are two possible types of strike-slip motion possible. The eastern side of the fault can either move north or south relative to the western side. These two forms of motion are named based upon a simple convention. Imagine standing astride the trace of the fault, looking north, with your right foot on the eastern block and your left on the western block. If the eastern block moves south, past you, that sense of sheer is termed right lateral (imagine your right hand sliding back past you as it follows the moving block). Conversely, if the western block moves south relative to the eastern block, this geometry is termed a left lateral motion. Importantly, the sense of motion is independent of east and west or north and south. A left lateral fault is left lateral no matter what orientation it is observed from. The same is true of right lateral motion.

Joints:

A **joint** is a break (fracture) of natural origin in the continuity of either a layer or body of rock that lacks any visible or measurable movement parallel to the surface (plane) of the fracture. Although they can occur singly, they most frequently occur as joint sets and systems. A **joint set** is family of parallel, evenly spaced joints that can be identified through mapping and analysis of the orientations, spacing, and physical properties. A **joint system** consists of two or more interlocking joint sets. The distinction between joints and faults hinges on the terms *visible* or *measurable* which depends on the scale of observation. Faults differ from joints in that they exhibit visible or measurable lateral movement between the opposite surfaces of the fracture. As a result, a joint may have been created by either strict movement of a rock layer or body perpendicular to the fracture or by varying degrees of lateral displacement parallel to the surface (plane) of the fracture that remains “invisible” at the scale of observation.[1][2][3]

Joints are among the most universal geologic structures as they are found in most every exposure of rock. They vary greatly in appearance, dimensions, and arrangement, and occur in quite different tectonic environments. Often, the specific origin of the stresses that created certain joints and associated joint sets can be quite ambiguous, unclear, and sometimes controversial. The most prominent joints occur in the most well-consolidated, lithified, and highly competent rocks, such as sandstone, limestone, quartzite, and granite. Joints may be open fractures or filled by various materials. Joints, which are infilled by precipitated minerals are called veins and joints filled by solidified magma are called dikes.

Types of joints

Joints are classified either by the processes responsible for their formation or their geometry.

Classification of joints by geometry

The geometry of joints refers to the orientation of joints as either plotted on stereonets and rose-diagrams or observed in rock exposures. In terms of geometry, three major types of joints, nonsystematic joints, systematic joints, and columnar jointing are recognized.[2][4]

Nonsystematic joints are joints that are so irregular in form, spacing, and orientation. They are so irregular, they cannot be readily grouped into distinctive, through-going joint sets.[2][4]

Systematic joints are planar, parallel, joints that can be traced for some distance, and occur at regularly, evenly spaced distances on the order centimeters, meters, tens of meters, or even hundreds of meters. As a result, they occur as families of joints that form recognizable joint sets. Typically, exposures or ourcrops within a given area or region of study contains two or more sets of systematic joints, each with its own distinctive properties such as orientation and spacing, that intersect to form well-defined joint systems.

Based upon the angle at which joint sets of systematic joints intersect to form a joint system, systematic joints can be subdivided into conjugate and orthogonal joint sets. The angles at which joint sets within a joint system commonly intersect is called by structural geologists as the *dihedral angles.*When the dihedral angles are nearly 90° within a joint system, the joint sets are known as *orthogonal joint sets*. When the dihedral angles are from 30 to 60° within a joint system, the joint sets are known as *conjugate joint sets*.

Within regions that have experienced tectonic deformation, systematic joints are typically associated with either layered or bedded strata that has beenfolded into anticlines and synclines. Such joints can be classified according to their orientation in respect to the axial planes of the folds as they often commonly form in a predictable pattern with respect to the hinge trends of folded strata. Based upon their orientation to the axial planes and axes of folds, the types of systematic joints are:

- *Longitudinal joints* – Joints which are roughly parallel to fold axes and often fan around the fold.

- *Cross-joints* – Joints which are approximately perpendicular to fold axes.
- *Diagonal joints* – Joints which typically occur as conjugate joint sets that trend oblique to the fold axes.
- *Strike joints* – Joints which trend parallel to the strike of the axial plane of a fold.
- *Cross-strike joints* – Joints which cut across the axial plane of a fold.[2][4]

Columnar jointing is a distinctive type of joints that join together at triple junctions either at or about 120° angles. These joints split a rock body into long, prisms or columns. Typically, such columns are hexangonal, although 3-, 4-, 5- and 7-sided columns are relatively common. The diameter of these prismatic columns range from a few centimeters to several metres.

