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

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Lecture - 40
Review of the Course (Contd.)

Welcome to today's lecture, the last lecture of the series on Fluid Inclusions in Minerals. So, you have been discussing about a certain issues, certain questions that would arise in the minds of beginner when he starting the fluid inclusion work and I just taken up and getting acquainted to seeing fluid inclusions, taking measurements using a micro thermometric apparatus and also following up with many different things.

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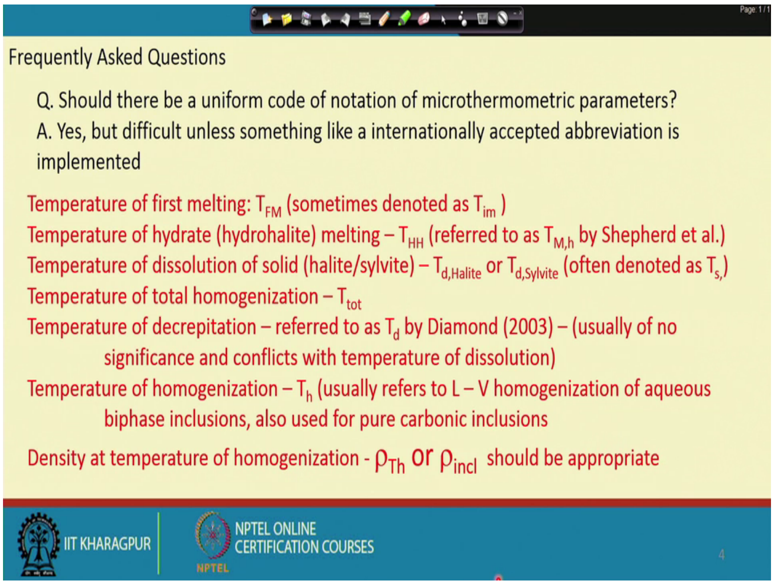

Frequently Asked Questions

Q. Should there be a uniform code of notation of microthermometric parameters?
A. Yes, but difficult unless something like a internationally accepted abbreviation is implemented

Temperature of first melting: T_{FM} (sometimes denoted as T_{im})
Temperature of hydrate (hydrohalite) melting – T_{HH} (referred to as $T_{M,h}$ by Shepherd et al.)
Temperature of dissolution of solid (halite/sylvite) – $T_{d,Halite}$ or $T_{d,Sylvite}$ (often denoted as $T_{s,}$)
Temperature of total homogenization – T_{tot}
Temperature of decrepitation – referred to as T_d by Diamond (2003) – (usually of no significance and conflicts with temperature of dissolution)
Temperature of homogenization – T_h (usually refers to L – V homogenization of aqueous biphase inclusions, also used for pure carbonic inclusions
Density at temperature of homogenization - ρ_{Th} or ρ_{incl} should be appropriate

To continue one part, we were discussing in the last class that sometimes it would be advisable to have some term in terms met and the denominator the way we denote many of the micro thermometric parameters. If it could be uniform all across that is that becomes convenient and is there could be many other sometimes many other parameters which come up but generally these are the once which is which are the common once. And in addition to that we other terms of derive parameters like mole fraction of any of the gaseous phase is present in the gas mixture and so on. The isochore many many terminology which are there of course, I am not getting into details of that and you could refer to this particular paper of Lay and Diamond which came up in 2003 in the mineralogical association of Canada's short course on fluid inclusions where many of the commonly used terms are discussed, but move those terms generally will not have much of a conflict in any description are when need record of the fluid inclusion go out.

But for general would matter, much would be any kind of confusion arising out the way the way there been denoted. Although many of the times the terms are defined before they are being used for the first time or even there are some times in a documentation we can also write by defining or by explaining the abbreviation which are used.

Yet, I would say that if there are some internationally accepted agreed upon terminologies for the microthermo parameters it becomes easier ok.

