ENVIRONMENTAL GEOSCIENCES

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Lecture-13

Dip, Strike, Folds & Fault its Environmental interpretation

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We have already covered the module one and module two. Now today we will start the module three which is related to dip, strike, folds and falls and its environmental interpretation and few geological hazards like earthquake, volcanoes, floods and landslides. So today, in this module three, we will start the lecture one, which are related with the structural geology, that is, dip, strike, folds and faults, and its environmental interpretation. The important concepts will be covered like dip, types of dip, strike, relation between dip and strike, clinometer compass, introduction to the folds and faults, parts of a fold and fault, classification of folds and faults, recognition of faults in the field, effects of folds and faults on outcrops.

So what is dip and strike? As we know, inside the Earth's surface, rocks are originally deposited either on flat surface or very gently inclined surfaces. Sometimes, of course, as a result of special circumstances, certain beds may have started with an initial inclination. But somewhere great thickness of strata tilted into conspicuously inclined position, so here the beds have been tilted by movements that occurred after their deposition. The components of inclined bed attitude refer to the two key measures used to describe the orientation of a tilted or inclined rock layer and these are termed as dip and strike.

Now what is dip? Dip is an angle of inclination of the bed. It is just an angle of inclination of the bed. It is defined as the amount of inclination of a bed with respect to horizontal plane measured on a vertical plane lying at right angles to the strike of the bedding plane. The direction along which the inclination of the bedding plane occurs is called as dip direction.

The dip of a bed has got two components, like direction the one component and the other component is magnitude that's why dip is a vector quantity and the adjacent figure you can see the lines going from east to west is the strike and just perpendicular to it the line going inside is the your dip direction. The amount of dip is the angle which varies from 0° to 90° according to the disposition of the bed. In case of horizontal beds generally the dip remains 0° and for a vertical bed dip remains 90°. And this dip can be measured using a clinometer compass. So this is all about the dip.

Now next is the, according to the degree of the dip the symbolic representation is also mentioned here you can see in the case of horizontal bed in the case of horizontal bed the top one is the Dip remains always 0°. Two different beds are there. You can see two different beds means these are the two different bedding plane of the different type of rocks.

You can see the dip is 0° and the symbol remains just like the plus one. This is the symbol which represents the horizontal bedding on the surface of the rock layer. Now in next figure the dip is 90°. You can see the rock bed is just lying 90° with the other one. So here the symbol is given here. And in the case of inclined bed you can see different beds are remaining but they are neither in horizontal position nor in vertical position but they are in inclined position.

So here dip varies from 0° to 90°. So, in this way, dip is symbolically represented in a map. Now, there are types of dip. There are two types of dip. One is the true dip, second is the apparent dip.

True dip, now what is true dip? True dip is the maximum amount of slope along a line perpendicular to the strike. In other words, it is the maximum slope with respect to the horizon. It may also be stated as the geographical direction along which the line of the quickest descent slopes down. So here the angle α indicates about the true dip.

Apparent dip. Apparent dip along any direction other than that of the true dip, the gradient is scheduled to be much less and therefore it is defined as an apparent dip. The apparent dip of any bed towards any direction must always be less than its true dip. So here angle β shows the angle of the apparent dip. Here δ is the angle between true dip and apparent dip.

Now there is a relation between true dip and apparent dip. So let beta is equal to apparent dip angle. α is true dip angle. And δ is the angle between true dip and apparent dip. Now let us suppose a triangle having OBA, ODC and OBD which is a right angle triangle and in this angle OBA, angle ODC and OBD is the 90°. Then

$$\tan\alpha = \frac{AB}{OB}, \quad \text{and}$$

$$\tan\beta = \frac{CD}{OD}, \text{ since AB is equal to CD, then}$$

$$\frac{\tan\beta}{\tan\alpha} = \frac{OB}{OD}$$

And we observe in triangle OBD that

$$\cos\delta = \frac{OB}{OD}$$

Therefore, the relation will be

$$\tan\beta = \cos\delta\tan\alpha$$

Based on this relation, one numerical is given here. You can see a sedimentary bed has an apparent dip of 30° measured in a direction 60° away from the true dip direction. Now calculate the true dip of the bed. We will start from the relationship. The relationship between true dip and apparent dip as we have seen is

$$\tan\beta = \cos\delta\tan\alpha$$

Given in the question is

apparent dip, $\beta = 30°$.

