Energy Resources and Technology
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Lecture - 35
Geothermal Energy

So, today we will start with geothermal energy.

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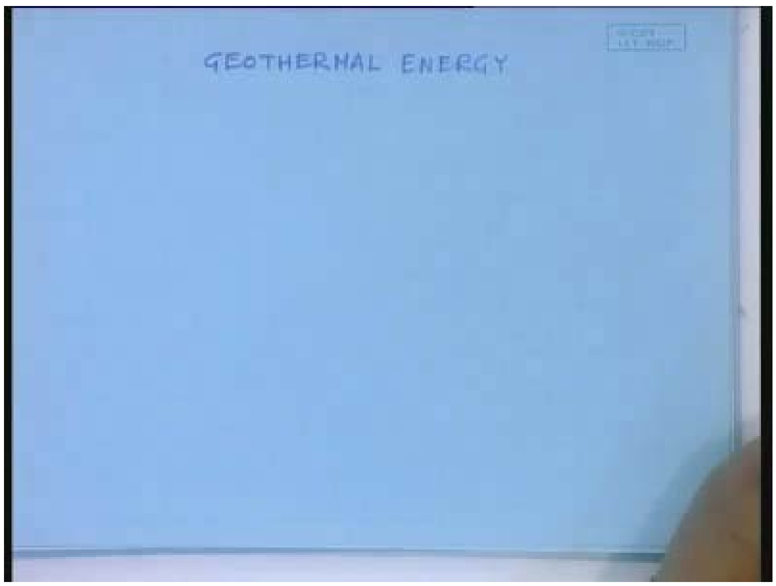

Geothermal energy is essentially the energy that is available inside the Earth and even though logically that is finite, because the Earth itself is finite, but for all practical purposes its quantity is infinite, because the amount of heat available is sufficient to run the mankind for another million years. So, obviously we are not talking in that line scale, time scale. So, it is huge amount of energy that is available. However, so where is that huge amount of energy available?

Obviously in the Earth's interior and where we left off in the last class that is how was Earth created or what creates that heat in the interior of the Earth? Now, in all probability in your school you have learnt that Earth was created by cooling of hot gas that has emanated from the body of the sun due to some reason like say, some kind of a star passing by which pulled a part of the mass of the sun and that cooled into the planets. That is probably what you have learnt in school, right. Let me tell you that that is wrong. The worldwide researchers concluded without any doubt that that is wrong.

The Earth's process of formation or the solar system's process of formation was different. In fact, Earth and all the planets along with the sun were found together. It is not that sun was existing earlier and then the other things were created. They formed together from the same nebulae. The process of formation of any star is from a nebula, the dispersed mass of gas and dust which at some point of time collapse. It is called gravitational collapse and then, there are various mechanisms to trigger such a gravitational collapse. But, it is not difficult to see that if you have a mass like this, mass of gas, it has gravity of its own. The gravity acts toward the center, therefore the individual particles will feel an attraction towards the center. The more it goes inwards, the more the density increases and as a result, the gravity also increases. So, that leads to a collapsing situation, the whole thing collapses.

Now, if the initial nebula has a very tiny amount of angular momentum, then due to the law of conservation of angular momentum the momentum would be conserved, as a result of which while it is shrinking, collapsing, it will start spinning faster, right, because it is a smaller body, a smaller body in expanse, if it has to conserve the same amount of angular momentum, it has to spin faster, so it was spinning. So, if a body of gas spins, it is quite natural to expect that that would take the shape of a disc, right, flattened; it will become flattened along the equatorial plane.

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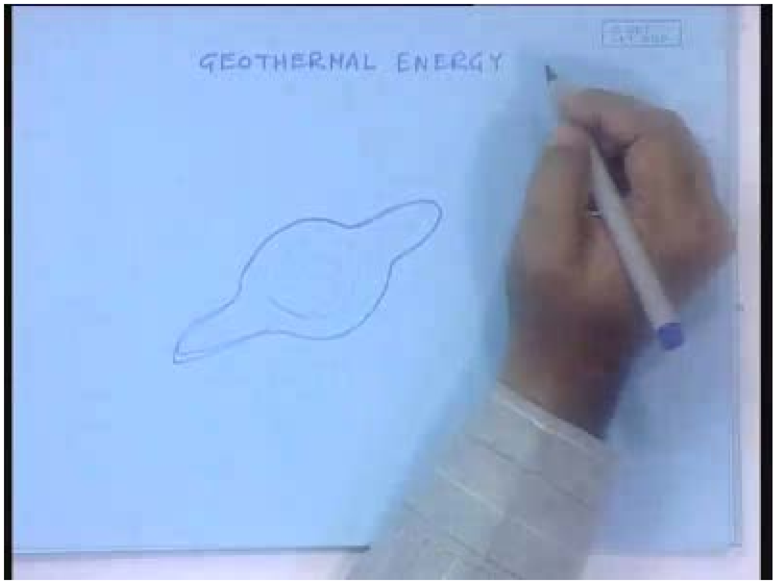

So, it is not difficult to see that the structure of the whole thing would be something like this. So, this is central part, the central bulge and here is the disc shaped material. Now, it is understood that the central part collapsed into forming the sun and the equatorial bulge that was actually the outer part of the disc that is where the planets condensed. So, the point is that the planets condensed not out of hot gas, but out of cold material. That is the initial point. That means when the Earth was formed, it formed of out of cold material.

The second point is that gas, obviously it cannot condense. Gas means at that time it was hydrogen and helium. They both have, you cannot really liquefy hydrogen and helium so easily. They liquefy at much lower temperature. So obviously, so obviously the condensation must start with some kind of solid. What kind of solid was that? The volatile gases like the ammonia, carbon dioxide, methane, these things very easily condense into solids, right. So, they were solids, also the water, water vapour they condensed into solids. So, there were ice particles in that nebula.

Those ice particles first condensed into a body and then, that body that means you can imagine the planets growing out of mainly the ice particles as well as the dust. Dust means basically silicate kind of material and then when it grew to a large size, then only it would be able to attract gravitationally some amount of the gases. So, that was the essential process which means that the interior of the Earth was cold at that time and made of mainly the ice as well as the rocky material, the silicate kind of material, the kind of composition that you see today in the comets.

Now, what happens later? Firstly what happened was after the sun started its thermonuclear reaction, there was the solar wind. That means the high velocity particles emanating from the sun that blew off most of the hydrogen and helium from the interior planets. Interior planets means the Mercury, Venus, Earth, Mars, they do not have much of hydrogen and helium. Outer planets have, they have still retained most of the hydrogen and helium. So, that is why Earth's atmosphere does not have these gases in great quantities, while Jupiter has. Most of the Jupiter's composition is hydrogen and helium. The interior that also trapped, along with these materials that I mentioned, also trapped the radioactive materials, because it was there, the radioactive materials were there. Radioactive materials by themselves decay and generate heat.

So, a solid body whose interior was then generating heat, what will happen? What will happen? Obviously, the solid body has very bad heat transfer coefficient. So, that would cause the melting of the interior. That is how the interior of the Earth melted. There were also other sources of energy, for example, as the interior melts, what will happen? The volatile gases will come out, right, would come out and that form the initial atmosphere, point number 1. Point number 2, the relatively heavier material that were outside that would then flow towards the inside. So, there would be a transport of materials. The lighter material will go to the outside and the heavier material will go to the inside. As it moves, if some heavy material is on the outside, it has potential energy. If it is moving towards the inside it loses the potential energy. So, what happens to the potential energy? Huge quantity, it has to also get transferred into heat.

So, there are many sources of heat really. Not only the radioactive material, but due to all these heats, there was an interior process going on which resulted in melting of almost the whole of the Earth's interior and then later the whole thing cooled and that is how you see it. I am not going into the details of each of these formations, because you should really learn about it separately. The point is that there was at some point, the whole of the Earth's interior at some point melted and then they again started cooling off and as they cooled off, the whole of the Earth's surface was not, the whole of the Earth's surface was not just a single shell. It was as if, have you seen the, I mean when you make, when you boil milk and let it cool, it forms the cream on the top, right and that is that is somewhat solidish. So, the same kind of process was going on, same kind of process was going on and that formed what are known as plates.

So, the Earth's surface is actually composed of many plates and the plates move. Initially the plates were thin. Now, they are pretty thick, but nevertheless they all the time move. So, Earth is actually an active geological system, due to which it is not difficult to realize that the accessibility of the heat at the interior would depend on how far down I have to dig. So, even though now there is a huge amount of energy available in the Earth's interior, it is not really accessible in most places. Theoretically yes, you can always dig, but digging a few kilometers down is not economically viable. So, nevertheless the advantage is that since the Earth's surface, Earth's crust is not a single body, it is made of individual plates which move, therefore it is not difficult to see that at the plate boundaries there would be, the access to the interior molten lava would be easier at the plate boundaries and that is exactly where all the volcanoes occur. That is exactly where all the, you know, geological processes take place like the Earthquakes and stuff.

So, point is when we talk about using or employing geological energy that can be done only in specific places, not just anywhere and those specific places atleast probabilistically are located close to the plate boundaries. In this talk, I will use some of the slides. Can we show?

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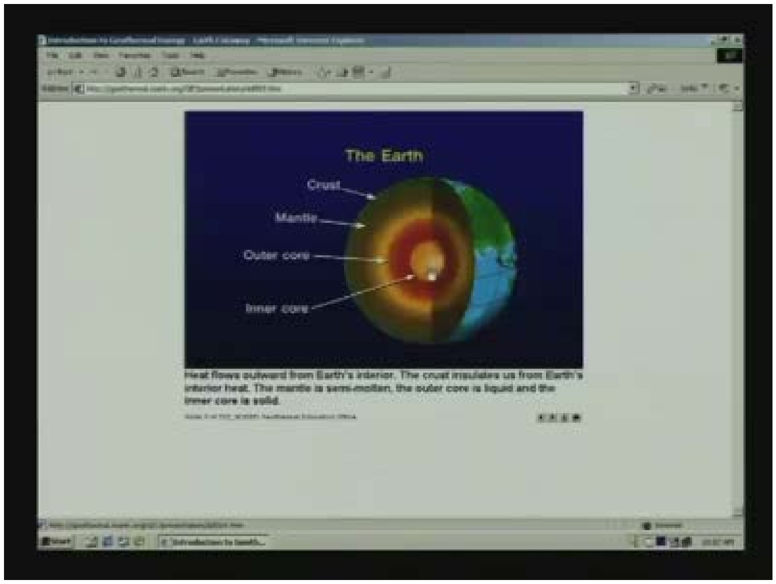

Yeah and this is kind of a slide show that is available on the net. So, this is the present Earth. Inside there is a core that is called the inner core, then the outer core and then the mantle. Mantle is a semisolid substance on which the crust floats. So, the heated part is towards the interior, but obviously that is the place where we cannot really reach and we have to be content with the places where the interior material somehow finds its way close to the crust and as I told you this should be close to the plate boundaries.

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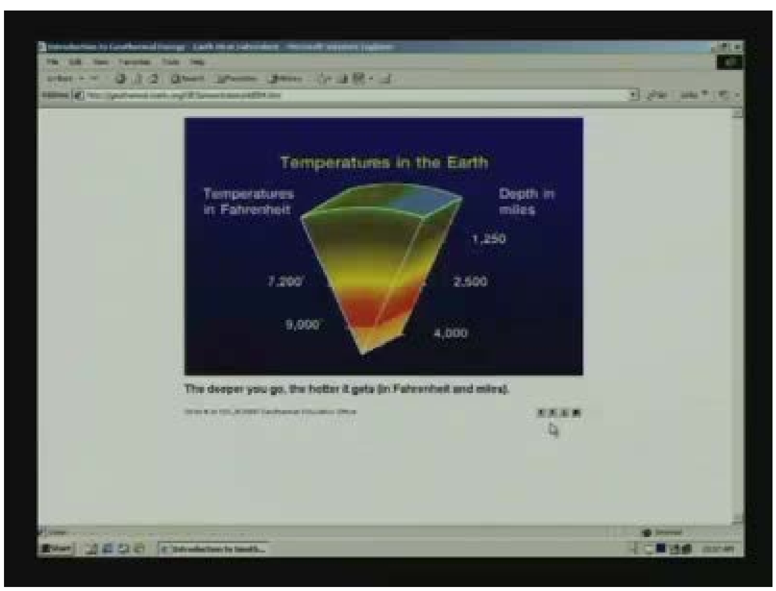

Now, if you look at the temperatures, I will go to the temperature in Celsius.

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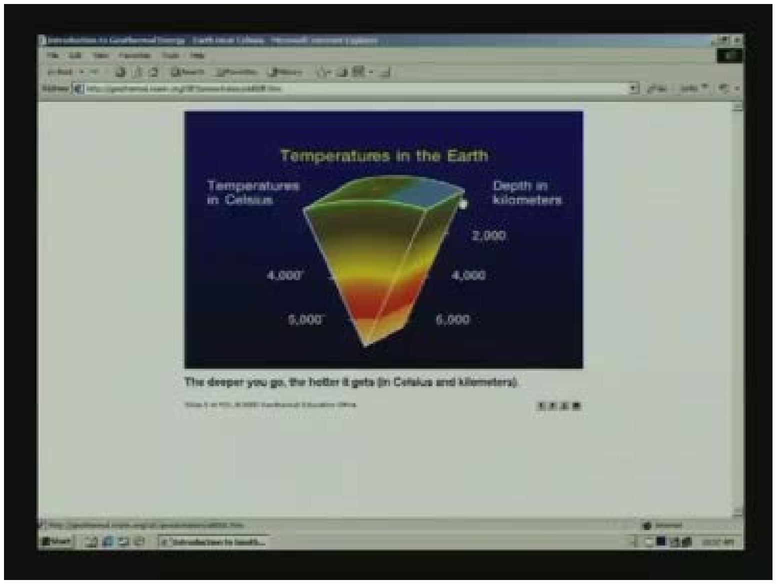

As you go deeper and deeper that means so many 6000 kilometers deep, interior the temperatures are 5000 degrees and as you go up, this is the normal temperature. So, there is a great gradient. Though this is a very large length and that is why even though there is a great gradient, that gradient is rather small in our accessibility scale. So, we need to find such places where we can use it.