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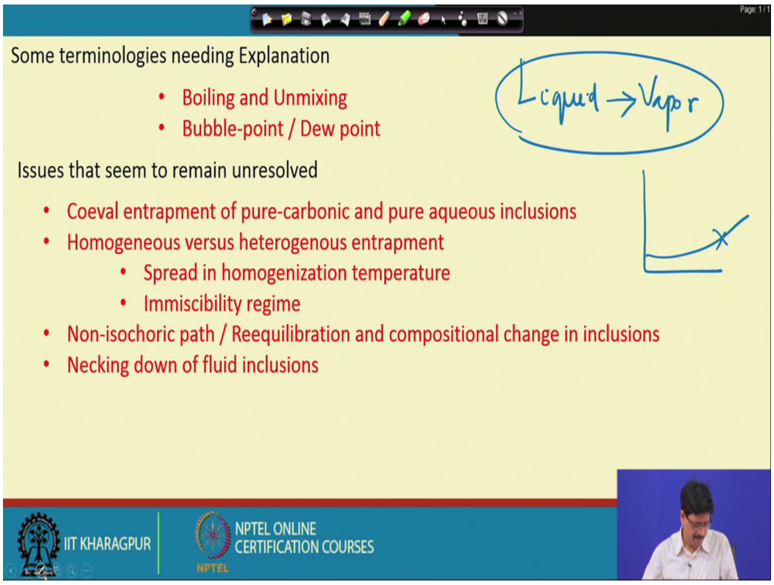

Some terminologies needing Explanation

- Boiling and Unmixing
- Bubble-point / Dew point

Issues that seem to remain unresolved

- Coeval entrapment of pure-carbonic and pure aqueous inclusions
- Homogeneous versus heterogenous entrapment
    - Spread in homogenization temperature
    - Immiscibility regime
- Non-isochoric path / Reequilibration and compositional change in inclusions
- Necking down of fluid inclusions

Liquid → Vapor

So, sometimes there are some terminologies which are used which becomes a little confusing. So, for boiling and unmixing; boiling as a as per my understanding is a situation which corresponds to the existence, coexistence of a liquid and it is corresponding or a vapor of a same composition is a water, liquid water and water vapor. So, this is a situation in which one homogeneous liquid is splitting up into a coexistence of liquid and vapor and we all know that happens on a boiling curve.

The curve the temperature pressure conditions corresponding to the boiling curve is the situation where the fluid is boiling is in equilibrium which is vapor. In many many of the cases, what is referred to as boiling sometimes in case of mixed say; for example, one aqueous carbonic fluid.

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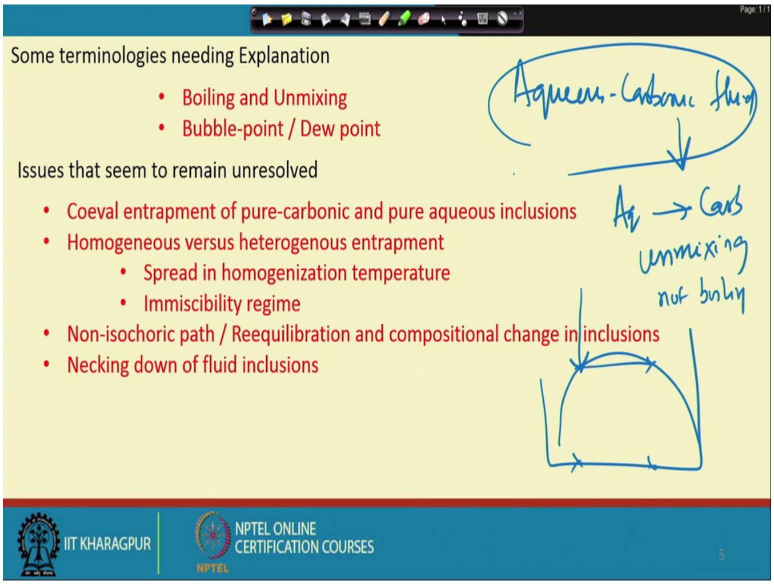