Angle between true dip direction and apparent dip direction = 60°. Therefore,

$$\tan\alpha = \frac{\tan\beta}{\cos\delta}$$

So,

$$\tan\alpha = \frac{\tan 30°}{\cos 60°}$$

So,

$$\tan\alpha = \frac{(1/\sqrt{3})}{(1/2)}$$

Therefore,

$$\tan\alpha = 2/\sqrt{3}$$

Hence,

true dip (α) = tan inverse ($2/\sqrt{3}$) ≈ 49°

So, this is the solution of this numerical. Now, after dip, the strike will come. The strike, the direction of the line along which an inclined bed intersects a horizontal plane is known as the strike of the bed. It is a scalar quantity as it has got only one component that is direction only not the magnitude. The strike of the bed is independent of its amount of dip. It is always perpendicular to the dip direction of the bed. Strike is measured in degrees from 0° to 30° in clockwise direction from the north and clinometer compass is generally used to measure the strike by holding it horizontally against the rock surface.

What is the relation between dip and strike? The direction of dip and strike of any inclined bed must lie at right angles to each other. True dip remains in the direction along a perpendicular to the strike. In the figure also you can see strike line, dip direction. Now, importance of dip and strike.

In structural geology, strike and deep are quite important for the following purposes. First is to determine the younger bed of formation. It is well known that younger beds will always be found in the direction of dip. If we go in the direction of dip, relatively beds of younger age will be found to outcrop and older beds in the opposite direction. Second purpose is in the classification and nomenclature of faults, folds, joints and unconfirmities.

The nature of deep and strike is of paramount significance. Thus the attitude which refers to the three-dimensional orientation of some geological structure is defined by their dip and strike. This is the instrument through which we can measure the dip and strike. It is clinometer compass. You can see in it a circular plane graduated from 0° to 360°.

A magnetic needle which gives the direction of north and south. It is also helpful in the determination of the strike of an inclined bed. A pointer is attached with a freely oscillating pendulum for the determination of dip of any inclined bed and their direction. It contains a beam which can be only rotated through an angle of 90°. It is also having a small hole at one end and a vertical window at the other with its vertical separator.

Therefore, clinometer compass is used for determining the dip and strike of the beds in the field or for surveying etc. Environmental interpretation of dip and strike, the structural geologist has significant role to perform for the benefit of society. The crust of the earth is structurally very complicated. It has undergone many modifications in the geological time scale. The study of structural geology enables our understanding in unraveling the mysteries of the Earth crust. It is important for planning mining activities also.

Dip and Strike is very much helpful in the exploration, mapping and exploitation of mineral resources or earth resources depending upon careful interpretation of structural geologists. Artificial groundwater recharge projects and rainwater harvesting techniques require study of structural features of the geological terrain. The selection of site of engineering projects depend on the structural setting the sites are even changed or rejected because of the adverse structural settings. Now after this we will start the folds and faults. Folds and faults are key structural features of the Earth crust representing responses to tectonic stresses. They provide crucial insights into the dynamic processes shaping our planets such as plate tectonics mountain building and seismic activity.

Folds represent bending or warping of rock layers due to the compressional stress, whereas falls are fractures in rocks with significant displacement caused by tectonic forces. Now, fold. The bending of rock strata due to compressional forces acting tangentially or horizontally towards a common point or plane from opposite direction is known as folding. In the figure also you can see the rock strata has bended because of the compressional stresses. It results in the crumbing of strata forming wavy undulations which are known as folds.

These are the wavy undulations which have formed. This is known as fold. Folds occur when rocks are subjected to stresses causing them to deform plastically without breaking. In the case of fold, the rocks are subjected to stress. They deform but they are not broken.

They remains in the place. Now parts of fold. There are few terminology for the fold. The wavy undulations are formed of a series of alternate crests and troughs. So this is the crest, this portion is the crest and this portion is the trough.

Crest is the highest point in the profile section of the fold whereas trough is the lowest point in the profile section of the fold. Limb, the stretch of the rock beds lying between any crest and any of the adjacent troughs means from here this is the crest and this is the trough and this is the stretch of the bed which is called as limb. In this case you can also see this is the limb. Again the trough will be here. So the stretch of the rock beds are called as limb.

Axial plane, the imaginary plane which divides the fold as symmetrical as possible. So this plane, you can see here, this hatched portion, this is the axial plane dividing this fold, this is the folded strata, into equal or unequal halves. Hinge, the line along which a change in the amount and or direction of dip takes place. You can see in this figure, this is the hinge line. Through this line, the change in the amount and the direction of dip take place and this line is called as hinge line and many fold it coincides with the position of the maximum curvature.