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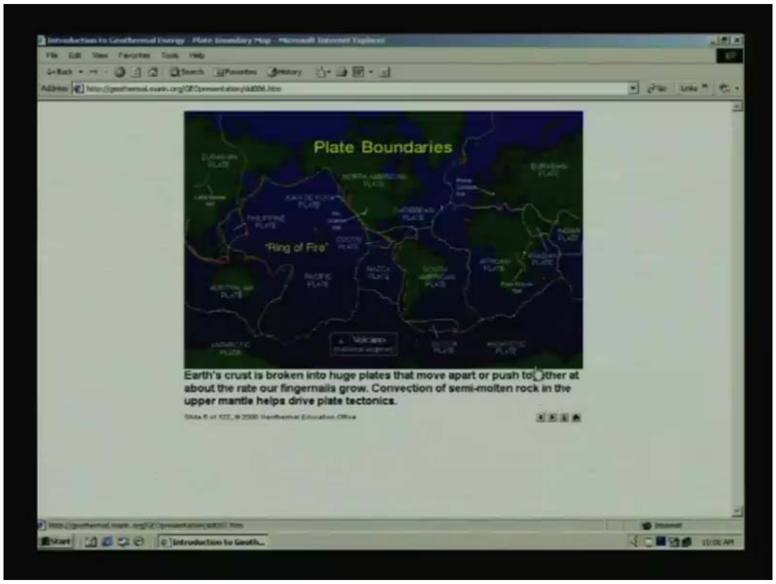

Now, this is a picture of the plate boundaries. Can you see? All right.

Students: Bright, more brightness.

If you increase the brightness, that might not help. Okay, fine, will come to that later.

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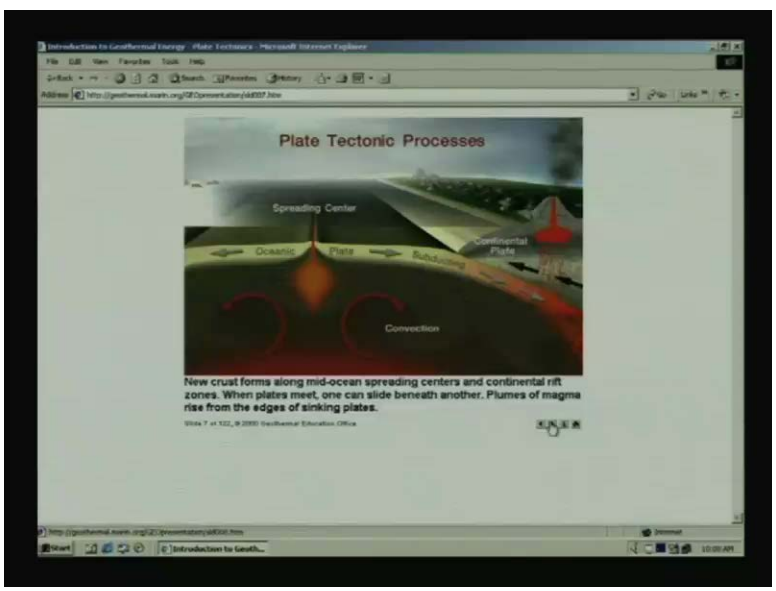

We will come to that later, because this picture probably you can see, right. Here, there is an internal mantle structure in which there is a convection current. That convection current is very slow due to which the plates move and the movement of the plates is very slow like the growth of your nail; finger nail, very slow process, but nevertheless there is. If you really let it grow, then it will grow to unmanageable sizes. So, here also the same thing happens. So, you have the plates moving like, one plate may be going like this, another plate may be going like that and there can be another plate. So, this plate is going underneath the other plate. So, that kind of situations may happen. If I draw it would be something like this.

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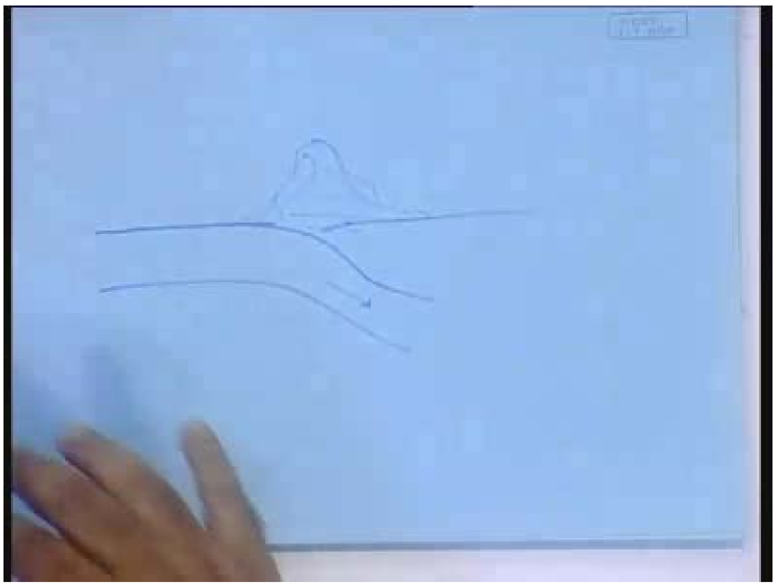

If you bring it here, yeah, say there is a plate here and there is another plate here, so it may be, so that this plate is going down. This is the direction of movement, while here it is. So, if that is so, then this plate is going down, there is something here. As it goes down, what do we expect to happen? One plate is there, another is going down, so whatever was here will be pushed up. So, whatever was here will be pushed up. This is the process of formation of mountains. In case of India, there is a plate that is called the Indian plate that is now going underneath the Chinese plate and as a result of which the whole of the Himalayan mountains formed.

So, for India we can logically expect there to be geothermal sites under the plate boundary. Now, where is the plate boundary located? In the Himalayas, so that is true. So, whenever we try to look for feasible places of geothermal energy utilization, we have to look for these places. So, India has this kind of a phenomenon where the Indian plate is going under the Chinese plate and that is pushing up the Himalayas which is still being pushed up. That means Himalayas are still being formed, it is a active geological process.

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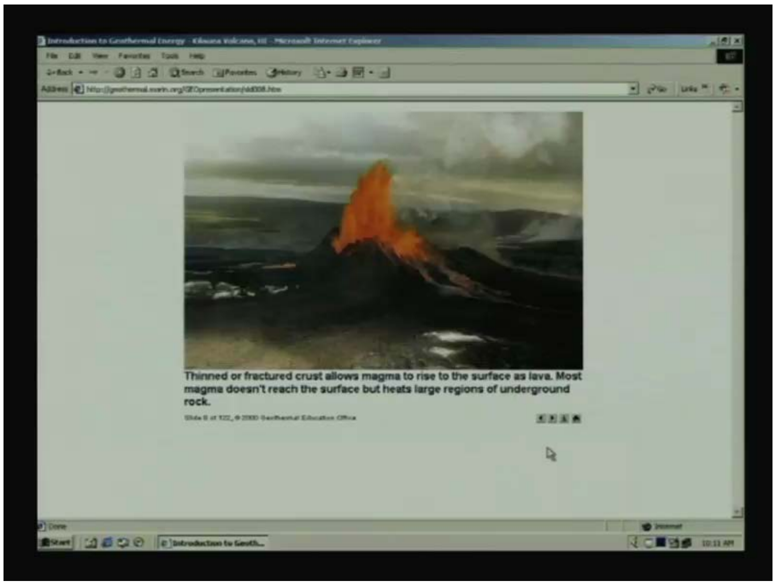

So, the crust where these plate boundaries occur, these places often have these geological activities expressed in the form of volcanoes. For example, here is a picture of a volcano, very violent geological activity. Do you know of any place where volcanoes occur within India?

Students: Andamans

Andamans, yes.

Students: Barren islands.

Yes, so there is a place atleast, a place atleast where volcano occurs within the Indian territory. That is in Andamans that is another part of the plate boundary. So, if we are looking for places where we want to utilize geothermal energy, obviously we will look for places where places that are located close to the plate boundaries. For India, we have understood that we have to look for places under the Himalayas. But, it is not always that the places would be exactly on the plate boundaries, because often there are hot spots. Hot spots means due to some geological reason, due to a fault may be, there may be some such spots, where Earthquakes are created or things like that, away from the plate boundaries, local faults.

For example, a few years back there was a big Earthquake in Bhuj. Do you remember that? A few years before that, there was a big Earthquake in Latur, right. So, these were not on the plate boundaries, but there were Earthquakes means there are local faults. So, there can be such hot spots created due to the local faults also. So, what exactly are the places in India, I will come to a little later. But essentially, from those places, the places that are geologically active, you can often have some surface manifestations, in what form? The surface manifestations are always in the form of some kind of either hot water or steam or even superheated steam coming out of the ground.

How does that happen? That happens because, there is some kind of hot spot either the lava or hot rock, whatever it is, trapped relatively close to the surface, under the surface and the rain water seeps through various creeks and crevices and that reaches the hot spot, either gets boiling or gets heated up and then through other creeks it goes up. That is why you see hot springs and you see what are known as geysers. These are only surface manifestations. These are not the places where you really utilize it. Why because, this only indicates that there is a hot spot down there, but these may not be situated on top of the hot spot.

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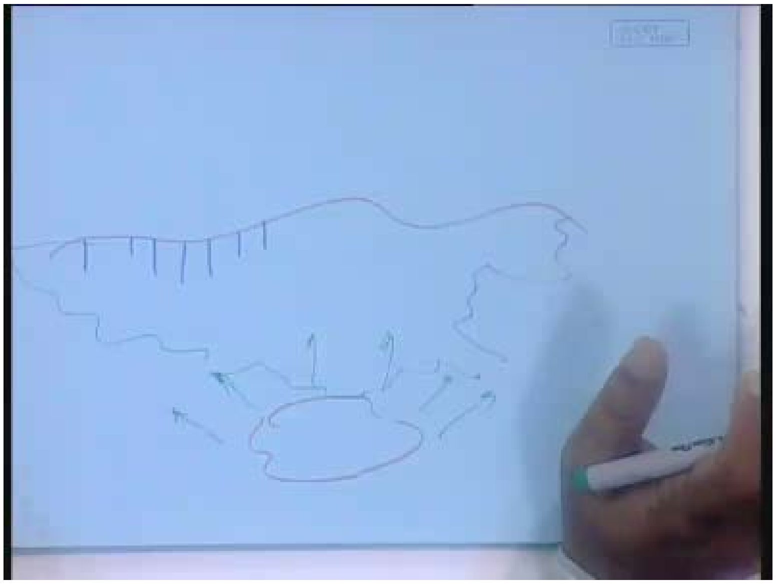

Because, often you will have, the hot spot may be here and say this is the surface and water may be seeping through like this and reaching it and from here it is going up, may be another completely different route and the distance between this point and this point may be something like 100 kilometers and that is why it is, the hot spots that you see, the hot springs that you see, there are many in India, something like 250 hot springs are there in India. They indicate that there are hot spots underneath the surface in India, in the Indian territory, but that does not mean that it is just down there.

So, in order to locate the hot spot, there has to be a process that is similar to finding oil. What do you do to find oil? You will first do some initial survey, then you have to sink wells and most of the wells that you sink would be unproductive, you find nothing. So, after you sink about 100 wells, suddenly you find something and that particular find, when you find something that is so productive that it offsets all the expenditure in all the unproductive wells, so it works that way.

Similarly, in case of the geothermal energy also, there has to be something that is called geothermal prospect. That means people look for the site by means of some scientific means. How do you think one would look for? For example one can sink wells close to the surface and measure the temperature gradient as you go down. As you measure the temperature gradient, suppose you are, you are sinking wells in this, this place, so here and different places you are sinking wells and finding that here there is a temperature gradient, here there is the temperature gradient, here there is temperature gradient and if you have something like this, it would emanate.

The heat would be not radiated, from here it would be conducted outwards. Then you expect some kind of a temperature gradient. This linear temperature gradient actually does not occur. Nevertheless, by sinking wells and measuring the temperature gradient, one can, one can make what is known, what are known as the isothermal lines. That means the temperature is same over this line, temperature is the same over this line, temperature is the same over this line and that way you can home into the actual hot spot. So, that is normally the process.

Let us see some pictures.

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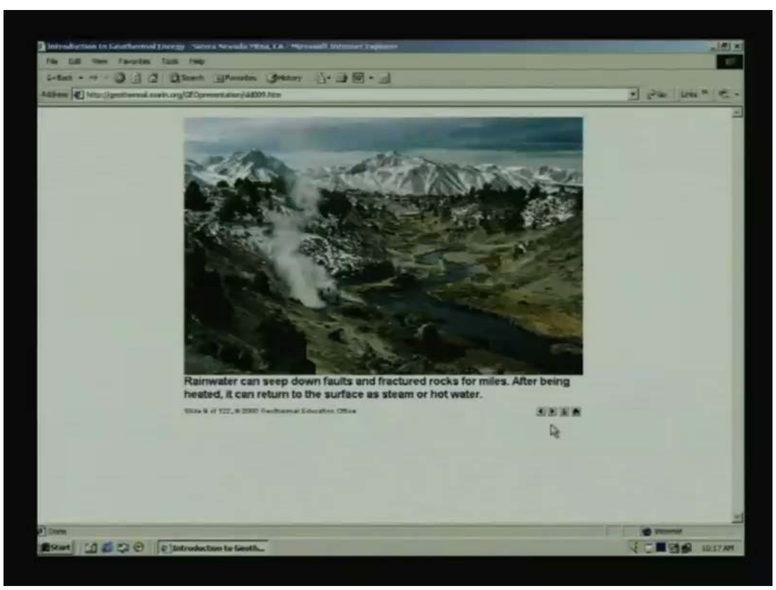

So, the rain water normally seeps down the falls and after being heated that comes out.

The surface manifestations would often be like this. Somewhere you suddenly find steam coming out.

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Another place, this steaming ground is in the Philippines. So, such surface manifestations are often there.

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Sometimes the surface manifestations are in the form of the steaming ground, sometimes in the form of hot springs to the extent of parts being boiling, sometimes in form of mud pots, you know, mud boiling and as a result of which such structures form and where they form that is also a surface indication of there being some kind of a hot spot down there.

