Fluid Inclusion in Minerals: Principles, Methodology, Practice and Application

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Lecture – 01
Introduction

Welcome to this lecture series on Fluid Inclusions in Minerals: Principles, Methodology, Practice and Applications. To begin with, let me tell you that this course is actually meant to popularize this technique of study in Geology which generate very important information and which can be used to understand the various earth processes.

So, to popularize this and to generate interest among young, undergraduate students and the future researches so that more number people use this technique which this the Fluid Inclusion studies is one of the methodology or technique in Geology to understand the earth processes which form a modified rocks in different regimes. Begun about one and half centuries ago and within these time period starting with very primitive way of generation of information using standard micro microscopic technique of reservation and using very simple device for conducting heating-freezing experiments under the microscope which we call them as micro thermometric experiments.

Within these, time this technique has improved to a very high level of sophistication with use of many precision, analytical equipment, microwave techniques such as the Raman Spectroscopic technique, the laser ablation inductively coupled plasma mass spectrometry like LAICPMS and many other sophisticated micro beam techniques like X-ray photon spectroscopy and proton induced X-ray emission spectroscopy.

So, all these techniques are being used regularly, routinely in different develop laboratories for characterization of the fluid that we will be discussing though this lecture series. So, the basic idea is that and before actually going in to subject of fluid inclusions, how to study them; what kind that we are going to generate through this study; what kind of data that we are going to generate? It is important to and to realize that why first of all why we study this fluid inclusions in and to begin with let me point out that this is a characteristic of the minerals, the constituent minerals in rocks or the minerals when they are occurring as in the mono mineralic form like say for example, a Quartz Vein or a Calcite Vein or situation like that.

So, these are not bulk rock properties. These are essentially the individual minerals, attributes. And we will through the series of this lecture we will see that how they come into existence under the natural conditions.

So, the first thing is that before going to understand what this fluid inclusions are, the basic idea is that we are basically trying to understand the fluid. The fluid as we know is we are talking about fluid.

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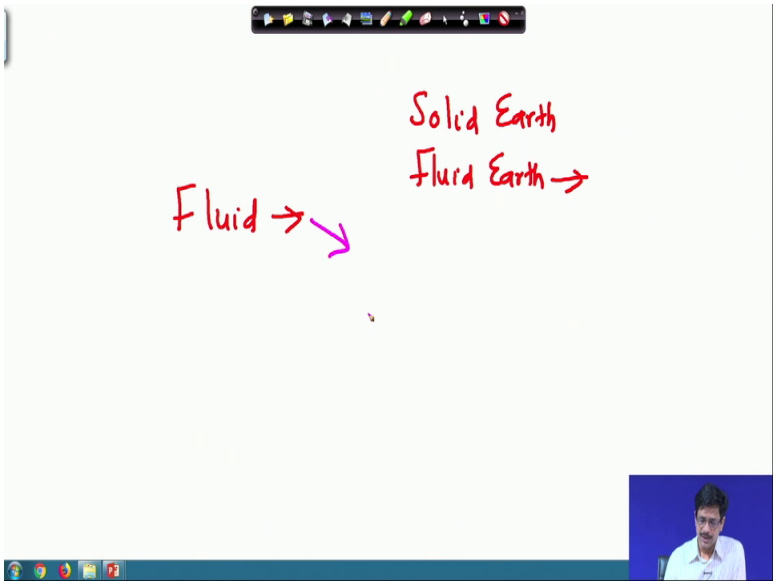

When we describe the earth, we generally split into broad components of the earth as the Solid Earth and the Fluid Earth. And many situations where the solid earth and the fluid earth are distinctly separate like as we know that the fluid earth the atmosphere which surrounds the surface of the earth, and the hydrosphere constituting the oceans and the flowing river and the stagnant river, they would stagnant waters.

They constitute the fluid earth which is we see on the surface of their planet and which is physically distinct from the rest of the earth which is the solid earth; but there is a vast regime in which the fluid is very much in contact with the solid; that means, the rocks and in different depth regions of the earth; starting from the very surface going to the very deep interior of the earth that. You can imagine up to the lower mantle depth almost about 600 700 kilometers up to depth; up to depth that kind of the depth range also the fluid is present. In the presence of the fluid is detected is understood to be there and the

important aspect is that this fluid actually, the fluid essentially operates and results in a whole lot of processes.

