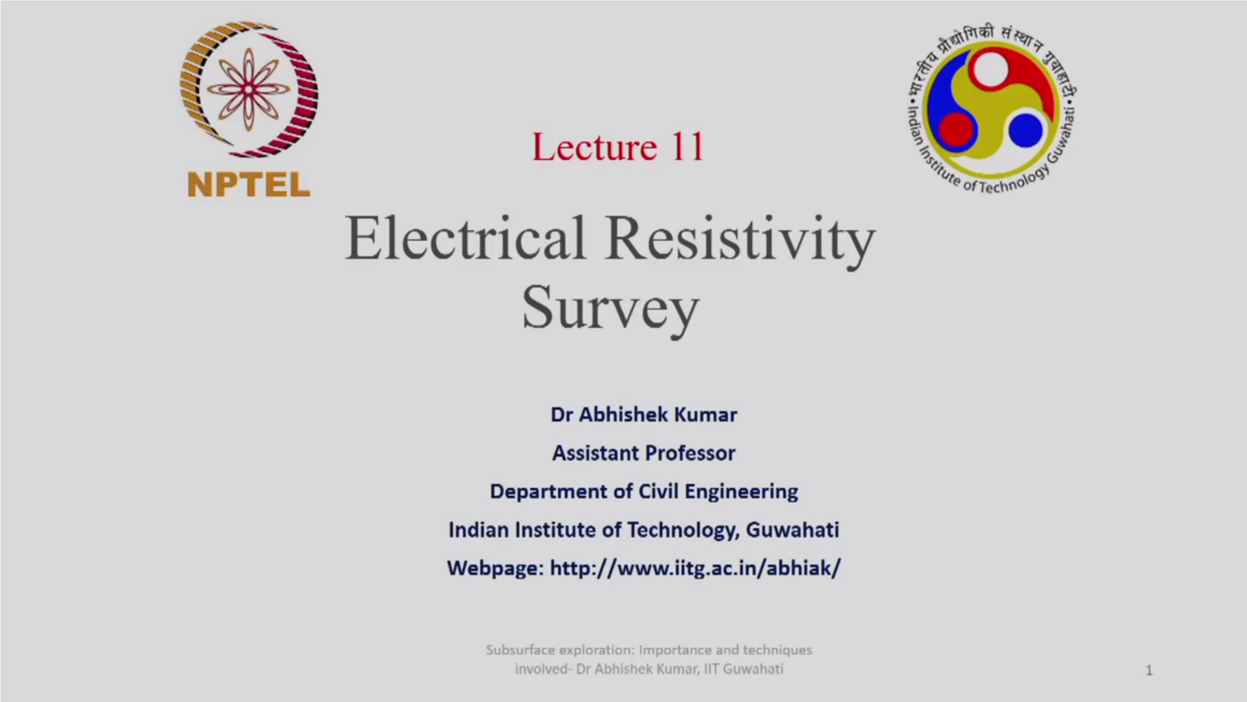



Dr. Abhishek Kumar: Welcome all. Today we are going to discuss about another method on geophysical investigation. So this lecture will be lecture 11 under this course and under module 3 that is geophysical investigation. This is third kind of investigation we will be discussing.

So far under module 3 we have discussed like what are the -- I had given an introduction about geophysical methods, why geophysical methods are important, because of nondestructive nature considering most of the methods here, then the ability of the methods to penetrate deeper depths for investigation, then even larger area you can go for investigation without much interpolation in between the testing locations, and particularly for quality control, third one whenever we are interested to go for any kind of forensic investigation, we can go for geophysical methods, because those are nondestructive methods it will be very easy. In comparison to technical method performing geophysical methods will be relatively easier to conduct at the site which are undergoing any kind of distress or failure or showing any other indication which is lacking for serviceability criteria.

Then we discussed about seismic reflection survey. Under seismic reflection survey we discussed like what can be the potential sources, which can induce shocks or shock vibrations in the medium Once the wave passes through the medium, depending upon the kind of wave, it will offer some kind of maybe compression or it may be inducing here, and depending upon the resistance offered by the material to those kinds of wave or the motion in the particles because of the propagation of those waves, we will be able to distinguish between different materials considering the resistance offered by the material. So this method can be used particularly for variety of geophysical investigations like for oil exploration, mineral exploration and all that.

Then we started with seismic refraction survey. I mentioned last time like whenever shockwave starts from the source, it will be -- depending upon the angle of incidents, there will be a wide range of angle of incidents of because of wave fronts that will give you better indication. So there will be refraction which is happening quite away from the normal. There will be refraction which is happening at lesser inclination with respect to the normal depending upon the ratio of physical properties like VP1 and VP2 ratio and the angle of incidents of refraction in incident wave.

Then the incident wave which are falling at critical angle, so the refraction for those cases will be happening along the interface. That is mostly at 90 degree you can consider as angle of refraction. So further, so because after refraction the waves are traveling through stiffer medium, so the time required for the wave to propagation in the stiff medium will be significantly lesser in comparison to the wave which are traveling in relative softer medium. That’s how we will be able to interpret, based on the time of arrival of refracted wave from deeper depths what kind of lithology is available, what are the thickness and what are other properties of subsurface medium. It will be very difficult to interpret based on single geophone. So it is always desired to go for multiple geophones that is called is geophone arrays or seismic arrays or microtremor studies also you can use, so that you will be able to understand what kind of different lithologies available at a particular site of interest.

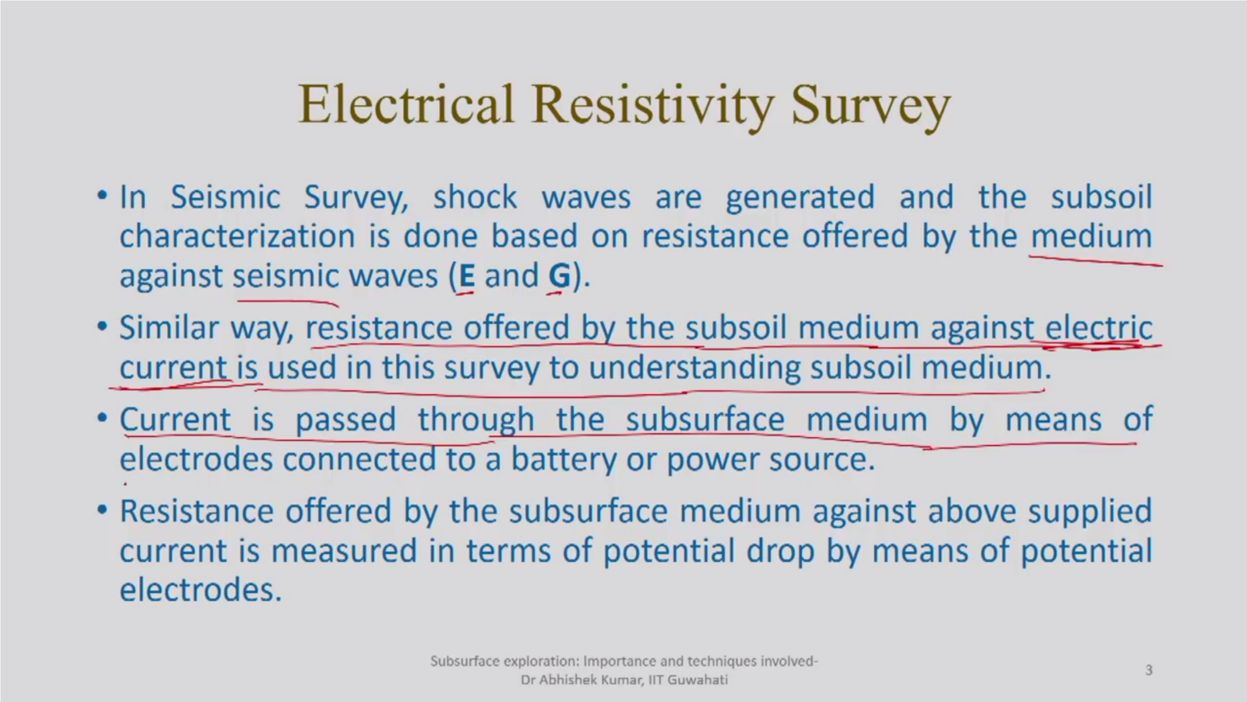
But I mentioned major disadvantage here is seismic refraction survey you cannot use when the shear velocity or primary wave velocity -- the medium stiffness if it reduces with respect to the depth, then the refraction will never reach to the geophone, and because it's not reaching, the time of arrival of refracted wave you cannot record and that's how you cannot do the interpretation part. So it will be only possible when the medium stiffness is increasing with the depth that you can use seismic refraction survey. So subsequently refractions will be happening from deeper layers, will be detected by the geophones. You can interpret.