Types of joints with respect to formation[edit]

Joints can also be classified according to their origin. On the basis of their origin, joints have been divided into a number of different types that include tectonic, hydraulic, exfoliation, unloading (release), and cooling joints depending on the specific author and publication. Also, the origin of many joint sets often can be unclear and quite ambiguous. Often, different authors have proposed multiple and contradictory hypotheses for specific joint sets and types. Finally, it should be kept in mind that different joints in the same outcrop may have formed at different times and for different reasons.

Tectonic joints are joints that formed by the relative displacement of the joint walls is normal to its plane as the result of brittle deformation of bedrock in response to regional or local tectonic deformation of bedrock. Such joints form when directed tectonic stress causes the tensile strength of bedrock to be exceeded as the result of the stretching of rock layers under conditions of elevated pore fluid pressure and directed tectonic stress. Tectonic joints often reflect local tectonic stresses associated with local folding and faulting. Tectonic joints occur as both nonsystematic and systematic joints, including orthogonal and conjugate joint sets.

Hydraulic joints are joints thought to have formed when pore fluid pressure became elevated as a result of vertical gravitational loading. In simple terms, the accumulation of either sediments, volcanic, or other material causes an increase in the pore pressure of groundwater and other fluids in the underlying rock when they cannot move either laterally of vertically in response to this pressure. This also causes an increase in pore pressure in preexisting cracks that increases the tensile stress on them perpendicular to the minimum principal stress (the direction in which the rock is being stretched). If the tensile stress exceeds the magnitude of the least principal compressive stress the rock will fail in a brittle manner and these cracks propagate in a process called *hydraulic fracturing*. Hydraulic joints occur as both nonsystematic and systematic joints, including orthogonal and conjugate joint sets. In some cases, joint sets can be a tectonic - hydraulic hybrid.

Exfoliation joints are sets of flat-lying, curved, and large joints that are restricted to massively exposed rock faces in an deeply eroded landscape. Exfoliation jointing consists of fan-shaped fractures varying from a few meters to tens of meters in size that lie sub-parallel to the topography. The vertical, gravitational load of the mass of a mountain-size bedrock mass drives longitudinal splitting and causes outward buckling toward the free air. In addition, paleostress sealed in the granite before the granite was exhumed by erosion and released by exhumation and canyon cutting is also a driving force for the actual spalling.

Unloading joints or **release joints** are joints formed near the surface during uplift and erosion. As bedded sedimentary rocks are brought closer to the surface during uplift and erosion, they cool, contract and become relaxed elastically. This causes stress buildup that eventually exceeds the tensile strength of the bedrock and results in the formation of jointing. In the case of unloading joints, compressive stress is released either along preexisting structural elements (such as cleavage) or perpendicular to the former direction of tectonic compression.

Cooling joints are columnar joints that result from the cooling of either lava from the exposed surface of a lava lake or flood basalt flow or the sides of a tabular igneous, typically basaltic, intrusion. They exhibit a pattern of joints that join together at triple junctions either at or about 120° angles. They split a rock body into long, prisms or columns that are typically hexagonal, although 3-, 4-, 5- and 7-sided columns are relatively common. They form as a result of a cooling front that moves from some surface, either the exposed surface of a lava lake or flood basalt flow or the sides of a tabular igneous intrusion into either lava of the lake or lava flow or magma of a dike or sill.

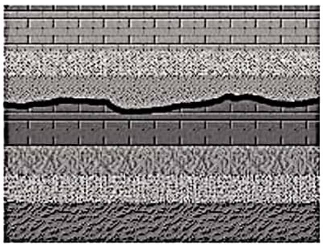
Uncofmities:

An unconformity is a buried erosional or non-depositional surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous. In general, the older layer was exposed to erosion for an interval of time before deposition of the younger, but the term is used to describe any break in the sedimentary geologic record.

The rocks above an unconformity are younger than the rocks beneath (unless the sequence has been overturned). An unconformity represents time during which no sediments were preserved in a region. The local record for that time interval is missing and geologists must use other clues to discover that part of the geologic history of that area. The interval of geologic time not represented is called a *hiatus*.