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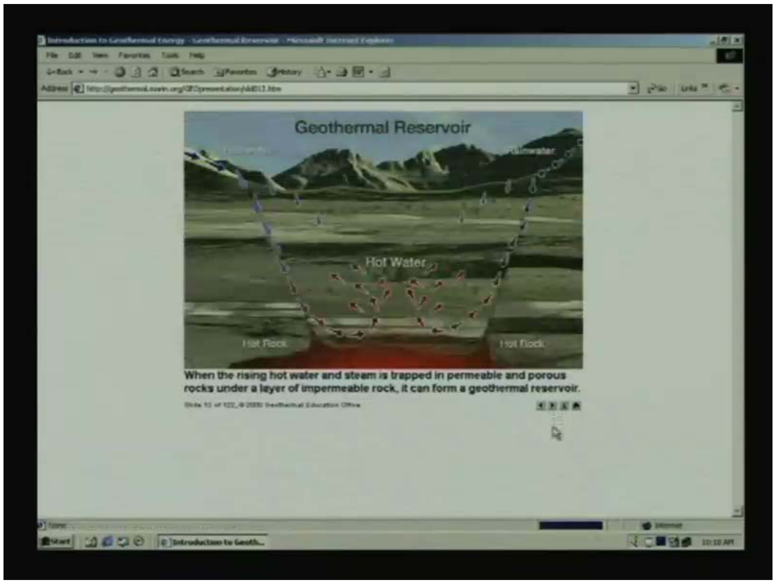

So, here there can be some hot spot and rain water may seep in like this and then hot water may, may go out somewhere, right. So, the distance between these places may be sometimes quite large.

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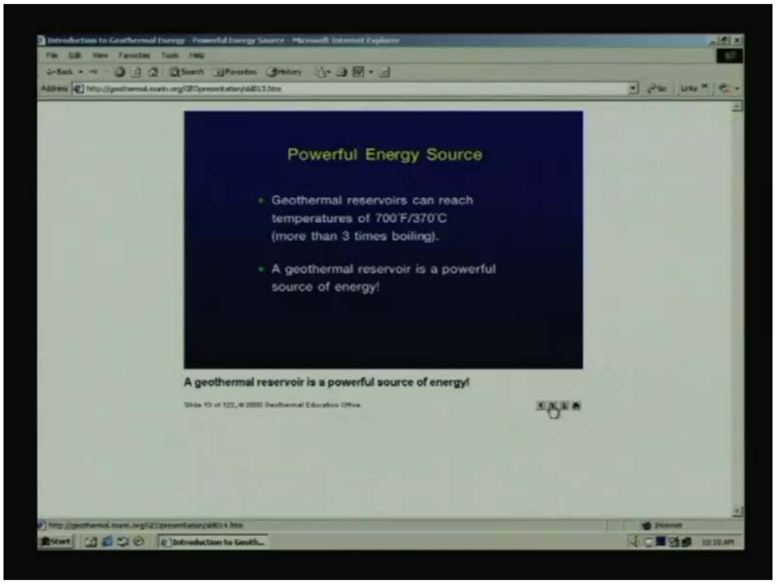

Geothermal reservoirs, where you find really exploitable geothermal energy may reach temperature something like 370 degrees centigrade. So, it is a, it is a large amount of …

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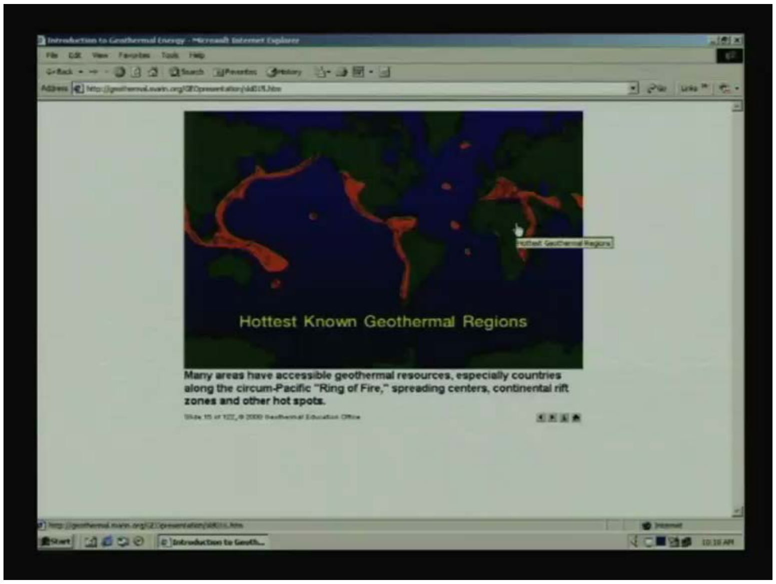

So, where would you look? You would look essentially on the hot spots. That means the areas that are on the plate boundary. Do you know some very prominent plate boundaries?

Student: Japan

Japan is close to a plate boundary. Yes, that is why you have very frequent, Japan and Philippines, frequent …

Student: California

California is one, yes. In fact California is in the other side. There are two different plates; there is a fissure in between. Yes, California is a hot area, although Silicon Valley people are sitting on top of a very dangerous place really. Any other place?

Student: Ring of fire?

Ring of fire, where is it?

Student: ….

Okay, that is one, yes. Anything else? There is the most interesting plate boundary is the mid-Atlantic Ridge. There is a, there is a plate boundary running across from the South to the North of the Atlantic Ocean. So you have, since it is not very clearly visible, let me draw.

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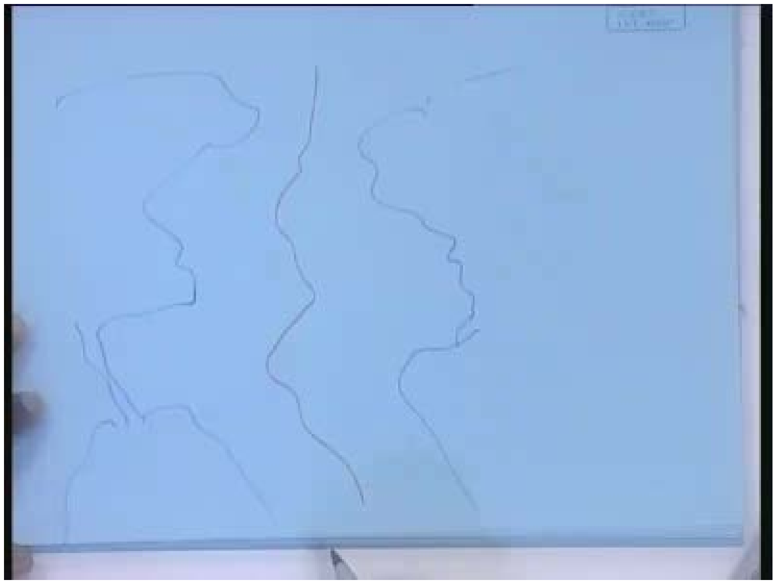

Here you have the European part and here you have Africa and here you have the American continent and here it is thin and then it is South America. The plate boundary runs actually through and in this, this plate boundary, this plate boundary is where magma is, the lava is coming out. So, it is not that one is going below the other. This is the place where both the plates are being created, they are going away. So, the lava is boiling out. Under the sea therefore, there would be this boiling water and all the time the lava is coming out there, under the sea and there peculiar creatures occur.

For example, there would be sulphur rich gases coming out, H 2 S mainly, coming out and there are organisms that survive not on any of the things that we know. They survive on the sulphur, the energy contained in the sulphur. There are such organisms there, but notice that this one goes up and finally land somewhere. Where is it? Where does is it end up?

Students: Greenland.

No, Greenland is somewhere here. It actually goes close to the place, the country called Iceland. Iceland is very close to the North Pole, so you expect that to be, you know, freezing temperature all the time, right. Wrong; there is no ice in Iceland, because the ground itself is hot. If you simply take a spade and start digging, some feet below you will find hot water. It is not that you have to dig a greater depth and that is why the whole of the town of Reykjavik, the capital of Iceland is heated by simply putting the pipes below the ground, running it below the ground for some length and then taking up; that is it. So, very simple method of heating that is possible only because that place is sitting on top of a plate boundary. So, obviously when you look for possible places, you look for places close to the plate boundaries.

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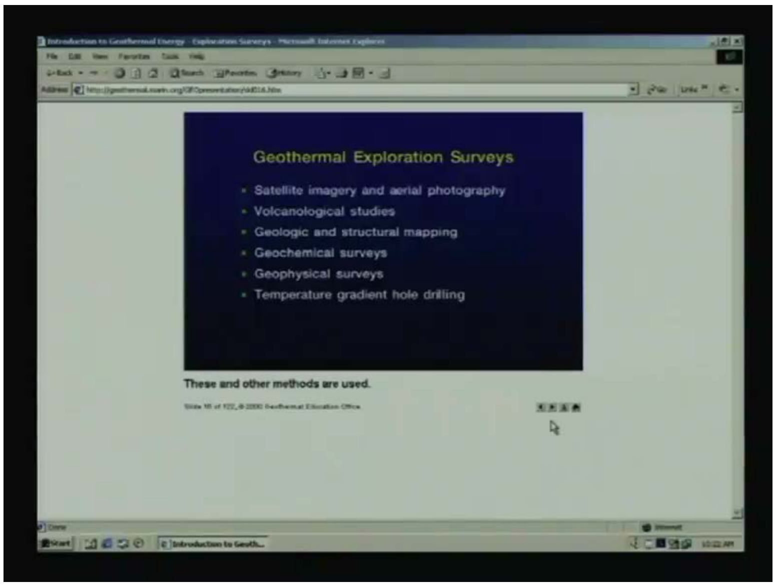

So, while we do the survey, first we do some satellite imagery and then, we find out where the volcanoes occur or there is a history of volcanism. There may be no longer active volcano, but there was a history of volcanism in some place. Then we do some geological and structural mapping, which means that the geologists go to the place and they map the different kinds of rock that occur in these places and that also gives some indication of the kind of temperature that you find. Then, there is a geochemical survey, the kind of rock means what kind of composition is there in the rocks. Geophysical survey means what kind of temperature gradient is there, what kind of salinity difference is there, what is the conductivity of the Earth, what is the magnetism of the Earth, those things are measured and they give rise to interesting results and then we have to find out the temperature gradient through hole drilling.

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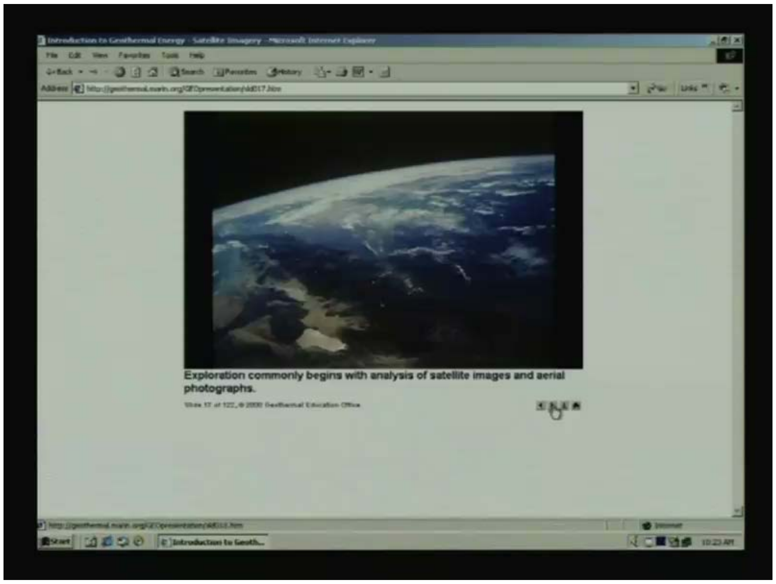

For example, here you have the aerial photograph of some region, from where you can see whether there is a, there is a ring of volcanoes or volcanic activity along a certain belt.

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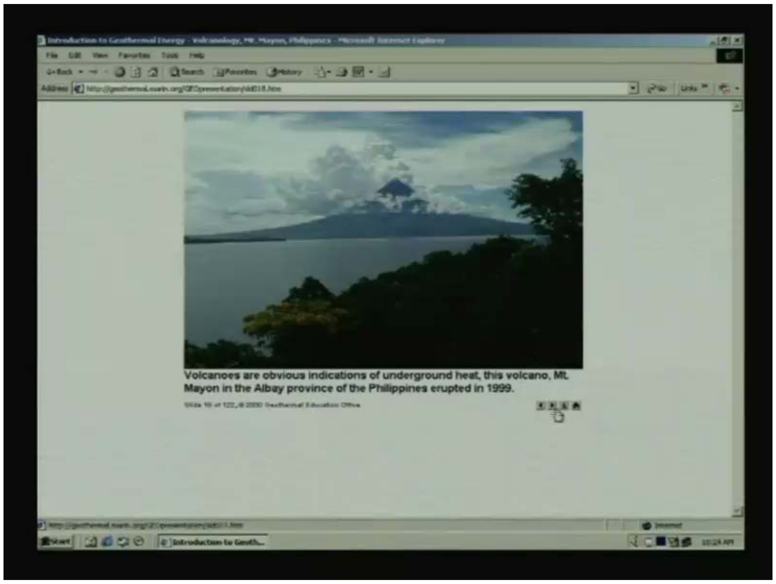

Or there can be a old, non active volcano which you can look at.

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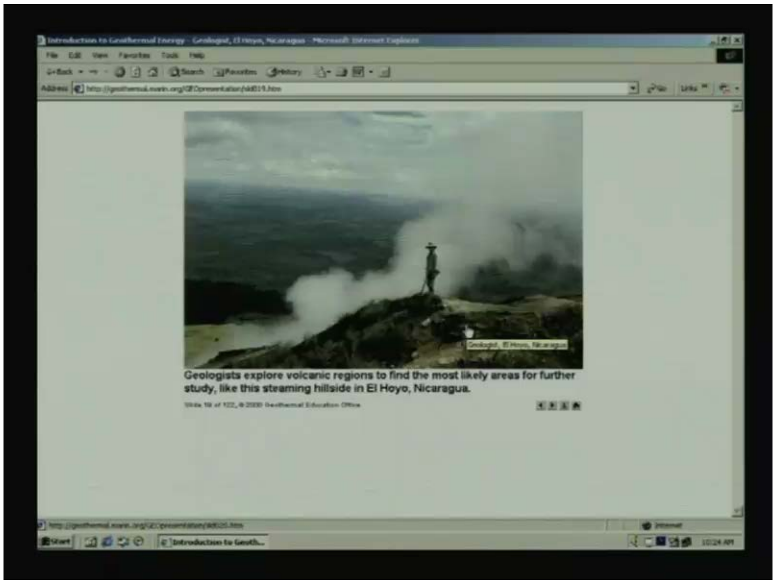

Also, there are surface manifestations. Suddenly, in some place you will find steam coming out of the ground. So, these are the surface manifestations and for example, this is a steaming hillside in El Hoyo in Nicaragua. By just looking at it you know that there is a hot spot down there.