I also mentioned depending upon the kind of source wee are using for a shockwave generation that will give you an idea whether the generated shockwaves will be dominated by primary waves or it will be dominated by a shear wave, so that your geophone is recording what kind of wave, you will get to know an idea about that. So that is all about seismic method.

One important thing which I would like to highlight here, like in geophysical method or any kind of subsurface investigation, our objective is to understand the subsurface medium by any ways considering its physical property or consider its resistance to any kind of external loading or disturbance. So that disturbance or the resistance offered if it is matching with the contrast in the physical properties of the medium as well that will resolve our purpose, because our objective is to identify by some means the layer which are different from each other in terms of their physical properties. So based on geophysical method we try to quantify those characteristics of the material which are showing some indication of variation and is consistent with the physical properties of the medium.

So when we started with geophysical methods like seismic reflection survey, seismic refraction survey, we were trying to identify or we were trying to understand the variation and lithology with reference to the resistance offered to seismic waves, whether it can be shear waves or it can be surface waves also.

So same with there are methods which induce different other -- you can say like resistance offered by the medium to different kind of disturbances or different kind of waves which you are inducing, so based on the resistance offered to those kind of external disturbances, you will be able to quantify the variation in the physical properties of the medium depending upon how much the resistance, the medium at different, different layers are offering to the disturbance.




So one among these is we discussed about seismic methods, now we will be discussing about electrical resistivity method. So what electrical resistivity does like in seismic refraction, I mentioned you are interested to find out -- first of all, you generate shockwaves and then the subsoil resistance offered against the passage of shockwave is interpreted or estimated based on multiple geophones and that’s how you will be able to understand the medium characteristics against seismic wave, which can be in terms of young modular if it is primary wave, shear modular if it is secondary wave of shear waves. Similarly way, very much similar to this in electrical resistivity survey what we are interested to find out, we are interested to find out the resistance offered by the subsurface medium, again, the resistance comes into picture, but this resistance will be different from the resistance which the material was offering to seismic wave. Here the material is offering resistance or the subsurface medium is offering resistance against electric current. So we are inducing some way electric current into the subsoil medium and we are interested to find out how much the resistance, different, different layers, it can be one lithology, one particular depth, or along the depth what kind of resistance medium at different, different depths on an overall are offering against electric current.

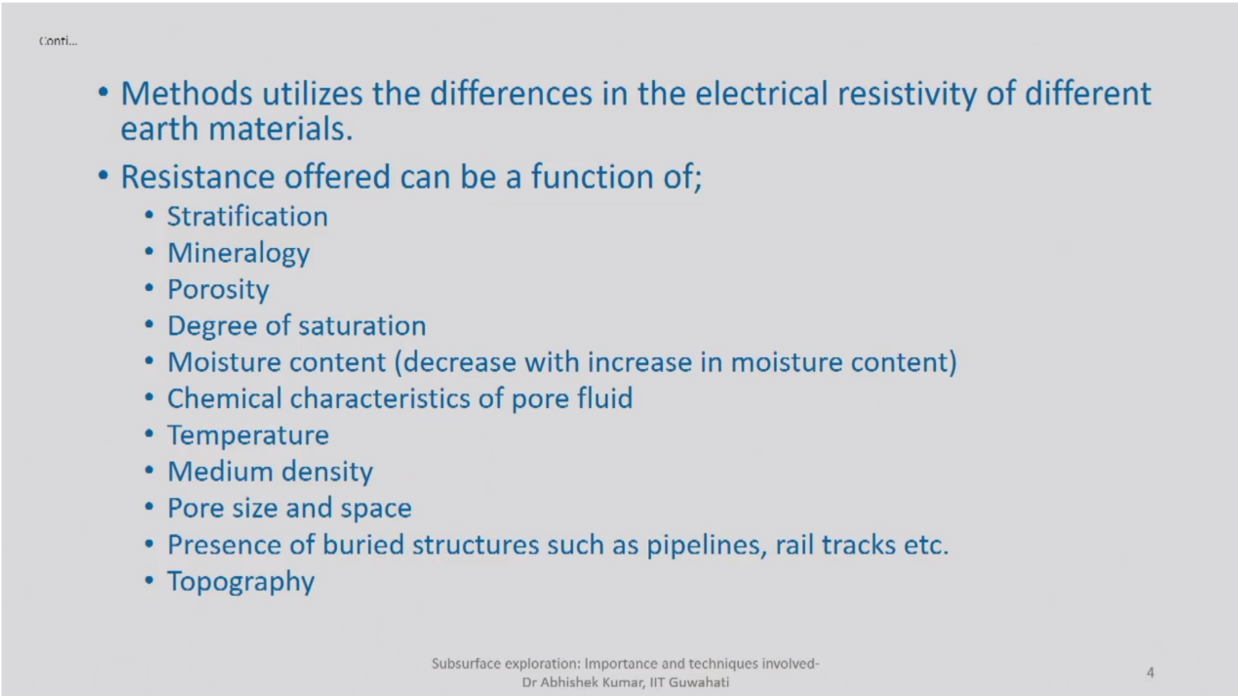
So this is most important thing when you go for electrical resistivity survey, we are interested to quantify the physical properties of the medium. We are interested to identify the medium based on what kind of resistance the soil is offering against electrical current. This electric current will not be there by default in the soil. So generally by means of external source of current, we are inducing those electric current into the soil. So this is used int his survey in order to understand subsoil medium. So remember in mind, like our objective is to classify the soil and depending upon the choice of the method, there are different ways you are able to quantify or understand the soil type based on the resistance offered by the soil to any kind of disturbance or vibration of any other features.

So the current is passed, how it goes, the current is passed through the sub soil medium by means of electrodes. So electrode will be metal strips kind of things or rods which we will push directly into the ground and through these rods you will actually try to complete your circuit, because once the circuit is complete, there would be flow of current form one electrode generally towards other electrode depending upon which side you have cathode and which side you have anode. So these electrodes will be connected to a battery or any other power source.

Now this is about external loading. This is very much similar to -- if we compare this with the seismic method, this is very much similar to shockwaves. So there you are generating shockwaves, here you are generating or you are inducing some kind of current into the soil, so how you quantify the soil properties, you will again measure here in the previous one, you are measuring the resistance of two shockwaves, here you are interested to find out or quantify the material type based on the resistance offered by the subsurface medium against above applied current. So here you will be interested to find out depending upon -- see different material will be there depending upon them mineral composition of the material, depending upon the porosity of the material, depending upon so many properties.

