The suitability of aggregate for use in concrete can be assessed on the following criteria:

a. The aggregate should be free from sulphide minerals, clay and organic matter.

b. The specific gravity should usually be high.

c. The material should be well graded with a wide range of particle sizes.

d. The fragments should have a rough surface, so that a good bond can be achieved between the aggregate and the cement paste.

e. Chalcedonic silica (flint, chert, agate) and glassy siliceous rocks (rhyolite, pitchstone) are often undesirable in gravel aggregate since they react with highly alkaline cements.

f. The amount of acid-soluble material (sulphate) should be measured.

g. The shrinkage of the concrete as it dries should be measured.

4. Road Aggregate

Aggregate constitutes the basic material for road construction and is quarried in the same way as aggregate for concrete. One of the most important parameters of road aggregate is the polished stone value, which influences skid resistance. Because it forms the greater part of a road surface, rock aggregate used as road metal must be:

a. Fresh with high strength, to bear the main stresses imposed by traffic.

b. High resistance to impact and abrasion, polishing and skidding, and frost action.

c. It must also be impermeable,

d. Chemically inert and

e. Possess a low coefficient of expansion.

Most igneous and contact metamorphic rocks meet the requirements demanded of good roadstone. The main groups used as aggregates are basalt, gabbro, granite, porphyry hornfels, schist, quartzite, limestone, flint types.

Of the ***sedimentary rocks***, limestone and greywacke frequently are used as roadstone. Greywacke, in particular, has high strength, resists wear and develops a good skid resistance. In fact, the use of gravel aggregates is increasing.

Igneous rocks are commonly used for roadstone. Dolerite and basalt have been used extensively. They usually have a high strength and resist abrasion and impact. The coarse-grained igneous rocks such as granite are generally not as suitable as the fine-grained types, as they crush more easily. On the other hand, the very-fine-grained and glassy volcanics are often unsuitable since they produce chips with sharp edges when crushed, and they tend to develop a high polish. Igneous rocks with high silica content resist abrasion better than those in which the proportion of ferromagnesian minerals is high, in other words, acid rocks such as rhyolites are harder than basic rocks such as basalts.

On the other hand, many ***metamorphic rocks*** that are either cleaved or schistose and are therefore unsuitable for roadstone. Some rocks that are the products of thermal metamorphism, such as hornfels and quartzite, because of their high strength and resistance to wear, make good roadstones. In contrast, many rocks of regional metamorphic origin, because of their cleavage and schistosity, are unsuitable. Coarse-grained gneisses offer a similar performance to that of granites.

5. Gravels and Sands

Gravel

Gravel deposits usually represent local accumulations, for example, channel fillings. A gravel deposit consists of a framework of pebbles between which are voids. The voids are rarely empty, being occupied by sand, silt or clay material. The shape and surface texture of the pebbles in a gravel deposit are influenced by the agent responsible for its transportation and the length of time taken in transport, although shape is also dependent on the initial shape of the fragment, which in turn is controlled by the fracture pattern within the parental rock. Gravel particles can be classified as rounded, irregular, angular, flaky and elongated in shape. The composition of a gravel deposit reflects not only the type of rocks in the source area, but is also influenced by the agents responsible for its formation and the climatic regime in which it was or is being deposited.

Sand

The shape of sand grains, however, is not greatly influenced by the length of transport. Sands used for building purposes should have the following characteristics:

1. Sands are used for building purposes to give bulk to concrete, mortars, plasters and renderings.
2. Sand consisting of a range of grade sizes gives a lower proportion of voids than one in which the grains are of uniform size.
3. Sands used for building purposes are usually siliceous in composition
4. Sand should be as free from impurities as possible.
5. Ideally, they should contain less than 3%, by weight, of silt or clay, since they need a high water content to produce a workable concrete mix. A high water content leads to shrinkage and cracking in concrete on drying.
6. The presence of feldspars in sands used in concrete has sometimes given rise to hair cracking.
7. Mica and particles of shale adversely affect the strength of concrete.
8. If iron pyrite occurs in sand, then it gives rise to unsightly rust stains when used in concrete.
9. The salt content of marine sands is unlikely to produce any serious adverse effects in good-quality concrete, although it probably will give rise to efflorescence. Salt can be removed by washing sand.

6. Lime, Cement and Plaster

Lime is made by heating limestone, including chalk, to a temperature between 1100^{o}C and 1200^{o}C in a current of air, at which point carbon dioxide is driven off to produce quicklime (CaO). Carbonate rocks vary from place to place both in chemical composition and physical properties so that the lime produced in different districts varies somewhat in its behavior.

Portland cement is manufactured by burning pure limestone or chalk with suitable argillaceous material (clay, mud or shale) in the proportion 3:1. The raw materials are crushed and ground to a powder, and then blended.

When gypsum ($CaSO4.2H_2O$) is heated to a temperature of 170^{o}C, it loses three quarters of its water of crystallization, becoming calcium sulphate hemi-hydrate, or ***plaster of Paris***. Anhydrous calcium sulphate forms at higher temperatures. These two substances are the chief materials used in plasters. Gypsum plasters have now more or less replaced lime plasters.

7. Clays and Clay Products

Sedimentary rocks occupy about three-quarter of the world's land surface and clays (including shales) form well over 50% of the sedimentary rocks. Clay sediments are collected by agencies of water, wind or of ice. The principal clay minerals belong to the kaolinite, illite, smectite, vermiculite and palygorskite families. Kaolinite is the chief member, are the most abundant clay minerals. Deposits of kaolin or china clay are associated with granite masses that have undergone kaolinization.

Kaolin is used in the manufacture of white earthenware and stoneware, in white Portland cement and for special refractories.

Ball clays are composed almost entirely of kaolinite, these clays have a high plasticity. Their plasticity at times is enhanced by the presence of montmorillonite. They contain a low percentage of iron oxide and, consequently, give a light cream color when burnt. They are used for the manufacture of sanitary ware and refractories.

If a clay or shale can be used to manufacture refractory bricks, then it is termed a ***fireclay***. Such material should not fuse below 1600°C and should be capable of taking a glaze. The crushed fireclay is mixed with water and moulded. Bricks, tiles and sanitary ware are made from fireclay.

Bentonite, when water is added to bentonite, it swells to many times its original volume to produce a soft gel. Bentonite is markedly thixotropic and this, together with its plastic properties, has given the clay a wide range of uses. For example, it is added to poorly plastic clays to make them more workable and to cement mortars for the same purpose. In the construction industry, it is used as a material for clay grouting, drilling mud.

Evaluation of Mudrocks for Brick Making

The mineralogy of the raw material influences its behavior during the brick-making process and hence the properties of the finished product. Mudrocks consist of clay minerals and non-clay minerals, mainly quartz. Mudrocks containing a high proportion of clay minerals produce less permeable products than clays with a high proportion of quartz, but the former types of clays may have a high drying shrinkage. The presence of quartz in significant amounts gives strength and durability to a brick.

The suitability of a raw material for brick making is determined by its physical, chemical and mineralogical character, and the changes that occur when it is fired. The ***unfired properties***, such as plasticity, workability (i.e. the ability of clay to be moulded into shape without fracturing), dry strength, dry shrinkage and vitrification range, are dependent on the source material. But the ***fired properties*** such as color, strength, total shrinkage on firing, porosity, water absorption, bulk density are controlled by the nature of the firing process. The ideal raw material should possess moderate plasticity, good workability, high dry strength, total shrinkage on firing of less than 10%.

6.7 Iraqi Geological Materials

The following is a summary of rocks in investment projects in Iraq (Fig.6.5):

1. Silica Sands (Glass Sands)

Silica sand is mainly located in Ardhumma quarry west of Rutba in Western Desert to produce glass sand and supplying some to the Ramadi Glass Factory, as raw materials for silica bricks industry, in addition to the foundry factory. Glass sands must have a silica content of over 95%. The amount of iron oxides present in glass sands must be very low.

2. Marble

Considerably large quantities of marble are available in different colors and kinds which are distributed in various districts north the country. Marble blocks started in production quarries of Salahuddin, Rayat, Darbandikhan and Panjawin.

3. Limestone for building purposes

In many parts of Iraq, limestone suitable for building is available. Extracting and quarrying these rocks needs some requirements such as free from fissure and fractures as well as relative softness of rock. One of these quarries is Jalla in Anbar Governorate for the rock blocks which then transferred to a factory where they are cut into the required sizes by means of saws and diamond vibrators. Other three projects have been implemented, and distributed on Sarchanar and Sinjar north of Iraq and Haklan in Anbar Governorate.

4. Sands and Gravel

There are many quarries of sands and gravels and constructing factories together with their washing and sorting in various districts of Iraq and with large quantities. These include Nabai centre , Sinam cente, Tieb centre, gravel centre in Mosul-Hammam Alil, gravel centre in qaim-Akashat.

5. Salinas

To cover the requirements of mankind and animal consumption, all necessary investigations were made on internal Salinas sea Salinas in Fao. In order to produce refined salts suitable for human and animal consumption, as well as for industrial purposes, steps are taken to develop some of the internal Salinas in order to produce natural sodium sulphate, and secondary chemical compounds for bromide and magnesium compounds at later stages.

6. Clays

a. Ceramic clays: They are composed mainly of kaolinite and quartz with some alumina content and iron oxides. There are many quarries of kaolin clays (white and colored) in Koua district, Duekhla quarry and Hussainiyat valley in the western desert suitable for manufacture of some ceramic products utilizing one of the site to supply ceramic factory in Ramadi and white cement factory in Falluja. In addition they are used for colored roof tiles and many construction industries.

b. Bentonite Clays: Bentonite clays are composed mainly of montmorillonite mineral. Bentonite clays are widespread in Qara Tappa and Zurluk in Kirkuk. These clays have been used in civil engineering such as driving piles, excavation works (digging of wells), purification and treatment works as well as metallurgic works (sand casting).

c. Flint clays

These clays are available in Hussainiyat vally in western desert. They consist of kaolinite and quartz with alumina 35-41% and silica 38-46%. They are used for manufacture of white cement and ceramic materials.

7. Porcellanite Rocks

These rocks are of high porosity consists mainly silica (85%) and alumina (10%). They are widespread in western desert of Iraq. They were deposited in marine depositional environment with the accumulation of great quantities of diatoms rich in silica. It is used in many construction materials and as abrasive material.

8. Quartzite and Silicrete Rocks

Quartzite rocks are one of the main siliceous deposits that are widely spread in Western Desert of Iraq. These deposits are with high hardness and are suitable for high quality silica refractories (silica bricks) due to its high silica content reaching to 97% with low alumina (Al_2O_3) (<1.5%).

Silcrete rocks are a type of quartzite siliceous deposits widespread in in western desert. They consist mainly quartz in the range of 95-99% with some iron oxide and carbonate as a cementing material. It is used mainly for manufacturing of acidic refractories (silica bricks).

9. Bauxite

It is hydrous alumina available in Hussainiyat valley in western desert, Iraq. It consists of kaolinite, quartz and alumina (47-62%) and silica (14-40%). It is used for cement manufacture, abrasive material and refractories and may other chemical industries.

10. Chert

These rocks are strong rock with high content of silica reaching to 94% with low amount of oxides of calcium, magnesium and iron. They are widespread in Akashat in western desert.

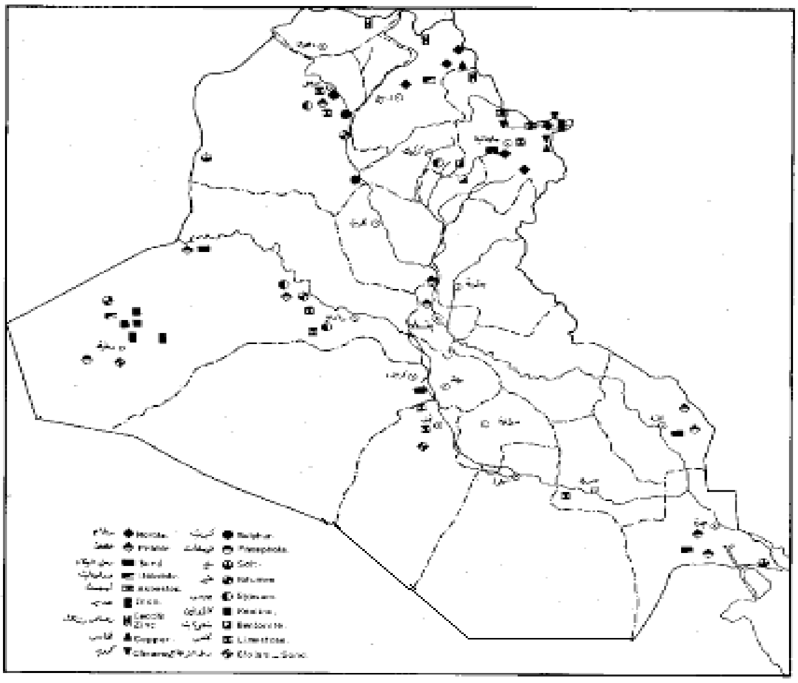


Fig. (6.5). Map shows the location of some Iraqi rocks and minerals used in construction.

REVIEW QUESTIONS

6.1 State whether the following statements are True or False.

1. One of the main task of a geologist is to investigate and geological materials for building and paving.
2. One of the most important stages in the geological investigation for construction materials and paving is the validity of the quarry to work.
3. One of the first stages of the survey of the quarry is to determine their positions with regard to the means of transport and the location of the project to be established.
4. Generally, the intended purpose of the geological investigation is to determine the form of quarry or mine capacity and its kind in terms of materials and minerals to be extracted.
5. Of the important things for investigating geological material in the quarry or mine is to determine the reserves of materials and determine the investment plan.
6. The requirements for stone quarry, its shape and size are mainly dependent on the purpose for which this quarry will be used.
7. The composition of a gravel deposit reflects not only the type of rocks in the source area, but is also influenced by the agents responsible for its formation and the climatic regime in which it was or is being deposited.

6.2 What are the main factors affecting building rocks?
6.3What are the main types of aggregates? Classify them.
6.4 What are the main characteristics of crushed and natural aggregates?
6.5 List the main physical properties of building rocks.
6.6 List the main damages that can occur to rocks.
6.7 List the main methods of quarrying building rocks.
6.8 List the main rocks used in roofing and facing materials.
6.9 Define armourstone and what are they used for?
6.10 What are the main rocks that are used as concrete aggregates?
6.11 What are the main characteristics of rocks used for road aggregates?
6.12 What are the main characteristics of sands that are used for building purposes?
6. 13 List the main rocks used for cement and plaster manufacture.
6.14 List the different types of clay products used in industry.
6.15 Evaluate mudrocks for brick manufacture.
6.16 List the main Iraqi geological materials used for building and construction.
6.17 List the most important locations of sand and gravel quarries in Iraq?
6.18 What are the main compositions of the following deposits?
Quartzite, silcrete, bauxite, porcellanite

7. Structural Geology

6.1 Introduction

Structural Geology is the science dealt with studying the deformations that happened in the rocks of earth crust and their causes, phenomena and resulting rock forms.

Earth movements are subdivided into two main categories:

1- Epirogenic: Vertical slow continuous movement causes uplift and subsidence and such deformation is regular.

2- Orogenic Movements (Orogenesis): Horizontal violent periodic movements produce a mountain system, such deformation is irregular. Mountain systems show evidence of enormous forces which have folded, faulted, and generally deformed large sections of the earth's crust.

7.2 Types of Strata

When rocks are subjected to stresses greater than their own strength, they begin to deform, usually by folding or fracturing. It is easy to visualize how individual rocks break, but how are large rock units bent into intricate folds without being appreciably broken during the process?

Due to the above mentioned movements, rocks are subjected to deformation, tension folding and faulting, thus sedimentary layers will be under three main cases:

1- Conformable Strata: Layers of rock are said to be ***conformable*** when they are found to have been deposited without interruption that is the older layers in the bottom and the younger ones in the top (Fig.7.1). However, there is no place on earth contains a complete set of conformable strata.

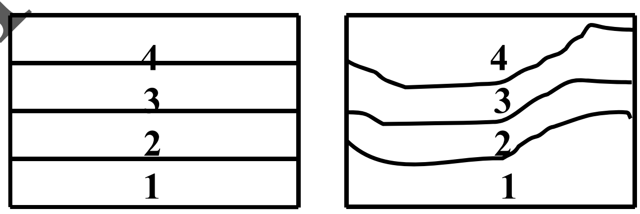


Fig. (7.1). Conformable strata .

2- Unconformable Strata: For a particular span of time, when rock layers do not have a complete sequence of rocks representing the entire period, such breaks in the rocks record are termed ***unconformities***. There are two main types of unconformities:

a- Angular Unconformity: It consists of tilted or folded sedimentary rocks that are overlain by other, more flat-lying strata (Fig.7.2-a). These are called ***angular***

unconformities and perhaps indicate the most easily recognized type of unconformities.

b- Disconformity: This type of unconformity records a period of erosion of older horizontal rocks followed by deposition of younger, flat-lying sedimentary rocks. It is more difficult to recognize because the strata on either side of these unconformities are essentially parallel (Fig.7.2-b). ***Disconformities*** may represent either a period of non-deposition or a period of erosion.