So, it is very essential to understand the fluid to characterize in terms of its constituents, competitions to understand the Physio chemical environment in which the fluid operate.

So, if you look at the entire spectrum.

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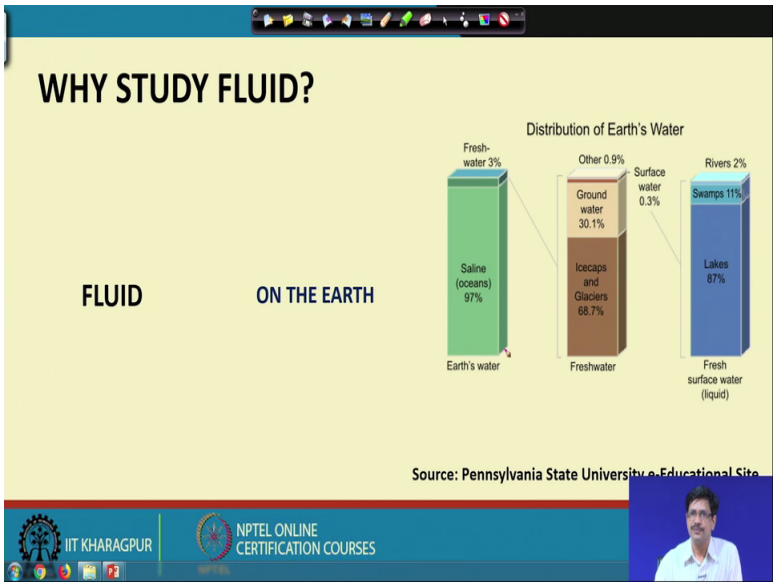

So, this is our this is this is the this is the fluid which we see on the earth; out of which this is the part which constitutes the saline oceans which constitutes about the 97 percent of it. The fresh water which is 3 percent and the fresh out of the fresh water is the constitutes the ground water.

The ice cap and the other water which is about 0.9 percent of that and from that surface water which constitutes about 0.3 percent is the fresh the fresh in the saline lakes which constitute about 87 percent. This is fresh surface water and 11 percent of it are locked in the swarms and the river only is 2 percent.

So, the situation is that this is the excluding the atmosphere which we just mentioned. The fluid how that we see on the earth. We know how this fluid actually shapes the surface of the earth; results in different types of landscapes through erosion. And also such kind of water also give rise to different types of formations as a secondary processes alteration and generation of new types of rocks and soils on their earth surface.

But, a substantial portion of it and this water is actually is see has a hydrologic cycle through which it evaporates to the atmosphere. And then, precipitation in the form rain and this is how we understand the nature of hydrologic cycle which works.

Now, if we talk about the and this water is the water that you presently see we have fare idea about its compositions and we can pick them up a samples and analyze. Although, there at this is the water which often and in many of this instances which also travels deeper in to into the earth crust, interacts with a different rocks.

And results in different types of phenomena including sometimes they participate information of different types of deposits of metals which we recover them from different types of ore deposits.

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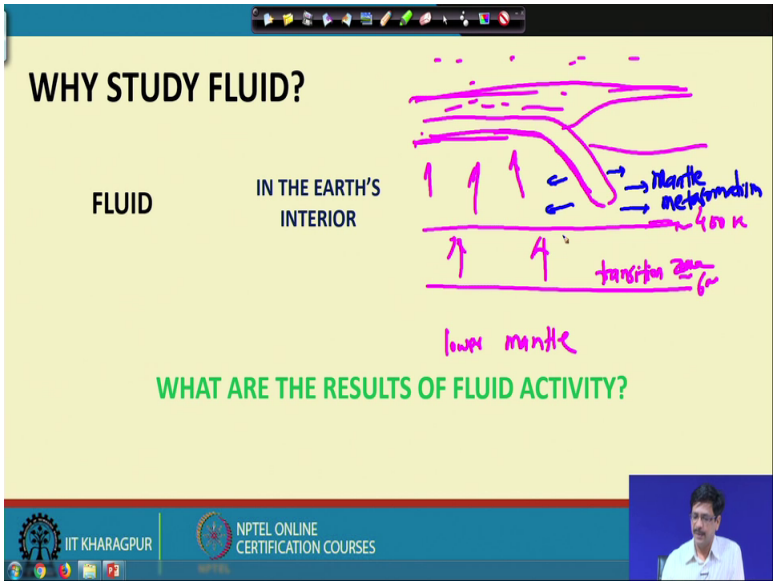