Maybe one material is offering more resistance in comparison to the other material, so if you know some way how much is the resistance offered by the material at different, different depth, depth also you will get an idea depending upon how much of the spread is there, what is the geometry of your setup at the site of interest that is going to give you an idea about probably what is the depth of the exploration. So if you know the depth of exploration, if you know the resistance, this will help you to identify the thickness of the layer as well as the type of the soil which is available in that particular thickness.

So this is measured, so the resistance is measured by means of potential drop. So in order to measure potential drop again there will be potential electrode which will be kept at known distance from the current electrode by means of -- okay, so there will be potential drop. Why potential drop will be there, because the soil which is available between the source of current and the source where you are actually recording the potential, there will be always a drop because the resistance offered by the material, and what is the material, material is the medium or the soil which is available between the current electrode and the potential electrode. So depending upon how much is the resistance we will be offering.




Now method utilizes the difference in electrical resistance or the resistance offered. We call it as apparent resistance, because depending upon the electrode space between current and potential, every time your electrode will be showing potential drop because of some geometry or some -- yeah some geometry of the field setup. So every time it is going to give you, it keeps on changing if you change the spacing between the electrodes. It is going to give you a new value, because it’s not fixed value, we call it as apparent resistance or apparent resistivity of the medium. So this method utilizes the differences in the electrical resistivity. So one material might be offering more resistance, another might be offering less resistance. Once you complete your setup, you will be able to understand with respect to the electrode spacing, how much is the resistance offered by the material.

If you are able to interpret the spacing between the electrode with respect to the depth, that will also give you an indication just like your SPTN value, just like your shear wave velocity or primary wave velocity with respect to depth, it will be like with respect to the depth how much is the variation with respect to -- in terms of apparent resistivity of the medium.

Now if apparent resistivity or the resistance offered by the material against electric current is not a fixed thing, rather it is function of stratification, how many number of layers, thickness of layers, what are the characteristics of those layers minerology, what are the mineral composition. One mineral may be a good conductor, another mineral maybe relatively lesser conductor of electricity; or accordingly, if it is better conductor, the resistance offered will be lesser, and so on and so forth. Then porosity of the medium, more pores is the medium, more resistance it will offer; degree of saturation, with respect to whether the soil is dry, it is partially saturated, it is completely statured, the resistance offered by the material will vary accordingly, considering the material which is available in the pore spaces, it is good conductor or bad conductor of electricity. So accordingly, whether it is dry condition or wet condition or saturated condition, you will get an idea about whether the resistance offered by the soil will be more, less or it will not be there.

Moisture content decreases -- so the resistance decreases with increase in moisture content, because considering water is a good conductor of electricity, so more is the quantity of water present or more moisture the soil, less will be the resistance offered, then chemical characteristic, that’s what I was mentioning point of four also, degree of saturation, like chemical characteristics of the pore fluid. If the pore fluid itself is offering more resistance, then if you keep on increasing the percentage of pore fluid in the pours, the resistance will keep on increasing.

On the other hand, the pore fluid is good conductor of electricity, then depending upon its quantity in the pore spaces, the resistance offered will be accordingly changing. Then temperature, medium density, medium density will also get an idea like how much is the continuity in the material characteristics or material properties. Then pore sizes and shape, depending upon how much is the pore size, larger is the pore size, you may get -- the soil may offer more resistance, and similarly about the pore spaces. Larger the density of pore space, more resistance offered, because there will be -- the medium discontinuity will be there.

Then present of buried structure. It might be possible at your site of interest, like you are having one kind of soil layer, but within that soil layer, you might find some buried pipeline. Now what will happen? Depending upon the material of the pipeline, if it is PVC pipe, it will not offer any -- it will not offer some resistance or it may not offer. If it is metal pipeline, it may reduce the resistance offered. So accordingly, the presence of buried structure, which are generally like pipelines at times you may find some buried portions of tracks of rails, particularly from railway line, even you can get some buried cables also. Overall, it is like depending upon what kind of medium, you can call it as foreign material, which is actually inducing some kind of either more resistance or less resistance in comparison to the general tendency of the ground, because of which the resistance of the material will change, it may increase, it may decrease, depending upon what material it is composed of, what is the characteristics in situ condition and so on and so forth.

Then the last one is topography of the medium. Topography of the medium will also determine the resistance offered by the material, because depending upon the topography, you may see more undulation, you may see lesser undulation of material which is able to offer more resistance or less resistance.

Conti...

| Material | Resistivity (ohm-m) |
|---|---|
| Clay | 1-20 |
| Sand | 20-200 |
| Shale | 1-500 |
| Porous limestone | 100-1,000 |
| Dense limestone | $1,000\text{-}10^6$ |
| Metamorphic rocks | $50\text{-}10^6$ |
| Igneous rocks | $100\text{-}10^6$ |

Ref: US Corps of Engineers, (1979)

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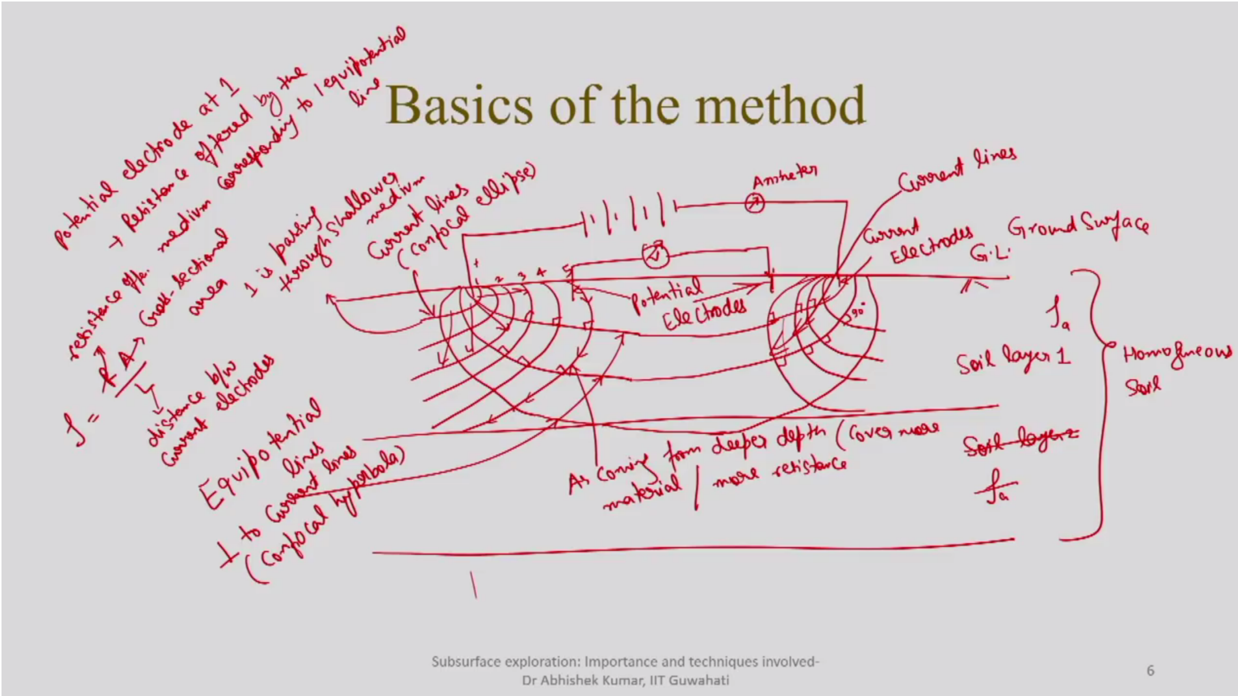
Now I have been talking about the fact that the material of a resistance, which will be quantified in terms of resistance offered per meter. I mean resistance offered in terms of ohm meter. So ohm is the unit of resistance and then resistivity will be measured in ohm meter, so you can get form this table. If you are able to quantify the apparent resistivity of the medium, that will give you some idea about what kind of soil is there. So if you’re talking about resistivity of the order of 1 to 20 clay soil will be there, 20 to 100 -- this has been given as per US Corps of Engineers in the year 1979. Then shale is there, then porous limestone, then dense limestone is there. So you can get an idea depending upon the medium it may offer more resistance, it may offer less resistance, and since at the field, you are interested to record this resistance. So once you know these values, depending upon the range of the values, you will be able to find out or you will be able to back interpret what kind of medium is available at the site of the interest again below the ground surface.