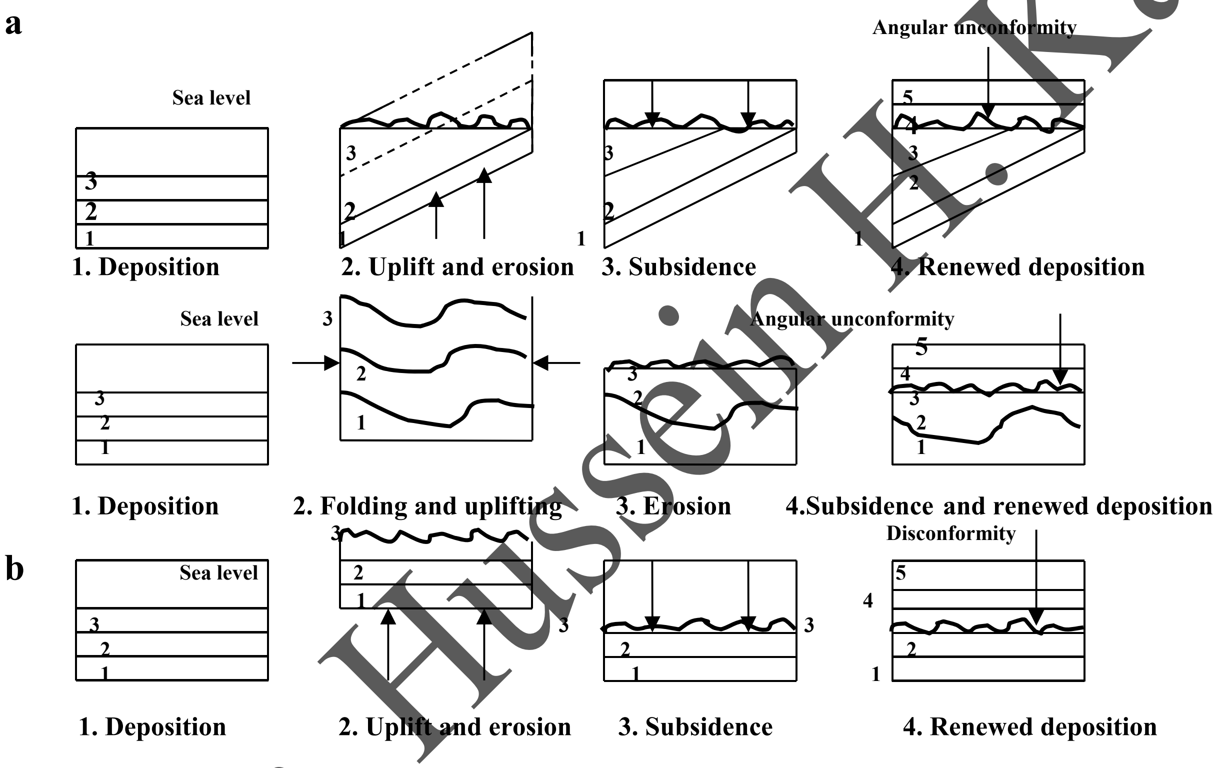


Fig. (7.2). Development of unconformities : a- Two examples of angular unconformities : b- Erosion resulting in a disconformity.

3- False Bedding: These features of layered sediments occur in specific regions and cases due to change in direction of water currents or wind. They occur in large scale in aeolian deposits, such as sand dunes and in a very small scale in sediments deposited from moving water currents and are found mostly in sands and the rocks formed from them. These thin layers are dipping in different directions, with respect the original ones, due to change in wind or water current (Fig. 7.3).

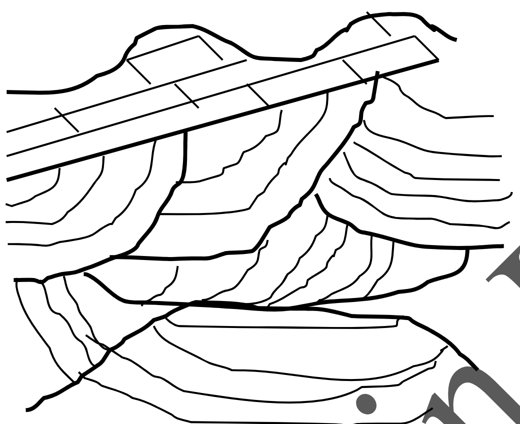


Fig. (7.3). False bedding.

7.3 Stratum (Bed) and Bedding Planes

Original layering in sediments is called ***stratification*** or ***bedding*** (different terms are used for the layering produced by other igneous and metamorphic processes). Each layer is referred to as a ***stratum*** (plural, ***strata***) or ***bed*****,** though the latter term is normally applied only to sedimentary rocks and volcanic ash layers. It is never applied to the layer formed by a basaltic or rhyolitic lava flow. The interfaces between beds are called ***bedding planes***. The outcrops of major bedding planes that separate thick beds of different rock type are depicted on geological maps. Bedding planes may also occur within a thick layer of sandstone, where minor changes of composition or texture, or even a break in deposition, are present. These are planes of weakness, or potential planes of failure, and their presence produces a change of mechanical properties of the rock with the direction in which they are measured (that is, the bulk properties of the rock are anisotropic). Minor bedding planes are abundant in micaceous shale.

7.4 Outcrop of the Bed (Layer)

The outcrop of a body of rock (such as a layer of shale) is the area that emerges at the surface where the rock is present, or lies immediately below a cover of vegetation, soil, or other superficial deposit. Those parts of the outcrop where rock is visible at the surface, and where observations may be made, are called

outcrops exposures. The exposed portion of the rock layers on the earth surface could be horizontal, inclined and vertical strata. When the layers are horizontal so they will mask all the underling layers and hence their geologic boundaries will be parallel to the contour lines. But, when the strata are inclined ,which are common, some parts of these strata exposed on the earth surface and their geologic boundaries intersect contour lines. The general distribution of rocks in the subsurface may be inferred by studying the outcrops, and by relating a particular pattern to the structural model that would produce a similar one. Exposures are usually found in the banks of streams, in road cuttings, on cliff or scarp faces, and in quarries.

7.5 Strike of the Bed (Layer)

The strike of a bed is the direction of its continuity on the surface. It is also expressed as the direction of a line of intersection which the layer makes with the horizontal plane. The strike direction is normally expressed with reference to north on a 360◦ scale. Figure 6.4 shows an example for dipping sandstone bed where the strike of the bed is E-W and the north is the direction of maximum or true dip. A line drawn in this direction on the bed is horizontal, and since it is thus a line joining points at the same height on the bed, it is a ***stratum contour*** or ***strike line***.

7.6 Dip of the Bed

The dip of a bed is the angle which the bed makes with the horizontal plane. It is measured in the direction at right angles to the strike. Dip is a vector quantity and both the amount ($\boldsymbol{\theta}$) in degrees and direction of the slope are always specified.

In the example shown below (Fig. 7.4), the sandstone bed strike is E-W direction with the dip toward the north. If the dip angle ($\boldsymbol{\theta}$) is measured exactly at right angle to the strike, it is known as the ***true dip*** which is the maximum angle. In any other direction between true dip and strike, the angle of dip observed between bedding plane and horizontal depends on the true dip and the angle ***B*** in the figure (or $\boldsymbol{\theta}$). A value of this type is referred to as an ***apparent di*****p.** There will be one true dip, but more than one apparent dip.

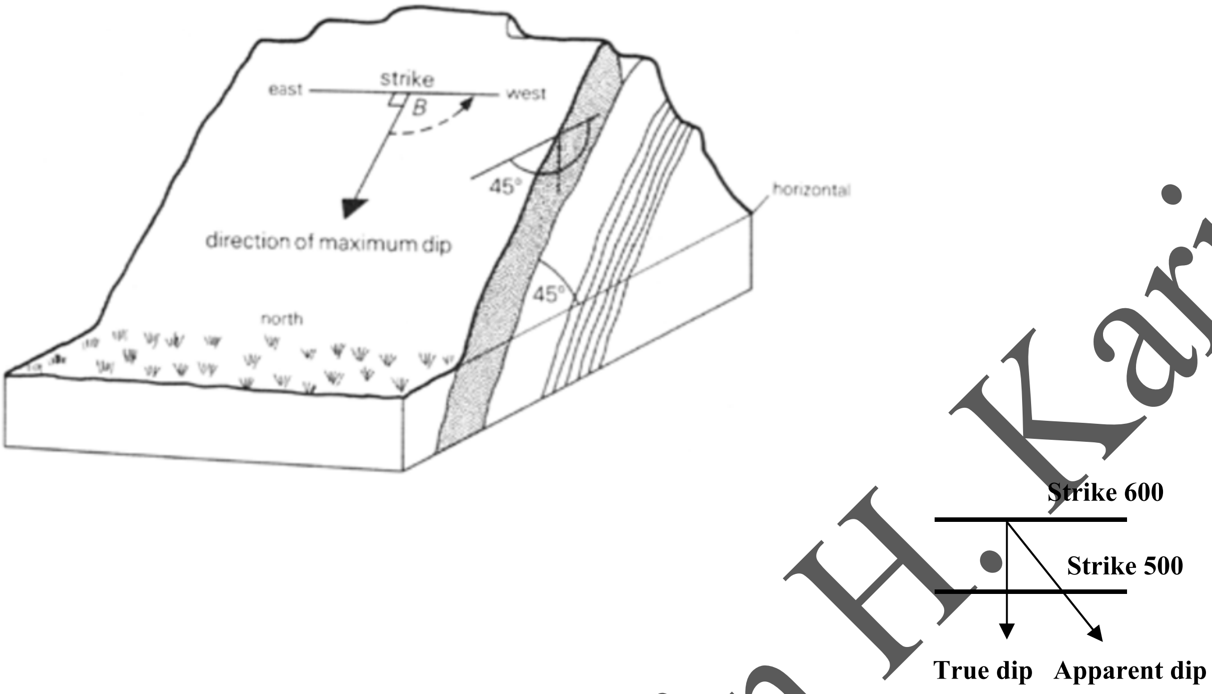


Fig.(7.4). The layer of sandstone is tilted to the north at an angle of 45° to the horizontal. The dip observed is 45°. When an angle of dip is read in any other direction on the bedding plane (that is, at some angle *B* with the direction of maximum dip), the apparent dip observed is less than 45°. In the limiting case where *B*=90°, the apparent dip is zero. This direction is called the strike of the dipping layer.

7.7 Folds

7.7.1 Components of Folds

If subjected to stresses beyond those that their strength can resist, strata are permanently deformed by either buckling or fracturing. The type of deformation depends on the mechanical properties of the rocks and the nature of the stresses. In general, stresses which are applied slowly, either deep within the Earth where the confining pressure produced by overburden is high, or to rocks that are not brittle, tend to produce ***folds*** by buckling or plastic flow. A fold where the limbs diverge downwards (that is, where the dips of the ***limb*** are away from the ***hinge***) is an ***anticline***; a fold where dips are towards the hinge is a ***syncline***.

The essential characteristic of a fold is a ***change of dip***. This occurs at the ***hinge*** of the fold. On either side of the hinge is a ***limb*, where the dip is comparatively steady. In real folds the change of dip is seldom restricted to a line, but is concentrated in a liner zone. The plane of symmetry that bisects the angle between the limbs is the ***axial plane***. The intersection of the axial plane with each bedding plane is an ***axis of the fold***. If the axis is not horizontal, the fold is said to ***plunge,*** with the amount of plunge being the angle between the axis and the horizontal line vertically above it. The highest points of the fold are called ***fold crest***, while the lowest points are called the ***fold trough***.

The symmetry of a fold about its axial plane is reflected in its outcrop pattern (Fig. 7.5). The sequence of beds cropping out on one side of the trace of the axial plane on the ground surface is repeated, but ***in reverse order***, on the other side. Thus for each fold, there is one strike direction but with two dip directions. The oldest strata that crop out are present near the axis of an anticline, and the youngest strata at the axis of a syncline. These patterns, plus the dips, may be used to recognize folds on a map or in the field, where a fold is too large to be visible in one exposure.

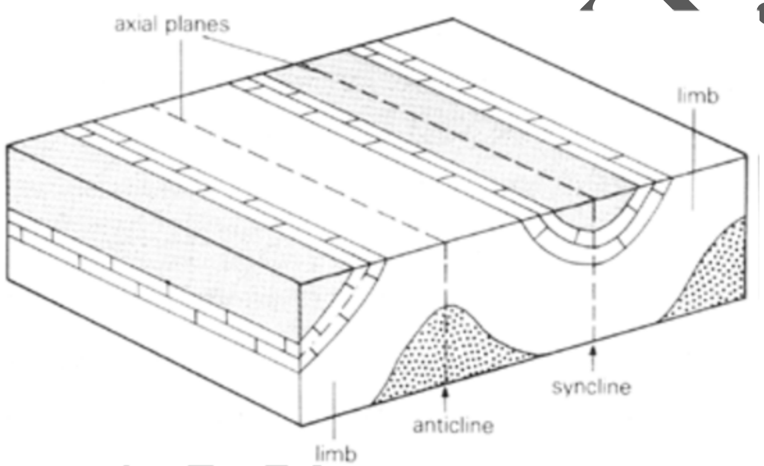


Fig. (7.5). A block model showing the distribution of folded strata on a map (the upper Surface) and on two vertical sections. The axial planes of an anticline and syncline are shown by broken lines. The outcrops on the map are symmetrical about the traces of the axial planes.

If the axis is not horizontal, the fold is said to ***plunge,*** with the amount of plunge being the angle between the axis and the horizontal line vertically above it. The ***U-shaped outcrop*** of a plunging fold is shown in Figure 7.6. As a result of the plunge, the map is an oblique section across the fold hinge and reveals its shape, including the nature and width of the hinge zone. If the plunge were 90° and the area of the map were flat and level, the map would show the true thicknesses of the beds. As the plunge decreases from this maximum value, the U-shaped outcrop is progressively elongated in the axial direction.

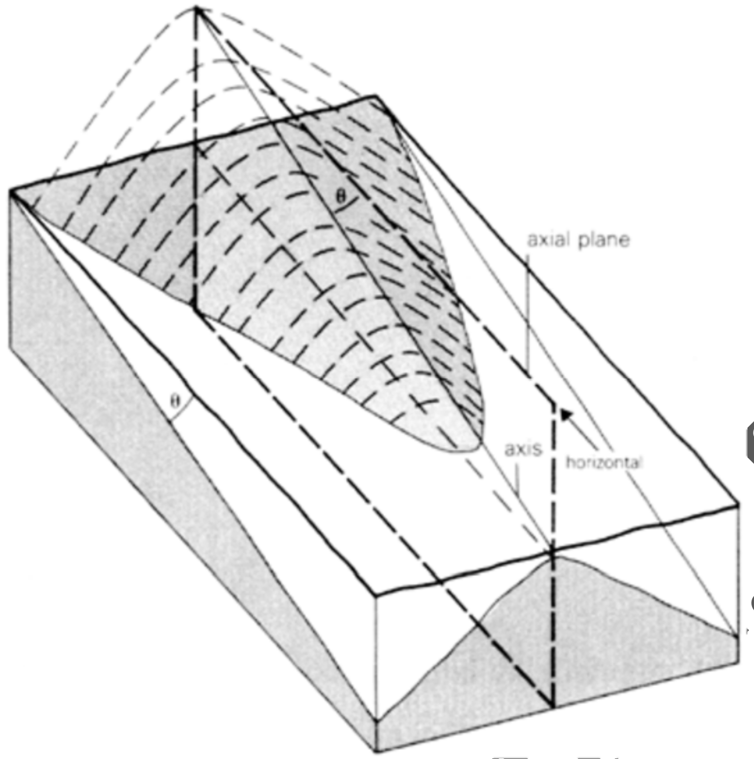


Fig. (7.6). A block model showing the outcrop of an anticline plunging at angle *θ*. The axial plane, an axis, and the former continuation of a bedding plane above the map are represented.

Depending upon their orientation , anticlines and synclines are said to be symmetrical, asymmetrical or overturned if one limb has been tilted beyond the vertical. Some of folds are said to be plunging, since the axis of the fold is plunging into the ground. Although, most folds are caused by compressional stresses that squeeze and crumble strata, some folds are a consequence of vertical displacement. When upwarping produces a circular or somewhat elongated structure, the feature is called ***dome***. Downwarped structure having a similar shape are termed ***basins***.

7.7.2 Classification of Folds

Folds are described and classified by certain features of their geometry which are diagnostic of how they were formed. The criteria and the terms used to define folds are illustrated in Figure 6.7; they are as follows:

(a) The ***dip of the axial plane***: Where it is vertical the dip of each limb is the same in magnitude, but opposite in direction, and the width of outcrop of any bed is the same on both sides of the axis. In inclined folds, one limb is steeper and its outcrop is correspondingly narrower than that of the other. Overfolding occurs where one limb is overturned, such that both limbs dip the same way. The rotation of the axial plane, seen from left to right in the diagram, is probably produced by transport of the fold with relative drag at its base.

(b) The size of the ***angle between the limbs***: This reflects the intensity of compression of the fold.

(c) The ***relative lengths of both limbs***.

(d) The ***style of folding***: That is, the manners in which different types of rock have behaved mechanically, particularly whether they are competent (that is, comparatively strong) or incompetent. Under the stresses of folding, an incompetent layer tends to flow and change thickness, sometimes to a stage where it is discontinuous. Arenaceous rocks are usually competent and clay rocks are incompetent.

7.7.3 Types of Folds

According to the dip of the axial plane, folds are subdivided into (Fig. 7.7):

1- Symmetrical fold: In which the dip of the strata is equal and opposite in direction.
2- Asymmetrical fold: In which the dip of the strata is unequal and in both directions.
3- Overturned (or Overfolded) fold: They occur when one limb is overturned such that both limbs dip in the same direction but with unequal magnitudes.
4- Recumbent fold: Folds in which the axial plane is horizontal.
5- Isoclinal fold: Folds with equal dip (in direction and magnitude) in both sides of the axis.
6- Plunging Fold: If the axis is not horizontal dipping in a third direction differed from the other two directions.
7- Dome and Basin: They are folds with approximately homogeneous and equal dip in all directions.