Types of unconformities

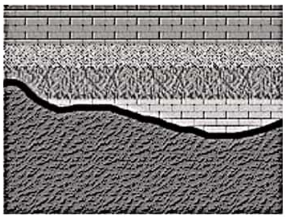
Disconformity



Disconformity

A disconformity is an unconformity between parallel layers of sedimentary rocks which represents a period of erosion or non-deposition.[3] Disconformities are marked by features of subaerial erosion. This type of erosion can leave channels and paleosols in the rock record.[4] A paraconformity is a type of disconformity in which the separation is a simple bedding plane with no obvious buried erosional surface.[5]

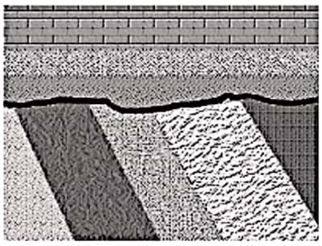
Nonconformity



Nonconformity

A nonconformity exists between sedimentary rocks and metamorphic or igneous rocks when the sedimentary rock lies above and was deposited on the pre-existing and eroded metamorphic or igneous rock. Namely, if the rock below the break is igneous or has lost its bedding by metamorphism, the plane of juncture is a nonconformity

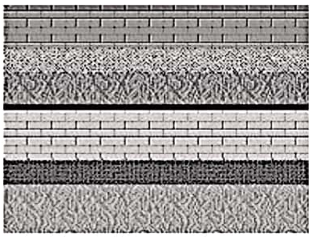
Angular unconformity



Angular unconformity

An angular unconformity is an unconformity where horizontally parallel strata of sedimentary rock are deposited on tilted and eroded layers, producing an angular discordance with the overlying horizontal layers. The whole sequence may later be deformed and tilted by further orogenic activity. A typical case history is presented by the paleotectonic evolution of the Briançonnais realm (Swiss and French Prealps) during the Jurassic (Septfontaine, 1984, 1995).

Paraconformity



A paraconformity is a type of unconformity in which strata are parallel; there is little apparent erosion and the unconformity surface resembles a simple bedding plane. It is also called nondepositional unconformity or pseudoconformity.

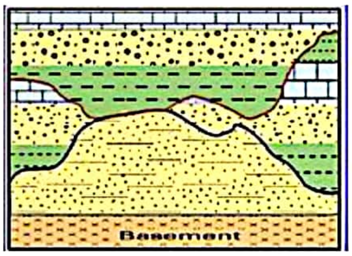
Buttress unconformity

A buttress unconformity is when younger bedding is deposited against older strata thus influencing its bedding structure.

Blended unconformity

A blended unconformity is a type of disconformity or nonconformity with no distinct separation plane or contact, sometimes consisting of soils, paleosols, or beds of pebbles derived from the underlying rock.

Biconformity



Biconformity

A biconformity is when an older unconformity is directly overlain by a younger unconformity. Biconformity is an unconformity surface that represents two known unconformity surfaces of different ages but directly overlying each other as though they both were a single unconformity surface.

Experiment No.-6

OBJECT: To Study the geological maps.

THEORY:

Geologic maps are not like other maps. Geologic maps, like all maps, are designed to show where things are. But, whereas the maps we know best show the distribution of roads or rivers or county boundaries, a geologic map shows the distribution of geologic features, including different kinds of rocks and faults. A geologic map is usually printed on top of a regular map (called a base map) to help you locate yourself on the map. The base map is printed with light colors, so it doesn't interfere with seeing the geologic features on the map. The geology is represented by colors, lines, and special symbols unique to geologic maps. Understanding these features will allow you to understand much of the geology shown in almost any standard geologic map.

Significance of Colored Areas on Geological Maps-

The most striking features of geologic maps are its colors. Each color represents a different geologic unit. A geologic unit is a volume of a certain kind of rock of a given age range. So asandstone of one age might be colored bright orange, while a sandstone of a different age might be colored pale brown. Many geologic units are given names that relate to where their characteristics are best displayed, or where they were first studied. For example, the Briones sandstone was first described in Briones Valley,California.

Some geologic units have not yet been named, so those are identified with terms related to the kind of rock in the unit like 'Sandstone and shale,' 'Unnamed sandstone', or 'Undivided shale'. But all units, named and unnamed, have a color on the geologic map, and the area of a given color is the area where that geologic unit is the one at the surface (usually the soil on top of the rocks is disregarded).

Geologic units are named and defined by the geologists who made the geologic map, based on their observations of the kinds of rocks and their investigations of the age of the rocks. As more information is gathered, perhaps by other geologists, new geologic units might be defined. These disagreements can be a basis for scientific progress, and illustrate the need for continuing to investigate the geology of an area.