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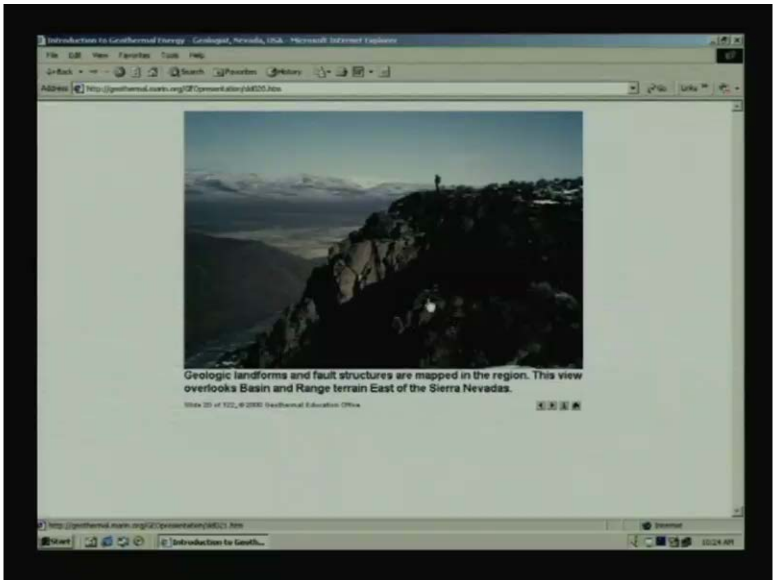

Or there can be land forms that talk about the structure. That is a structure could have formed only in some very heated regions. So, there has been a history of melting of the rock in recent past. So, those things can also be taken into account while selecting a site to investigate.

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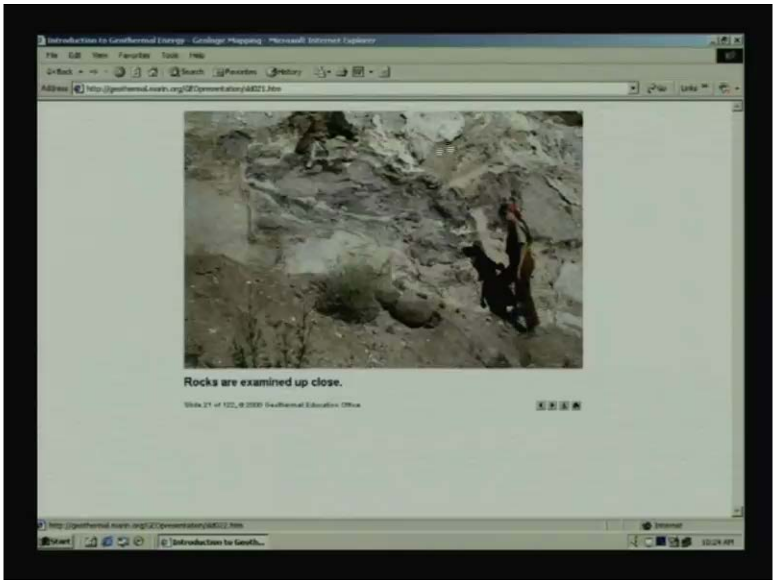

Then, the geologists have to go close and find out the character of the particular rocks.

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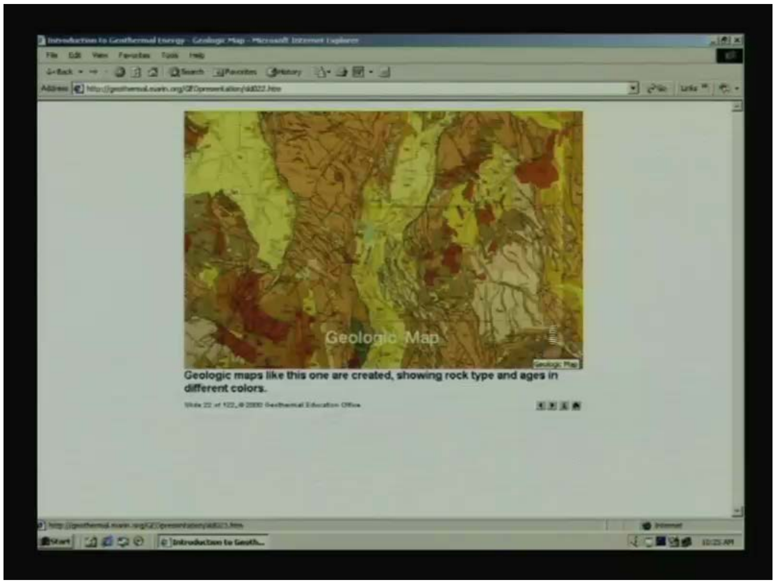

They finally make a map something like this. In fact in India, Geological Survey of India has mapped the Indian region and they have produced such maps showing the different types of rocks, the rock types and other properties.

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Then some measurement has to be made as to the electrical conductivity, the magnetism, that means overall there is a magnetism - North South, but locally the magnetism varies, because of the local property of the materials. So, those things are also indicated and one has to also take into account seismic history that means whether there are small Earthquakes or not in particular region.

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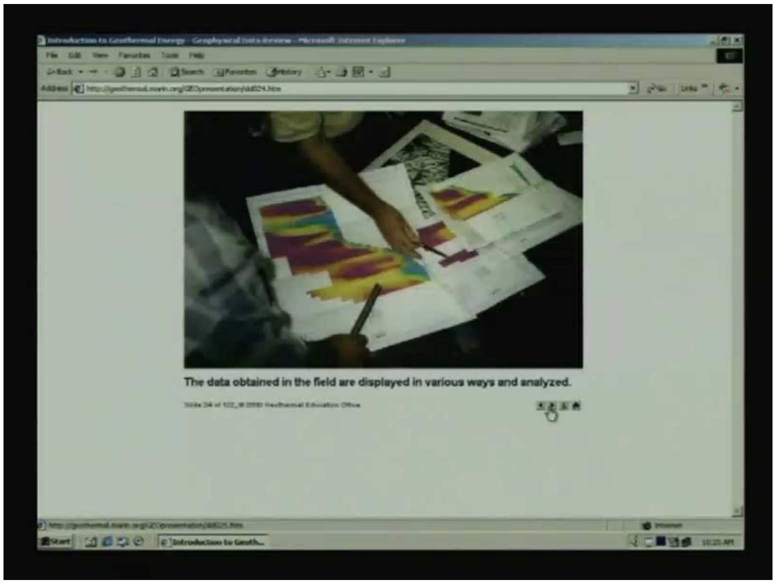

Then, these data are analyzed.

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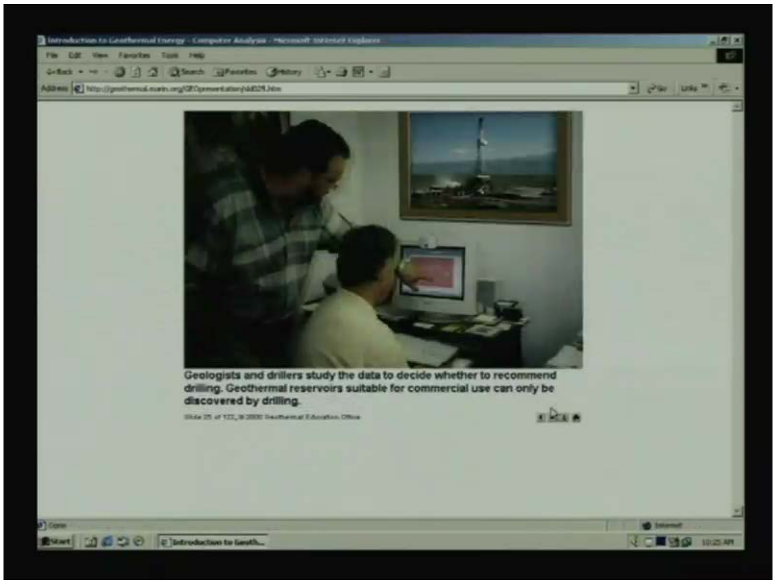

And finally, the drilling decision is taken.

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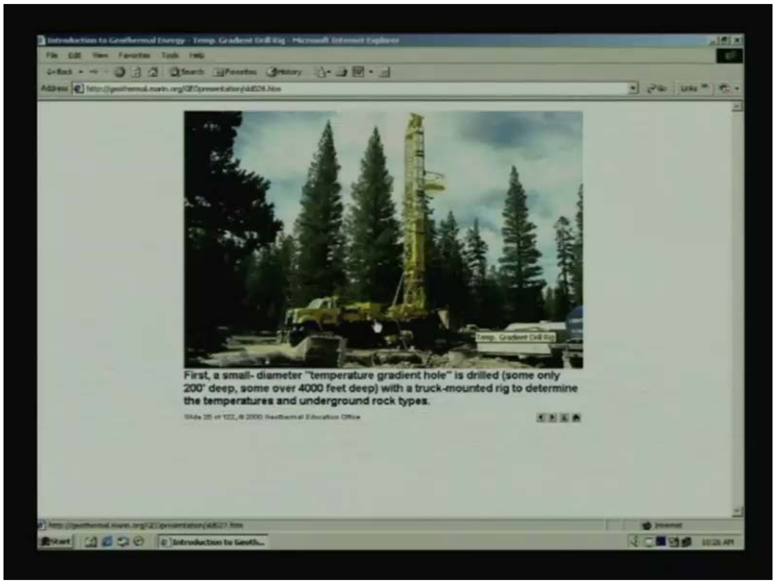

So, drilling is often done initially by small drillers that are truck mounted. India has this kind of drillers. So, India has conducted such drilling operation in many places, I will come to that a little later. So, you have this kind of small, relatively small exploratory drilling rigs that go something like 200 feet deep. Essentially, these are used to measure the temperature gradient, as you go down you measure the temperature.

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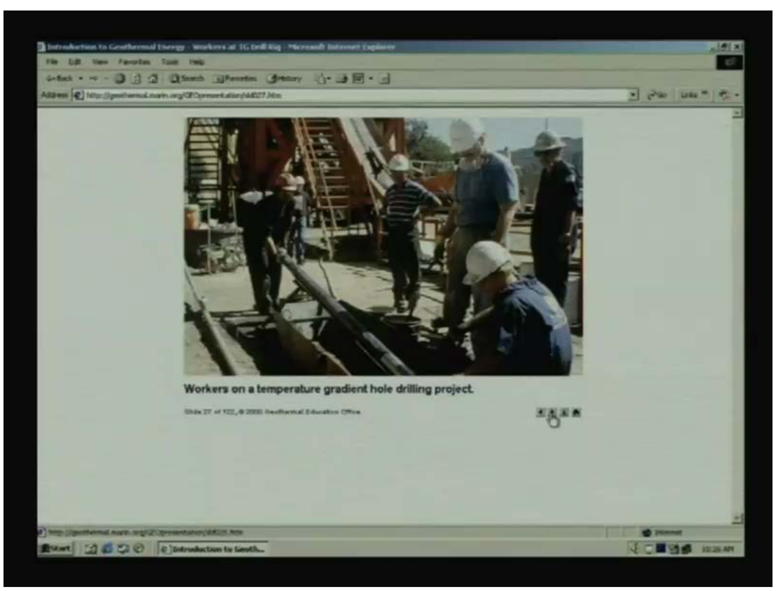

And finally, this is a picture of workers working on a temperature gradient hole project.

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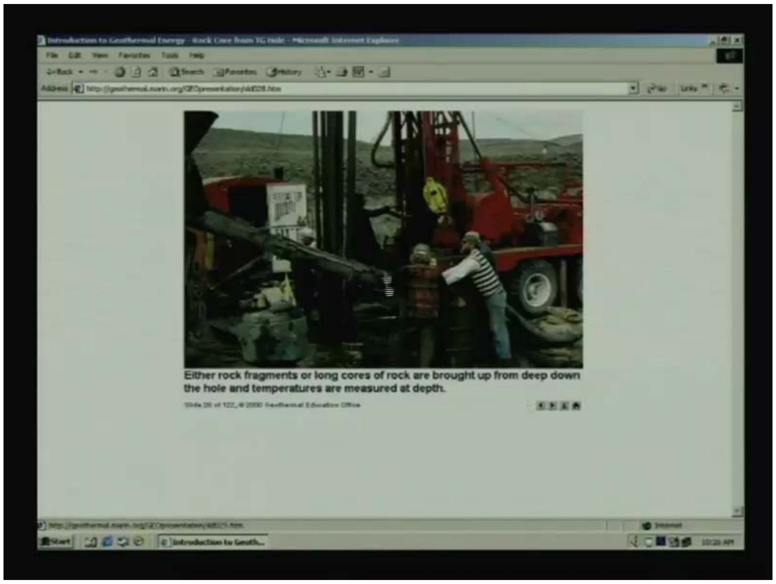

Sometimes you have relatively larger cross section of the, of the drillers, as a result of which you can take out these, the rock samples from the core and these things are then analyzed to find out their geological history.

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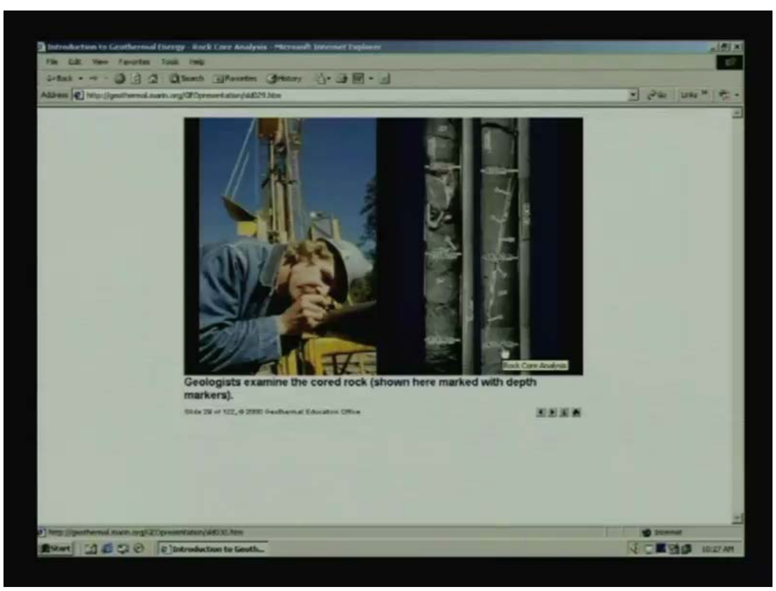

And finally, here is a, here there are two rock samples, cores taken out from the drill holes and as a result of which you can find out what kind of materials form, what kind of materials are found as you go down and they, geologist can find out the history whether or not there has been some melting in recent past, which would say whether it will be worth drilling this spot.