So these are about few terminology related to the folds. Now classification of folds. Folds have been classified into various types on the basis of appearance in cross section, symmetry of fold, thickness of limb, inter limb angle, attitude of the fold, mechanism of folding, origin, tectonic origin, non tectonic origin and special types. I will discuss few of the important type of the fold one by one. Now first on the basis of appearance in cross section,

The name of the fold is antiform. Any upwardly convex structure, you can see here, any upwardly convex structure, this is the convex structure, is termed as an antiform. Here the age relationship between the upper and lower sets of bed is of complex type. Synform, this is synform, this one is synform. Any upwardly concave structure, that is flexure in the form of a trough is known as synform.

So this is the antiform and this is the synform. Anticline, it is generally convex upwards. This is anticline, this is convex upwards where the limbs commonly slope away from the axial plane. You can see if the axial plane are here, if the axial plane are here, then what is happening? It is going away from the axial plane, not coming towards the axial plane.

So it is generally convex upwards and where the limbs commonly slope away from the axial plane, whereas sincline it is a fold which is concave upwards and the limbs dip towards the axial plane. So this is the difference between anticline and syncline. Anti-clinorium and synclinorium. A large anticline with secondary folds of smaller size. You can see these are the secondary folds in the anticline.

So then it is termed as anticlinorium and when we are getting the secondary force in the syncline then it is termed as synclinorium. Anticlinal head or monocline, it is due to the local steepening of a bed, whereby there occurs a sudden increase in the dip of a bed. So this is the case of the anticline where we are getting anticlinal bend. Synclinal bend or structural terrace, in case of dipping bed due to local flattening of the beds at a particular spot, the beds acquire horizontality and then again follow their original dip without any change in the direction of dip. These are also known as structural bench.

So this is the figure of the structural terrace or synclinal bend. So these are about the different types of the fold. Now symmetry of fold, on the basis of symmetry of fold, the fold are classified into symmetrical fold and asymmetrical fold. When the axial plane is vertical and bisects the fold, you can see, this is just axial plane, these are the hatched portion is the axial plane, which is just bisecting fold. The fold is said to be symmetrical or upright.

There may be anticlinal or there may be synclinal in nature. Whereas asymmetrical fold, here you can see, unequal halfs, the limb if the axial plane has dip the fold is described as inclined or asymmetrical fold in this case both the limbs dip at different angles and the axial plane cannot divide the fold into two symmetrical halves. So these are about the symmetrical and asymmetrical fold. Now this is very important type fold which is known as recumbent fold it is also called as an overturned fold. In which the axial plane is horizontal or more nearly so. So here you can see the axial plane is this one which is horizontal. The strata in the inverted limb are usually much thinner, you can see these are the inverted limb which is much thinner than the strata of the your normal limb. now few terminologies associated with recumbent fold are first is the arc bend Now few terminologies associated with recumbent fold are first is the arc bend

The curved part of the fold between the normal and inverted limb is known as arc bend. So this is the normal limb, this is the inverted limb. So in between the portion, this is called as arc bend. The outer and inner parts of the fold are known as shell and core. So this is the outer part, shell, and this is the inner part, that is core.

Subsidiary folds attached to the recumbent folds are known as digitations. So here you can see some subsidiary folds are generated and these are called as digitations. Sometimes the recumbent folds are also known as nappes. Sometimes we are calling the recumbent folds as nappes or an overturned fold. Some special type of folds.

Chevron folds. These are angular folds having straight limbs and sharp hinges. You can see here straight limbs and sharp hinge is there. They are also known as zigzag, concertina or accordion folds. Fan folding.

If in any fold both the limbs are overturned and the fold assume the shape of a fan where the crest and troughs are sufficiently rounded. Here you can see the crest and trough have become rounded. In anticlinal fan folds both the limbs dip towards each other and in synclinal fan folds both the limbs away from each other. So these are about the special type of folds. Effects on outcrops force cause shortening of the crust of the Earth and their subsequent thickening. It is usually observed that streams follow the axial portion of the anticlinal ridges and highlands and domed structures occur along the axis of the synclines.

Repetition of beds in their occurrence in the field generally infers the presence of a fold. Environmental interpretation of the fold is folding exposes the deep-seated rocks on the surface of the earth. It enhances the possibility of mineral deposits because of repetition of layers due to folding occurs in a limited area. It facilitates more development of site for deposition of mineral-bearing solution. Folds serve as good host for oil and natural gas.