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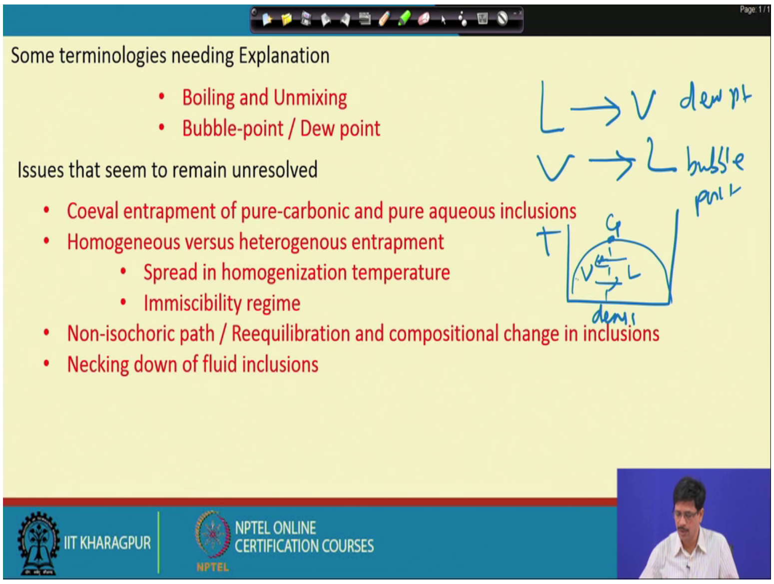
Sometimes the a word and the boiling is also used to it, but this would correct strictly correspondent into if a homogeneous aqueous carbonic fluid is actually splitting up into two components as an aqueous component and the carbonic component. This strictly corresponds to phenomena of unmixing, but not boiling. Because we know that that is happening because of the solve us which is there and any composition which is coming here and then getting splitted up into to two and that is a process unmixing. A carbonic liquid can always be in equilibrium which is vapor and that is corresponds to the boiling curve of carbon dioxide did you saw before or you could be aqueous.

But then in case of an mix system, the use of the word boiling would be misleading and there it is a the and the unmixing which is a better which is more appropriate and also we know that such kind of unmixing has got a very important significance in terms of the transport properties of the aqueous of the mixed aqueous carbonic homogeneous fluid and also, indicating pressure temperature conditions of entrapment and many very very important implications can made out of this.

And often, you will see what is the term terms is used is Bubble point or Dew point where bubble point actually some vapor is actually condensing to liquid or the opposite of a vapor of a liquid is getting evaporator coming to coexisting which as vapor. (Refer Slide Time: 05:58)



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So, it is essentially I mean a liquid getting into the vapor phase; or a liquid entering into it is vapor phase or a vapor getting condensing and getting into it liquid phase.

So, here it is a Dew point and this is as bubble point, but we know, so, as for the they may be because they would the deigns that we saw before for example, on a typically on a temperature and density plot we also where we also have this kind of a field where this is a critical point and we know that this part is a vapor and this for as the liquid.

And going from liquid to vapor to be like dew point and from vapor to liquid is bubble point. They can be represented on this kind of temperature molar volume or temperature density kind of plot, whereas on a we know that on a temperature and pressure space, P T space it could only represent a boiling curve and that would actually take care of whether any vapor is actually getting into the liquid field or a liquid is getting into the vapor field which will be representing the cross over or actually crossing the boiling curve.

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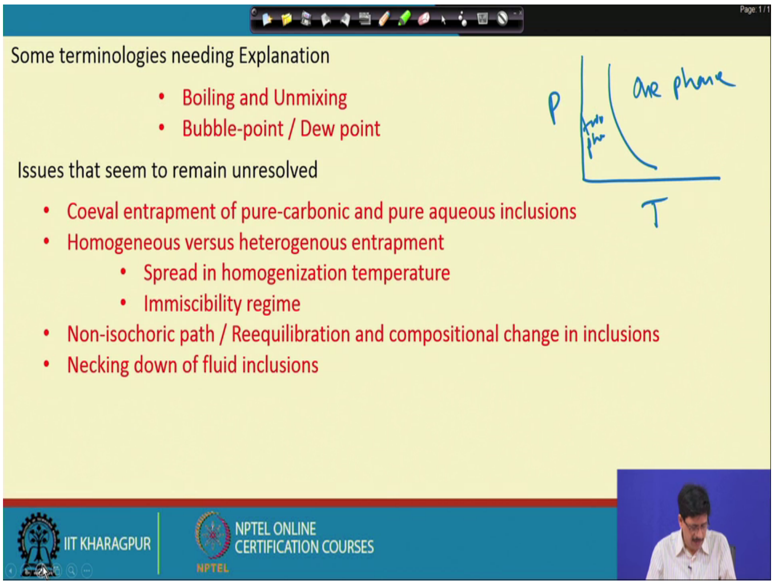