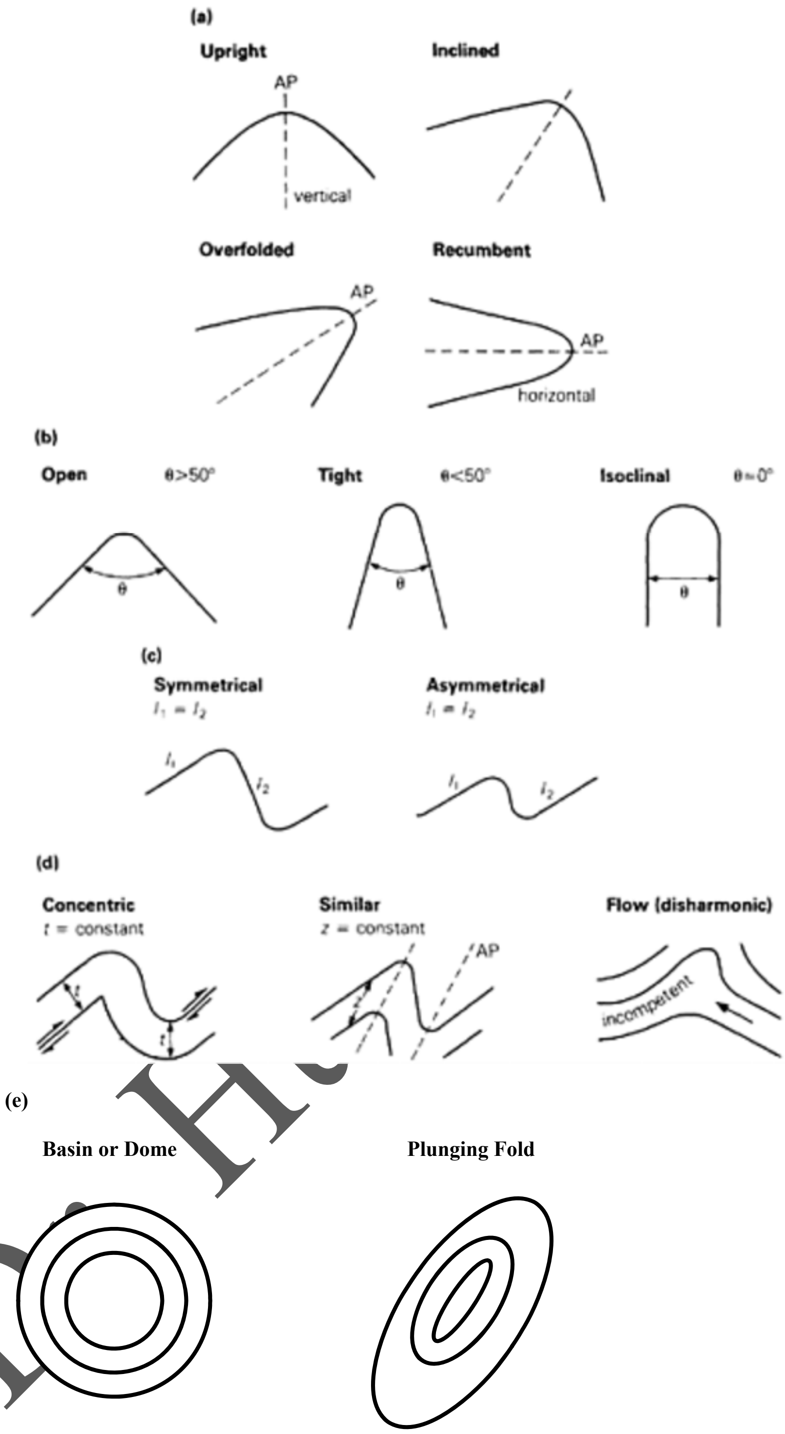


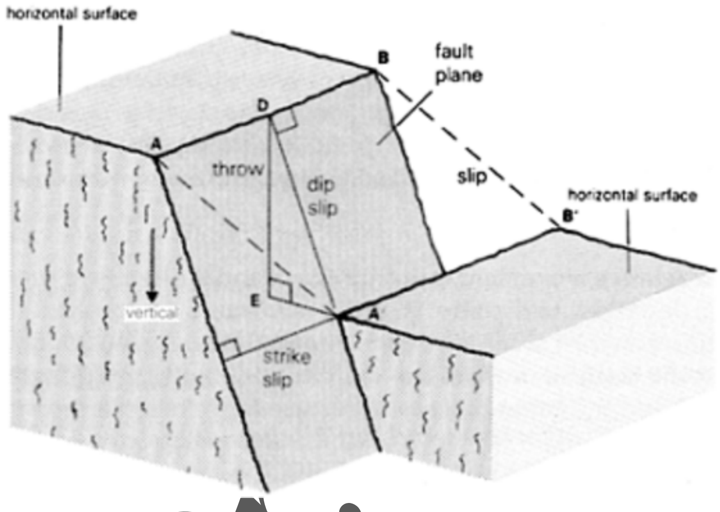
Fig. (7.7). Classification and nomenclature of folds according to
(a) dip of the axial plane (AP),
(b) size of angle between limbs,
(c) relative lengths of both limbs, and
(d) style of folding.

7.8 Faults

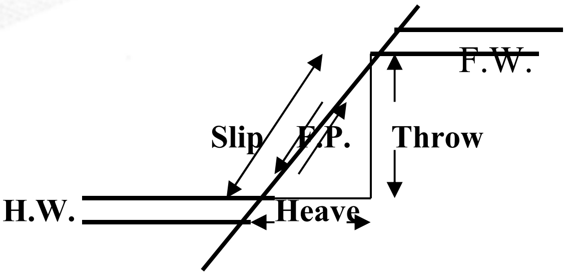
7.8.1 Components of Faults

Brittle rocks deform by fracturing, especially if stress is applied rapidly. Whether or not a given rock is brittle depends not only on its texture and composition but also on its temperature, on the confining pressure around it, and on any fluids present within it. In general, fracturing takes place at shallower levels in the earth than folding, though both may occur in the same place at the same time. Larger shear fractures, where there are significant displacements of rock bodies across the plane, are called ***faults*** (see Fig. 6.8).

As with all structural surfaces, the orientation of a fault is expressed by its strike and dip. The displacement across a fault is called its ***slip*,** and the terms used to describe the components of ***slip*** (***strike slip*, *dip slip***, ***throw*** **and** ***heave***) are illustrated in Figure 6.8. Only very small faults have a simple, clean-cut plane of movement. The majority are zones of shearing, usually a few meters across, but major faults may be more than 1 km wide. The rock above the fault plane is called the ***hanging wall***, while the rock below the fault plane is called the ***foot wall***.



(a) Block diagram



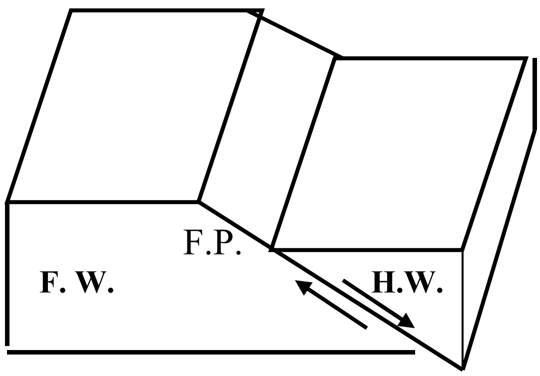
(b) Section (for dip slip)

Fig. (7.8). Before fault movement A and A' and B and B' were adjacent to each other. The total displacement A–A' measured along the fault plane is called the slip of the fault. It may be resolved into strike slip and dip slip, which are respectively horizontal and vertical components, in the plane of the fault. Dip slip may also be resolved into a horizontal component (the heave) and into a vertical component (the throw of the fault).

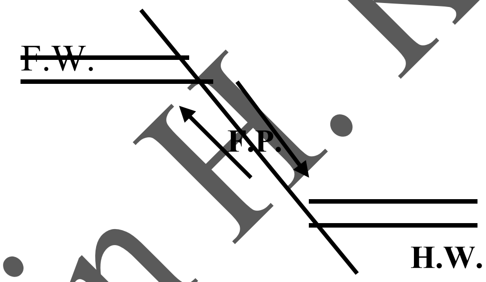
7.8.2 Types of Faults

There are two main types of faults classified with respect to genesis that reflects the nature of the stresses which created them:

1- Normal fault (or Dip-slip fault): Where relative movement is up and down and strike slip is almost zero, a fault is described as ***dip slip***. If its dip is towards the lowered side (that is, the ***downthrown side***), the fault is ***normal*** (Fig. 7.9). The most common one resulted from tensional stresses in which the hanging wall moves down relative to the foot wall, where the dip of the fault plane is > 45º (about 60º).



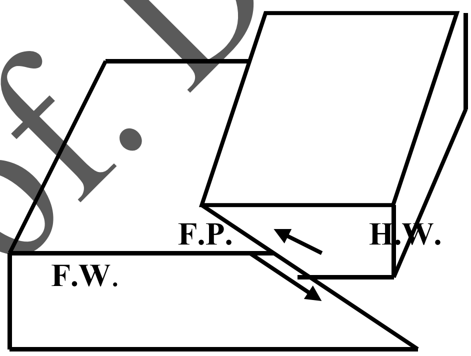
(a) Block diagram.



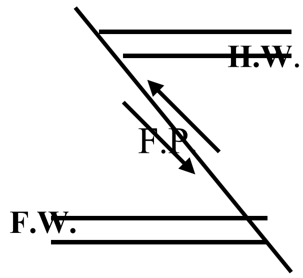
(b) Section (for dip slip).

Fig. (7.9). Normal fault.

2- Reverse fault : They are resulted from the compressional stresses and created when the hanging wall moves up relative to the foot wall. If the dip is towards the ***upthrown side***, the fault is ***reverse*** (Figs. 7.10 and 7.11). When reverse faults having a very low angle (about 30º) to the horizontal are also referred to as ***thrust fault***.



(a) Block diagram.



(b) Section.

Fig. (7.10). Reverse fault.

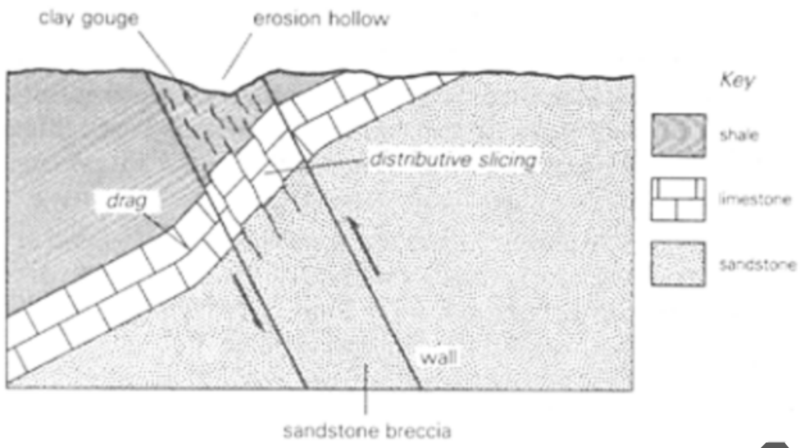
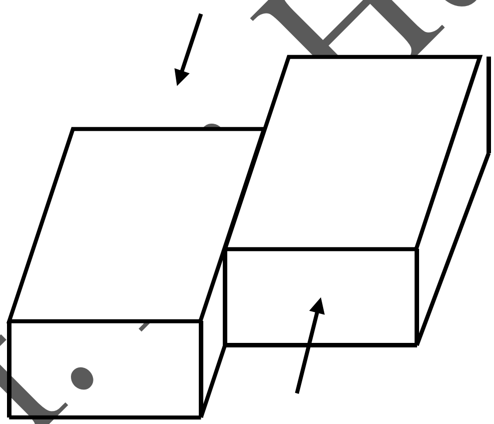


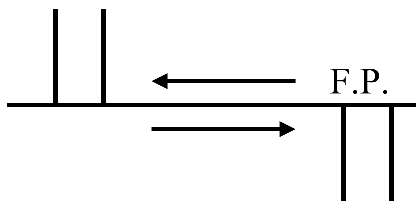
Fig. (7.11). The section shows a reverse fault cutting a sequence of strata, sandstone-limestone-shale. Shearing within the fault zone has produced clay gouge from the shale, and fault breccia from the sandstone. The softer gouge in the fault has weathered out as an erosion hollow. The limestone is displaced in steps (that is, distributive slicing) by minor shears within the fault zone. The zone of shearing is bounded by the walls of the major fault, but some deformation (terminal drag in the directions of movement) is seen just beyond them.

Other types of faults are:

3- Horizontal (or Tear) fault : Faults in which the dominant displacement is along the strike of the fault and are called strike-slip fault (Fig. 7.12).



(a) Block diagram.



(b) Section.

Fig. (7.12). A horizontal (Tear) fault.

4- Vertical faults : Faults in which the dominant displacement is vertical (about 90º) with the absence of both hanging and foot walls (Fig. 7.13).

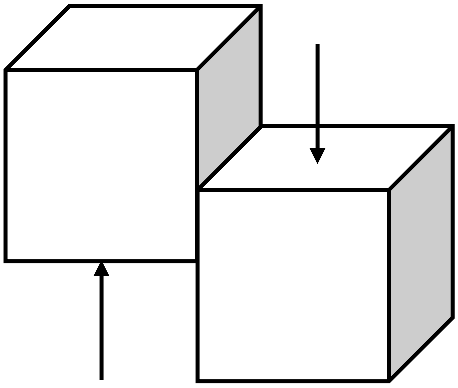


Fig. (7.13). A vertical fault.

5- Step faults:

a- Graben: A central block is bounded by normal faults and produce an elongated valley bounded by upfaulted structures called horsts (Fig. 7.14).

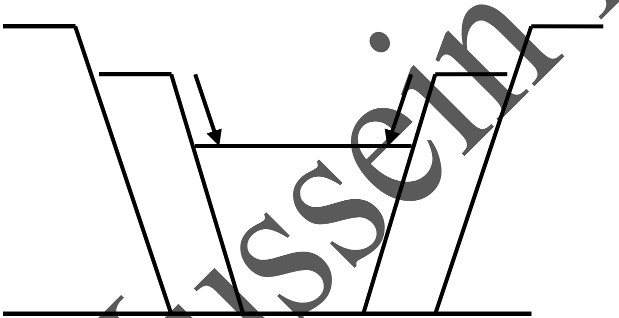


Fig. (7.14). A graben.

b- Horsts: A central block is bounded by normal faults and produce an upfaulted structures bounded by downfaulted block (graben) (Fig. 7.15).

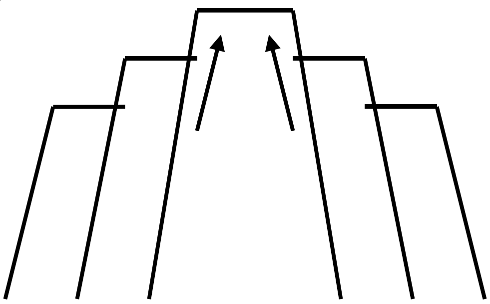


Fig. (7.15). A horst.

6- Rotational faults: These faults occur when part of the rock mass moved downward and the other part moves upward while the axis of this movements remains vertical with the fault plane (Fig. 7.16).

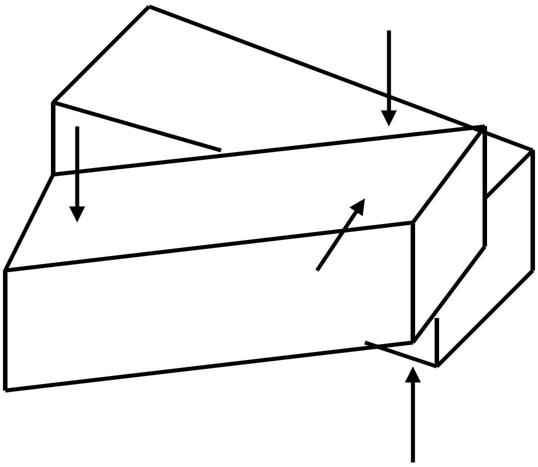


Fig. (7.16). A rotational fault.

7.8.3 Importance of Faults and their Recognition

Faults may be ***active*** along which movement has occurred during historical time or ***inactive*** in which no movement has occurred during historical time. The presence of faults is important to nearly all fields of economic geology. Faults, if frequent, have a considerable effect on the bulk properties of a rock mass such as mechanical properties. Faults affect the strength and stability of the rock mass. Faults affect rocks because they are concentrated zones of weakness and of percolation, which may receive local remedial treatment in engineering works. Analysis of the geometry of faults is advisable in most construction projects, for example: where excavation can take advantage of planes of weakness; where rock bolts or other strengthening devices can be placed and orientated to be most effective; where design of major structures, such as dams, should be modified to avoid placing the maximum stress parallel to a plane of weakness; or where grouting has to be done to seal fractures against leakage. This latter is best achieved by drilling holes perpendicular to the faults.

7.8.4 Field Recognition of Faults

Faults can be recognized from their effects on the pattern of outcrops.

1- Strike faults (Fig.7.17a) produce a repetition of the succession of strata (but unlike a fold, repetition is in the same order) if the downthrow across the fault is in the opposite direction from the dip of the strata.
2- Dip faults and oblique faults truncate and displace the outcrops (Fig. 7.17b).
3- They produce an omission of part of the normal succession of strata (which do not crop out because of the fault) if the downthrow is in the same direction as the dip.
4- The association of the phenomena of mineral filling (quartz).
5- The presence of crushed materials called ***mylonites*** and striations on fault planes called ***slickensides.***

6- Within the ***fault zone*** there may be a number of planes of movement displacing the strata by ***distributive slicing*** , or the rock may be completely fragmented to form a fault ***breccia*** where competent rocks are affected, or ***clay gouge*** where ***incompetent rocks*** have been smeared out by shearing. (***Gouge*** often acts as a seal to make the fault zone locally impervious to groundwater circulation). At the ***walls*** (Fig. 7.11) of the fault the strata may show ***terminal drag*** in the direction of relative movement.