So, we as I mentioned that a the major part of the fluid is in the earth's interior and what we see on the surface is oceans and the river water or the water which is locked or I mean the low then shallow ground water, almost equal or more in dimension more in magnitude that much of water is locked in the layers in the in the subsurface in different types of rocks, if we rocks of the crust in the mantle.

If we just have an idea about what this subsurface processes they operate. This is the ethosphere and this is the atmosphere which can which is say up to around 400 about 400 kilometer and we do have about 600 kilometer which is the transition zone and then, the

lower mantle. What is believed is that possibly the earth's core is possibly devoid of water, maybe during the process that this core formed from the solar nebula. There was no much of water that could get accommodated into the metallic iron metallic core. But almost of the rest of the part of the formation of the earth, this water was initially locked up initially was present in this deeper region. And it is also believed that during the process of differentiation of the earth, because of the release of these volatiles from the deeper region actually from the atmosphere in from the ocean.

And the atmosphere and whatever we see the water which is present in the ocean is also it gets recycled in to the deeper part of the lithosphere and cause sometimes which is basically the mantle metasomatism. So, it is kind of a recycling of the water which already once was devolatilized or was expelled from the interior part of the earth during the process of such kind of recycling, during the subduction of the oceanic and the countdown the lithosphere into the ethosphere. They do carry the water and add up to the materials in the mantle and along with that they do add many of the constituents like the large and lithophile elements the more soluble the lighter elements and the low the light ware earths and many of the elements.

Again, they enrich the this part of the mantle which becomes an enriched mantle which is which again when gives rise to different rocks by melting leaves their signature on that. And so the basic idea of discussing all this thing is that what we know as the these the fluid.

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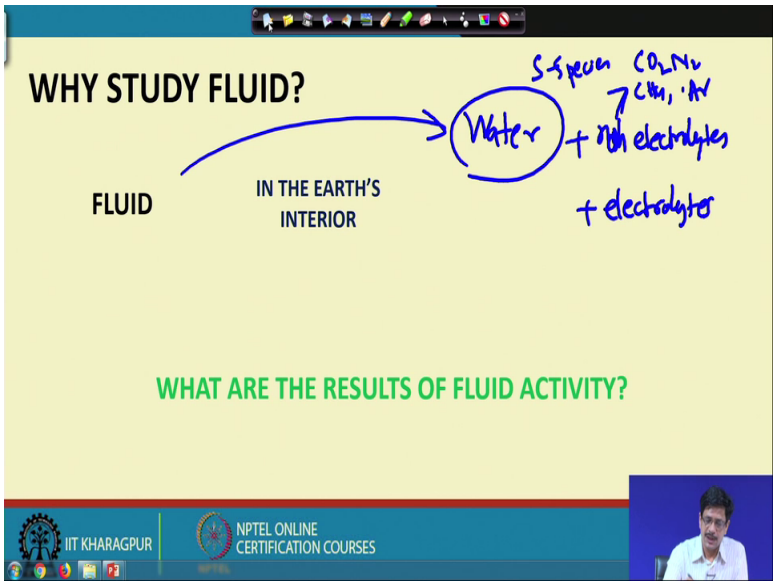

This fluid is maturity of its constituent interaction is actually water and this water is charged with many types of other soluble constituents as the we can say that water plus various non electrolytes. And then, various electrolytes and this water which is which pervades into the many interior part of the earth in the lithosphere, in the crust in the mantle regions by virtue of the higher pressure and temperature condition.

They have a very substantial portion of this various types of non electrolytes which are your which are our gaseous species like carbon dioxide, methane. Sometimes nitrogen, argon and many of the sulphurous species like a these are all they remain dissolved in substantial quantity in the water which does a lot of activity and gives rise to a lot of processes.

So, the spectrum is.