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So, on a P T space, it could only be the liquid vapor or the boiling curve and when we are also kind of just briefly discuss about the situation where there fluid mixture. For example, if it is a mixture of water plus carbon dioxide, then we know that they represent situation which is like is a phase boundary on the higher pressure temperature side it is one face.

And of the lower side it is two phases; that means, it is a one phase homogeneous fluid or liquid. Here, it is an aqueous liquid plus carbonic liquid just split up depending on when it crosses these two phase boundary. So, this also can be translated into T x kind of diagram on which we could also and that is the re situation in which the referred to as the dew point or the bubble point, but there should be more.

So, these are the some of the points which need to be understood while following the fluid inclusion literature. And then, with also it is all also I have warranted the some of the issues that are unresolved also should be kept in mind. There could be many more just I could just pick up this a few number of points.

Say for example, the coeval entrapment of pure carbonic and pure aqueous inclusions; we definitely see in your those circumstances where we see that there are pure carbonic and pure aqueous inclusions which coexist in the same host, same grain of the host mineral a part of the three dimensional network satisfying the criteria of being primary in the origin or even if they do occur on a heel crack, they do very much fulfill the criteria of being began trap together on to the same pressure temperature condition.

But then, phase relationships we always indicate that getting a pure carbonic fluid would be difficult, but then we definitely need to explain them from what kind of special circumstances could be there so that and take a homogeneous fluid aqueous carbonic fluid is at least treated in a way where the carbonic component is pure carbon dioxide or mixed with a little bit of other soluble species like methane, etcetera.

But no water and the aqueous part will also be pure aqueous without any dissolved carbon dioxide in it. Even though we know that the solvus is an asymmetric solvus means the solubility room, if it considered room temperature solubility, then the solubility of carbon dioxide in water at room temperature is about 2.3 mole percent.But the solubility of water and carbon dioxide is not that even much lower than that.

There are certain instructions instances in which it is proposed that, so, if it happens to be in very high temperature pressure conditions like in a grammrite get metamorphic rock, they are the carbon dioxide other been pure needs to be definitely needs to or to be explain or and that is a reason why on many instances they have been suggested to be of much deeper origin as degassing of the mantle.

And this kind of hypothesis were proposed in case of meaning of the grammrite belts in world including the one in South India. And also, it might so happen that if the conditions is in presenting are corresponding to a much lower temperature pressure conditions.

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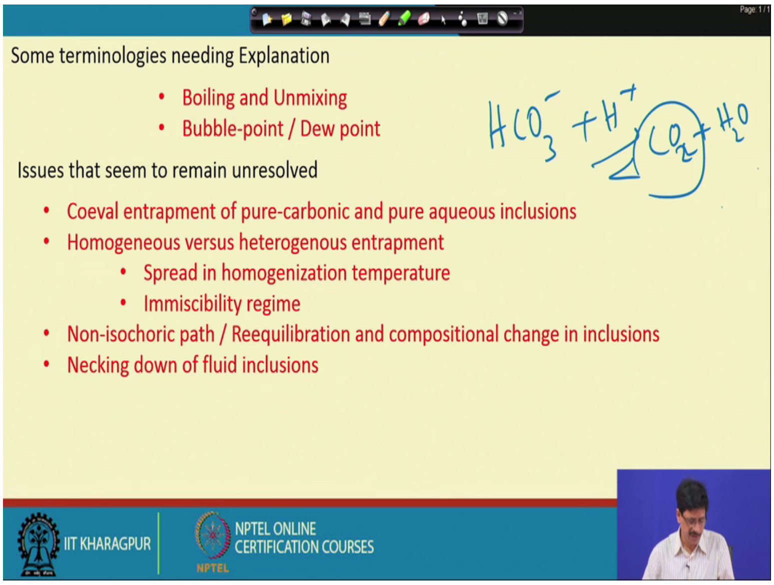