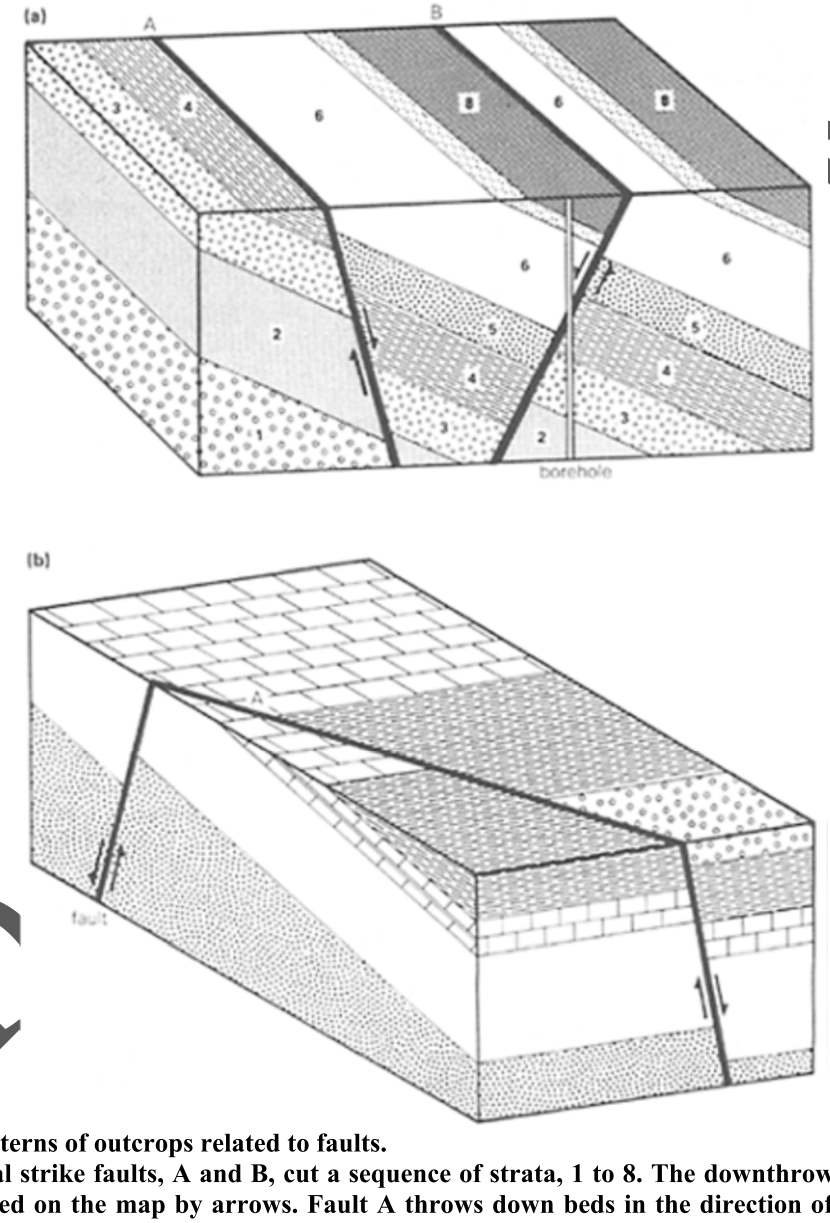


Fig. (7.17). The patterns of outcrops related to faults.
(a) Two normal strike faults, A and B, cut a sequence of strata, 1 to 8. The downthrown side of each fault is indicated on the map by arrows. Fault A throws down beds in the direction of dip, and as a result layer 5 does not crop out at the surface. There is *omission* of part of the sequence of strata as the fault is crossed. Fault B throws down beds in the opposite direction and produces *repetition* of the outcrops of layers 6, 7 and 8. Note that a borehole through the fault plane does not necessarily pass through a complete sequence of beds—layer 5 and parts of 4 and 6 are missed.
(b) An oblique fault throws down the strata on the far side of the block and produces an offset of the outcrops, each of which is truncated by the fault. The amount of throw is equal to the thickness of the limestone layer; and top and bottom of that layer are aligned both in vertical section and on the map. The amount of throw of a fault can be read directly from the map, if the sequence and thicknesses are known, by seeing which beds are brought in contact and using this relationship.

7.9 Joints

7.9.1 Definitions

A joint is a fracture in rock along which there has been no movement . Joints may be non-systematic, but often occur as a set of parallel planes. If two or more sets are present, they form a system of joints. Prominent joints which are continuous as a single plane surface for hundreds of meters are called ***master joints***. **Major joints** cross only a few beds before dying out. ***Minor joints*** are confined to one layer. In folded strata, joints are described as ***longitudinal*** if their strike is parallel to the fold axes, and otherwise as ***cross*** or ***diagonal joints***.

7.9.2 Classification of Joints

Joints are classified according to their mode of formation to:

1- **Cooling Joints**: In igneous rocks, a simple system of ***cooling*** or ***contraction joints*** is usually formed in lava flows, sills, dykes and other minor intrusions shortly after they are emplaced.
2- **Shrinkage Joints**: These joints occur mainly in sedimentary rocks especially in mudstones after losing their water by evaporation. Also they occur in limestones due to dissolution.
3- **Tectonic Joints**: In addition to any regional joint system, there are likely to be local concentrations of radiating tensional cracks caused by stretching at the hinges of folds, and formed close to fault zones as minor shears associated with the fault movements (Fig. 7.18). In sedimentary strata, a joint system may be present over a wide region and be related in whole, or in part, to the same stresses that produced folds and faults in the same rocks. These joints result from compressional and tensional stresses accompanied with the formation of folds and faults. They are either tension joints or shear joints. (The distinction between a "***shear joint*** " and a ***"small fault"*** is arbitrary, depending on circumstances and significance, but the former term usually suggests a displacement of a few centimeters).
4- **Stress-Relief Joints**: The relief of pressure produced as the load of overburden is stripped away by erosion. Tensional joints resulted from rock layers load removal by erosion process .
5- **Columnar Joints:** Where columnar joints growing from opposite margins meet near the middle of a dyke or sill, a ***median joint*** should develop, but is not always present.

Other mechanisms which can create regional joint sets are the very minor, but daily, distortion of the solid earth by tidal stresses, and the frequency of joints in a layer is related to the rock type and the thickness. In general, the space between joints is less in brittle rocks with good elastic properties, and increases in proportion to the thickness. A thin layer of crystalline limestone is usually well jointed. Joint frequency appears also to be increased by weathering, so that joints are more pronounced at the surface than underground.

The economic advantages of joints is representing in assessing the movement and accumulation of groundwater, hydrocarbons and other economic minerals. Joints may be tensional fractures or small shears. Their mode of formation may be shown by the correlation of disrupted structures across the joint, by ***slickensides*** or by crenulations on the joint surface. Different geological conditions produce different patterns of joints. It is not possible to predict from general theory the position of individual joints, or the precise degree of development of any set in an unexplored site, but models of joint patterns and generalities about their probable development are of use in guiding further exploration.

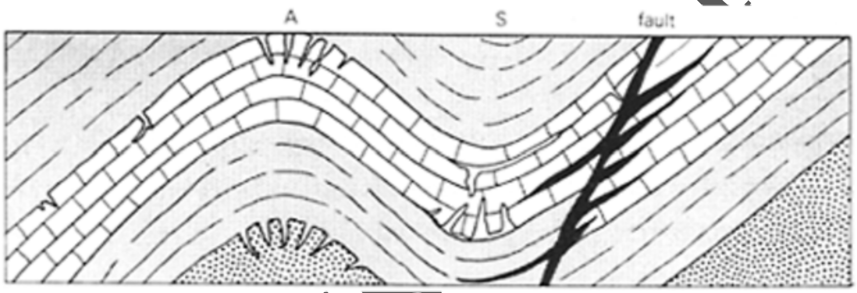


Fig. (7.18). The increased curvature of the competent limestone and sandstone layers at the axial planes of the folds (A and S) produces the radiating joints shown. Minor shears, some parallel to the fault and others belonging to the complementary set of shears, are present as joints near to the fault zone.

7.9.3 Importance of Structural Geology in Civil Engineering

The geological structures affect the safety of the engineering in different ways:

1- The presence and orientation of folds, faults and joints have significant effects on the bulk properties of rocks, and their description is an important stage in most site investigations. From the engineering point of view, their presence decrease the strength of rocks on which the engineering structures are constructed such as dams and tunnels.
2- Active faults, (those in which movements have occurred and further movements can be expected at any time) may destroy any overlying structure.

3- Chemical and mineralogical transformations along joints and fault planes reduce bearing capacity of rocks.
4- Analysis of the geometry of fractures (joints and faults) is advisable in most construction projects, for example: where excavation can take advantage of planes of weakness; where rock bolts or other strengthening devices can be placed and orientated to be most effective.
5- The geological structures have a great effect on the movement and accumulation of groundwater, hydrocarbons and other economic minerals.

REVIEW QUESTIONS

6.1 Contrast between:
a- Apparent and true dip.
b- Apparent and true thickness

6.2 Differentiate between:
a- Orogeny and epirogeny
b- Conformable and unconformable beds
c- Regular and angular unconformity
d- Joints and faults

6.3 Define the term unconformity. What conditions favor for its formation?

6.4 What conditions favor rock deformation by folding? By faulting?

6.5 Compare the movement of normal and reverse faults. What type of force produces each?

6.6 Contrast between the following:
a- Stratification and bedding.
b- Active and inactive faults.
c- Repetition and omission.

6.7 How can we identify faults in the fields?

6.8 What are the main components of a fold and a fault?

6.9 Compare and contrast between the following:
a- Anticlines and synclines.
b- Symmetric and asymmetric folds.
c- Domes and basins.
d- Anticlines and domes.

6.10 Differentiate between transform faults and other faults.

6.11 Describe how a horst and a graben are formed?

8. Topographic and Geologic Maps

The knowledge and understanding the topographic and geologic maps assess in putting the suitable design for engineering projects.

8.1 Topographic (Contour) Maps

A topographic map is a two dimensional diagram representing the horizontal projection of different elevations of an area with a specific scale, besides tying together cultural features and accurate elevations and configurations of the earth surface. In addition, it forms the base on which geological formations are indicated.

8.1.1 Importance of Topographic Maps

The importance of topographic maps in civil engineering are:

1- For proper evaluation of an area as regards its suitability for any construction project in civil engineering practice, it is essential to prepare a detailed topographic map.
2- For such map, a cross-sections are drawn at chosen sites to understand the subsurface geological status as to how the various formations continue with depth in order to estimate cut and fill and avoiding highly-cost earth works sites.
3- They are important for finding the most suitable sites for large engineering structures such as dams, reservoirs, highways, railways, pipe lines and water canals.
4- They are used for calculating the amount of water in lakes and reservoirs.
5- Also, they are very essential for military purposes.

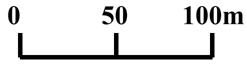
8.1.2 Components of Topographic Maps

1- **Contour line**: It is a line connecting points of equal elevation above sea level (a.s.l.).
2- Contour Interval (C.I): It is the vertical difference in elevation between any two adjacent contour lines in the topographic map.
3- Topographic Profile: It represents a vertical view of landscape as seen directly from above and give an excellent perspective for regional relations.
4- **Relief**: It is the difference in elevation between higher and lower points in the area represented by the topographic map.
5- **Legend**: It is the key of the map explains the symbols which are used as an abbreviations to indicate both natural and cultural features.
6- **Scale of the map**: It is the distance on the map to that on the ground which is:
a- Simple fraction scale: It is a fixed ratio between linear measurements on the map and corresponding distances on the ground. \it is sometimes called the ***representative fraction*** or ***R.F*,** such as 1 / 100 000.

b- Proportion scale: such as 1: 100 000.
For both simple and proportion this means that 1unit of distance on the map represents 100 000 of the same unit on the ground.

c- Absolute scale: such as 1cm = 1000 m.

d- Bar or graphic scale : It consists of a line divided into number of segments, for example



7- **Coordinates** (latitudes and longitudes).

8- **North direction** : ↑N

8.1.3 Contour Lines and their Characteristics

Topographic maps are essential tools in geologic studies because they show the configuration of the earth surface in remarkable details. This is accomplished by means of carefully surveyed contour lines. The contour line is a line connecting points of equal elevation above sea level (a.s.l.). Natural expression of contour lines are illustrated by old lake levels, raised shore lines along the coast .

The concept of contours may be clarified by considering an island in a lake and the patterns made by receding water levels. The shore line represents the same elevation all around the island and thus a contour line. Suppose that the water level of the lake should drop (3 m) and the position of the former shore line is marked by a gravel beach. Two contour lines (the lake level and the old beach) would now be indicated and each would accurately reflect the shape of the island at these two elevations. If the water level should continue to drop in increments of (3 m) additional contours would be formed. Each accurately expressing the island's configuration at different elevations. If dropped on a map the contours thus formed would indicate the shape of the island.

A careful study of topographic map reveals the following characteristics of contour lines:

1- All points located on the same contour line have the same elevation.
2- Contour lines do not cross or divide.
3- All contour intervals in the middle of the map must be closed except those located in the edges of the map.
4- A contour line with a specific value must not lie between two other contour lines with higher or lower value.
5- Closely spaced contour lines represent steep slopes , while contours spaced far apart represent gentle slopes.
6- Equal distances between contours indicate regularity of the earth surface.
7- Contour lines trend upvalley, cross the stream and return down the valley on the opposite side. Thus, contours form a V-shape which point upstream.
8- Mountain and depression areas represented by closed contours where highest value in the interior for mountains while the lowest value in the interior for depressions.

8.1.4 Determining Elevations

Elevation refers to the height above sea level (a.s.l.) and is synonymous with altitude. Specific elevations are shown on topographic maps in different ways, e.g., ***bench mark***. Elevations may be shown by color patterns and different methods are used to give the optical illusion of hills and valleys. Elevations between contour lines can be approximated by interpolation. For example, a point mid-way between the contours 40m and 60m would most likely be 50m and a point located adjacent to the 60m contour line would be probably close to 59m. Such approximations are based on the assumption that the slopes have a constant gradient and the elevation is proportional to the horizontal distance. This, of course, is not always true but a careful study of slope trends permits one to estimate elevation between contours. The local relief of an area may easily be determined by finding the highest and lowest elevations and subtracting the differences. Height and depth are measurements made relative to some other features, for example, a monument is 175m above the ground but the elevation of the top of the monument is 1175m because the area upon which it is located is 1000m above sea level.

8.1.5 Topographic Profile

Topographic maps represent a view of landscape as seen directly from above and give an excellent perspective for regional relations. This view, however, is unnatural for we are accustomed to seeing hills and valleys from the side. In detailed studies of land forms it is desirable to construct a profile or cross-section through certain critical areas so that the various features may give a more natural view. An accurate profile may be constructed quickly across any straight line on a map by following the procedure outlined below:

1- Lay a strip of paper along the line across which the profile is to be constructed.
2- Mark on the paper the exact place where each contour cut the strip.
3- Label each mark to correspond with the elevation of the contour it represents. If contour lines are closely spaced ,it is sufficient to label only the index contours.
4- Prepare a vertical scale on profile paper by labeling horizontal lines corresponding to the elevation of each contour line.
5- Place the paper with the labeled contour lines at the bottom of the profile paper, and project each contour to the horizontal line of the same elevation.
6- Connect all points with a smooth line .

Obviously the appearance of the profile will vary depending on the spacing of the horizontal lines on the graph paper. If the vertical scale is the same as the horizontal map scale, the profile will be nearly flat except on very small scale maps or in areas of extremely rugged topography. Therefore, one generally exaggerates the vertical scale to show local relief. When this is done always state the vertical exaggeration used. To determine the vertical exaggeration, divide the horizontal map scale by vertical scale. For example, if the vertical scale is such as that 1cm = 500 m, the proportion would be 1: 50 000 since there are 50 000cm in 500 m. If the map scale is 1: 150 000, the vertical exaggeration would be 150 000/50 000 or 3X.

8.1.6 Gradients

The gradient of a stream may easily be determined by measuring a representative section of the stream and dividing this distance (in kilometers) into the vertical difference (in meters) between the starting point and ending point. The result is an expression of decrease of elevation in meter per kilometer (m/km). Rivers with higher gradients and higher discharge are more potent in eroding their beds than rivers with lower gradients and lower discharge.

EXAMPLE 8.1: On a certain map, 2.8 cm is equal to 1 km on the ground. Express this absolute scale as an R.F.

R.F.= distance on map / distance on ground
R.F.= 2.8 cm on the map / 1km on the ground
It is necessary to change the denominator of the equation to centimeters, because both terms in R.F. must be expressed in the same units, so
1km * 100 000 = 100 000 cm
Now the relation is
R.F.= 2.8cm / 100 000
Then , we need to express the numerator as unity , and so the numerator must be divided by itself. In order not to change the value of the fraction, we must also divide the dominator by the same number, 2.8. So the problem resolves itself into
R.F.= (2.8 / 2.8) / (100 000 / 2.8) = 1 / 35714
or rounded off to 1 / 36000

EXAMPLE 8.2: Figure below (8.1) shows a map of an area with heights values area, it is required to draw a topographic map with contour interval 10 m. and draw its topographic profile along the line A-B using vertical scale 1cm = 10 m.