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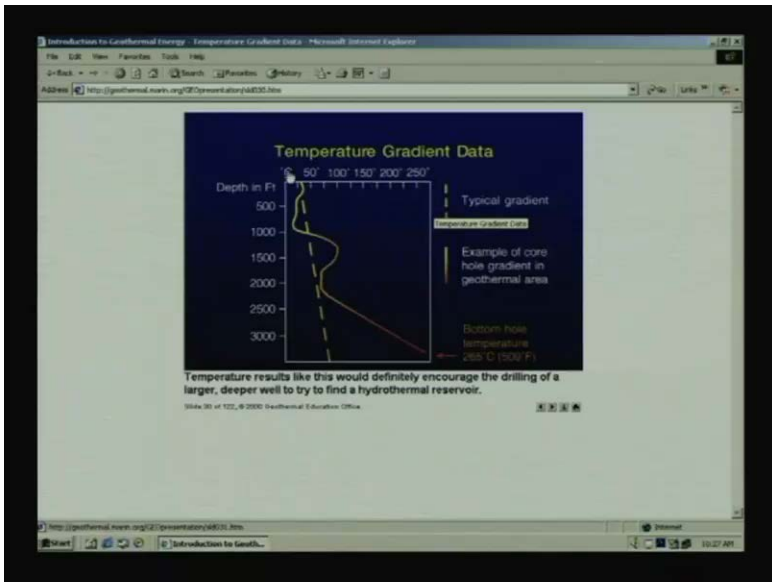

And finally, one has to plot the temperature gradient data. That means as you go down the temperature is plotted here. So, you see that here the temperature after a certain depth is going up which means that if you find such a spot it would mean that, yes, you are very close to the actual hot spot. In India, such studies have been conducted. For example in India, there have been three or four regions that have been identified as geologically or geothermally active regions. One is in Puga valley. Puga is in the Himachal Pradesh in Himalayas. The second is I suppose in Uttaranchal that means Manikaran. Manikaran is now in Uttaranchal know, yeah.

So, the place near Manikaran you have a large number of hot springs there. So, that is a place where the Geological Survey of India has identified as one of the possible geothermal areas. The third is what was earlier a part of Madhya Pradesh, but probably now it is in Chhattisgarh. There is a called place called Tattapani. Heard of it? There is a place called …

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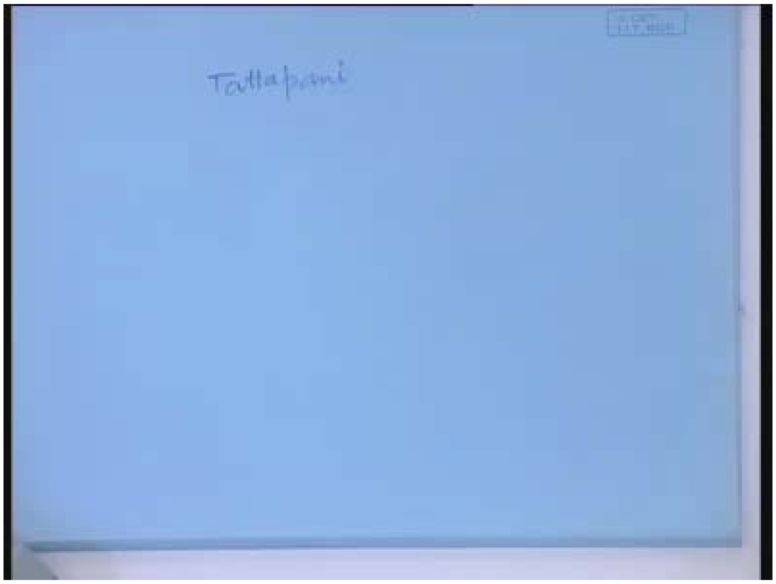

These three places are known to be geothermally active places. In addition, in the present Bihar, Jharkhand, West Bengal region, you know that there are large number of hot springs. Can you, can you name a few? Rajgir is one, yes. Bakreshwar is one, within West Bengal. Then, you have many in fact in that region. If you really tour the region, you find there are large number of hot springs which indicate that there must be some kind of a hot spot somewhere there. But, this region has not been extensively explored by actually drilling rigs. I will show you a page from the Geological Survey of India's release.

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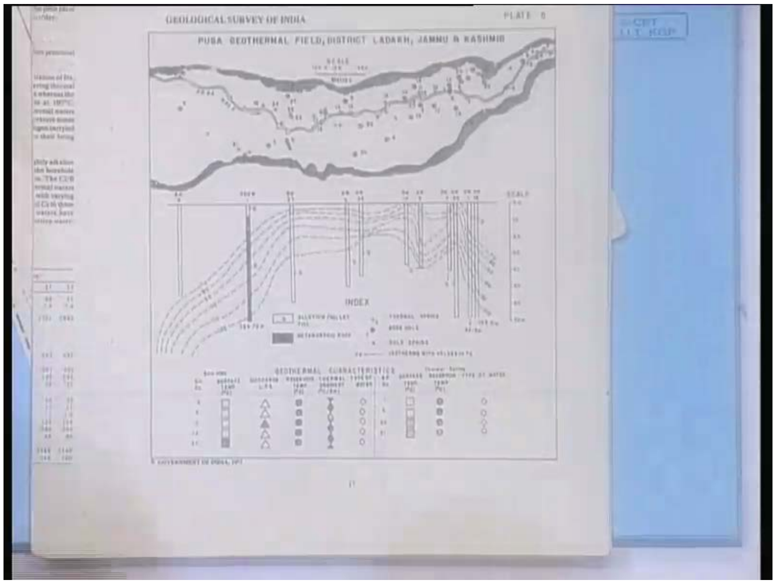

Here is a report of the exploration in the Puga valley. So, here is the Puga valley's map, aerial view or just, just the map and you will find that there are places with, can you see? Probably they are too small. There are places that are marked by cross. These are the places where hot springs occur. I can see atleast 20 of them in a same region, hot springs and the Geological Survey of India has drilled rigs in the places that are marked by a cross with a circle, 1 2 3 4 5 6 7, there are many. They have drilled the rigs to various depths and to what depths those things are marked here.

You see, these are the different depths to which the drillings have been done and as a result of which they have been able to draw the isothermal lines and they indicate that there should be some kind of hot spot somewhere here, right and in fact, even though the hot spot actually has not been reached, but nevertheless they have found sufficiently hot water in one of these rigs, so that they can get something like 110 degrees centigrade steam and there is an existing geothermal plant there. It has been installed, it is working. So, this is how the exploration is actually conducted.

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In some, some cases you have to dig production size rigs. That means the rigs with larger diameter, so that if you actually reach the spot. you can use that hole itself for production of steam and sometimes these are drilled something like 2 miles deep in order to reach that particular spot. So, the message that I am trying to get across is that the common sense view is that wherever hot springs occur, you would essentially use that water as the source of energy. No, that is never done.

You have to really find the place which is creating the heat, which is the hot spot and then you have to drill a rig to reach that place, so that you can pump in water, you can get out steam. That is how it is used really. So, for that extensive survey has to be done and finally you have to drill relatively thicker rigs through which you can, these are production size rigs, so that you can use that for the production purpose. So, these are the thick rigs that are being drilled.

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Now, if steam if you reach the spot the scene would be something like this. If you reach the spot, then it will be, the high pressure steam will be coming out like this, right and immediately you will know that you have hit a jackpot, huge amount of energy is available right there. So, once these are found, then you have to tap the place, so that you can control the amount of heat and other things and then you can put a hole pipeline there.

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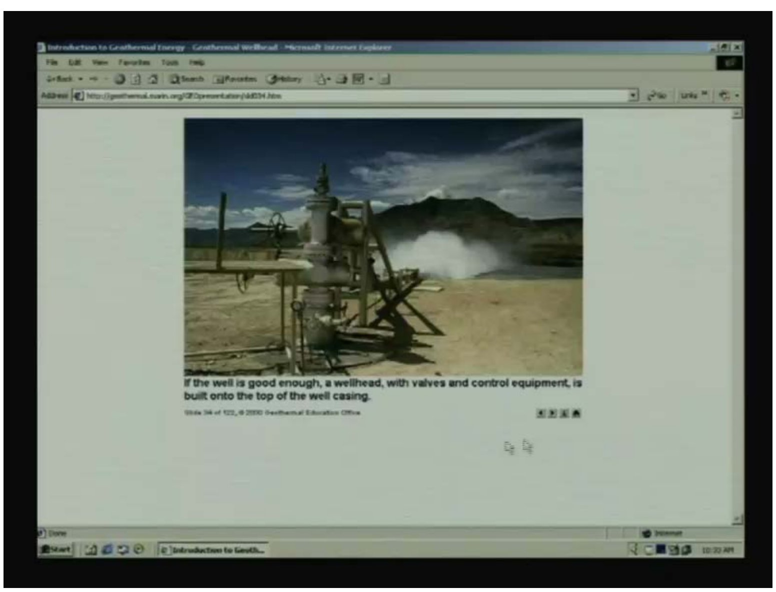

That means at the well head you have to put the valves and other control equipment, once it is found. So, initially it is found and then you have to put this control equipment at the well head.

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This is a picture of a recently found geothermal field. That means there was no surface manifestation at the, right at this spot earlier. People drilled a rig, found the place and that is how steam is coming out. So, when you really reach the place, the picture is something like this; huge amount of steam would be coming out. So, this is the place in the Nevada desert in United States.

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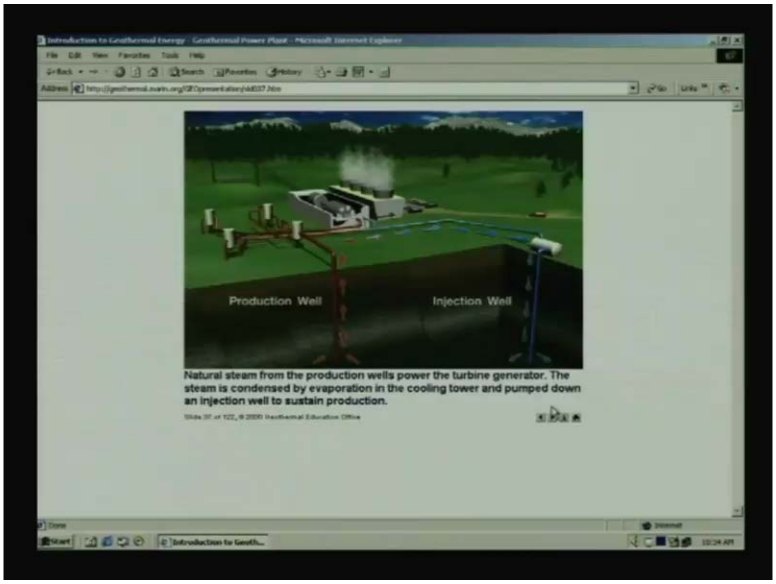

Now, when it comes to generation of electricity, let me explain it here, there are three things that can be found. Either it can be superheated steam that is coming out of the ground. There are a few places in the world where actually superheated steam comes out.

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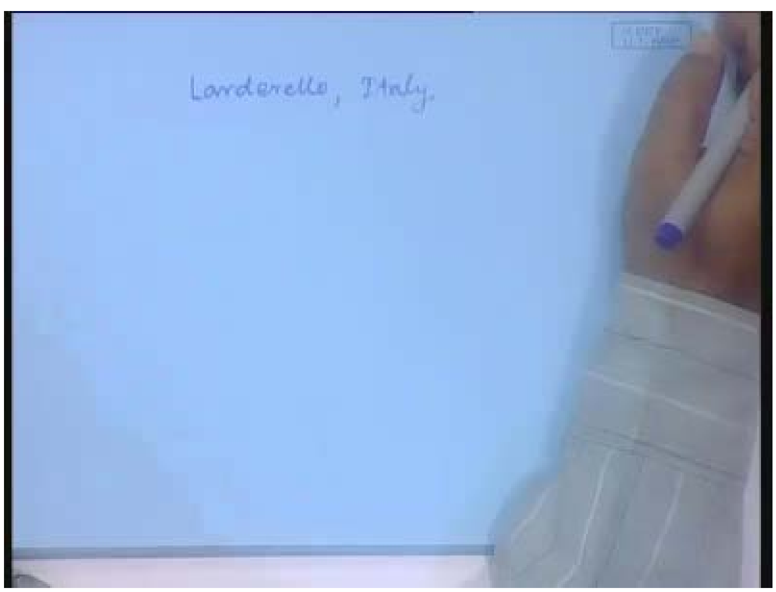

For example, the place called Larderello in Italy, in Italy, that has superheated steam coming out and there a geothermal power plant was installed right in the beginning of the last century, very early. Then, there are such fields in, nowadays in Philippines; there are such fields also in US. So, there are places, but very rare where superheated steam is found. There are more number of places that means more frequent, where saturated steam is found. What comes out is saturated steam, not superheated steam. So, we have to have some means of utilizing that and thirdly there are places, even more number of places, where you find hot water, close to 100 degrees though, like 100 degrees 90 degrees, something like that.

For example in Puga valley, the water that is coming out which is being used for power generation now is about 91 degrees. So, these three are the inputs. So, what will you do if you have the three types of inputs? First, let us consider the case of the superheated steam. Directly superheated steam is coming out of the ground, what will you do with it?