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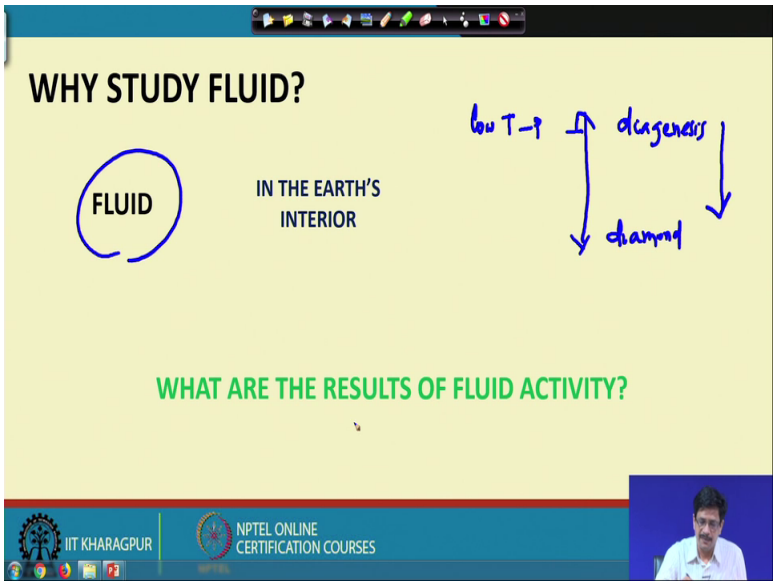

So, wide that this fluid is fluid activity results in very low temperature and pressure regimes such as the very low grade metamorphism that happens in the diagenesis of sedimentary basins when they are just subjected to very low pressure and temperature condition. So, condition as low pressure temperature situation says diagnosis to very high pressure temperature condition situations pertaining to a situation where for the diamond, form in the different in some specific part of the upper mantle.

So, the range of operation of this fluid is wide and so operate in the very wide spectrum of pressure and temperature. And in between lies a whole spectrum of processes such as deposition such as result of mineral deposits or views dimension which are our major contributor of metals, different types of metals you get them from the different types of mineral deposits which are exposed, which formed in much in such kind of higher pressure conditions and.

So, this justifies. So, then this fluid that we are talking about, it needs to be well understood and characterized; and we need to aid retrieve the conditions at which such kind of such fluid operated in the interior and give rise to different types of features, different types of rocks, mineral deposits and melting of rocks and so on.

So, it is the situation that it is essential that we understand of we apply this kind of techniques which basically to understand the process, which we are operating in the interior. And the results of the fluid activity as we have discussed is pretty.

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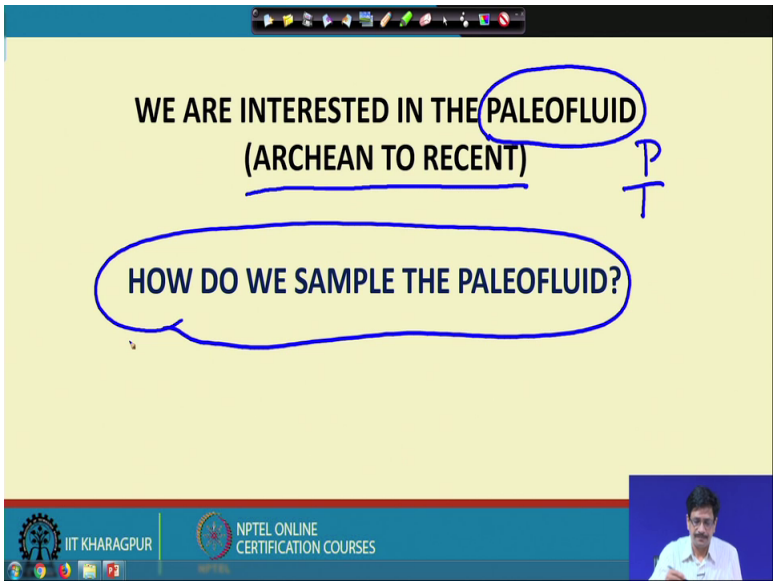

So, we know that the fluid activity that we are talking about has been going on science since the very beginning of the formation of the earth.

So, we can say that that this fluid activity has been very much from the Archean to Recent. We know that it we see the ocean was existing has been existing right from the Archean is some idea is to how the ocean water evolved you also have got to know from some other evidence. So, the fluid that we are talking about, essentially we are interested in the in the Paleo fluid.