Now this was about, if you know that resistance offered by the material at different, different depths, but what is happening at the site of the interest, we are interested to know that. So let me draw one very clear example here like what is happening, what we are interested to basics of the method. So I am telling here like this is your ground level or ground surface. This is your soil, I can call it as soil layer 1, soil layer 2. Each of this soil is offering some kind of resistance. I am calling it as apparent resistance. So in order to against current. So first of all, we have to put some wave in which we can be able to determine the current here. It should be slightly lesser because we are targeting for -- so in comparison to the thickness of the layer, I am calling these are the current electrodes, which are connected to some battery. Yeah we have to put some emitter also here which is able to measure your current.

So because this circuit is complete, but how this circuit will be complete or how will be the flow of current, that will be in terms of you can get an idea about in terms of. So just like your -- if you remember in case of seismic method, we discussed like this is a source because of which there will be wave front which is indicating the direction of propagation of wave. So again, this is like telling the direction of flow of current. These will be called as current lines, which are generally confocal ellipse.

Now perpendicular to these lines will be, it should be 90 degree here everywhere, then same way it will be like this. Same thing is happening here also. So you will be having current electrode, because of which there will be current lines here. So these all are called as current lines, as a result of which these current lines, there will be again perpendicular to these current lines, there will be -- so the first one was called as current lines and again these are also at 90 degree. These lines are called as equipotential lines, joining the point of same equipotential, perpendicular to current lines and are confocal hyperbola.

Now you see here, these lines, the current lines are showing the direction in which there is flow current, and then you have equipotential lines which are the lines joining the points of same equipotential or same potential drop. So if I consider here like equipotential line maybe like 1, 2, 3, 4, 5 if I consider here. So number 1 equipotential line is penetrating or is joining the points, first of all it is close to the source from which the current started flowing. Moreover, it is so with respect to the current electrode, it is very closer. So because the current is able to flow through a limited distance, definitely the resistance offered till equipotential line 1 will be relatively lesser in comparison to the current or resistance offered till potential line 2, 3, and so on and so forth.

This is one thing, second thing if you see the equipotential line 1 is passing through shallower medium, I can write here also one is passing through shallower medium. So two comparisons are there. One is with respect to the depth, second with respect to the electrode or current electrode. How far are these each equipotential line. So because it is passing those shallower medium. Again, so very much similar to the distance between the current electrode and equipotential line, it is increasing as you are going away from the electrode. Second is with respect to the current electrode again. If you are going to equipotential line 1, 2, 3, 4, it is coming from -- it is joining the points from deeper medium, like equipotential line which is the fifth one, it is passing through the all -- it is joining the points showing equal potential drop along this depth, along this length.

So definitely the resistance offered along equipotential line 5 will be significantly more than in comparison to 1, first because the distance between the potential line and current electrode is less. Second thing, based on the distance or the depth from which the equipotential line is coming, as it is going deeper and deeper, it is definitely connecting the points, which have more resistance, I mean it is joining the points corresponding to more resistance of more potential drop.

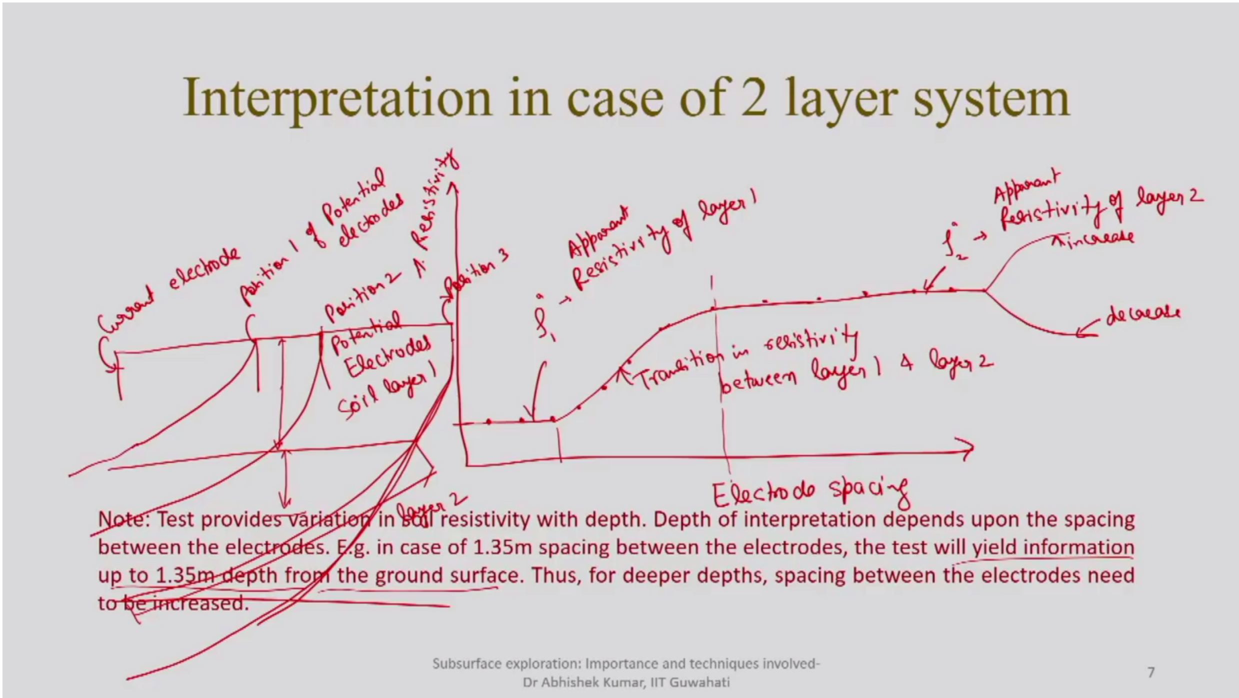
So if I put -- so this is going to give you an indication, if I put one potential electrode maybe at 1, if I put potential electrode at 1, what it is going to give you, it is going to give me some indication about resistance offered by the medium corresponding to 1 equipotential line.

Same way if I go for equipotential line 5 as coming from deeper depths, covers more material or which has offered more resistance, more is the material through which the current is passing, more will be the resistance offered. For understanding, probably we can consider just one layer rather than layer 1 and 2, so I am just removing this. So it is considered, like entire region is like homogenous layer, because unlike seismic reflection survey, in this case if the resistivity, it decreases also with the depth, this method will work. Only thing your field record accordingly what kind of interpretation, what kind of field plot will be there between resistance or resistivity in the distance.