Student: Turbine

Run a turbine, fine. After that? Turbine runs and you generate, all right. But, what do you do with the steam that comes out of the turbine? You might possibly release it into the atmosphere, nothing wrong with that. You might possibly, what else can I do? Condense it and after condensation what do we do with it? Again what? So, there are various possibilities. Out of these two things that you can do, either you release the steam into the atmosphere or you can condense it into water, whatever you have learnt about thermodynamics, whatever you have learnt about the production of normal thermal power plant, from that knowledge can you tell which is the desirable one?

Student: Condensation.

Why? Why is condensation more desirable? Because, if you, if you are not condensing it, you simply save on the condenser. So, you simply release it into the atmosphere. Why not?

Student: Its efficiency …

It is never done, it is never done. Why? Because if you have a condenser, then at the input end of the condenser you can produce almost vacuum pressures, because you are condensing it. A huge amount of gas is becoming a tiny amount of liquid, so you can bring down the pressure at the outlet part of the turbine, quite a lot, so that the turbine output power is very much increased. So, even if the steam that is coming out does not have much pressure, it has only, it is just a superheated steam, you can still use it for running a turbine, if the pressure at the outlet end is very low. That is what happens.

The point is that if you release it into the atmosphere, the outlet pressure of the turbine is the atmospheric pressure. Instead, if you condense it what you are doing? You are taking a large, very large amount of steam which occupies a large volume into a very, very tiny amount of water. So, the ratio is unimaginably large. That means steam condensed into water becomes very small in volume. As a result, as you are condensing it, if you are, if you are condensing it into very small volume, then what happens to the rest of the volume? That is occupied by nothing, as a result of which you create almost vacuum pressure.

So, the turbine then works against the inlet pressure that is obtained from the geothermal well and the outlet pressure is close to vacuum. Naturally, the amount of power that you can take out of the turbine is quite large and it will be quite small if you simply release it into the atmosphere. It will not be economically viable. That is why the condenser is always economically viable. So, what do you do with the water that is condensed? If you say, use it for some other purpose or release it into the atmosphere, what will happen? After sometime, the water that was coming out from the geothermal well that will end up. So, there has to be some way of replenishing that water. So, what is done is not one, but two holes are bored. Through one steam comes out and through the other you push it, push the water back into the well. So, the water goes into the well, gets heated up, comes out as steam. That is how you run the turbine and the condenser system and that is it. It will need nothing more.

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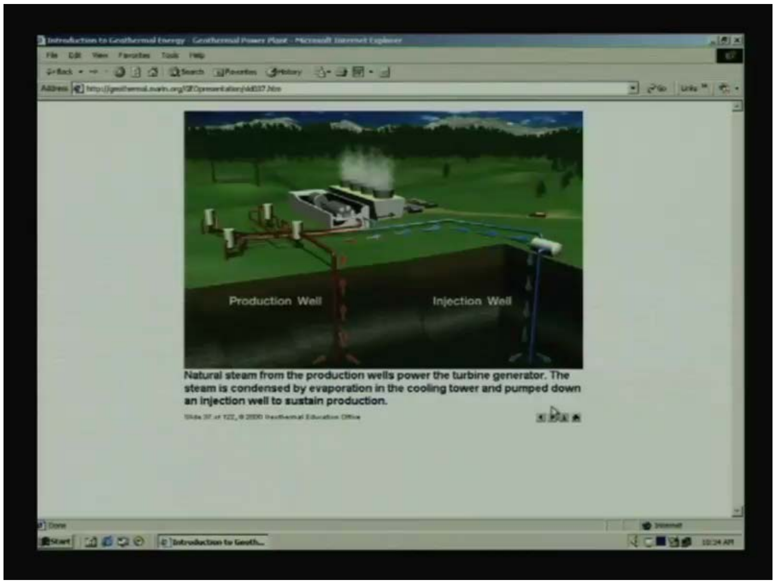

So, here you have this kind of a system shown, where you have the production well which goes and you have got the turbine generator system and here is the condenser. You have seen this kind of condenser in any of the thermal power plants. If you simply go to Calcutta, you see these condensers in the Kolaghat thermal power plant. Can you see that? Yes; so, from there again it comes out and it is again pushed back to the, so this is called the injection well and this is called the production, production well. There has to be two wells.

Student: …

In that case, you will need

Student: Refrigeration

Yes, you will need something else, another refrigerant fluid. Normally in this kind of places, I will come to that, refrigerant fluids are used, but not in the places where you have superheated steam, because superheated steam is a, is a huge amount of energy that is already available. So, you do not need refrigerant fluid.

Student: Sir, what happens …

Need not be; that depends on the temperature of the water that you are using for condensing it. Need not be and the colder it is the better, because the less will be the pressure at the outlet end of the turbine.

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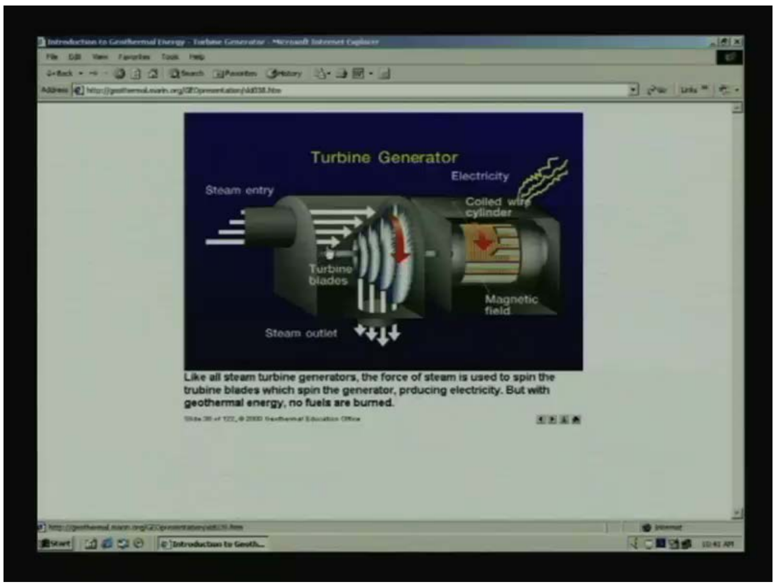

So, here you have the picture of the turbine generator. The turbines are normally such axial flow turbines, so you have to steam coming and the rotors like this.

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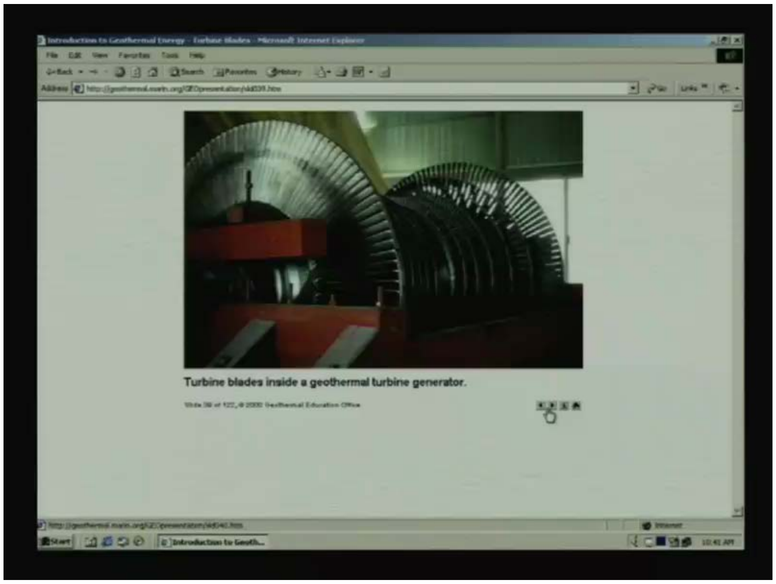

These are some pictures of the turbines that are actually used in geothermal sites. It has to have some properties. For example, the steam that comes out is not pure steam. In case of thermal power plant you can have pure steam, while the steam that comes out of a geothermal well is not really pure steam. It is mixed with various gases including some radioactive gases. For example, in many of the springs in India, you find radon. Radon is a radioactive gas, from which actually radium is manufactured in India. So, you have such kind of gases also. So, you need to have some anticorrosive arrangements made in the turbine blades.

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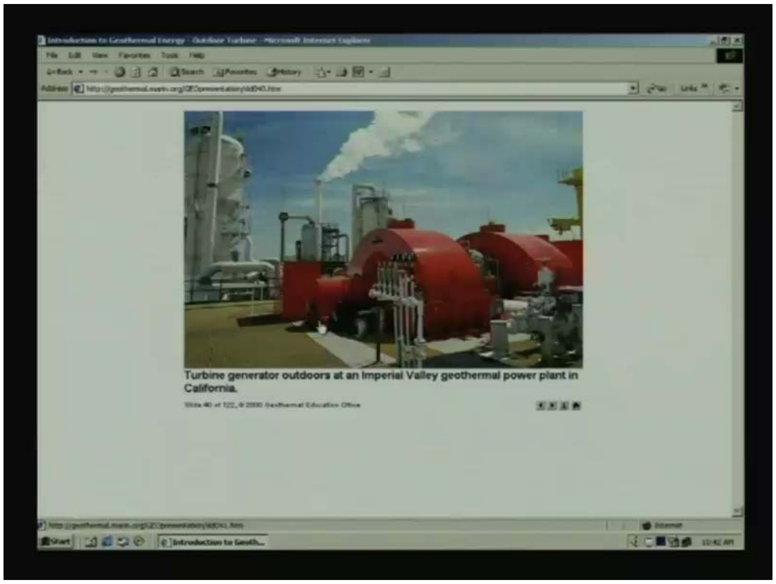

So, here is a turbine assembly system shown in the Imperial Valley. There is a geothermal plant in California. This is a picture of that. Can you see the size of the plant? Quite large, right.

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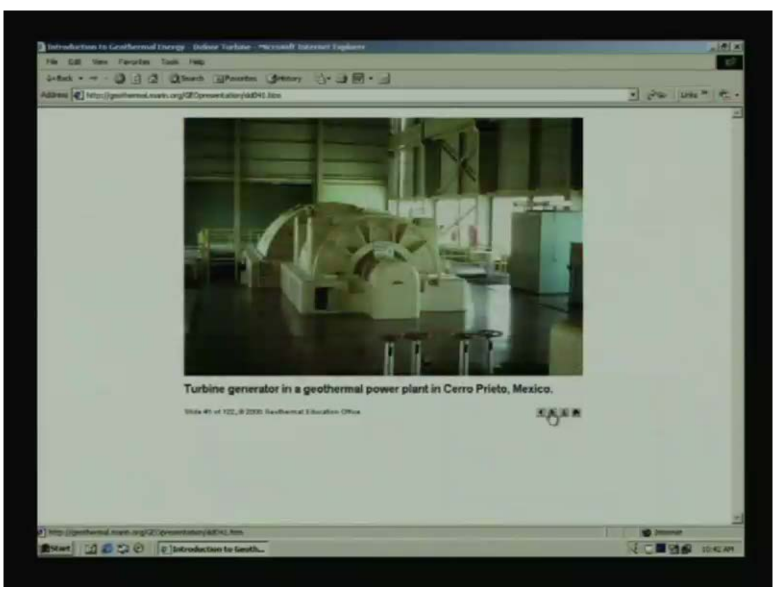

And this is a relatively smaller turbine generator system in Mexico.

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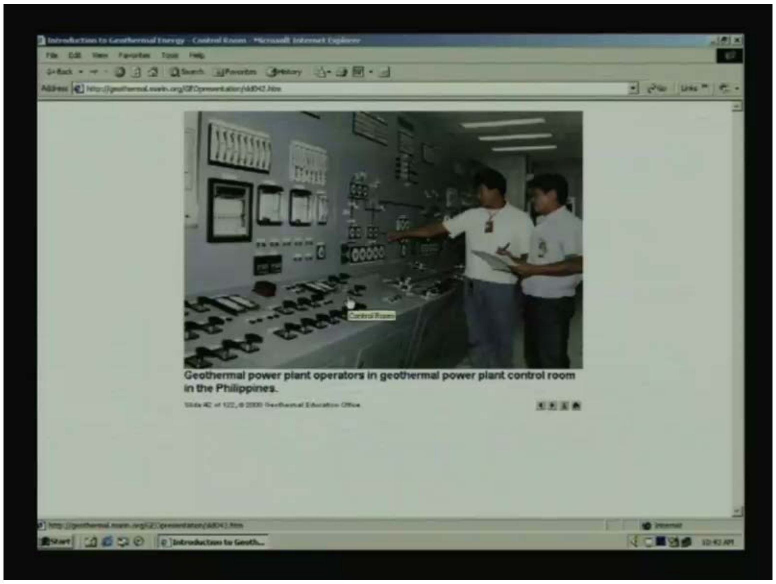

And here is a control room of a geothermal plant in the Philippines. Philippines has, is endowed with quite a large amount of geothermal energy.

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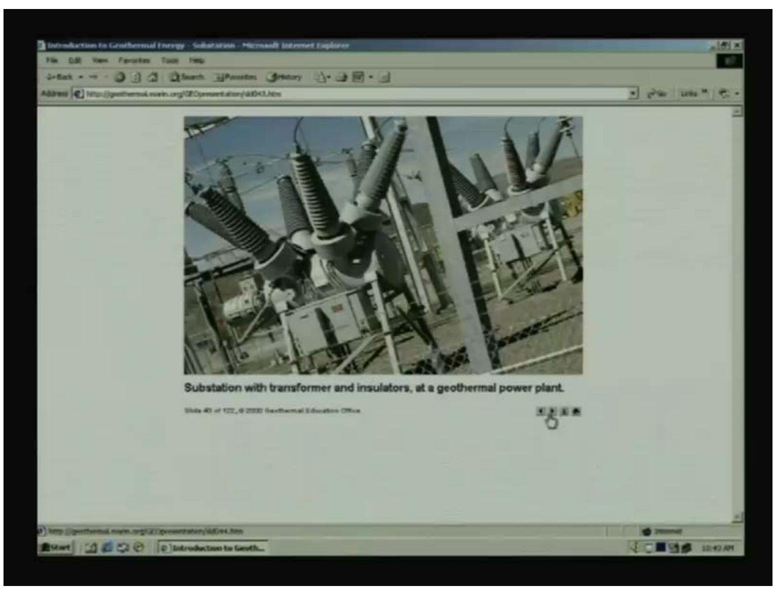

This is the, the outside of the geothermal plant, which is standard for any system though. So, in case of the normal plant, you have normal plant that take in superheated steam. You have the system something like this.