Letter Symbols

In addition to color, each geologic unit is assigned a set of letters to symbolize it on the map. Usually the symbol is the combination of an initial capital letter followed by one or more small letters. The capital letter represents the age of the geologic unit. Geologists have divided the history of the Earth into Eons (the largest division), Eras, Periods, and Epochs , mostly based on the fossils found in rocks. The most common division of time used in letter symbols on geologic maps is the Period. Rocks of the four most recent Periods are found in the San Francisco Bay area shown on this map, so most letter symbols begin with a capital letter representing one of the four Periods: J (Jurassic - 195 to 141 million years ago), K (Cretaceous - 141 to 65 million years ago), T (Tertiary - 65 to 2 million years ago), or Q (Quaternary - 2 million years ago until today).

Occasionally the age of a rock unit will span more than one period, if the period of many years required to create a body of rock happens to fall on both sides of a time boundary. In that case both capital letters are used. For example, QT would indicate that the rock unit began to form in Tertiary time and was completed in Quaternary time. The few geologic units formed an unknown amount of time ago have letter symbols with no capital letters.

The small letters indicate either the name of the unit, if it has one, or the type of rock, if the unit has no name. So Kjm (see 1 on map above) would be the symbol for the Joaquin Miller sandstone (formed in the Cretaceous Period), while Ks (location 2) would be the symbol for an unnamed unit of shale formed in the same Period, and gb (location 3) would be the symbol for gabbro (a dark-colored igneous rock) of unknown age.

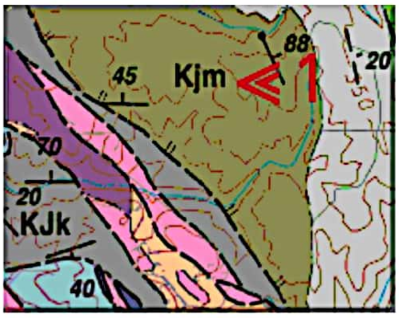
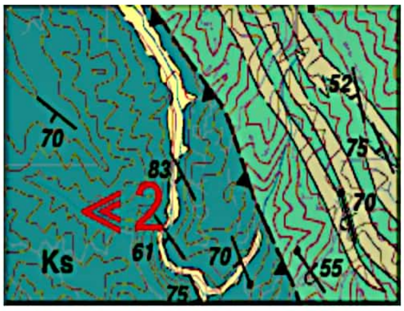
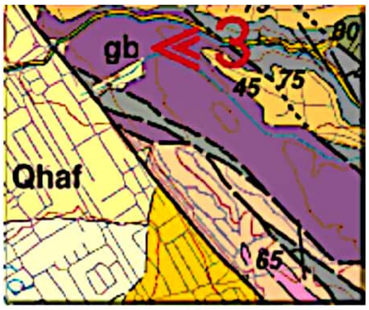


Fig: Location 1



Location 2



Location 3

Lines on the map

Contact Lines-

The place where two different geologic units are found next to each other is called a contact, and that is represented by different kinds of lines on the geologic map. The two main types of contacts shown on most geologic maps are depositional contacts and faults.

All geologic units are formed over, under, or beside other geologic units. For example, lava from a volcano flows over the landscape, and when the lava hardens into rock, the place where the lava-rock rests on the rocks underneath is a depositional contact. Where the original depositional contact between geologic units is preserved, it is shown on the geologic map as a thin line (location 4).

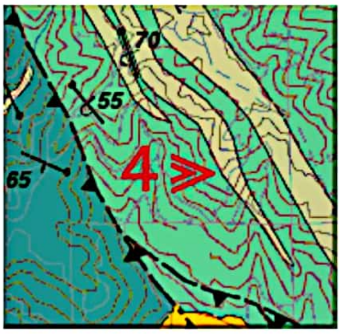
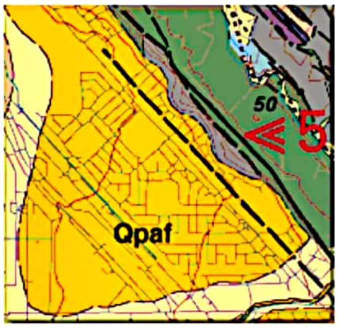
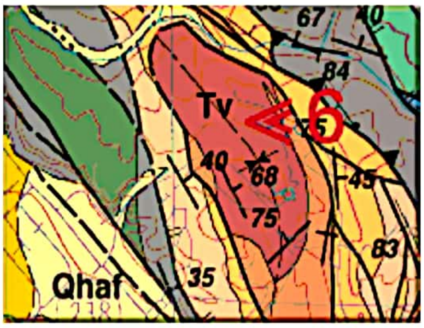


Fig: Location 4



Location 5



Location 6

Faults

However, in geologically active areas like the San Francisco Bay area, geologic units tend to be broken up and moved along faults (it is fault movements that cause earthquakes!). When different geologic units have been moved next to one another after they were formed, the contact is a fault contact, which is shown on the map by a thick line (location 5). Faults can cut through a single geologic unit. These faults are shown with the same thick line on the map, but have the same geologic unit on both sides.