Folding causes beautiful landscapes to develop which may enhance the geotourism. Now, after fold, we will discuss the fault. Fault is a fracture or zone of fractures in the Earth crust between two blocks of rock that allows the blocks to move relative to each other. In the case of folding, we have seen that has deformed portion remains at the same place. But here, in case of the fault, the relative movement take place.

The rock bed generally suffers some movement. Faults can range in length from a few millimeters to thousands of kilometers. They can be horizontal, vertical or at some angle in between. The attitude of faults are defined in terms of their strike and dip. The strike and dip of a fault are measured in the same way as they are for bedding planes.

Faults can move rapidly causing earthquakes or slowly causing creep also. Now parts of a fault. The important parts of fault are foot wall and hanging wall. You can see in the figure also. The foot wall and hanging wall of the two blocks lying on either side of the fault plane, one appears to rest on the other.

If you will see in the figure, it will appear that one is resting on the other. The former is known as the hanging wall side. And the latter, which supports the hanging wall, is known as footwall sides. So this is about the hanging wall and footwall. Now fault scrap.

Now the relative displacement on either side of the fault line results in an upstanding structure with a steep side, which is called fault scrap, as shown in the figure. Fault line, it owes its relief due to the differential erosion along a fault line. So these are the terminology of the parts of a fault. Now, downthrown side and upthrown side. In case of a fault, one of the dislocated block appears to have shifted downwards in comparison with the adjoining block lying on the other side of the fault plane.

If you will see these figures, it will appear that one portion of the rock has just shifted and one remains at former place. Former, therefore, is known as the downthrown side while the latter is described as the upthrown side. The important terminology associated with the fault, fault surface, fault plane, if it is a surface or plane along which the dislocation takes place. Fault zone, it is a zone of numerous small scale fractures constituting the fault. Dip of a fault, it is the angle of inclination of fault plane with respect to the horizontal and is measured on a vertical plane that strikes at right angles to the fault.

Strikes of the fault plane, strike of the fault is the trends of a horizontal line in the plane of the fault. Hade of the fault plane, it is the complement angle of dip, that is the angle which the fault plane makes with the vertical plane, that is 90° dip is called as head. So, in the figure also you can see the θ is the angle of dip and the ϕ is called as hade. Throw, the throw of a fault is the vertical component of the apparent displacement of bed measured along the direction of dip. A, B, In this figure, this AB is called as throw and BC is called as heave.

The heave of a fault is the horizontal component of the apparent displacement. It is also called as gape. It is very important. It is also called as gape. Stratigraphic throw, if the same bed occurs twice because of faulting, the perpendicular distance between them measured along a vertical section at right angles to the strike of the fault is generally termed as stratigraphic throw.

Net slip, it is the total amount of displacement due to a fault is described as net slip. Dip slip, it is the movement parallel to the dip direction of the fault plane. In the figure also you can see, DF is the dip separation. Now dip slip is the movement parallel to the dip direction of fault plane whereas a strike slip it is the movement parallel to the strike of the fault plane and net slip it is the total amount of displacement due to a fault is generally termed as net slip. Now classification of fault.

There are two important types of classification, geometrical classification and genetic classification. Geometrical classification, this classification is strictly based on the attitude of the faults. There are five bases of geometrical classification which are the rake of the net slip, the attitude of the fault, the patterns of the fault, the angle at which the fault dips and the apparent movement on the fault. On the basis of rake of the net slip, we are having the strike slip fault where the net slip is parallel to the fault and rake of the net slip is equal to zero. Dip slip fault, here the net slip is equal to the dip slip, rake of the net slip is therefore 90°.

And diagonal slip fault, where there is both a strike slip and dip slip component and the rake of the net slip is more than 0° but less than 90°. In the figure also, this has been shown about the strike slip fault, the dip slip fault and the diagonal slip fault. On the basis of attitude of fault, generally the faults are strike fault where the strike of the fault is parallel to the strike of the rock beds. Deep fault, where the strike of the fault is parallel to the deep or country rocks. Bedding fault, in this case the fault plane is parallel to the bedding planes of the adjacent rocks.

Now longitudinal fault, here the fault strikes parallel to the strike of the regional structures. Transverse fault, it strikes perpendicular or diagonally to the strike of the regional structure. Diagonal fault, it is also known as oblique fault which strikes diagonally to the strike of the adjacent rocks. So in the figure also the diagonal faults, longitudinal fault and transverse fault have been shown. Now fault pattern.