So, that the means the fluid which operated in the earth into (Refer Time: 18:36) in geological past in terms of 100 or 1000's of million years or billions of years ago. And we are interested to work out how to retrieve the information is to what was the characteristics of the fluid; what was the physical chemical parameters. So, where, we mean physical chemical parameters we essentially talk about the pressure and temperature and many other compositional characteristics.

So, now the question is that how do we sample the Paleo fluid? Are there ways that we could get these samples? So, the most direct way is if we could have the samples of the Paleo fluid, we could possibly subject them to all kinds of the studies that we can do in the laboratory and can understand them.

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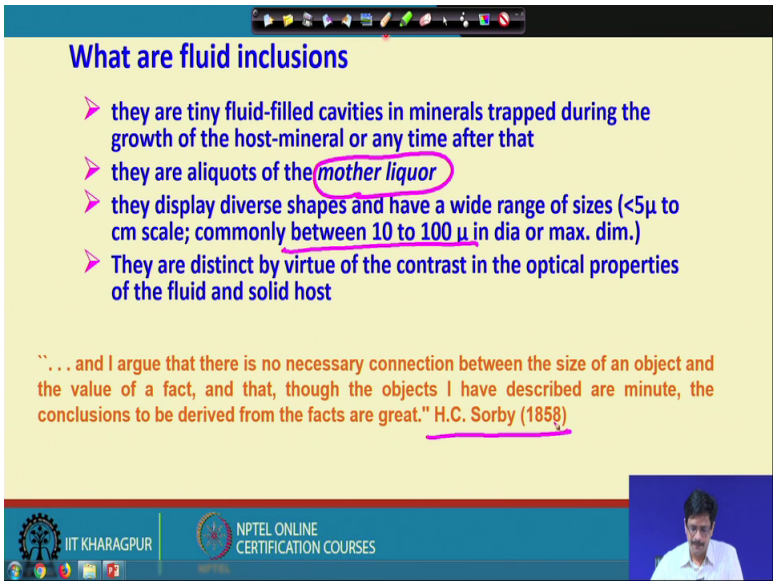

So, the answer is yes, we can. Till so far the way that is subject has been developed. We say that yes, we can sample the Paleo fluid.

So, where from: so the Paleo fluids which were operating in the different regimes, in the crust and the mantle; giving rise to different types of rocks, their constituent minerals. This particular fluid is actually encapsulated or entrapped within the minerals which they give rise to and those are those we study them as our as the as the materials which you call them as the fluid inclusions which will constitute our discussion for the next of the whole of the lecture series.

So, those are the fluid inclusions, their mineral properties. So, we see the fluid inclusions in minerals. So, let us first try to define what they are? So, they are actually tiny fluid field cavities in minerals trapped during the growth of the host mineral or any time after that. So, we will for the time being, we will only be considering where, we will keep this we will differ this particular point as any time after for a certain time.

So, their fluid field cavities so when we talk about a fluid essentially what we mean?

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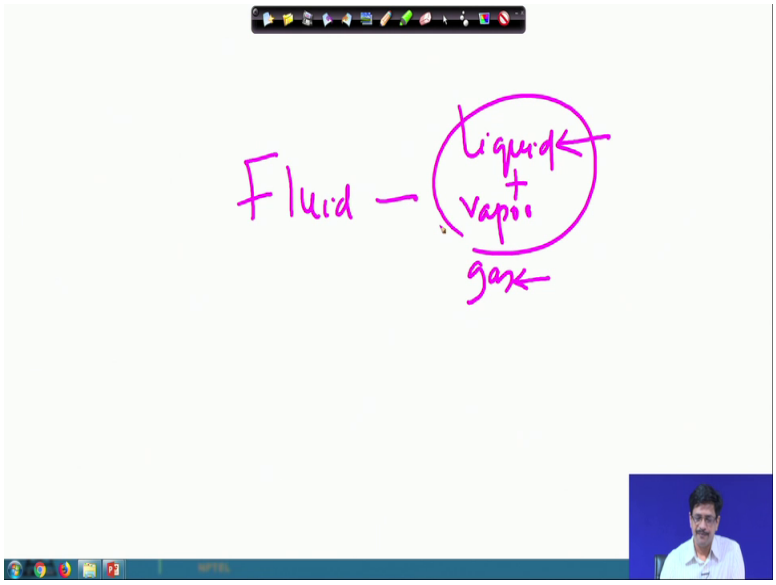

So, it could be liquid, a vapor gas. So, it could be anything of that of a combination of that which we can use a term generalized as fluid. So, it could be a pure, it could be a pure liquid or a pure liquid plus its vapor which could be so which ever condition. As we know as gas is essentially a super critical gas which cannot be compressed.