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$HCO_3^- + H^+ \rightarrow CO_2 + H_2O$

And there like if the if the chemistry such that you have bicarbonate and the pH of the fluid is somehow this is decreasing or in a way that the condition is such that you would just get them into C O 2 plus H 2 O.

And, both them in the pressure temperature conditions corresponding to the one phase liquid stability field, they would both the pure water and carbon dioxide. And then, there could be some this is one of the possibilities which could still be put some and the some questions what the other possibilities that the they may not be coeval, they may not have been entrap at the same time.

And these have to be very well substantiated by looking at the textural connects to the host mineral. If we find that there is no indications of the host mineral undergoing any kind of the crystallization or any recovery from deformation and those kind of features, then the chances that actually we are looking at a that a situation where they are actually trapped in the lattice of the host mineral as pure carbon dioxide and pure water would remain valid.

Even though, there are many kind of mechanism which are suggested that because they possibly had do have different contact angle with the host solid mineral, but then seeing them occurring together would definitely. It the observational fact goes that they were and definitely entrapped and if there entrapped this same time, then definitely some mechanisms has operated which we there yet to understand.

And then, and we have during the time of a application discussion and application the metamorphic rocks, we also discussed about the conditions are the proposition of recrystallized primary inclusions where it is suggested that originally trapped homogeneous aqueous carbonic inclusion during the recrystallization of the host mineral get splitted up into aqueous component and carbonic component. And because of their difference in the contact angle, carbon dioxide being used and water being acute, water populates through the grain boundaries where as the carbon dioxide is actually entrapped in the interior of the grain. But we do see innumerable circumstances where a carbonic inclusion and the aqueous inclusion are entrapped within the interior of the host mineral grain itself.

The other issue is that homogeneous versus heterogeneous entrapment. It has been a, there has been quite a lot of discussion which have been made on this particular issue that there are possibilities that the inclusion actually that means, our basic assumption is violated. Basic assumption of homogeneous entrapment; that means, a fluid at the time of entrapment was homogeneous fluid is sometime suspected.

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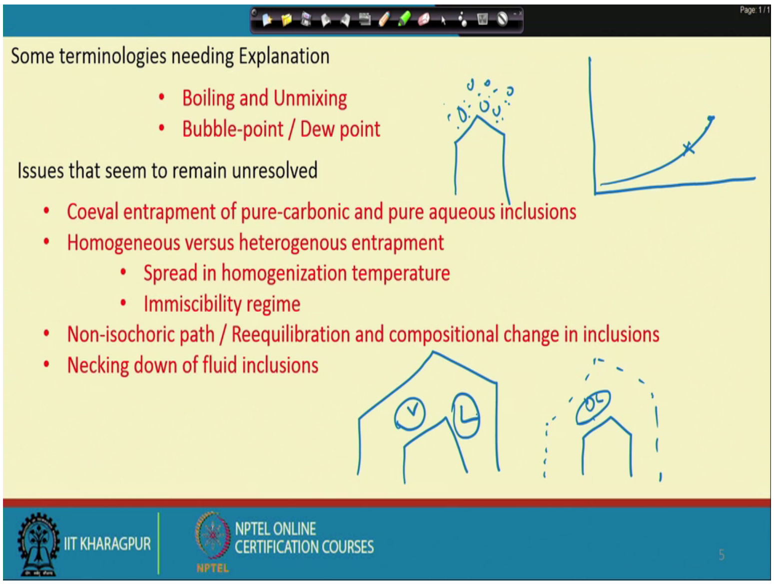

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That means, if although we know that we do have very well defined regions of invisibility or in homogeneity means, if there are possibilities of in homogeneous entrapment. They can only happens suppose in the context of a pure water or water plus electrolyte, water plus Na Cl or any other electrolyte mixture where this kind of relationship it remains very simple only with the changing of the critical point or the position of the liquid vapor homogeneous equilibrium curve or the boiling curve. So, we know that the and only possibility where such an in homogeneous entrapment is possible is very specific conditions corresponding to the corresponding to the boiling condition.