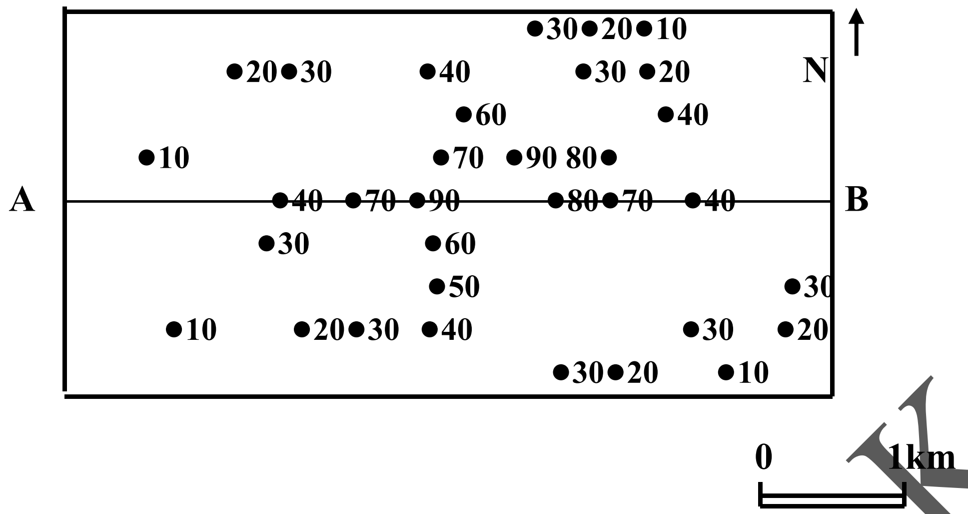


Fig. (8.1). Map for an area showing elevation points.

Answer

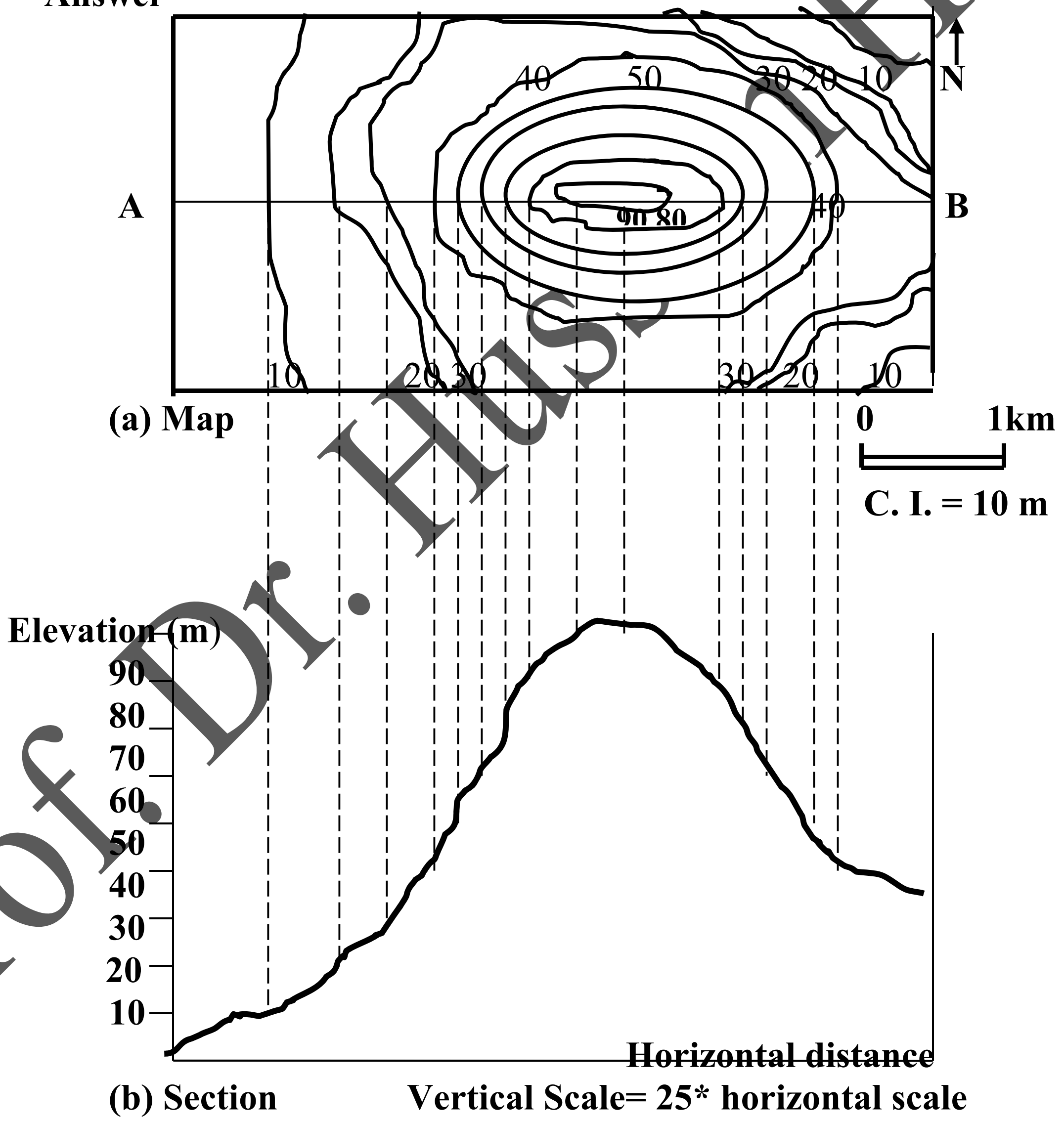


Fig. (8.2). Construction of topographic section from topographic map.

8.2 Geological Maps

A ***geological map*** (Fig.8.3) gives the details of the occurrences of geological formations , where the boundaries of the various formations and their attitude (strike and dip) are represented. Also it shows the geologic structures for strata as symbols. A geological map is, generally speaking, such a section, and the distribution of rocks in this case is the pattern of outcrops. The principal factor that may make a map more complicated than a vertical section is that the latter is a planar surface, whereas the ground surface is likely to be irregular. In order to avoid complication and to show geometric relationships clearly, both the stratigraphy and topography are kept simple. The rocks are layers of constant thickness and are without any lateral change of rock type. The ground surface approximates to a level plain except where it is dissected by river valleys. The direction of dip, the nature of folding of the strata and the amount of displacement across faults may be recognized quickly by inspection of a geological map of the area and used as a first step in analyzing the geology.

The structure of strata is usually shown on a map by symbols, such as dip arrows. A more convenient way for some purposes, where the structure is simple, is to draw contours relative to a datum and so represent the ups and downs of a particular geological interface (just as topographic contours depict the shape of the ground surface). The interface is usually a bedding plane separating two different layers. A common use of contours to depict geological structure in engineering geology is a ***contour map of rock head***, which shows the depth to solid rock and the shape of the bedrock surface. To distinguish them from topographic contours they are referred to as ***stratum contours*** or, when they are used in certain interpretative constructions, as ***strike lines*** (see next section for a full explanation). When irregularities of the ground surface are represented on a geological map by topographic contours, and when the structure of a geological interface is represented by stratum contours drawn at the same vertical interval (for example, at elevation difference of 25 m), then it is possible to construct the outcrop of the interface of the map.

8.2.1 Importance of Geologic Maps in Civil Engineering

1- Giving a complete understanding of the characteristic features of a site. The direction of dip , the nature of folding of the strata and the amount of displacement across faults may be recognized quickly by inspection of a geological map of the area and used as a first step in analyzing the geology.
2- It is essential prior to embarking on a civil engineering construction project.
3- Knowing the features including topography, nature and distribution of rocks, geologic formations, on the surface and at various depths.
4- Using such map in searching for rocks for building and industrial purposes

(bricks and cement manufactures).
5- Indicating the occurrences of weak zones , nature and thickness of weathered zones and soil cover.
6- Identifying the drainage pattern in the area and the situation of the groundwater table.
7- Reducing investigation processes to its minimum.
8- Choosing the best site for a suggested project or refusing it prior construction.

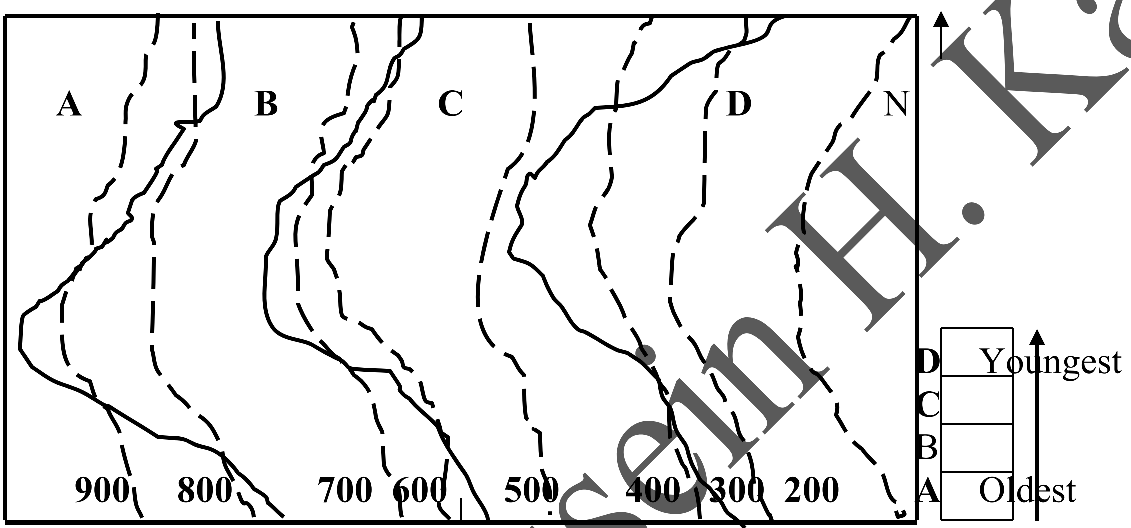


Fig. (8.3). A simple geologic map showing four inclined layers A, B, C and D.

8.2.2 Components of the Geologic Maps

The outcrop of a body of rock, such as a layer of shale, is the area that emerges at the surface where the rock is present, or lies immediately below a cover of vegetation, soil, or other superficial deposit. Those parts of the outcrop where rock is visible at the surface, and where observations may be made, are called ***exposures***. Exposures are usually found in the banks of streams, in road cuttings, on cliff or scarp faces, and in quarries. A ***geological map*** is an Ordnance Survey map, showing locations and topography, on which is superimposed geological information. This includes exposures, inferred outcrops and the nature of the boundaries between them, any deformation of the rocks such as fracturing or other observations, and a ***geological legend*** at the side of the map, explaining the symbols and colors used. Large geological departments in commercial companies and government scientific bodies, such as the **British Geological Survey** (***BGS***), have a prescribed set of geological symbols for use in their reports and maps. Each is known as the ***standard legend*** of the particular organization. Maps in this book conform to the standard legend of the ***BGS***. An arrow is used to indicate the precise location of an exposure and the inclination ***(dip)*** of any original layering (***stratification***). The arrow points in the direction of dip, and the amount of dip, measured from the horizontal in degrees, is given as a figure close to the tip of the arrow, which marks the precise location of the exposure; the observations refer only to what is seen there and not to the entire area straddled by the arrow. For horizontal and vertical layers, the position of the exposure is where the two bars of the symbol cross. The geologic maps characterize by presence the following components:

1- Contour lines which usually appear as dashed lines.
2- Geologic boundaries which are represented as solid lines intersect the contours for inclined beds but are parallel for horizontal beds.
3- Each geologic bed is expressed by a symbol indicating its type. For examples see the below Figure (7.4).

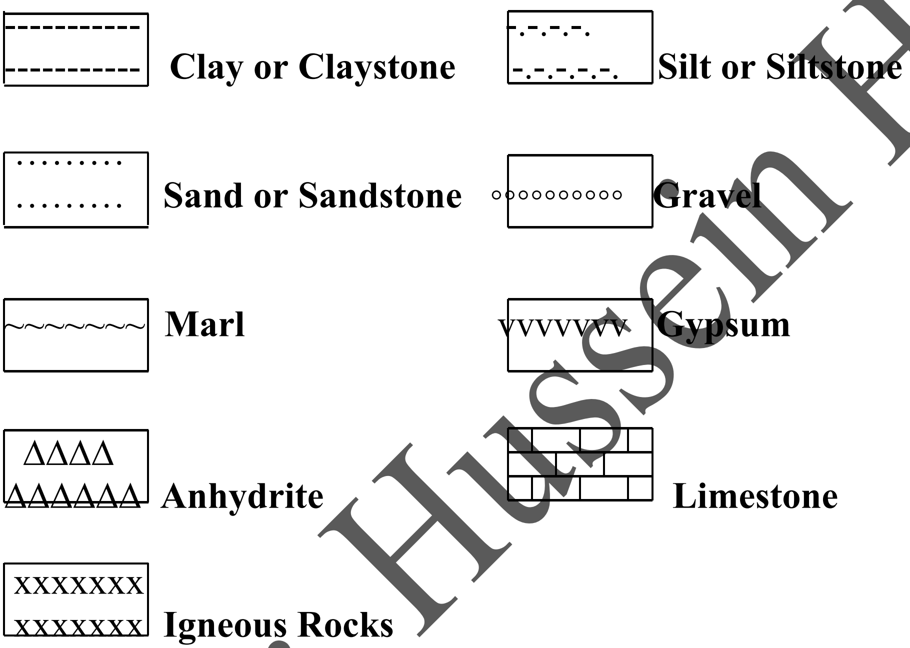
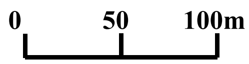


Fig. (8.4). Examples of some symbols used for geologic layers.

4- Legend: It is the key of the map explain the symbols .
5- Scale of the map: which is
 Simple fraction scale: such as, 1 / 100 000 .
 Proportion scale: such as 1 : 100 000 .
 Absolute scale :(1cm = 1000 m).
 Bar scale: for example



6- Coordinates (latitudes and longitudes).
7- North direction: N ↑

An outcrop of younger strata completely surrounded by older strata (the older beds being those occurring below the younger in the vertical succession of strata) is called an ***outlier***. An outcrop of older strata surrounded by younger is called an ***inlier***.

The distribution of rocks on a vertical plane (comparable to an 'elevation' in engineering drawing) below a particular line at the surface is called a ***vertical geological section*****,** or more simply a ***section***. A geological model of an area ABCD showing outcrops, and the section AB across it, are presented in Figure 7.5. This figure shows a block model showing the relationship between the outcrops and topography on the upper surface ABCD and the section AB. Contours at +100 and +200 m are drawn on the map. An exposure of the sandstone layer near the river is indicated by the dip arrow, and the figure 21 beside it gives the angle of dip in degrees**.** The figure also shows, within a scaled frame of a datum plus vertical and horizontal scales, what would be seen if a vertical cut were made through the earth along the line AB to reveal the side facing the viewer. The topographic profile of the ground surface shows the rises and falls along the same line. Sections are a conventional way of presenting information about the distribution of rocks below the surface. It is common practice to assist comprehension of a geological map by drawing one or more representative sections below it, and to present geological information needed for planning and costing excavations, such as tunnels, by drawing a section along the proposed line.

The relationships between the shape of the ground surface (that is, the topography), the outcrops, and the structure in idealized models in which layers are constant in rock type and in thickness over the area of the map, are discussed in this chapter. The relationship between surface geology and a section is also illustrated, and the way in which the section may be drawn is discussed. The construction of more elaborate sections, which combine structural deformation with stratigraphic change laterally and are based on real geological maps and reports, is also discussed.

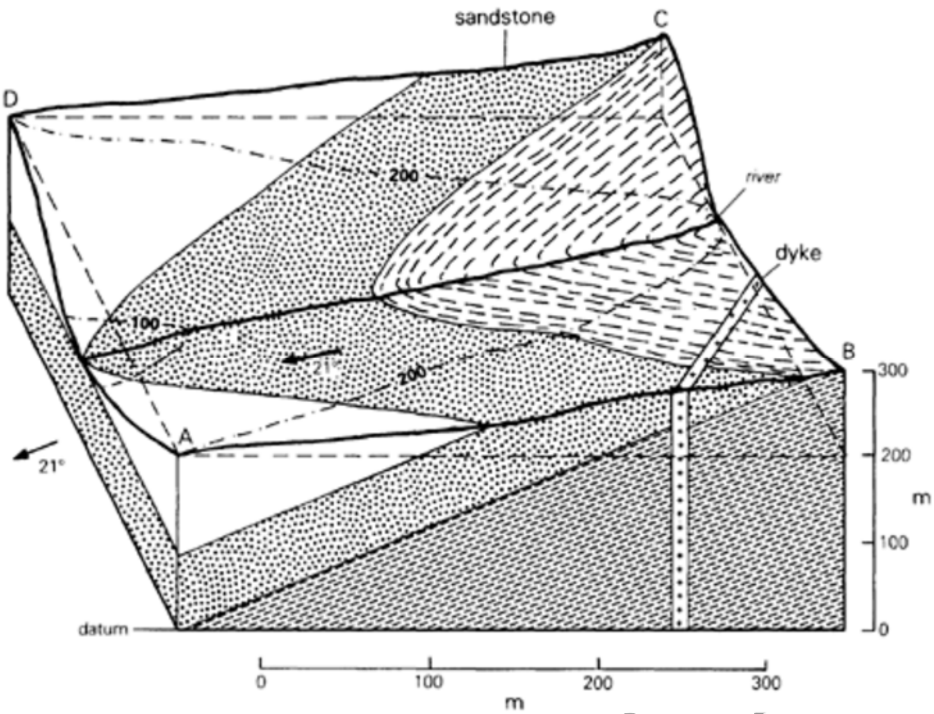


Fig. (8.5). A block model showing the relationship between the outcrops and topography on the upper surface ABCD and the section AB. Contours at +100 and +200 m are drawn on the map. An exposure of the sandstone layer near the river is indicated by the dip arrow, and the figure 21 beside it gives the angle of dip in degrees.

8.3 The Principles of Uniformitarianism and Superposition

A guiding principle of geology is that "***the present is the key to the past***". This concept is expressed more formally, and more fully, as the ***Principle of Uniformitarianism*,** which states that the processes that created and moulded the rocks of the earth in its past are by and large the same as those active today. Volcanic activity, which produces igneous rocks, and the deposition of eroded fragments to form sedimentary layers, proceeded in similar ways, if at different rates, in the past as they do at the present time. The earth's surface had environments—shallow seas, river deltas, deserts—similar to those found now, though not necessarily in the same places. The geography of our planet has changed continually, but the general physical conditions that may be found have remained qualitatively more or less the same for thousands of millions of years. The relative areas of seas, mountains, deserts and ice sheets have varied considerably, however, as time passed. The principle of ***Uniformitarianism*** is a particular version of one of the foundation stones of scientific thought; that is, the premise that the same laws can be applied to understanding the distant parts of our Universe, the frontiers of both space and time, as those derived from observations on earth at the present time. There is the qualification that human experience of limited space and time must be inadequate as a basis on which to conceive an infinite Universe, just as the terms of everyday experience are an inadequate language in which to express some modern cosmologies.