So generally we will be talking about the liquid and liquid plus vapor depending on what the condition was which get entrapped within the minerals and which can see them.

The thing is that we are saying that they are tiny fluid filed cavities so that means they need to be examined with higher magnification and we need to see them under the microscope. They are aliquots of the mother liquor; that means the fluid which is giving rise to the formation of this mineral which is the mother liquor that itself will get entrapped within the liquid.

The display diverse shapes and have wide range of sizes. So, that is which you are talking about. They can be very small as low as less than 5 microns to going to centimeter scale, but commonly when we see them under the microscope, getting different minerals from different types of rock associations.

They generally will be between 10 to 100 microns and there are very exceptional situations where they can be larger than that and sometimes even fluid inclusions can be seen in naked eye and such kind of situations are so exceptional that you can only see

them in the museum whenever they are they are encountered their seen. They better be preserved in the museum for people to see.

And they are distinct by virtue of the contrast in the optical properties of the fluid and the solid host which will I just saying that. So, the fact is that they are small; they are tiny. Measuring them just about few 10's of microns in their dimension, so that I would just read out. So, the pioneer in this study of the fluid inclusions along with many; so the most of the time we refer to H C Sorby who was a mid night 19 century European, scientist who first started this who first observed this fluid inclusion in minerals and realized that these minerals this fluid inclusions could possibly furnace lot of important information.

And our basic objective is that whatever information we retrieve from this tiny objects. We until and unless, we correlate them to broader earth processes and to address issues related to broader earth process. So Sorby said that: yes, and I argue that there is no necessary connection between the size of an object and the value of a fact and that though these objects have described a minute, the conclusions to be derived from the facts are great and we over the last one and half centuries time, we have realized that what Sorby said is very right.

We have generated enough of information on the fluid characteristics in different types of geological environment. Then the formation of ores starting from very low grade metamorphism to very high grade granulate grade metamorphism, and ore deposits of various sizes and various metals, and we have been able to understood those processes, and can address fundamental issues of earth processes through the steady of this inclusions ok.

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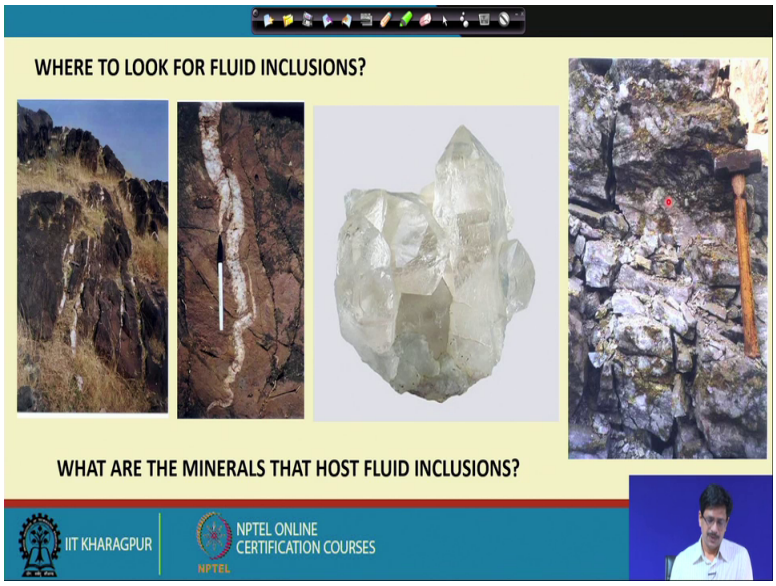

So, here is some of the earth's like because if we want to know where this fluid inclusions can be found; what kind of materials it could be possibly infinite and one has to and the kind of information one if you wants one tries to get this information from the what is available in public domain could be enormous. And just I have picked a very small such examples from where the fluid inclusions could be possibly be studied and we could rather intent to study fluid inclusions in such kind of situation.