Otherwise, we have the entire we have our entire vast field of pressure and temperature in which we get the of by the aqueous fluid is one. phase. Similarly, in the vapor; so, if at all there is a possibility of entrapment of in homogeneous entrapment. Suppose for example, if an entrapment is taking place over here and there is both liquid and vapor present during the growth of the mineral.

So; that means, when a mineral is going there are bubbles along with the along with the liquid water and when the mineral when the crystal is going, so it will entrap a mixture of liquid and vapor instead of entrapping either a liquid or a vapor. Means, we would have discuss situations where we believe that there are coefficients of liquid reach and vapor reach inclusions in the same host grain or mineral grain, same grain of the host mineral and we present that the vapor and the liquid where separately entrapped even though within the same domain which is basically measuring in terms of few microns in special distance. Means, whenever we are seeing an in a in a host minera,l there are two inclusion coexisting in the same field of view when we are seeing in the microscope.

Then these two inclusions are just about the few tense of microns a part and when they are going in nature in any resign it was the general is precipitating, then the situation would be such that the entrapment would give rise to situation where in one case, a vapor is entrapped. And the other case, liquid is entrapped and that basically will give us a situation which will be interpreted as the boiling condition. But in contrast to that we are considering the situation where the inclusion is trapped, taking a part liquid and a little bit a part of vapor.

Now, in that case the basic assumptions violated and the if we go for heating this particular inclusion in a in a homogenization run, then the value of the temperature homogenization that we get is actually not the condition of entrapment. So, that has been the will be the main important point of suspicion. And the many people have tried to demonstrate that where one could possibly suspects such kind of an in homogeneous entrapment by giving us idea that will if some if we if the histogram of the temperature of homogenization is observed, then it might be that, it could possibly show some spreads.

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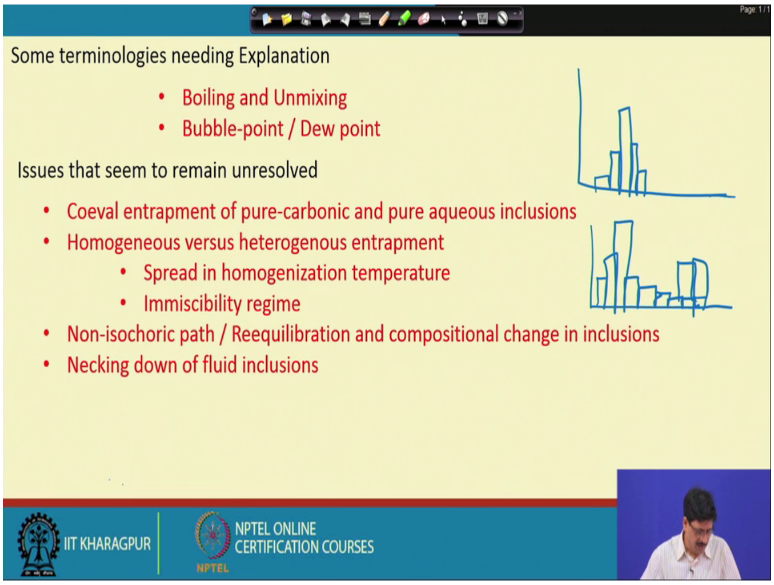

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Instead of normally if we see; for example, it could be a very simple case of a unimodal a distribution the temperature of homogenization in which case possibly we will say that it is a there is not been any in homogeneous entrapment of that is not been any reequilibration or the disturbance to the inclusions after their entrapped. But if we get some situation like sometimes the, the temperature range that is observed in the of homogenization range which is observed in the temperature of homogenization is to wide are sometimes even having some bimodal kind of distribution either positively or sometime negatively positively skewed or negatively skewed.