Remember, just because the map shows a fault doesn't mean that fault is still active and is likely to cause an earthquake. Rocks can preserve records of faults that have been inactive for many millions of years. But knowing where the faults are is the first step toward finding the ones that can move. Special geologic maps of the faults known to be still moving are constantly being upgraded here at the United States Geological Survey, as well as by State geological surveys and university researchers.

Folds

Another kind of line shown on most geologic maps is a fold axis. In addition to being moved by faults, geologic units can also be bent and warped by the same forces into rounded wavelike shapes calledfolds. A line that follows the crest or trough of the fold is called the fold axis. This is marked on a geologic map with a line a little thicker than a depositional contact, but thinner than a fault (location 6).

Solid, dashed, or dotted lines

All thicknesses of lines are also modified by being solid, dashed, or dotted. Often contacts are obscured by soil, vegetation, or human construction. Those places where the line is precisely located it is shown as solid, but where it is uncertain it is dashed (location 7). The shorter the dash, the more uncertain the location. A dotted line is the most uncertain of all, because it is covered by a geologic unit, so no amount of searching at the surface could ever locate it (location 8). The lines on the map may also be modified by other symbols on the line (triangles, small tic marks, arrows, and more) which give more information about the line. For example, faults with triangles on them (location 9) show that the side with the triangles has been thrust up and over the side without the triangles (that kind of fault is called a reverse fault or a thrust fault).

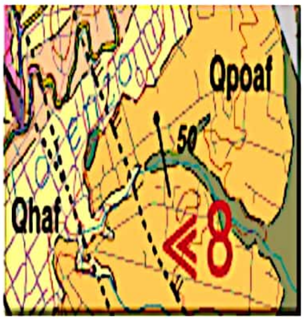
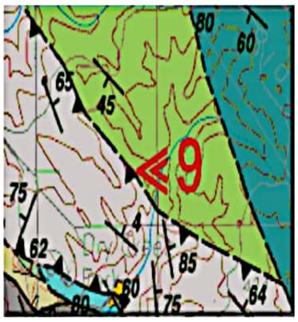
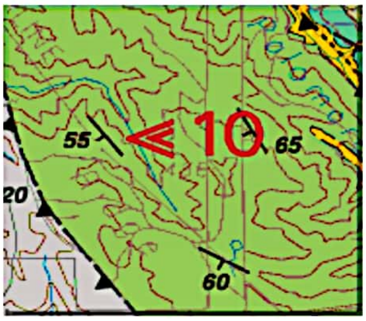


Fig: Location 8



Location 9



Location 10

Strike and dip

Many kinds of rocks form in broad, flat layers, called beds, that stack up like the layers of a cake. In areas like northern Arizona, thick stacks of rock beds that have built up over millions of years remain in their original flat orientation (where they can be viewed as multicolored horizontal layers of rock that make up the spectacular walls of the Grand Canyon). In places like California near active plate boundaries, however, the forces that make earthquakes don't leave the beds flat for long, but bend and tilt them.

Tilted beds are shown on a geological map with a strike and dip symbol (location 10). The symbol consists of three parts: a long line, a short line, and a number. The long line is called the strike line, and shows the direction in the bed that is still horizontal. Any tilted surface has a direction that is horizontal (think about walking on the side of a hill, there is always a way to go that is neither up nor down, but is level).

The strike line shows that horizontal direction in the beds. The short line is called the dip line, and shows which way the bed is tilted. The number is called the dip, and shows how much the bed is tilted, in degrees, from flat. The higher the number, the steeper the tilting of the bed, all the way up to 90 degrees if the bed is tilted all the way onto its side. Strike and dip symbols can be modified to give more information about the tilted beds just like lines can be, and these modifications are also explained in the MAP KEY.