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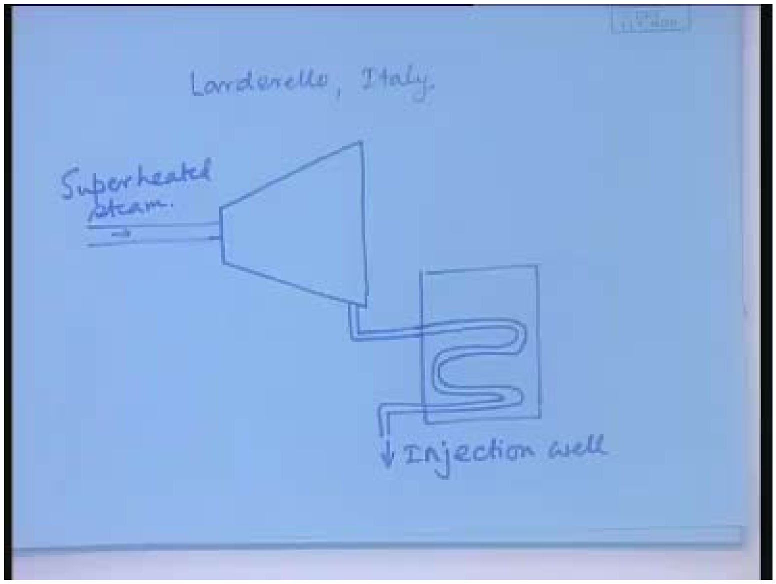

You have the superheated steam coming, then you have the generator, the turbine, the turbine output goes to the condenser. So, the condenser would be something like this and this goes to again the injection well, all right. So, the picture of a normal geothermal plant would look something like this. Remember, this fume is in no way toxic or anything. The fume that you often see in thermal power plant, that contains carbon dioxide as well as many other substances that come out of burning coal, while in this case it is only steam.

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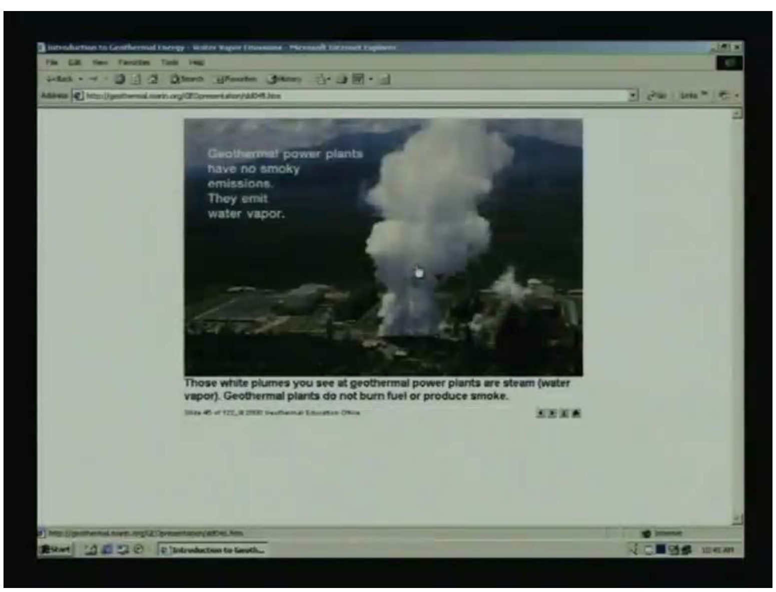

So, you do not expect to see any other polluting material in that steam. So, it is a very clean source of energy really.

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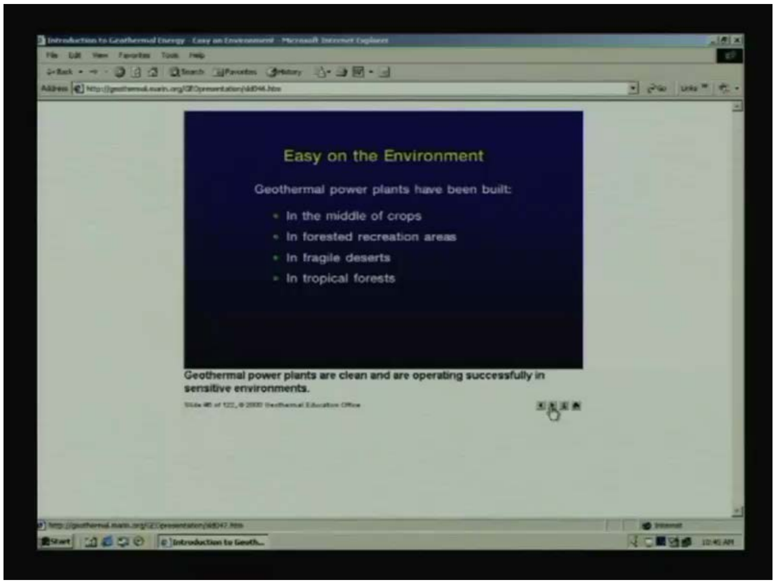

And actually, the geothermal plants have been installed in the middle of the crops, in the middle of forested areas, in the middle of fragile deserts as well as in tropical forests. In many other types of industries or power generator plants, there are environmental problems due to this power generation system, while in geothermal energy this is completely environmentally benign; nothing happens really to the environment.

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For example, you have this geothermal plant in the middle of a crop that is in California. Here it is in the middle of the Mohave dessert in California. Here, this is a geothermal plant in the middle of forested mountains in the Philippines. Can you see that? Pretty small, but nevertheless you can see there is steam coming out. So, you can place it anywhere depending on where it is available and because there is no environmental, environmentally polluting steam coming out, so this is quite safe.

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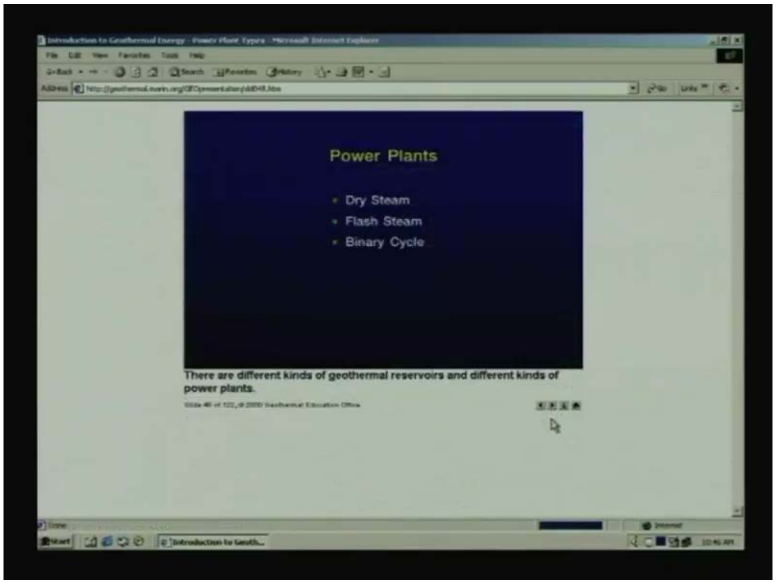

So, there are three types of cycle.

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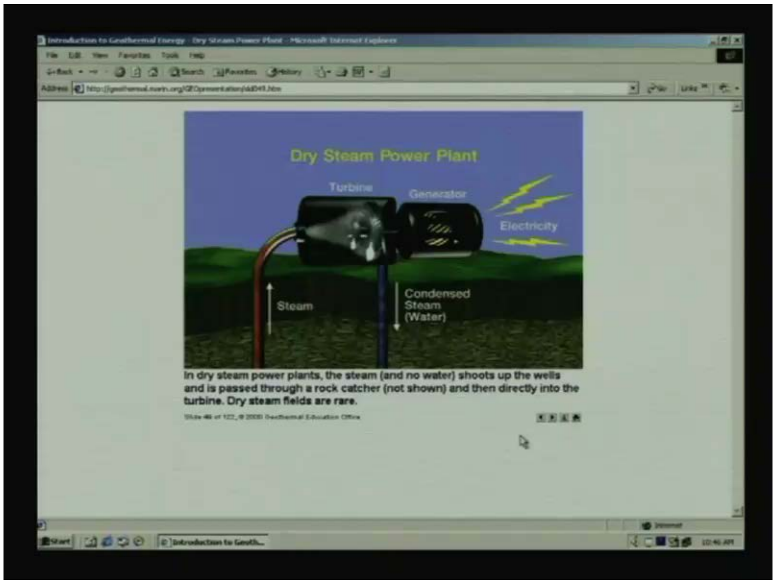

So, if you have dry steam coming, then it is simply the turbine and the generator that is it. Now, if you have the wet steam coming out or saturated steam coming out, then what do you do? There are very large number of places where you have saturated steam. For example, there is a field in New Zealand, it is called Wairakei. That place has a large number of, large amount of saturated steam coming out or it is a saturated steam field. Similarly, there are some fields in Philippines that are saturated steam. There are some fields in Mexico as well as United States that are making saturated steam.

What do you do then?

Student: …

His suggestion is heat them. Any other? You cannot put that directly into the turbine. What will happen? The turbine will corrode. Because the water droplets are formed, the turbine will corrode. So, what do, what do you do in order to avoid that? He says heat it. So, imagine that there is a power plant in the middle of nowhere, may be in India’s case, in the Puga valley up the Himalayas, what kind of fuel do you take there? Coal? Do you haul the coal up the Himalayas? You will not work. Take oil in helicopters, will not work. So, you cannot really do that. What else can you do? That is almost never done. In case of saturated steam heating up further with some kind of a fuel is never done.

Student: …

Use the electricity produced, to do what? Heat, oh no, that is never done, because there are better ways of doing it.

Student: …

But that comes later. For saturated steam also that is never done. As I told you, there are three types of things that again come out, either the superheated steam or saturated steam or hot water. The refrigerant fluid is done for hot water, but not for saturated steam. Something very simple is done, very simple. That is suppose this saturated steam is coming out, if you allow it to expand in a relatively lower pressure chamber, what will happen? At that pressure, at that temperature it will be superheated. So, if you simply allow the pressure to be lowered slightly, so that the steam becomes superheated that is enough. You do not need to add any water, you do not need to add any fuel, no heat. So, you simply allow the pressure to drop a bit before it enters the turbine. That does the trick and that process is called flashing.

So, flashing is a process by which you make superheated steam out of the saturated steam simply by allowing to expand in a chamber.

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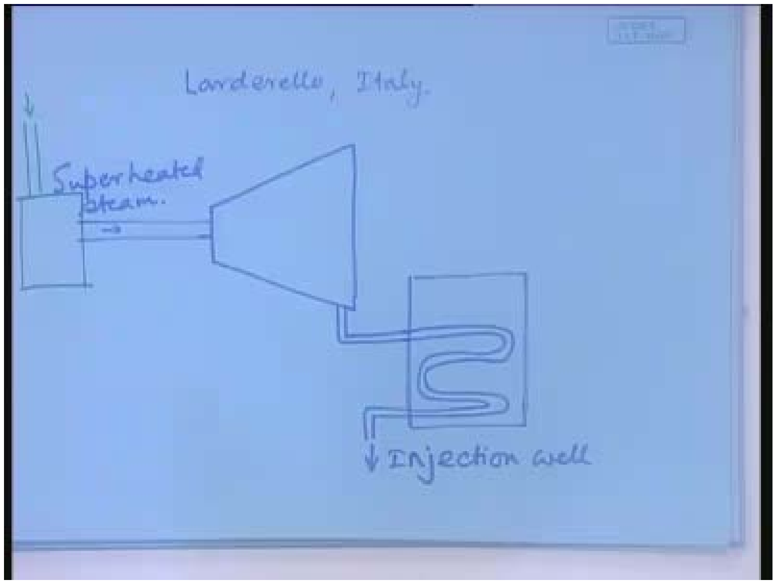

So, in that case you will have, before coming here there would be a chamber and this is where the saturated steam would be coming and this chamber is nothing but just a chamber in which only a accurately maintained pressure is created. So, the pressure here is accurately maintained and how can you maintain the pressure? Either you can suck some steam out or you can simply allow the turbine, here the pressure is known because it is given by the condensation and here the pressure will depend on how much energy you are taking out of the turbine, right. So, you can also create the pressure by adjusting the amount of energy that you withdraw by means of the turbine.

So, in any case, the point is that here a lower pressure is maintained. The saturated steam comes, expands and may become superheated and that superheated steam goes into the turbine. So, even though the pressure here is less than the pressure here, still you avoid corroding the blades. That is how it is done always. Wherever it is superheated, you will simply have a flashing cycle. So, this is called the flashing cycle.

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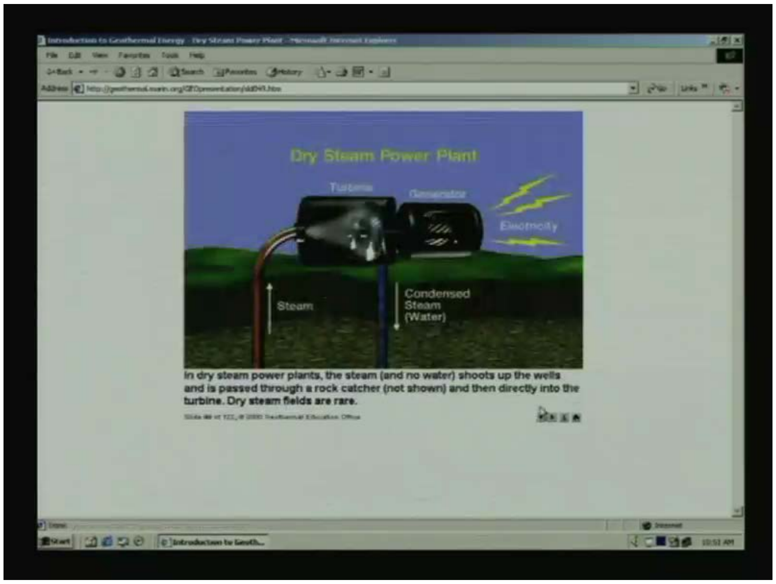

Schematically, first, this is dry steam system.