The processes that have produced rocks in the earth's past may be understood by studying how many rock types are being formed at the present. The cooling and solidification of a modern lava flow can be seen to create a layer of fine-grained igneous rock, such as basalt. It may be inferred that similar, but older, layers of basalt are ancient lava flows, and are a record of volcanic activity in the past. Each is an event in the ***geological history of the area***.

Each different rock layer is a record of a past event, and the sequence of events (that is, the geological history of the locality where they are observed) may be inferred using the ***Principle of Superposition***. This states that if one layer B lies above another A, then B was formed after A and is younger than it—unless it can be shown that the layers have been inverted from their original position by later earth movements. It may be possible to identify the original top and bottom of a layer by a way-up criterion such as graded or cross bedding (see Fig. 8.6).

The relative ages of rocks and of the structures that deform them may also be inferred from other observations. For example, the presence of pebbles of granite in a conglomerate shows that the granite is older. Other examples are given in Figure 8.6.

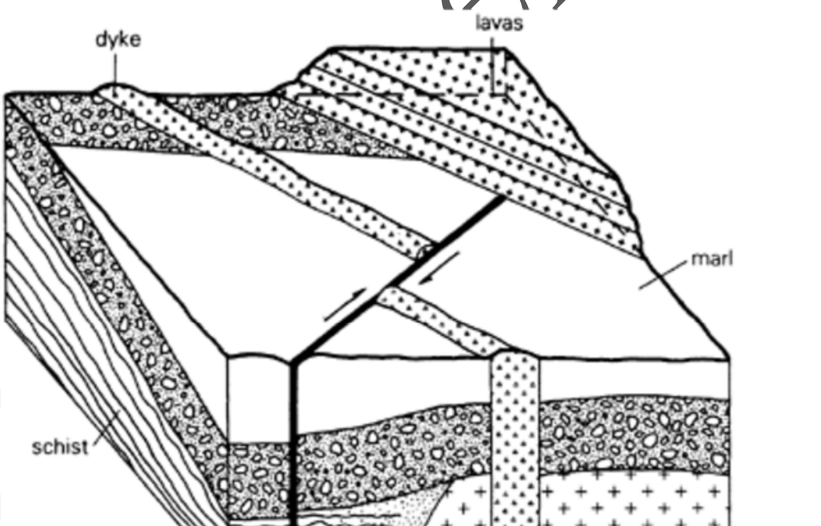


Fig. (8.6). The relative ages of rocks and geological events may be inferred from geometrical relationships and from the nature of some rocks. An example of the former is shown in the figure, where the superposition of the lavas on all other beds can be seen: the fault demonstrates that the lavas are the youngest strata present ; also, the emplacement of the dyke in the marl shows that the dyke is younger than the marl, and the displacement of the dyke by the fault shows that the fault is younger. Pebbles of the granite in the conglomerate confirm that the granite is older, and the thermal aureole in the schist shows that the granite is younger than the schist.

EXAMPLE 8.3: For the below Figure (8.7), it is required to:

1- Arrange the geologic layers and events with respect to their geologic history from the oldest to the youngest .

2- What are the composition of each layer.

3- List the number of geologic layers and events .

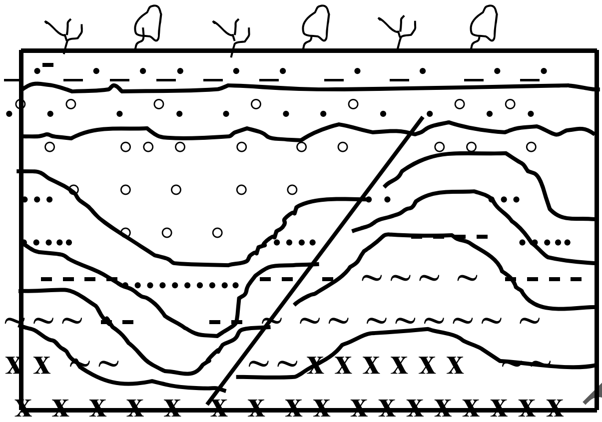
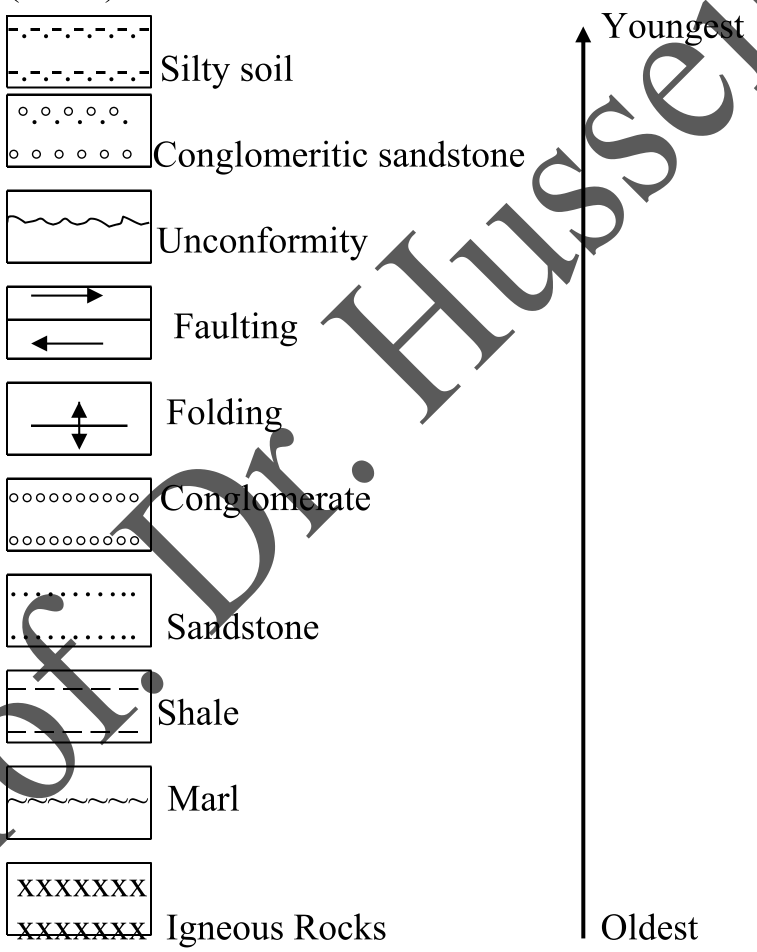


Fig. (8.7). Example 8.3

Answer

(1 & 2)



3- The number of geologic events are three: folding; faulting; and unconformity. The number of geologic layers are six.

8.4 A Procedure for the Determination of Strike and Dip of any Bed

Each bed has two surfaces of ***contact*** , the upper surface and the lower surface. For the determination of dip, we can choose any contact surface (***boundary)***. Since the dip is the angle of inclination of the surface with the horizontal plane, we can estimate the inclination if we have two horizontal lines on this surface, each situated at a particular height. The slope can be found out if the distance between these two lines and the difference in their altitudes are known (Fig.7.8). In a geological map, we can draw two strike lines for any contact surface. A ***strike line*** is a horizontal line on the plane along which all points are at equal height. Hence, for drawing the strike lines , points are chosen where a contour line cuts the particular contact surface. Two such strike lines at 900 m and 800 m are drawn for the contact surface between layers **A** and **B** (Fig. 8.9). If we take the shortest distance between these two strike lines we can construct the slope with the help of the height difference between them as shown in the figure . Point **X** is 100 m higher than point **Y**. Therefore, the contact surface can be drawn as in Fig. 7.9 and the angle (**θ**) it makes with the horizontal is the dip. Layer **A** is dipping in the direction of **Y** (Fig. 8.9). If we take the distance between these two strike lines in any other direction than the shortest distance, we get the apparent dip.

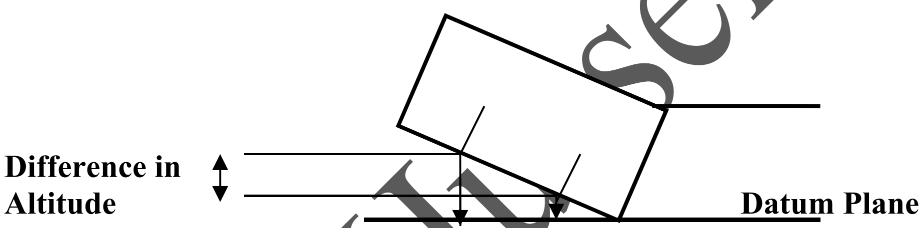


Fig. (8.8). Strike lines on an inclined plane.

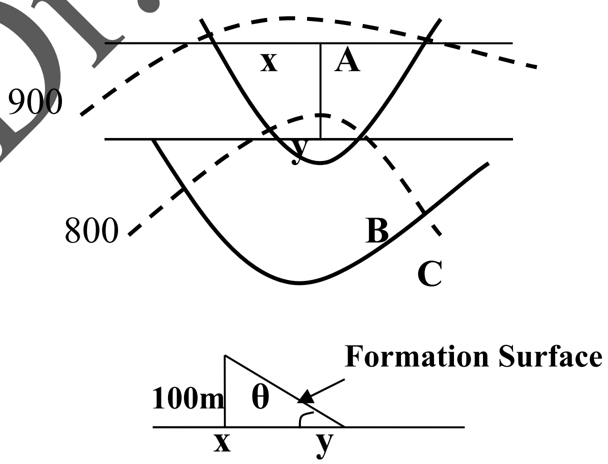


Fig. (8.9). A procedure for drawing strike lines and construction of dip for a formation surface.

Since all contours are parallel, the strike lines for any surface will be naturally parallel. If we get only one intersection point of the contact for a contact surface, we can draw a strike line for that surface parallel to the other strike lines.

The altitude of the bedding plane along its outcrop may be read directly from the map using the topographic contours that cross the outcrop. For example, in Figure 8.10 the bedding plane separating the sandstone and marl is at an altitude of 400 m at **A** and **C**, and at 350 m at **B**. Strike lines are drawn by joining points of equal altitude, for example **A** and **C**. A straight line is drawn as the simplest geometry of the bedding plane consistent with the observations. In practice, there is a partial check on the assumption that no fold (that is, change of dip and strike) is present between **A** and **C**. The apparent dips seen on the sides of the valley (that is, along **AB** and **CD**) are constant, and barring the presence of a very local, very complex and very unlikely structural peculiarity restricted within the area **ACD**, the assumption that the true dip does not change is valid. Nevertheless, the strike lines, and hence the structure, are ***inferred*** and not ***deduced***.

If strata are horizontal, then the entire surface of each bedding plane lies at the same altitude, and outcrops are parallel to topographic contours (Fig. 8.11). In this case the position of the outcrop of any bed is ***dependent entirely*** on the topography. Conversely, the presence of horizontal beds on a map may be recognized by inspection, from the control that topography has on their outcrops.

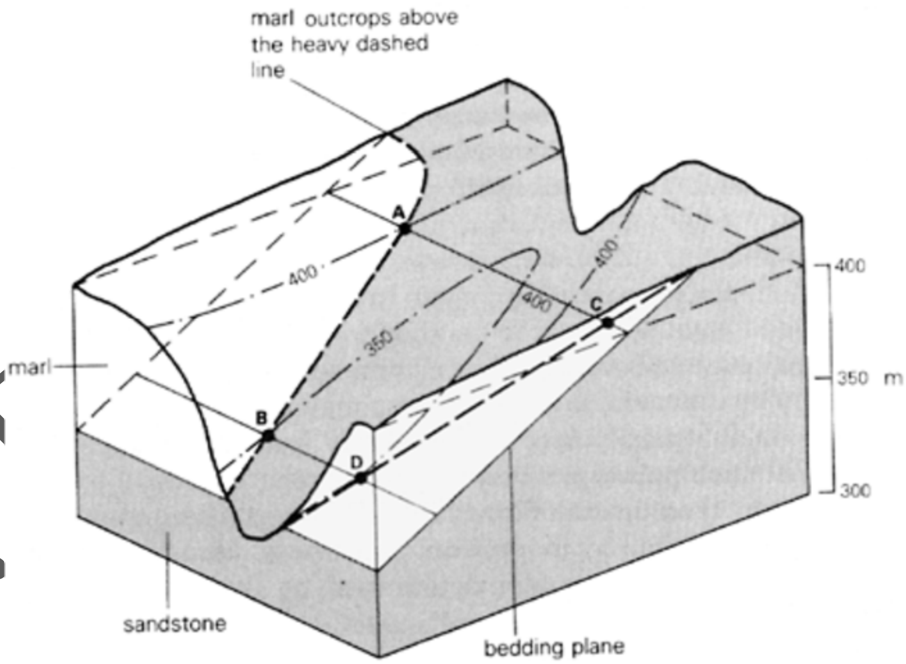


Fig. (8.10). A block model showing a layer of marl overlying sandstone : the outcrops of the bedding plane between marl and sandstone on the valley sides are shown, together with strike lines at +400 m from A to C, and at +350 m from B to D.

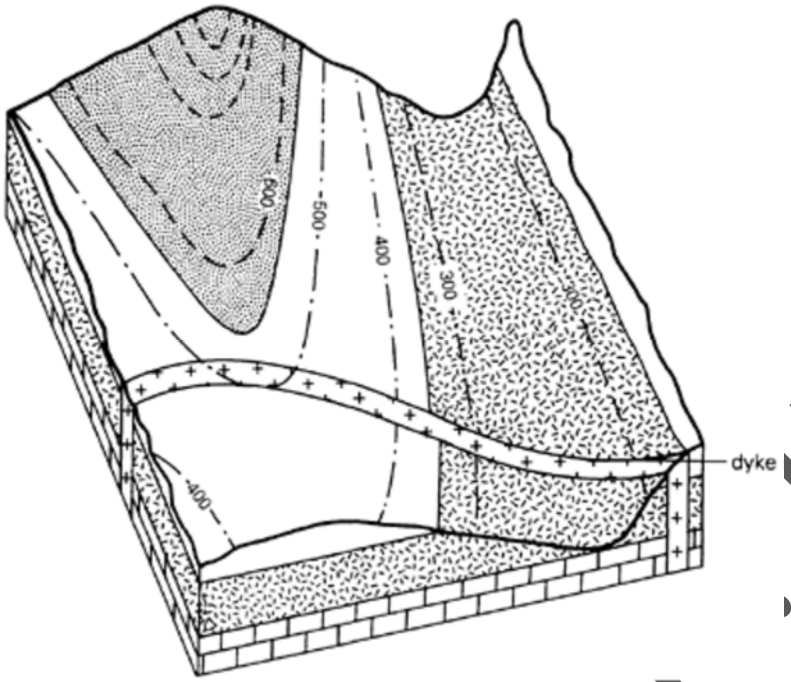
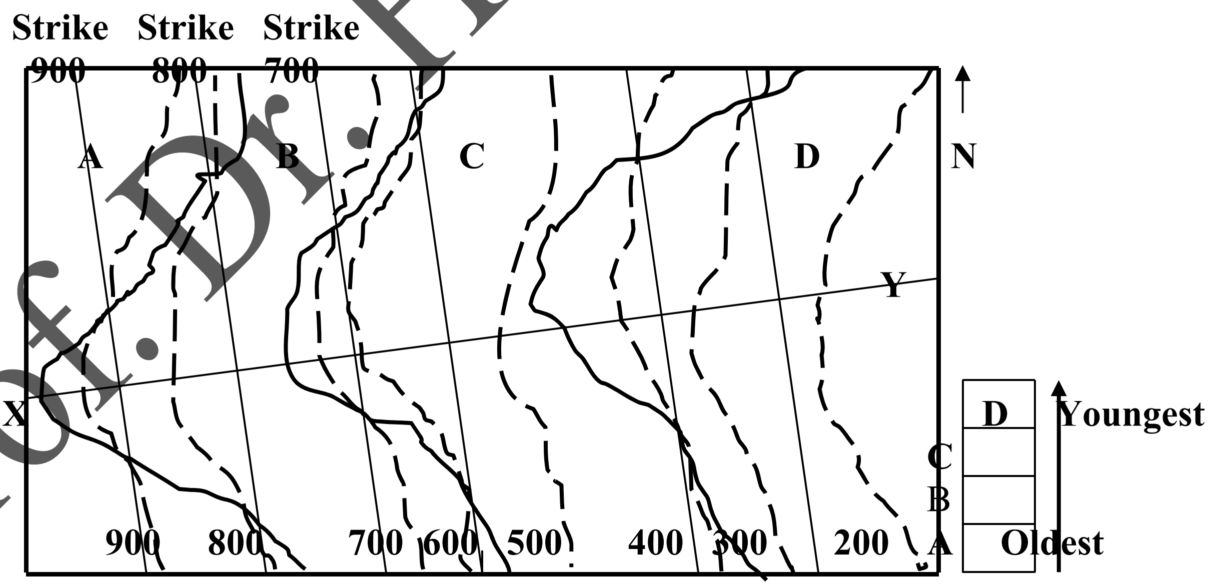


Fig. (8.11). A block model showing a sequence of horizontal strata cut by a vertical dyke, and their relationship to the irregular upper surface of the block. The hill and valley are shown in profile, and are also defined by topographic contours drawn on a 100 m interval. The distribution of outcrops on a map is similar to that portrayed on the upper surface . The horizontal layers are parallel to the contours , but the outcrop of the vertical dyke is a straight line and is completely independent of the contours.