Okay, so this is like homogenous soil, so that means throughout the depth, I am considering same type of soil is there. So resistance offered by the material number 1 will be relatively less in comparison to the material number 2 and so on and so forth. Now if I put -- so in order to find out how much is the resistance offered by the material, I can be able to determine this. So though the resistivity is equals to R A/L, so L is the distance between current electrodes, R is resistance offered, and A cross-sectional area. So this is like overall, so if you keep on increasing the distance between the electrodes, so if I put some potential electrode here and same way another potential electrode at equal distance from here, okay it should be this one and this one are called as potential electrodes. It is going to give you an idea about how much is the potential drop.

So again this will be connected to a voltmeter. This is going to give you an idea about how much is the potential drop between this current line and between the equipotential -- potential electrode. So that’s how if -- so I give you an example about homogenous soil, because homogenous soil is there. So you’re considering the resistance offered is same throughout the depth, but if you keep on increasing more number of layers, which I had given earlier. So as your equipotential line is penetrating deeper depth, and if you are putting your potential electrode at an equipotential line, which is generating far from the source, that is if you keep on increasing the distance between your current electrode and your potential electrode, you are actually targeting for deeper depth. So in case the deeper depth is showing some kind of increase in the resistance or decrease in the resistance, you will be able to capture that.

So in order to get more precise idea about hos the resistivity is increasing with respect to the depth, what we do, we keep on shifting your current electrode, sometime your potential electrode also, sometime both the electrodes, so that is going to give you an idea about how with respect to the spacing of the electrode, which is directly proportional to the depth of exploration, the resistivity is changing.




Now I am going to give you an idea about how this is going to work for a case of two layered system. so in order to give you an idea about two layered system, like I have put some -- so as I told here, I'll put some current electrode -- potential electrode, and this is current electrode. You keep on changing the distance between the electrodes, what you will be able to get here like if it is coming, first one is layer number 1, which is like this, layer number 2, so the equipotential line which is passing, which is coming from here, I can tell it is like position 1 of potential electrode, such that it is able to record or it is able to detect the potential equipotential line, which is penetrating only this particular depth. That is soil layer 1.

Then you put receiver to position 2, such that because it is away from the source that is higher chances. You may get -- you will be able to record equipotential line or potential drop from -- because of the medium which is available, so here you can see you are having some portion in soil layer 1 and some portion form soil layer 2. Now it is going to give me an idea like on an average what is the potential drop at position number 2. In between also if you keep on taking like if you gently keep on shifting a potential electrode, you will be able to get, so if I put here electrode spacing, and this one is resistivity. So depending upon your measurement -- so like suppose you put some electrodes, because of which you found some resistivity, then same way and then you see some gradual change, something like this.

So I am just showing you an indication like with each change in the spacing between the electrode, correspond this if you are measuring the resistivity. So considering first electrode, which is going to give you the resistivity or resistance offered by the metric only in shallower depth. So till he time your equipotential line is coming from layer number 1, you are going to get almost similar value, which is corresponding to ρ of 1, that is resistivity of layer 1. Now what will happen after this? It is gradually changing. Why it is changing? Because now your electrode spacing says that your potential electrode is far distance from the source or from the current electrode, says that it is able to detect the equipotential line, which is dominating all the characteristics equipotential line or the potential drop is dominated by second layer, but still there is a significant portion of equipotential line, which is coming from first layer, so this is some kind of transition. You can call it as transition in resistivity between layer 1 and layer 2.

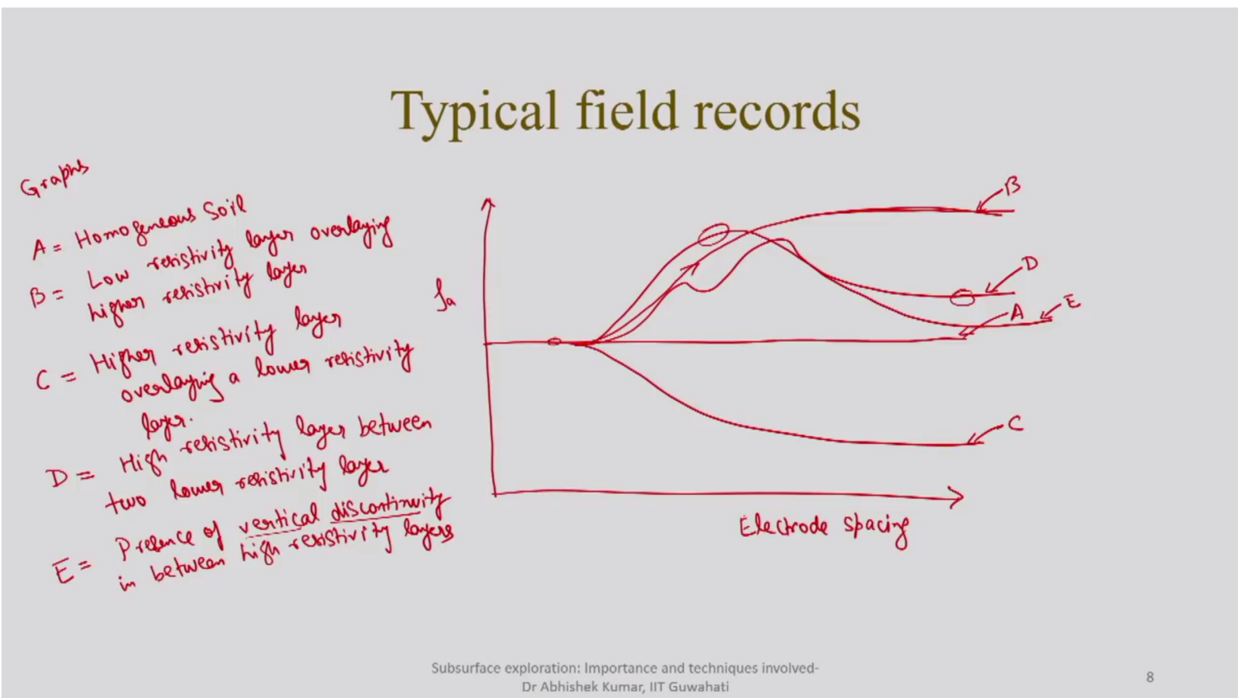
So because in layer 2, like as you again -- if I put another receiver maybe here, point 3, if I put to as position 3, what will happen. The potential line which you are targeting here it will be coming from further deeper depth or maybe like it should come this way, something like this so that you can get like this portion is dominated by layer 2 in comparison to layer 1. So sooner there will be a stage like there is a transition sooner with respect to the electrode spacing increase where resistance offered by the material is clearly giving you an indication like majority of the content you are getting from layer number 2. So this you can call it as $\rho 2$, this is $\rho 1$, resistance offered resistivity of layer 2.

Same way you can get an idea about subsequent layer again there will be if the resistivity is increasing with the depth, you can again see some kind of increase like this. If it is decreasing, you can get an idea about this decrease. This is like increase, this is like decrease. Now if it homogenous, then it will remain more or less constant value. One important observation which I would like to mention here is the resistivity what you are measuring here is the apparent resistivity. Why? Because depending upon the position of the potential electrode, it is able to detect or it is able to record the potential drop which is at that particular position. So if you shift it maybe slightly further or slightly before that particular position, it may give you some slightly different value, because it’s not going to give you the value of a particular layer, it’s going to give you a value on an average resistance offered by the equipotential line, which is passing through that particular location of the electrode.