What we see here as you can see here this is just a field photograph from the gold bearing schist belts in Karnataka, the Hutti Maski schist belt and here we can see that within this black crops which are the metamorphose mafic volcanic rocks which are calling then a metabasalts within them.

We could see these 5 part which are requires veins and these, these veins are they contain gold. When we go and deeper in the mined we see these are the veins which actually are odiferous and they are being mined out for gold. This is the same kind of a larger view has been from the exposure scale, where you could see that quartz when taking a shape, because of the way the fluid could just pass through the available open space or available space that if fluid could make through and deposit the quartz.

So, the first thing we (Refer Time: 27:20) we assume here that these particular process which we see as resulted in formation of this vein, is a processes which is resulted from the activity of a fluid and what we are observing at this surface actually this took place

several thousand meters. So, several kilometers below the surface where these kind of quartz when it is formed, as deposition from the fluid which was active during that particular time irrespective of whatever source the fluid could be.

This is an example of a it is a kind of museum specimen where you could see this is a quartz crystal with well developed faces is anybody can identify. This is a quartz crystal and this also has resulted or deposit being deposited from fluid this is one example of one of the rich copper deposit in India from Malanjkhand. And this is the body which is which is constituting entirely almost entirely of quartz. And this yellow part is basically the copper sulfide the chalcopyrite ore body.

So, these 3 situations that has been picked up here that the common thing is that they all are supposed to have been deposited or deformed by the activity of the fluid. So, if we take a sample from this occurrence and we should be able to see fluid inclusions in them.

So, if we just suppose if we want to study fluid inclusion in such kind of a mineral; so, what we have to do?

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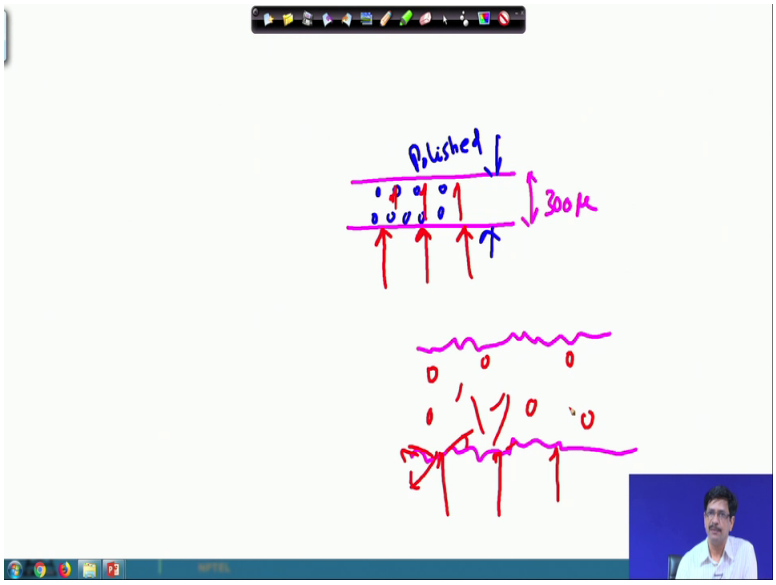

We have to prepare a slice or a section which is which should be about 300 micron in it is a in it is thickness because we know that the inclusions will be measuring in tense of microns in their dimension.

So, there will be a inclusions which will be, several such inclusions could be there. Within this, within this 300 micron thick slice that I have cut out from the samples that I just shown from the exposure and the only condition is that the surface that where that I am talking about here has to be very well polished on both the top and the bottom surface, if it is not well polished, if the if there are surface irregularities. Suppose for example, if there is some surface irregularities because of bad polish. And so when in this case, when light when we are examining them under the transmitted light or microscopy.

So, when light falls from below, this light will be able to pass through without any problem and we can get a very good view of the inclusions which will be within this thickness. Whereas, in this case if light when falls if because of the bar because of the irregular surface, this light will get scattered and very small or very small portion of the light will be entering through and the inclusions which will be there, will not will not get a good view or will not be able to see then very distinctly within the mineral that we want to see ok.