EXAMPLE 8.4: Showing the Procedure for Drawing a Geological Map.



Vertical Scale : 1cm = 200 m.

Fig. (8.12). A geologic map for Example 7.4.

In our example 8.4, after drawing strike lines and finding its direction taken with north direction which is (N 8˚ W) and with south direction is (S 8˚ E). While the dip direction is perpendicular to strike lines toward decreasing altitudes and found (82˚ NE). To find dip value, two methods are introduced, mathematical and graphical methods.

8.5 Calculating Dip

8.5.1 Mathematical Method for Calculating Dip

It is worth to mention that the strike interval is defined as the vertical distance between two adjacent strike lines which is measured with a ruler. In our previous example, it is found to be with an average 1.1 cm. Besides, the contour interval is 100 m, then the expression (8.1) for finding the dip angle is:

$$\tan\theta = \frac{\text{Contour Interval (C.I)}}{\text{Strike Interval (S.I)}} * \text{Scale} \quad (8.1)$$

$$\tan\theta = \frac{100\text{ m}}{1.1\text{ cm}} * \frac{1\text{ cm}}{200\text{ m}} = \frac{1}{2.2}$$

$$\theta = 24.4^\circ$$

This dip value will be used after drawing the topographic profile as explained later.

To draw the geologic cross-section ,as an illustration, consider the map given in Figure 7.12, it is required to draw a geologic cross-section along the line **X-Y**. The procedure is as follows:

1- Draw line **XY** to scale on a sheet of paper. Mark the points of intersections of the contour lines on the line.

2- Raise the points to their respective altitudes.

3- Join the raised points by a smooth profile which now represents the ground surface (Fig. 8.13).

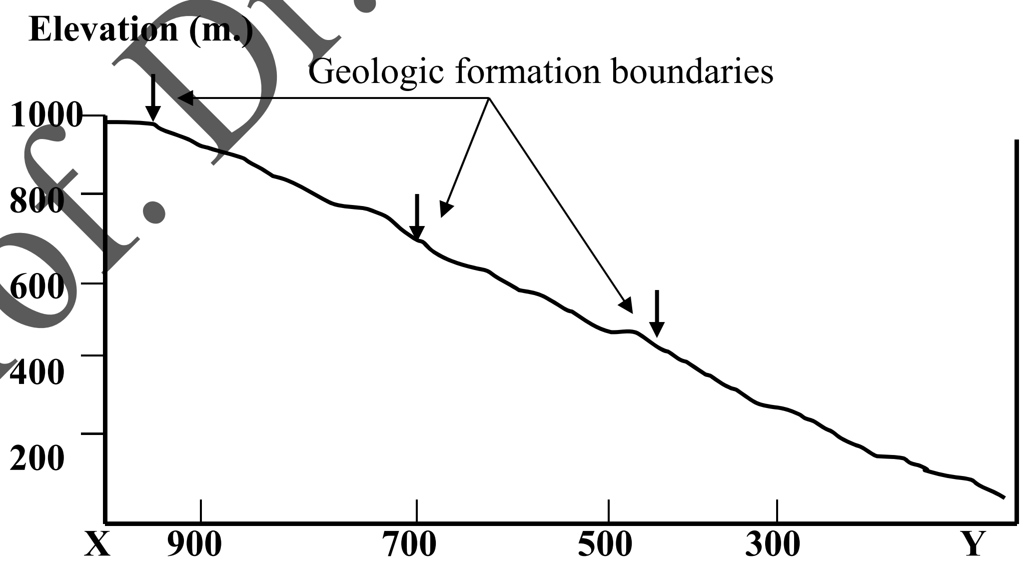


Fig. (8.13). Topographic profile along the line X-Y shown in Figure 7.12.

4- Transfer the points of intersection of contact surfaces for the geological layers along **X-Y**.
5- Raise the points vertically on to the ground surface already obtained in the profile.
6- By choosing strike lines, construct the dips for the layers and draw them in the profile at their respective positions. For convenience in drawing, the normal procedure is to draw a horizontal line parallel to the base line of the section and construct the dip as shown in Figure 7.12 . Then draw the planes on the section parallel to this surface (already drawn in the figure). Instead of using the strike values, we can use the calculated dip value by the mathematical method and draw a line from the raised layer boundaries dipping at an angle 24.4° with the horizontal toward point **Y** in NE direction.

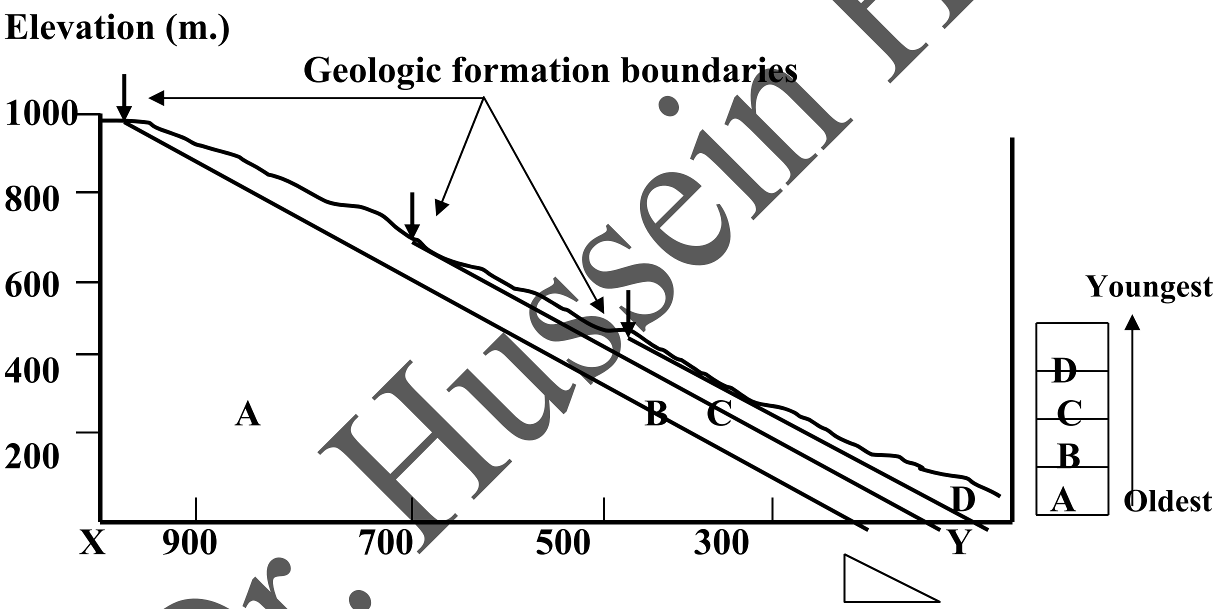


Fig. (8.14). Geological section along X-Y (in Fig. 8.12).

8.5.2 Graphical method for Calculating Dip

The amount of dip may be calculated graphically by taking any two adjacent strike lines intersecting the same layer boundary (i.e. either the upper or the lower boundary). In our above example, let the two strike lines 800 and 900 that intersect the upper boundary of the rock layer **A** (between layers **A** and **B**). Then raise these two strike points to their respective heights as they are elevation points. After that join the raised two points with the layer boundary (in our case upper boundary of layer **A**) by a straight line, so by this way the upper boundary of layer **A** (or the lower boundary of layer **B**) will be delineated. Then from the previously delineated positions of the other layer boundaries, construct parallel lines to that of layer **A**. Thus, we get a geological section along **X-Y**. The amount of dip can be calculated by using the protractor measured with respect to the horizontal.

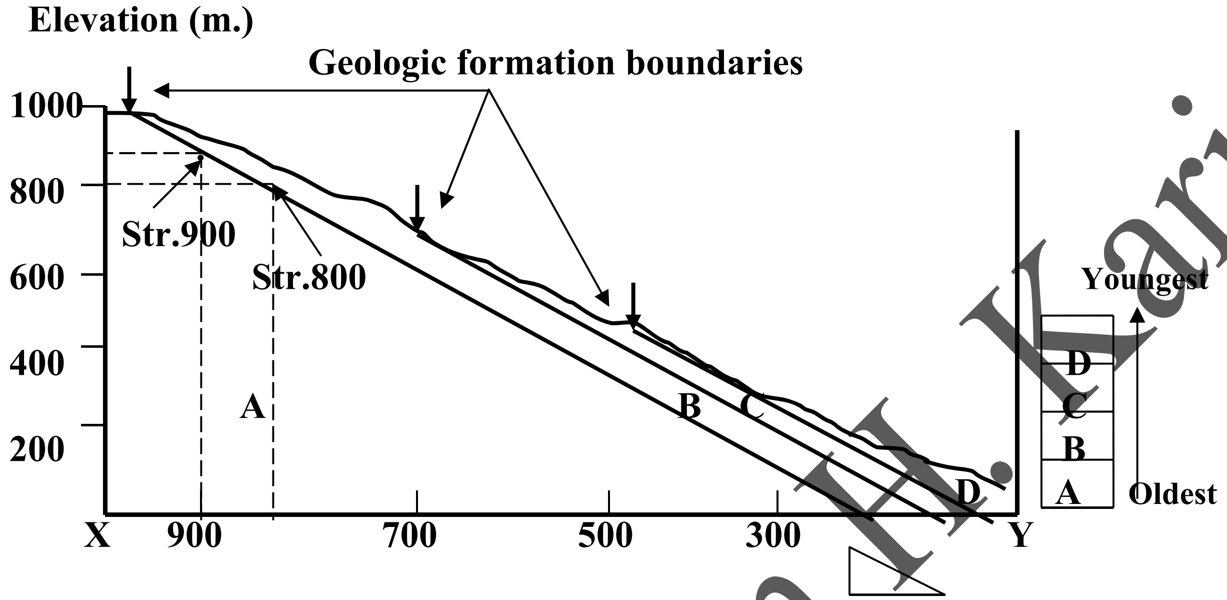


Fig. (8.15). Geological section along X-Y (in Fig. 8.12).

Thus the final results of the above example (Example 7.4) using both methods are as follows:
Strike direction : N 8˚ E
Dip direction : 82˚ NE
The amount of dip : ≈ 25˚

8.6 Finding True and Apparent Thicknesses for Layers

As most of the geologic layers are inclined, so the thickness of a layer is measured from the ground surface will not give the true thickness of such layer but it is really the apparent thickness(or the vertical thickness). To find its true thickness, the following expression (7.2) is used (Fig.7.16):

$$\cos\theta = \text{True Thickness / Apparent (Vertical) Thickness} = D / Z \qquad (8.2)$$

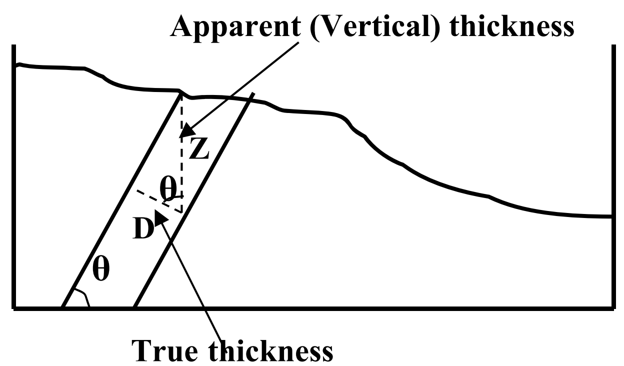


Fig. (8.16) Calculation of true and apparent thicknesses.

When the dip angle is not exceeding 5˚ then the true thickness is approximately equals the apparent thickness. Besides in our example, we could not find the thicknesses for both the 1st as it is subjected to erosion and the 2nd layers as it is unknown extension.

Final Results of the above Example (8.4)

The final results are as follows:
Strike direction: N 8˚ W
Dip direction: 82˚ NE
Dip Value: 24.4˚ ~ 25˚
Layer-A is the oldest; and Layer-B is the youngest .
Layer thicknesses: We could not find the thicknesses for both the 1st as it is subjected to erosion and the 2nd layers as it is unknown extension.

REVIEW QUESTIONS AND PROBLEMS

8.1 Define and give short notes oh the following terms :
Gradient
Contour interval
Relief
Topographic profile
Principle of superposition
Map Legend

8.2 What are the general characteristics of contour lines?

8.3 What are the main features of topographic maps?

8.4 Give examples for some geologic symbols used in geologic maps?

8.5 Show what of the following statements indicate:
a- The closely spaced contour lines.
b- The widely spaced contour lines.
c- The V shape contour lines.
d- Circular contour lines with increasing values toward the center of the closure.
e- Circular contour lines with decreasing values toward the center of the closure.

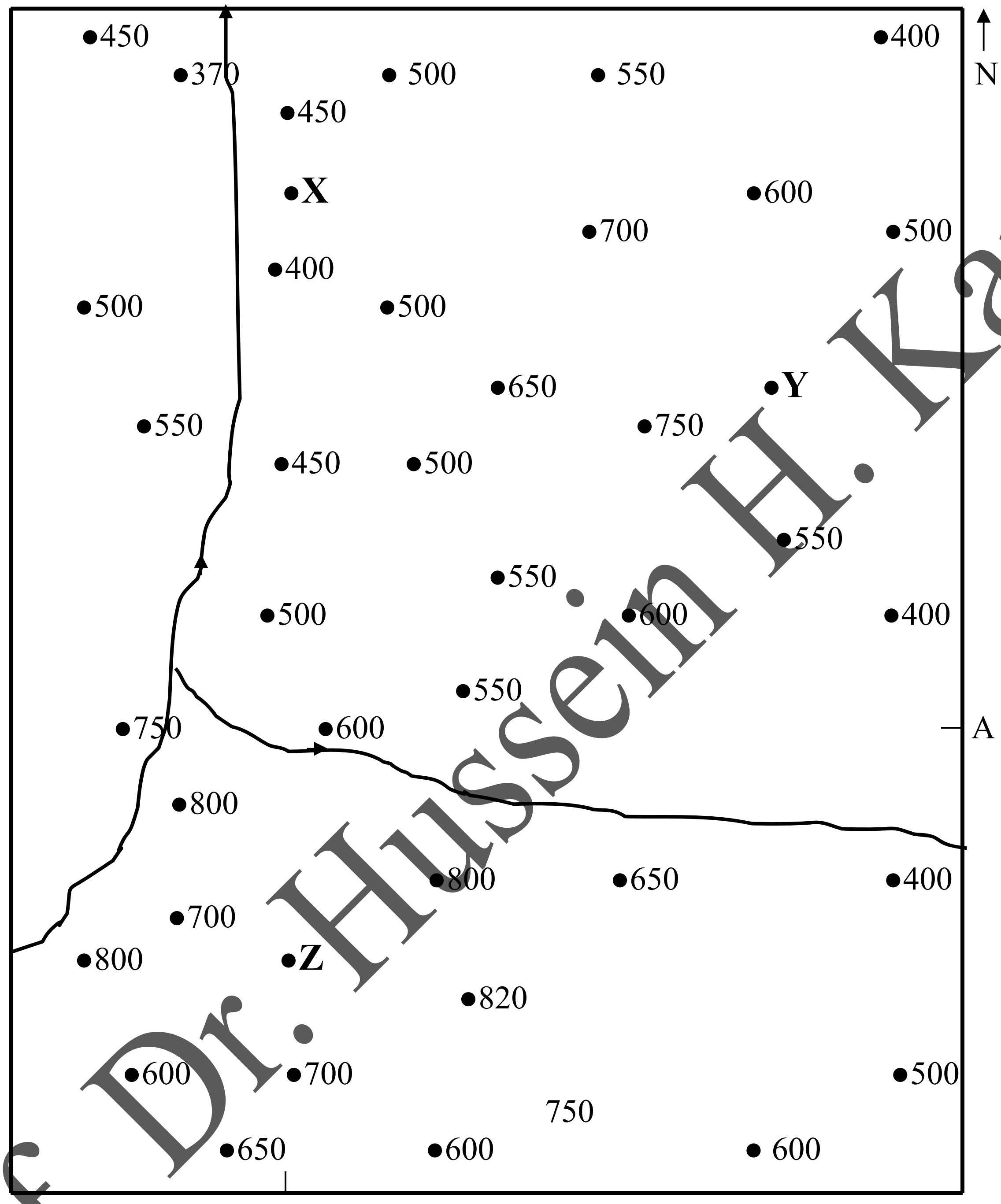
8.6 Convert the following representative fractions to ground distances equal to one centimeter on a map:
a- 1 : 1000 000
b- 1 : 48 000
c- 1 : 250 000

8.7 Convert an R.F. of 1 / 25 000 to an absolute scale in terms of centimeters per kilometer, how many kilometers on the ground are represented by 1centimeter on the map?
(Ans. 1 cm on the map =125 000 cm on the ground ; 1.25km)

8.8 A map has an R.F. of 1 / 500 000. How many kilometers on the ground are represented by 10 centimeters on the map?

8.9 A map of unknown scale shows two TV transmitting towers . On the map , The towers are 1.2 cm apart and the actual ground distance between them is is 1000m. What is the R.F. of the map?

8.10 For the below map (Fig. 8.17):



B

Scale 1 cm. = 100m.

Fig. (8.17). Problem 7.10.

It is required to find :

1- Draw a topographic map with contour interval of 100m.
2- Draw a cross-section from point **B** at an angle N20◦ E.
3- Draw a cross-section from point **B** at an angle N85◦ W.
4- Describe the topography of the area along the above cross-sections.
5- Find the elevations in meter (a.s.l.) for the points; **X**,**Y** and **Z**.