So that is more important, that’s why we call it as $\rho a$, that apparent resistance, I am calling it as $\rho a$ here, apparent resistance offered or apparent resistivity by layer 1, or layer 2. So that’s how -- so based on this field record, so every time you go to the site, you install your current electrode, you install your potential electrode and then pass the current and try to find out how much is the potential drop between your current electrode and potential electrode and based on that you will be able to detect how much is the apparent resistivity with respect to the spacing and this way you will be able to understand what is the value, and again this is going to give you how much is the overall -- what is thickness of different layers also you can get an idea.

So one important note to be mentioned here is the test provides variation in soil resistivity with respect to depth. The depth of interpretation depends upon the spacing between the electrodes, as I mentioned here, so keep on increasing the spacing, your equipotential line will be showing you overall resistance offered by the material -- I mean from large volume of material. So to give you an example, in case the spacing between the electrodes is 1.35 meter, your test will yield information up to 1.35 meter depth with respect to the ground surface. So if you are interested to go for maybe 200 meter, you put your electrodes at 200 meter distance and you will be able to determine how much is the variation in the electrical resistivity.

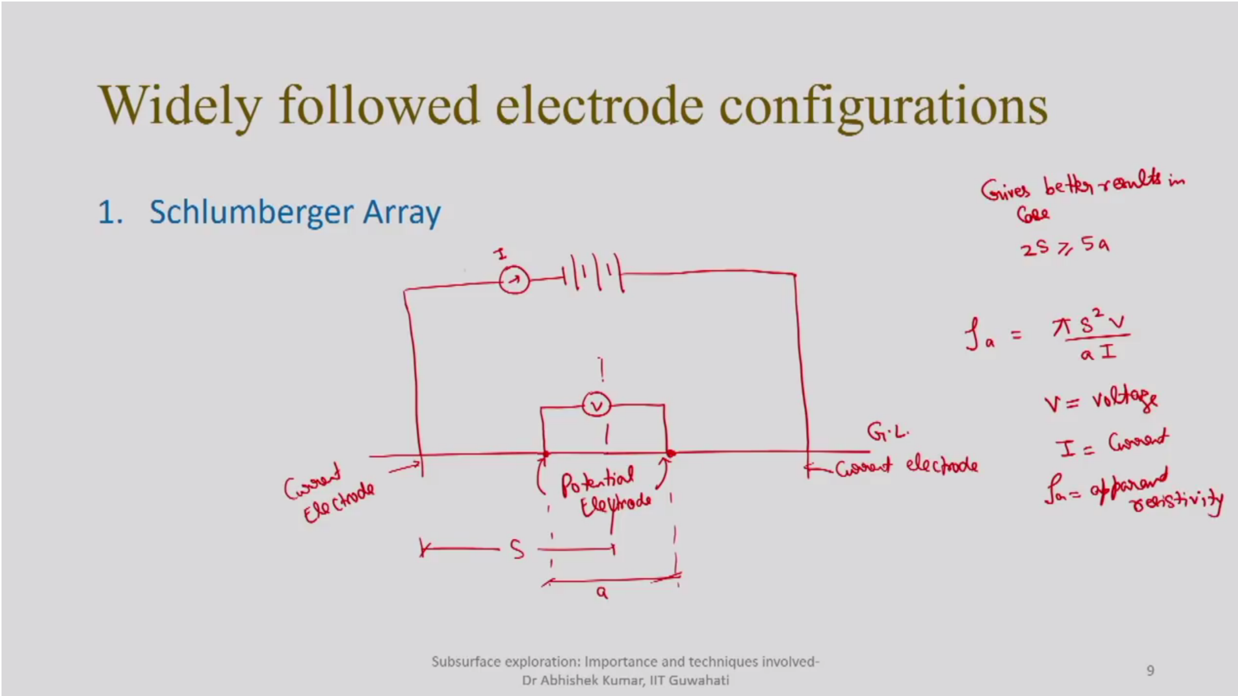
So first of all you put your current electrode and potential electrode nearer and then keep no increasing the distance between the electrodes, so that you will be able to determine how the resistivity is varying with respect to the depth.




So typical field record, as I mentioned earlier also, so depending upon the dimension, depending upon the subsoil properties, if I put it here there can be writing here, and this is electrode spacing. Okay so if the soil is homogenous, as I mentioned earlier, because the soil is homogenous, that means the soil is not offering any change in the resistivity or the resistivity of the other material is more or less constant. I am calling it as A, so A is representing homogenous soil, no change in the characteristics with respect to the depth. Second you can consider if the resistivity is increasing with respect to the depth, B should be like this. So B is, the graph B is indicating the resistivity is constant that is homogenous soil. B is indicating resistivity like low resistivity layer overlaying higher resistivity layer. So initially you were having low resistivity and then higher resistivity. That's why you can see increase in the resistivity with respect to the spacing or with respect to the depth.

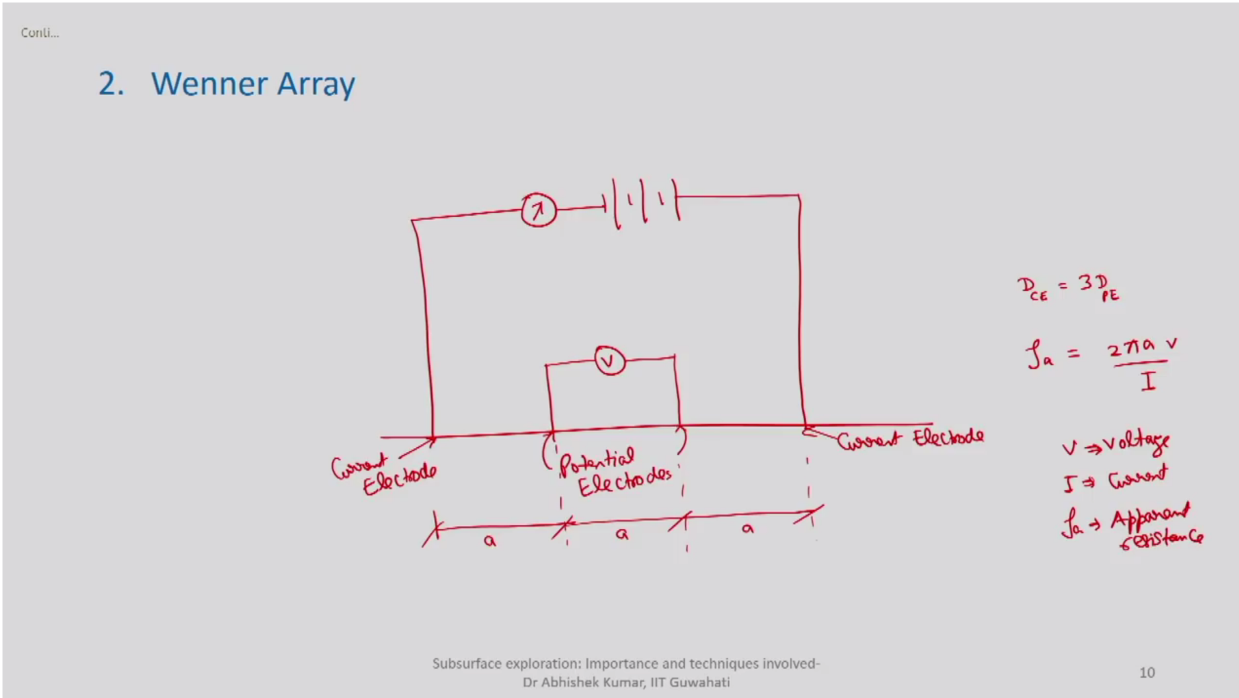
Then same way you can have another thing like this, C. So C is giving you indication about higher resistivity layer overlaying a low resistivity layer. So you have higher resistivity layer, you have low resistivity layer. So as I mentioned earlier also, this is not like where with respect to depth if resistivity is increasing, you cannot use this method. You can use it, in between also if the resistivity is showing some increase and then decrease, so it will be like this. Again, I am calling it as graph D, so D you call it as high resistivity layer between two lower resistivity layers. So if you see here, you have low resistivity layer, you are having lower resistivity here, but in between there is a increase in the resistivity. That's why you are calling it as higher resistivity layer is resenting in between two lower resistivity layers, and same way if you are having some kind of discontinuity and all that, you can get something like this. E, I am calling I as presence of vertical discontinuity in between higher resistivity layers. So that's why you are able to see some increases there, but suddenly there is a drop so that is because of vertical discontinuity.