Map Key

All geologic maps come with a table called a map key. In the map key, all the colors and symbols are shown and explained. The map key usually starts with a list showing the color and letter symbol of every geologic unit, starting with the youngest or most recently formed units (in the example map those are the man-made deposits), along with the name of the unit (if it has one) and a short description of the kinds of rocks in that unit and their age (in the key, the age is described by Epochs, subdivisions of the Periods shown in the letter symbol). After the list of geologic units, all the different types of lines on the map are explained, and then all the different strike and dip symbols. The map key will also include explanations of any other kinds of geologic symbols used on a map (locations where fossils were found, locations of deposits of precious metals, location of faults known to be active, and any other geologic feature that might be important in the area shown by the geologic map). Because the geology in every area is different, the map key is vital to understanding the geologic map.

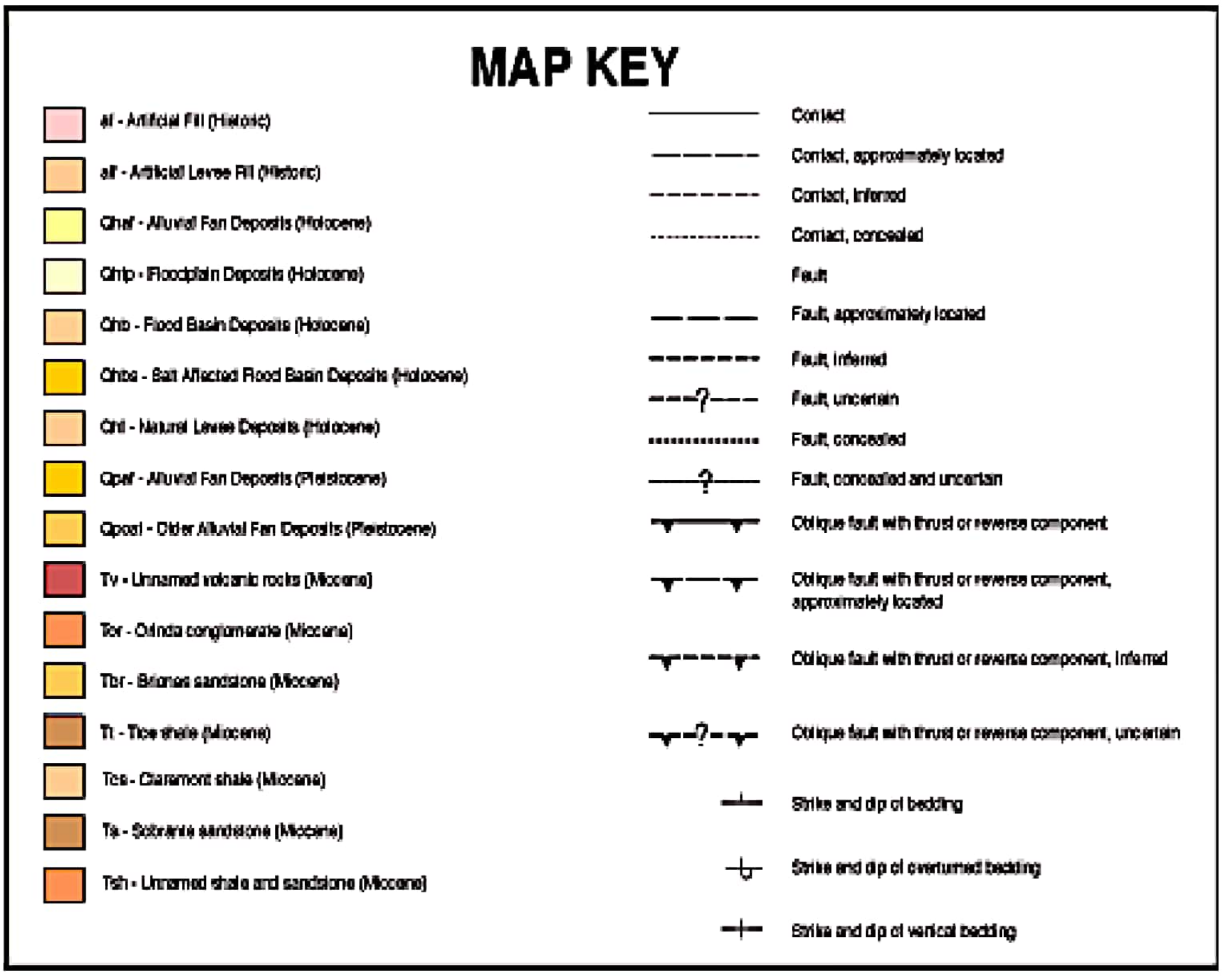


Fig.: Map Keys