Mostly the positively skewed, then it is interpreted that it may be due to because of in homogeneous entrapment other than homogeneous entrapment. So, these have to be very carefully sort of interpreted and the in they should be from the very beginning of the study of the fluid inclusions. The petrography and the consistency in the microthermometric data and they must be enough reasons, there are many expansions which are provided for that.

So, that is the situation sometimes which one is to be careful and the immiscibility regime that I have discussed whether it say if it is water, then you have to look into the where we are if we get some such situation; that means, the situation would be such that there would not be any vapor phase homogenization, but the temperature of homogenization is actually having a spread.

For one thing has to be very clearly remembered here that when we are looking at this situation, any kind of in homogeneous entrapment. If we can if we are looking at the same sample for the same host mineral grain, if we get such kind of distribution, then it would possibly a thought would possibly be go in that direction. Otherwise we when we are compiling the micro thermometric data in an in an, so for example, we are examine you can entire ore body in it is strike and the strike length and whatever depth that you have been able to sample and we are measuring inclusions in scores of such samples and then measuring them in hundreds or thousands in number, there they spread is of course, very expected and there are explanations because there could be many several stages. For example, if we look at the fluid inclusion data generated in many of the magnetic hydrothermal systems, we get a complete range of temperature of homogenization from of the fluid inclusions going to temperatures above 700 degree centigrade to coming to cut temperature correspondent even just 150, 200 degree Celsius.

In those conditions, we know that P S, they represented they are actually the manifestation of at evolution of a magnetic hydrothermal system from the very high when is high temperature and Iceland stage to a very low temperature low, salinity still and in those kind of cases, they are very very clear. But one thing possibly could be kept is it point of notion point generate of caution that, if we get some such kind of a spread within the single minerals was as the very simple sample or within the same grain or just a few neighboring grain within the same grain host mineral, then this kind of interpret the interpretation could possibly be made with some kind of some caution and keeping this in mind. And then the non isochoric path, reequilibration and composition will change in inclusion which is also sometimes look to be the issue when we come to the interpretation of our microthermometric data. Because non isochoric path has been shown as isothermal decompression or isobaric heating or isothermal loading kind of situations and the textural modification of the inclusions of which we discus.s

In such kind of situation also we have seen that if it is an isothermal decompression or isobaric heating, then the inclusion undergoes some kind of explosion texture. And there is a redistribution of the temperature of homogenization as to what could have been the case if the inclusion should not have been listed.

So, the these are the situations which also need to be resolved because in many of the situations we see that it is a function of the term inclusion size, there is a very good experimental relationship which is established that the extent of the magnitude of the internal overpressure that is exerted on the inclusion on the wall of the host mineral and the yield strength of the mineral and the pressure that would be exerted by the by such kind of non isochoric path.

And so, we have seen that the larger and irregular shaped inclusions are more likely to be destroyed or have undergone such kind of plastic deformation of the inclusion cavity or even sometimes little deformation of the inclusion cavity. But the careful petrography and textural observation of the inclusion of the sample would definitely help us in over to overcome such kind of situations.

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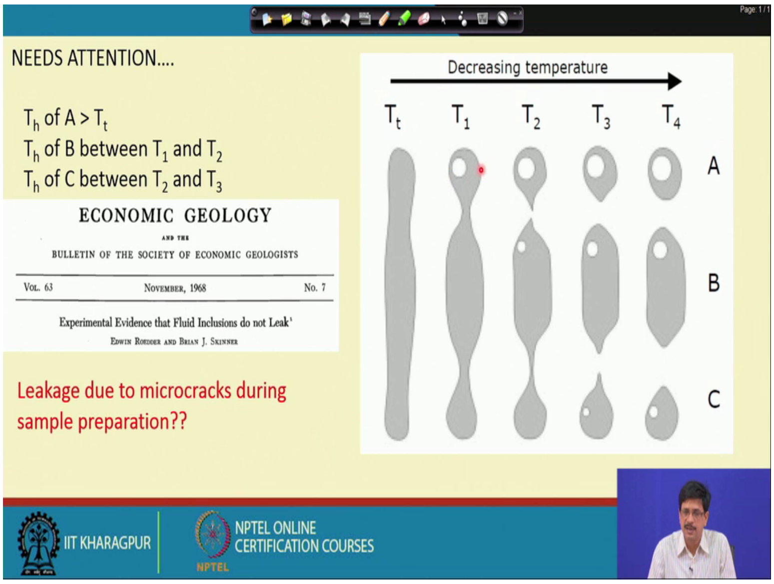

NEEDS ATTENTION....