So more or less, whenever you are going for a field investigation, you precisely get any of these kinds of graphs or combination of these graphs, depending upon how it is increasing, decreasing, so on and so forth.



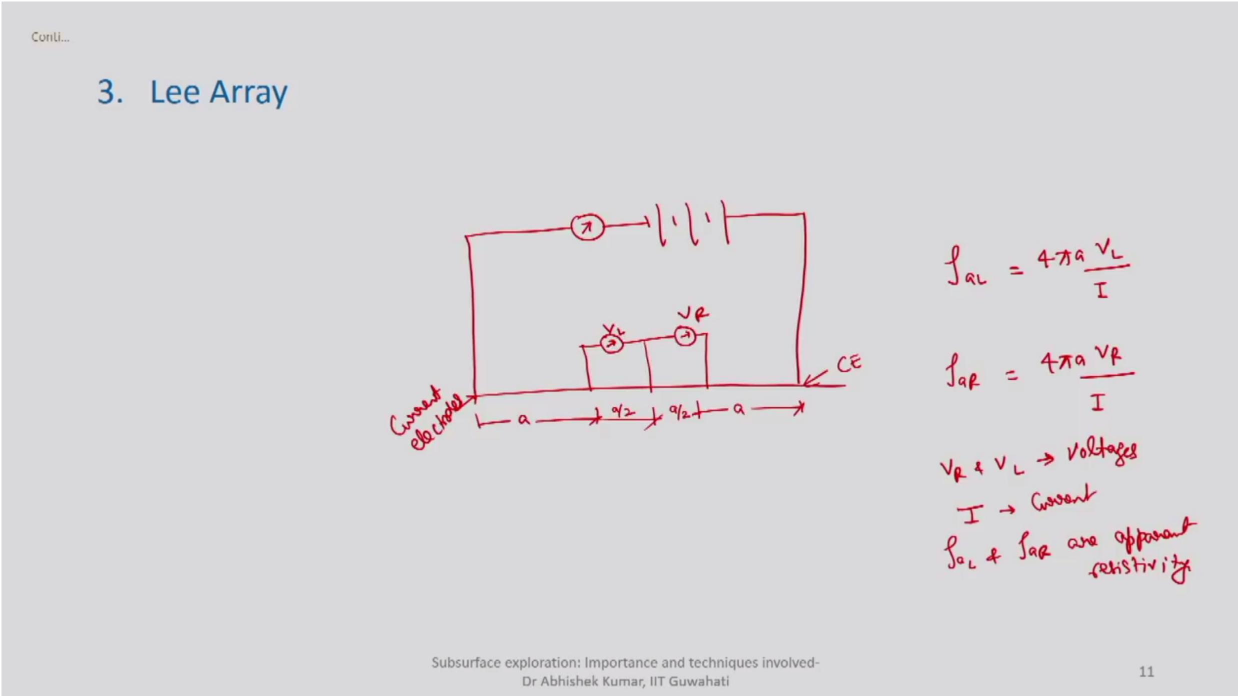

Now widely followed, I mentioned here like some spacing between the electrodes, current electrodes and so on and so forth. So based on people expertise, people experienced widely followed there are three configurations of geophone, current electrodes and potential electrode which are like -- so first one is called Schlumberger Array. I am going to give you like what is the field setup here. So this is your ground level, then you are having your current electrodes here. Then you are having -- so this is I meter, this is again current electrode, and then you are having potential electrodes here, which are generally porous cups, and then you having some measurement of potential drop here. V, I am calling this as potential electrodes. So configuration which is suggested here is the spacing between the center line of your spread, this is S, and the spacing between your potential electrodes, this is a. So this configuration gives, that is Schlumberger Array, gives better results in case of $2S \geq 5a$.

Now how you get the resistivity here, $\rho a = \pi S^2 V/aI$. So the value of S is given here, V is voltage, I is current, and ρa is apparent resistivity, which is measured by this method. That is Schlumberger Array.

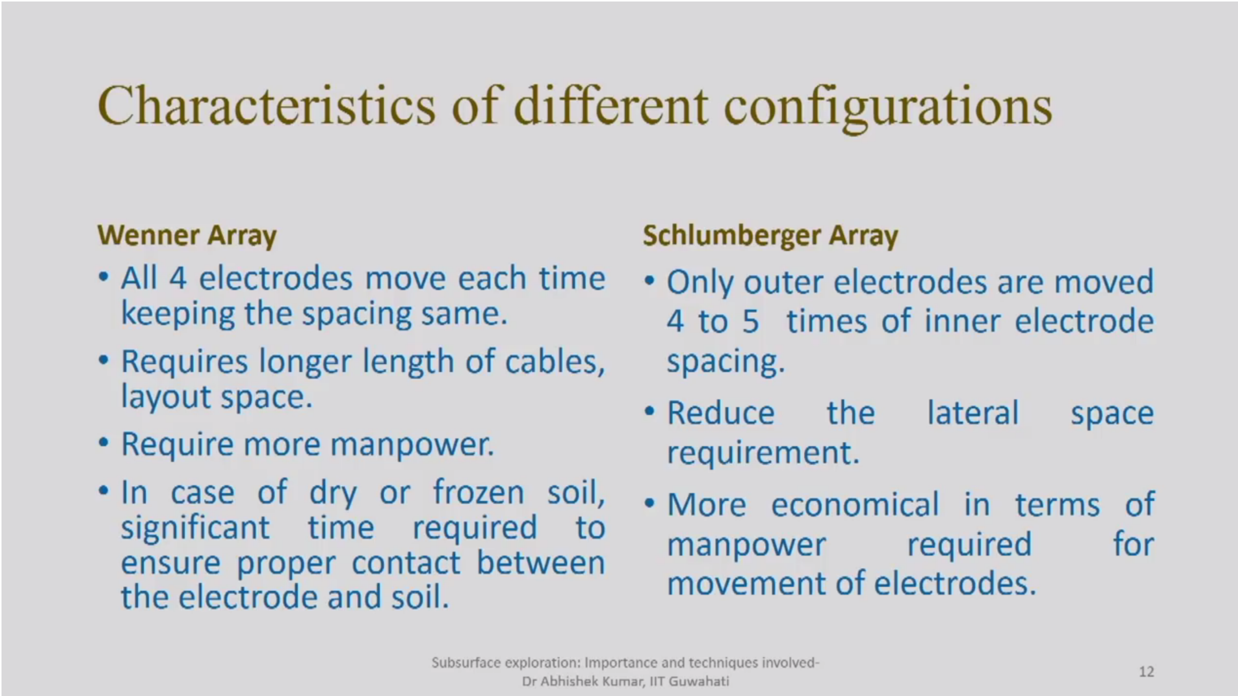



Then same way we can go for another array which is called as Wenner Array. So in Wenner Array, the configuration is like. So this is your equipotential electrodes and this one and this one are your current electrodes. Now the spacing if you see here, all will be a, that is the spacing between current electrodes, potential electrode is equal to the spacing between potential electrodes. So in this case, the distance between current electrodes should be three times the distance between potential electrodes.