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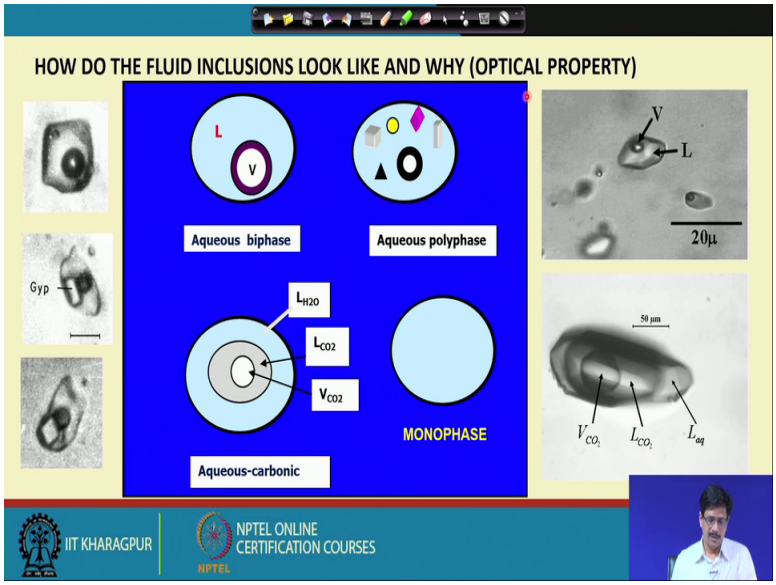

So, what does the minerals that what minerals, generally we see in the fluid inclusions?

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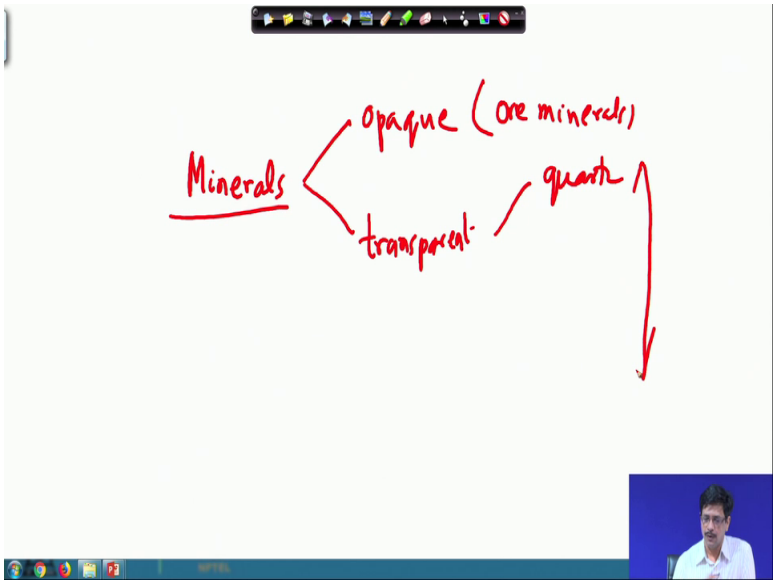

The minerals that we can see the fluid inclusions will be in fact, theoretically all minerals which deposit from the fluid. But, there are certain minerals which will be opaque to the visible range of the electromagnetic light.

There will be mostly be our ore minerals, the sulphate and the oxides which we cannot be which we cannot use for this study of fluid inclusions. So, the minerals which are transparent to the visible part of the electromagnetic spectrum can be used to see the fluid inclusions.

So, these transparent minerals could be the majority of the inclusion that we study are in quartz that could be calcite, fluoride, apatite kind of kind of minerals this is which you can see this inclusions. There are metamorphic minerals like even garnet, cordierite which you can be used for examination of these fluid inclusions in them.

So, in the way and going up to; as I mentioned that even if even you can see fluid inclusions in diamonds. So, the spectrum the range the different types of minerals that you can see fluid inclusions quite a lot and we will be discussing them in the course of this lecture. We will see how inclusions are occurring in all these types of minerals that we are talking about.

And so just have a quick look as to what this minerals; how the how the fluid inclusions they look like in transmitted light microscopy? And we will continue discussing about this in the next class.

Thank you.