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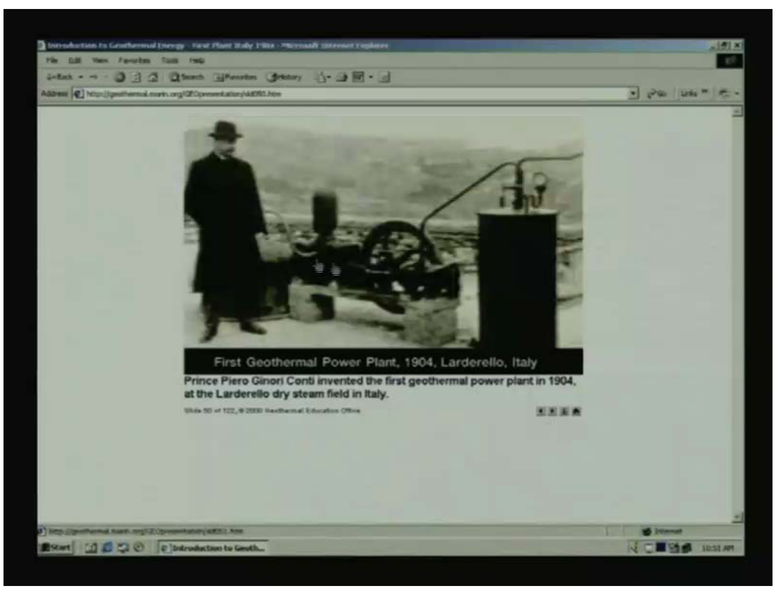

First it was installed in Larderello in Italy. That was do you know which year? 1904, so long back a geothermal plant was created there.

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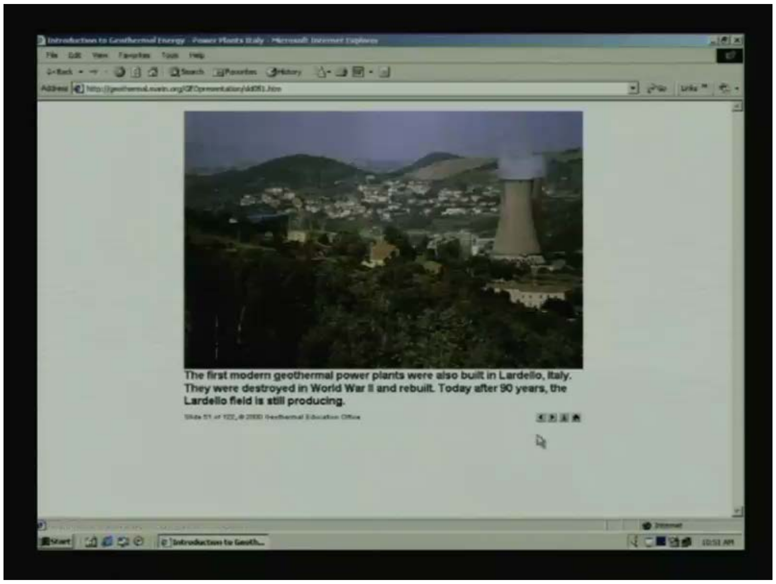

Nowadays, the geothermal plant looks like this. After 90 years it is still working.

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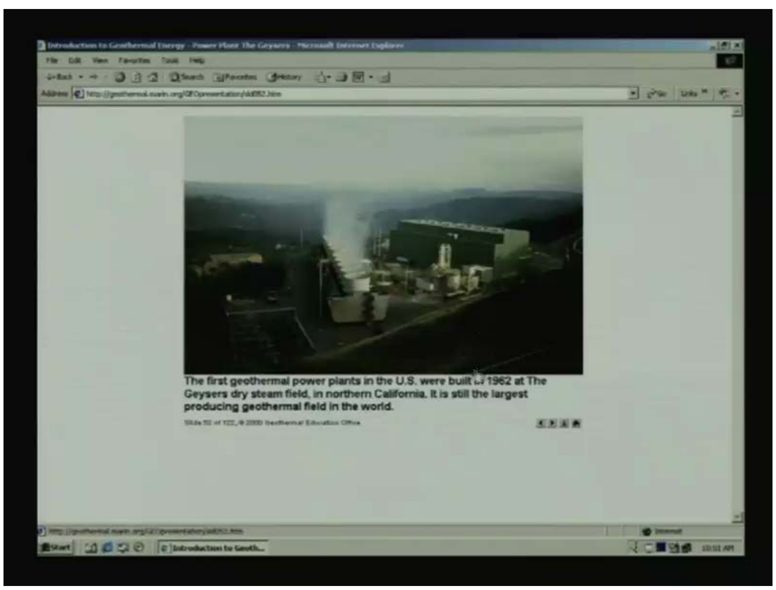

This geothermal plant is in US. It is from the Geysers field in California. In fact, it is the largest geothermal field in the world. So, the aerial view looks something like this.

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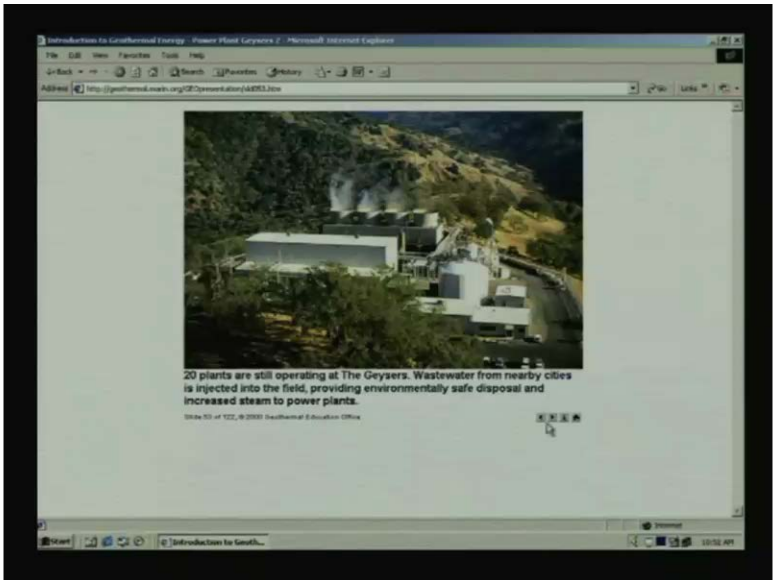

Here is, here is another picture of a geothermal plant.

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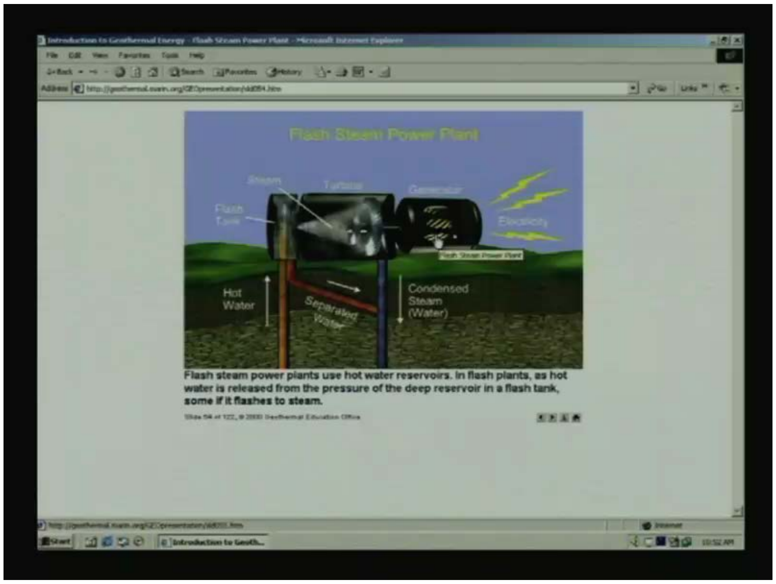

Now, you come to the flash steam cycle. Here you see the same system. This is a schematic diagram. It does not really look like that. It is not like there is a pipe and on top of that it is station like this; it is just a schematic diagram. Here you see the flash tank.

That means hot water coming here or saturated steam coming here and that is allowed to expand here. As a result, the steam comes and runs the turbine.

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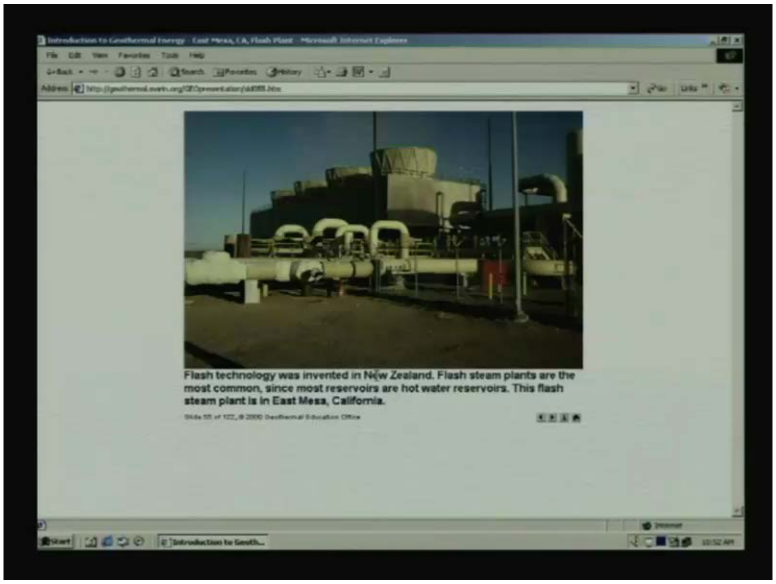

For example, here the flash technology is used in New Zealand. This is the Wairakei system, as I just mentioned and here, there are also saturated steam flashing cycle systems. In California, there is a plant in a place called East Mesa.

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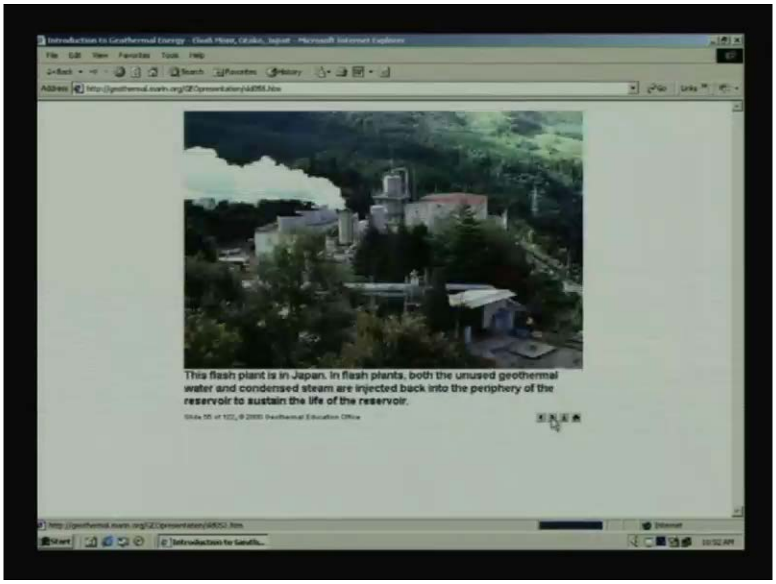

And here is a plant, again saturated steam plant in Japan.

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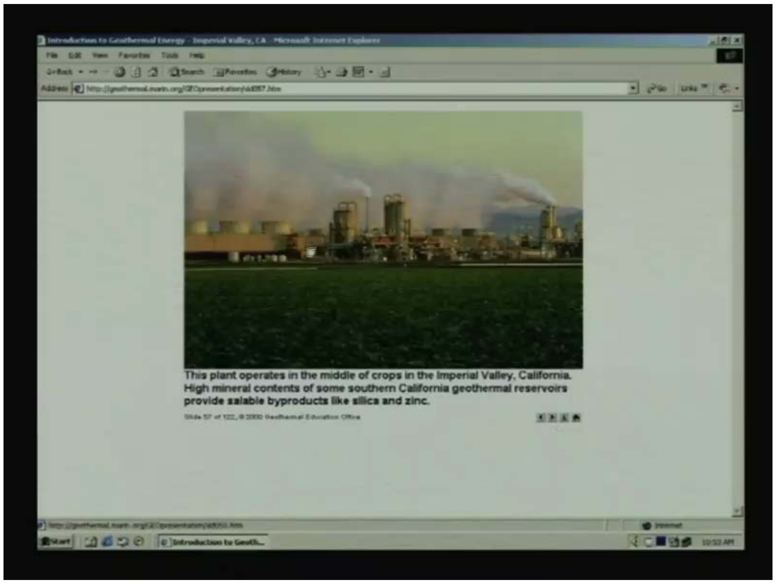

And here is, again in California. Can you see that? Here is a crop field and at the background you can see a huge plant. This is the Imperial Valley plant in California.

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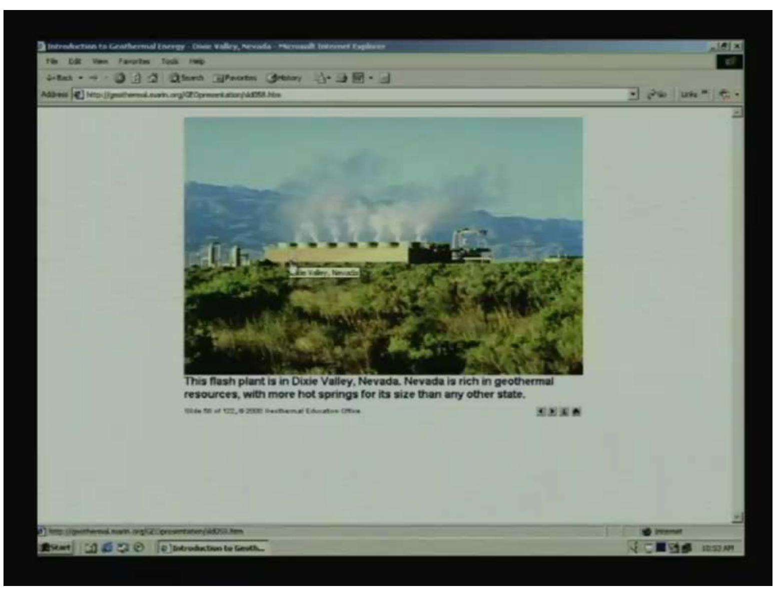

And this is another plant in the Nevada desert in United States. So, all these are actually plants that use saturated steam.

So, today we have covered the plants that are that use saturated steam and superheated steam and tomorrow we will come to the system that use also hot water.
Thank you very much.