On the basis of fault pattern, the important types of fault are parallel fault. It consists of a series of faults having the same dip and strike. You can see different series of fault in the figure also. Step faults. If in a series of parallel faults, the successive blocks are down thrown more and more towards a particular direction, then the resulting structure will be termed as step fault.

Enechelon faults, they are relatively short faults which overlap each other. Arcuate fault, these are also known as peripheral faults which have circular or arc-like outcrop on a level surface. Radial faults, here a number of faults belonging to the same system radiate out from a point. On the basis of dip value, two important types of fault, high angle fault where dip amount is more than 45° and low angle fault where the dip less, is less than 45°. On the basis of apparent movement, the faults are classified into two groups, normal fault and reverse fault.

Normal fault, is a normal fault which are inclined faults in which the hanging wall side appears to have moved relatively downwards in comparison to the adjoining footwall side. In this case, the fault plane dips toward the downthrown side. Generally, normal faults are produced by tensional forces. That's why they are also called as gravity faults. These faults indicate lengthening of the Earth's crust.

The subdivision of the crust into blocks by normal fault is called the block faulting Normal faults usually have a high angle dip. A reverse fault is one in which the footwall side appears to have been shifted downwards in comparison to the hanging walls. In this case the fault plane dips towards the upthrown side. The reverse faults are usually high angle faults.

They are produced by compressional forces. These faults indicate shortening of the Earth crust. Normally reverse faults have dips of the order of 45° or more. Intense compression produces low angle reverse fault which is called as thrust and thrust faults may curve at the bottom to merge with a bedding plane. So this is about the reverse fault.

Besides the above types of the fault, there is important type of fault known as pivot or scissor fault or hinge fault. In this case, one block appears to have rotated about a point on the fault plane such that for part of its length, the fault is normal with a decreasing throw. So this is the example of pivot or scissor or hinge fault. On the basis of genetic classification, the faults are classified into normal fault, strike fault and thrust fault. Hanging wall moving relatively downwards, it is also known as gravity fault or tensional fault. Strike slip fault, the displacement remains essentially parallel to the strike of the fault. And the thrust fault, the hanging wall moves relatively over the footwork. A horizontal or low-angle thrust fault in which the displacement is larger than it is called as overthrust.

The displacement of an overthrust may be measured in kilometers. The sheet of rock that has moved forward along the thrust plane is called nappe. Isolated parts of overthrust rock mass are also known as nappe outlier or klippe. Now recognition of faults in the field and their outcrops. In majority of cases, faults are recognized by stratigraphic and physiographic evidences like discontinuity of structures, repetition or omission of strata, silicification and mineralization, sudden change in the sedimentary phases and physiographic evidences.

Now, discontinuity of structure. If there is an abrupt termination of any geological structure, a fault can be expected near about the point of termination. Sudden termination of dykes and veins etc. also suggests the existence of a fault. Repetition and omission of strata. Sometimes a bed may suddenly terminate but occurs again somewhat off from the place where it has been terminated, besides, sometimes rock beds forming the country are found to be repeated or omitted indicates the occurrence of a fault.

Silicification and mineralization faults are often the avenues for the moving solution. The solution may replace the country rock with fine-grained quartz causing silicification and sometimes also they form mineral deposits at that site. It points to the occurrence of the fault in that area. Difference in sedimentary phases, different sedimentary phases of rocks of the same age may be brought into just opposition by large horizontal displacement is suggestive of faulting nearby. Physiographic evidence, the effects of faulting on outcrops constitute the physiographic evidence for faulting.

Now significance of folds and faults. Folds and falls are of major significance to environmental geologists because they often form structural traps for valuable mineral deposits and other natural sources. Faults that develop above an intrusive granite allow mineralizing fluids to pass into the overlying rocks. The deposits of minerals such as lead, tin, zinc, and copper ores are formed in this way. Faults that do not reach the surface may form channels through which oil and gas can rise.

In synclines where porous sand beds overlie impermeable clays and shale, collection of water from reservoirs which produce artesian springs. Correct interpretation of folds and faults is essential in mining. For example, recumbent folding and reverse faulting can cause coal seams to be repeated vertically, while normal faulting can cause a horizontal gap. A coal seam may thus be passed through several times in drilling or alternatively missed altogether. Along a fault zone, highly crust and sheared rocks are met with.

These zones being weak, unstable and highly permeable, poor expensive problems in civil engineering construction such as dams, reservoirs, highways. Thank you very much to all.