Now again in this case you will be having the value of apparent resistance given as 2πaV/I. So a value is given here, V is again voltage, I is current, ρa is apparent resistance.

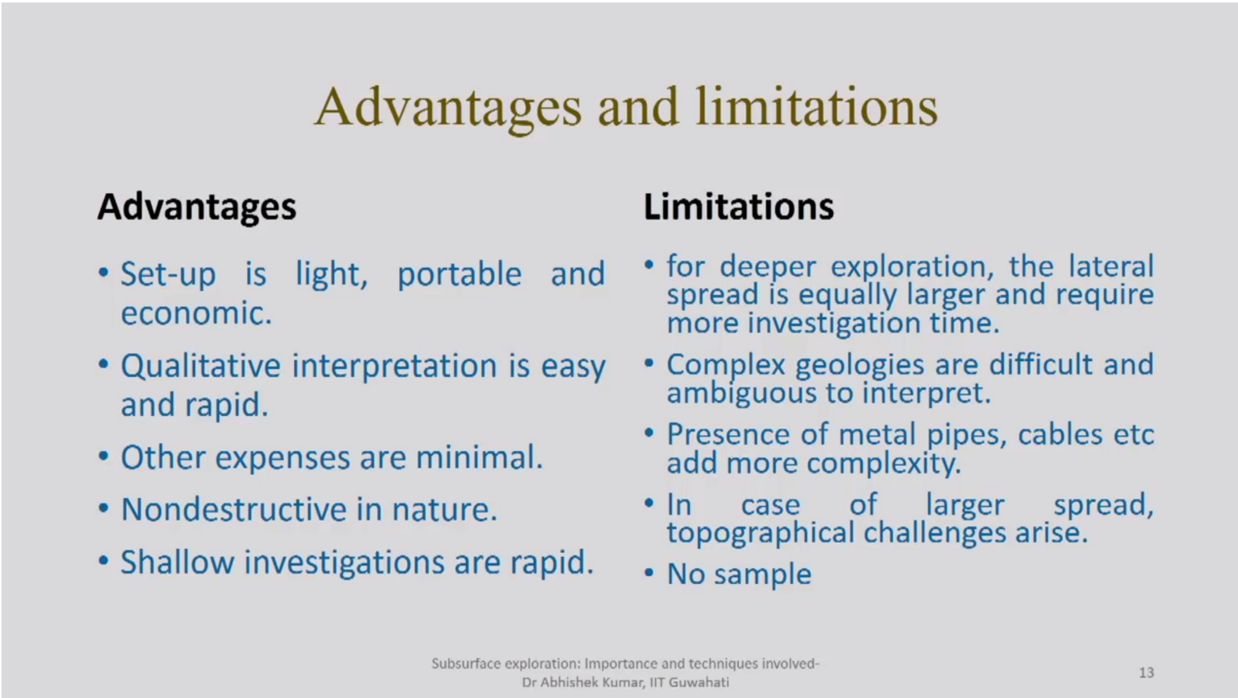



Okay, so same way the third one is also there, which is called as Lee Array, though not very widely covered. So this is a, so in between also -- so this is like VR, this is like VL, and this like a, this is like a/2, a/2 and this one. So this is called as Lee Array. The value of ρa longitudinal will be 4πa VL/I and ρaR = 4π VR/I. So VR and VL are voltage, and I is current, and ρaL and ρaR are apparent resistivity. So generally, any of these first two are more common as far as the area to be tested as well as these are current electrodes, this one also current electrodes, and these are potential electrodes. So this more common as far as we go for the first one, that's Schlumberger Array and Wenner Array are more common when we go for field investigation.




So the characteristics of different configuration, in case of Wenner Array, all the four electrodes are moved as every time. As I told like whenever we are interested to go for deeper medium exploration, we have to increase the distance between the electrodes, so in case of Wenner Array, we increase the distance between all the electrodes at the same time, so that's why it requires longer length of the cables, and because at the later stage of the investigation it might be possible that electrodes are too much far from each other, so you require at least individually one-one manpower with respect to respect to each electrode. Whenever some shifting is required, they can do it easily. And other thing is in case of dry or frozen soil, significant time is required so that the proper contact between the electrode as well as the surrounding soil should be established. Otherwise, if it is not there, then the resistance offered will be shown more than in comparison to the actual resistance offered by the soil.

Then in case of Schlumberger Array, only outer electrodes, that is current electrodes, are moved in the range of four time five times the inner electrode space. It reduces the requirement for lateral space, and then because only two electrodes are required to be moved, then it is in comparison to Wenner Array, it is at times economical.




Now I have been discussing basics about why and how the electrical resistivity survey work, how it is going to give you deeper layer information and in terms of apparent resistivity, then why it is called as apparent resistivity. So all these things we have discussed in today’s class. Now look at the advantage or disadvantages or limitation of electrical resistivity test.

So the advantages are as follows: Setup is light, so it’s not very bulky or it’s not very large volume contained setup, it is light, it is portable, and economical, qualitative interpretation is easy and rapid. So directly you are getting in terms of apparent resistance from the field records. You get it easily and interpretation is also easy, because you are getting, other than the transition you are getting directly an indication about how much is the resistance offered by the soil layer. Other expenses are minimal. Other than field setup, there is no additional requirement, because battery, cables, everything is there in the setup itself. It’s again nondestructive in nature. Only thing you require hardly maybe some dimension, minimal dimension is required, so that you can put your electrodes into the ground. So it s nondestructive more or less. Very thin electrodes are there, maybe of particular length, and then shallow investigations are rapid.

Then limitations: For deeper exploration, of course, you are interested to go for -- to understand the apparent resistance offered by the deeper layers. So in order to measure that, you have to ensure like your equipotential line should contain more potential drop from the deeper layers. So in order to ensure that you have to put your spacing between the electrodes will be very large or the lateral spread will be equally larger. To give you -- that’s why I had given an example like 1.35 meter depth exploration, you require at least 1.35 meter spread. Same way, if you are going for 200 meter or maybe 500 meter exploration almost equal amount of depth is required.

Another challenge which comes into investigation here, because you are targeting for maybe 500 meter exploration sometime. Topography also is a big challenge, because at times it is possible like within 500 meter stretch the topography itself is changing. You are not getting any kind of sample here. Presence of metal pipes cables add more complexity. So you are interested to find out resistance offered by the material -- soil layer, but if there are metal pipes, cables, that will offer either more resistance or less resistance depending upon the material characteristics, but it will add more complexity to your interpretation part. Same way is if you have complex geology, it will add more and more complexity to your interpretation of the results.

So I hope today’s lecture you will be able to understand like what is the basic of electrical resistivity survey, what is objective here whenever we go for electrical resistivity survey, how the method works, how it is possible and why it is possible to interpret deeper layers with respect to the change in spacing, particularly when you are going for heterogenous soil layers or stratification in the soil layers, and why it is not happening in the case of homogenous soil layer that variation in the resistivity, you are able to get from field recording. So this is all for electrical resistivity survey. Thank you all.