8.11 For the below geologic Map (Fig. 8.18):

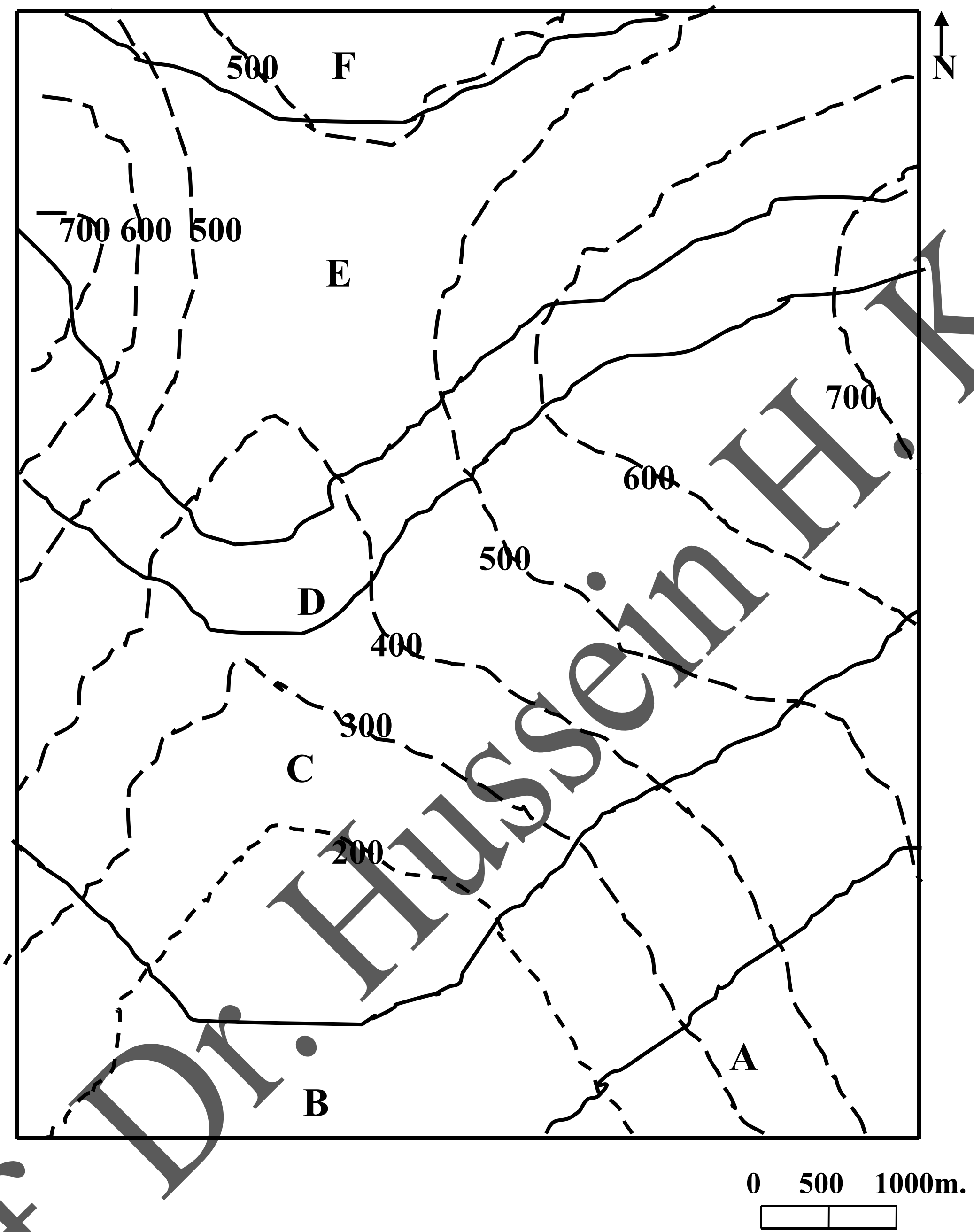


Fig. (8.18). Problem 8.11.

The solid lines represents the geologic boundaries separating the exposures of the inclined layers **A**, **B**, **C**, **D**, **E**, and **F**. It is required to:

1- Draw the strike lines for each layer.
2- Find the direction of the layers strike line.
3- Find the direction and amount of dip of the layers assuming the dip is regular.

8.12 For the below geologic map (Fig. 8.19):

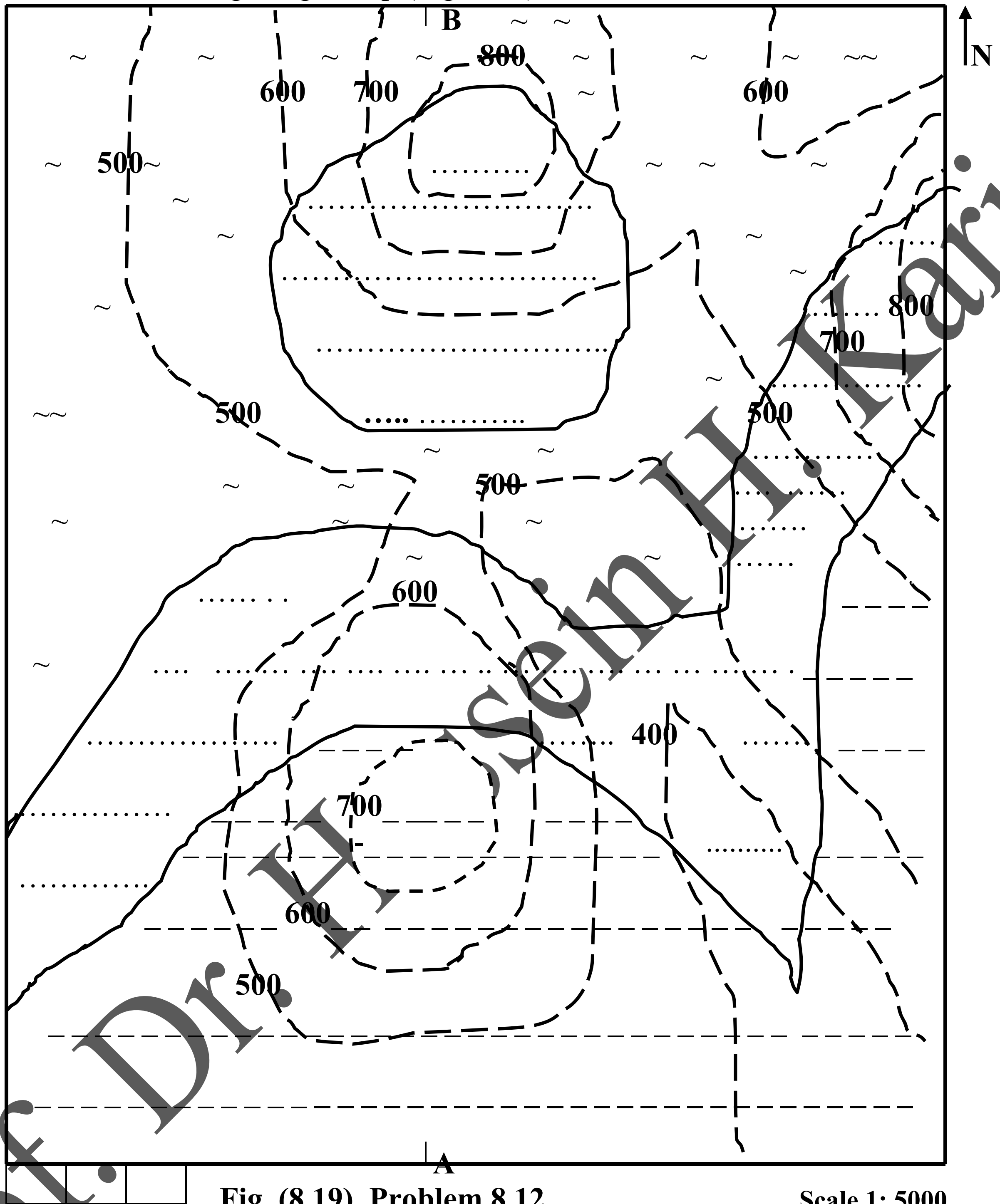


Fig. (8.19). Problem 8.12. **Scale 1: 5000**

It is required to:

1- Describe the topography of the area.

2- Find the direction of the layers strike lines and the direction and amount of dip of the layers.

3- Draw a geologic section along the line **A-B** to explain the layers structure.

4- Find the true and apparent thicknesses of each layer.

5- Fill the empty rectangles by the suitable layer symbols showing the oldest and youngest layers.

6- Show the priority of the events in the area.

8.13 For the below geologic map (Fig. 8.20):

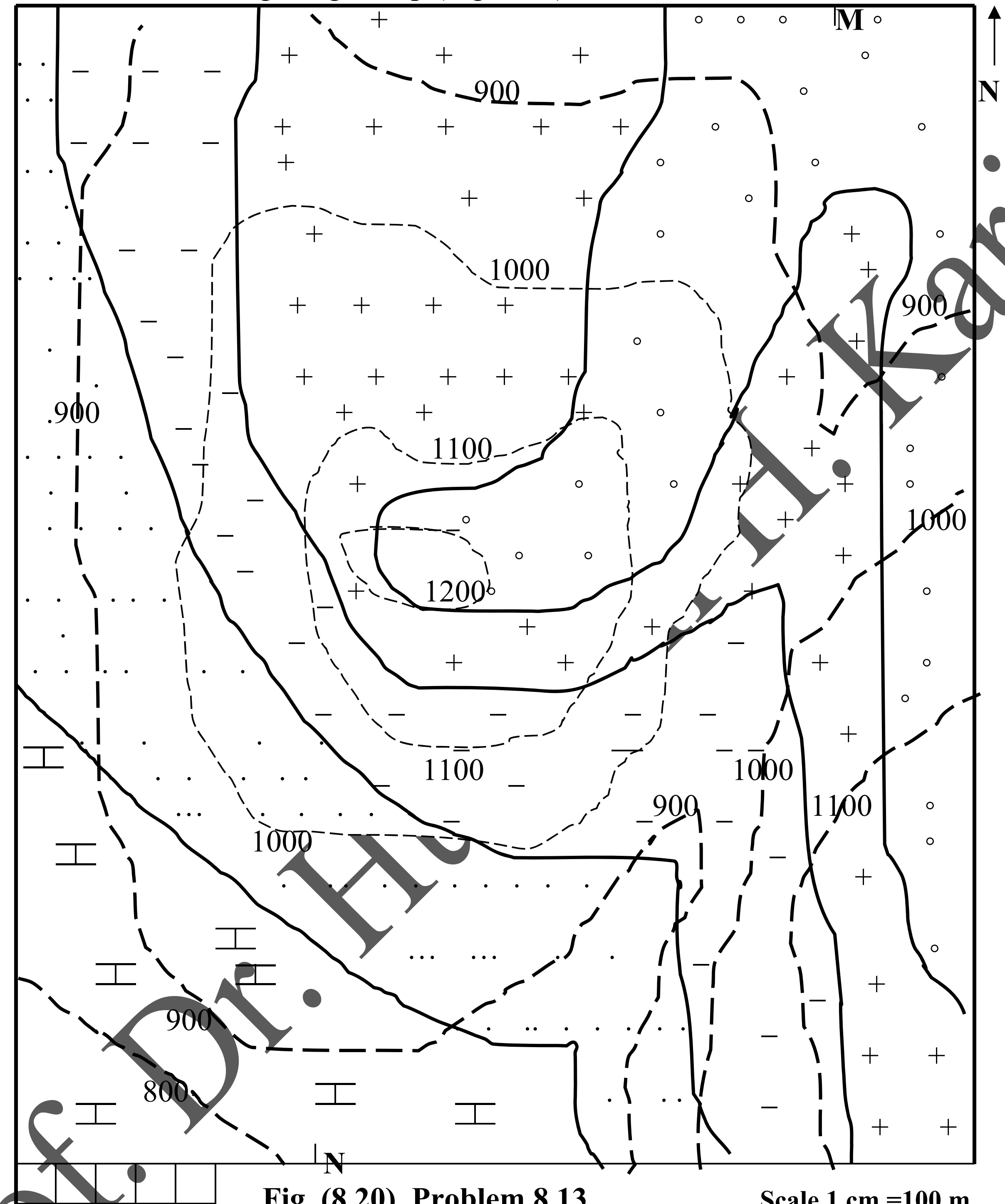


Fig. (8.20). Problem 8.13. **Scale 1 cm =100 m.**

It is required to:

1- Describe the topography of the area.

2- Find the direction of the layers strike lines and the direction and amount of dip of the layers.

3- Draw a geologic section along the line **M-N** to explain the layers structure.

4- Find the true and apparent thicknesses of each layer.

5- Fill the empty rectangles by the suitable layer symbols showing the oldest and youngest layers.

6- Show the priority of the events in the area.

8.14 For the below Figure (8.21); It is required to:

a- Arrange the geologic layers and events with respect to their geologic history from the oldest to the youngest.

b- What are the composition of layers **L**, **A_1** and **A_2**.

c- List the number of geologic layers and events.

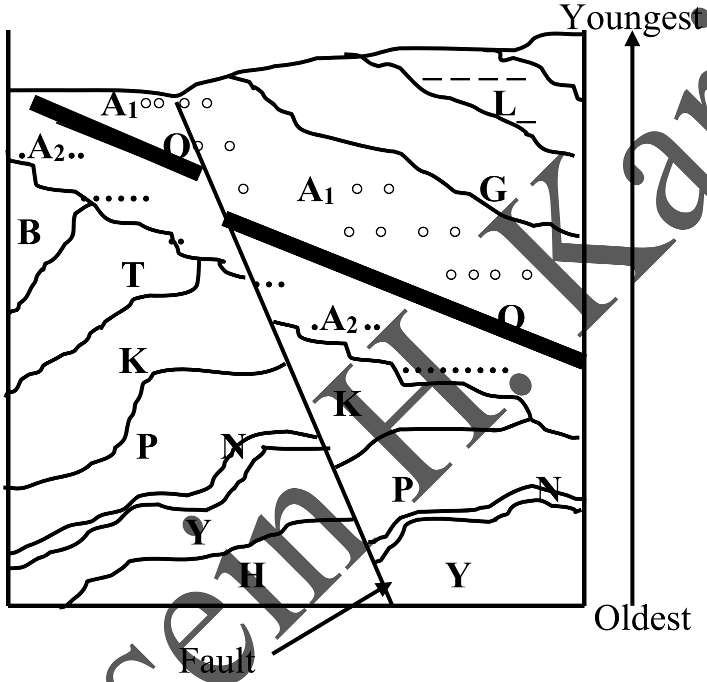


Fig. (8.21). Problem 8.12

8.15 For the below Figure (8.22), it is required to:

a- How many sedimentary layers are appeared in the diagram.

b- What are the igneous structures in the diagram.

c- What are the metamorphic rocks that are formed on both sides of the volcano.

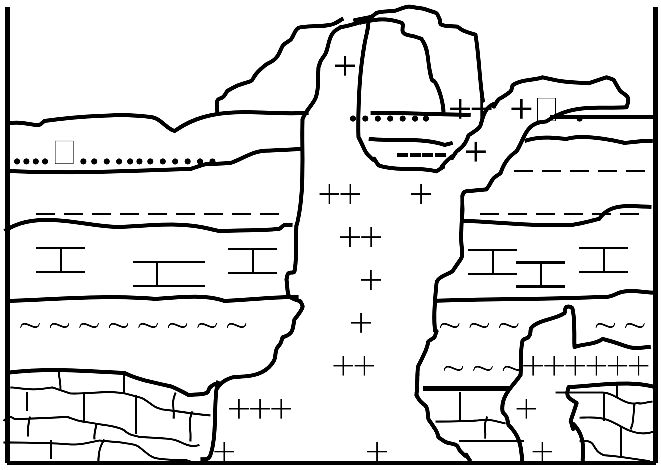


Fig. (8.22). Problem 8.15

8.16 What are the main characteristics of
a- Topographic maps
b- Geologic maps

8.17 Discuss the statement "***the present is the key to the past***" with respect to the principle of superposition.

References

Ambraseys, N. N. and S. K. Sarma. (1967). The response of earth dams to strong earthquakes. Geotechnique 17 , 181–213.

Arora, K. R. (2009) . Soil Mechanics and Foundation Engineering . Seventh Edition. Standard Publishers Distributors. 953P.

Das, B. M. (2006) . Principles of Geotechnical Engineering . Fifth Edition. Thomson Canada Limited. 589P.

Folk, R. L. (1974). Petrology of Sedimentary Rocks . Hemphill Publishing Company. 182P.

Derringh, E. (1998). Computational Engineering Geology. Prentice - Hall, Inc. 323 P.

Fetter, C. W. (2007). Applied Hydrogeology. Second Edition. CBS Publishers& Distributors. India. 592 P.

Gokhale, K.V.G.K and D. M. Rao. (1981). Experiments in Engineering Geology. TATA McGraw-Hill Publishing Company Limited, New Delhi. 142 P.

Goodman, R. E. (1989). Introduction to Rock Mechanics. Second Edition. John Wiley & Sons, Inc. 552 P.

Hobbs, B. E., W. D. Means and P. F. Williams (1976). An Outline of Structural Geology. John Wiley & Sons, Inc. 552 P.

Lutgens, F. K. and E. J. Tarbuck. (1982). Essentials of Geology. Second Edition. Merrill Publishing Company. 346 P.

Mclean, A. C. and C. D. Gribble (1985). Geology for Civil Engineers. Second Edition . E & FN SPON. 333 P.

Milligan, G.C. (1977). The Changing Earth . McGraw - Hill Ryerson Limited. 706P.

Montgomery, Carla W. (2006). Environmental Geology. Seventh Edition. Mc-Graw Hill Companies, Inc. 540P.

Raghunath, H. M. (2009). Ground Water. Third Edition. New Age International Publishers. 504P.

Reeves, G.M., Sims, I. and Cripps, J.C. (Editors). (2006). Clay materials used in construction. Geological Society Engineering Geology Special Publication No. 21. Published by Geological Society of London. 525 P.

Sharma, P. V. (1997). Environmental and Engineering Geophysics. Cambridge University Press. 475P.

Zumberge, J. H., R. H. Rutford and Carter, J. L. (2003). Laboratory Manual for Physical Geology, Eleventh Edition. Mc-Graw Hill Companies, Inc. 262P.