T_h of A > T_t
T_h of B between T_1 and T_2
T_h of C between T_2 and T_3

ECONOMIC GEOLOGY
AND THE
BULLETIN OF THE SOCIETY OF ECONOMIC GEOLOGISTS

Vol. 63 November, 1968 No. 7

Experimental Evidence that Fluid Inclusions do not Leak[1]
Edwin Roedder and Brian J. Skinner

Leakage due to microcracks during sample preparation??

Then, making down of fluid inclusion, here that is what I just to this diagram this diagram has been taken which is very which is also present there in the one of the chapters by Admin rider in the book geochemistry by hydrothermal deposits.

So, what is the portrait here is that it is a kind of making down of the inclusion which might result in this kind of this could be the end result of making down process. If this is an original inclusion which is trapped at temperature of trapping, it might so happen that if there making down; then they might end up in situations corresponding to A, B and C where the inclusion A could homogenized at temperature which is greater than trip temperature of trapping, inclusion B would be trapped and the homogenize between T 1 and T 2 and inclusion C it would be an T 2 and T 3. These kinds of a proposition which are made earlier also need very careful examination.

And in this context, just for just I have taken this image from one of the papers that was published in 1968, the title of the paper says that Experimental Evidence that Fluid Inclusions do not Leak. So, this was shown as maybe that this many of the natural inclusions where subjected to higher pressure and temperature conditions and the observation was that most of the inclusions remain intact.

And, pure the inclusions even sometimes were some kind of little fracture in was observed was ascribe to that leakage due to microcracks during sample preparation. In this kind of things are also suspected at some part of time, but this could possibly be somehow taken care of because they if the processor exactly the process that we adopt for preparation of the sample, wh we have taken enough care. So, that the samples are not actually effected because these there are very precision cutting equipment where the inclusion, where the sample could be cut to very thin slices and the thinning at the polishing could be done in such a way that the sample is simple remains intact and there is no external damage that is done to the sample.

But in on top of it to if we look at this kind of diagram free care for the critically, we find that it may not be the case all the time just has been as a inferred by this workers. Before that if this temperature of trapping has taken place at a temperature which is definitely higher and after that, if this inclusion is present initially as a liquid plus vapor, if it is a pure aqueous inclusion which is trapped A T T. Now at temperature of T 1, it has given rise to a vapor means it is already corresponding to it conditions which is on it is liquid vapor homogenization liquid vapor equilibrium curve and we know that there must be of pressure which is below 220 bars and temperature which is well below 370 every if it is containing little bit of solved, then it may be just been hired by a few degrees or a few tense of bar. And in those kinds of situations also bringing about the inclusion deformation is not that very easy.

So, this kind of interpretation which have been may could still be examined and they do give very good petrography indication and only thing is that, they this kind of inclusions would possibly be avoided during the microthermometric run. So, it is not only this, but they the results the experimental results which we have discused for the equilibrium reequilibration of the inclusions and deformation of the inclusion cavity which have got very very conspicuous, textural manifestation. When an when the sample is being studied during the preliminary petrography work. So, they can always be avoided by taking enough care this such kind of inclusions microthermometric data are not actually considered under normal circumstances unless it becomes very essential or to a when it only way talking about deciphering the conditions in which the sample underwent some deformation later reequilibration process. If that is what is the actually in our mind to work out, then only we will be considering the data of the inclusion, but if our objective is to work out the characteristic of the apparent fluid and the conditions of formation of the rock under that kind of an environment, then these inclusion data will not be helpful to us.

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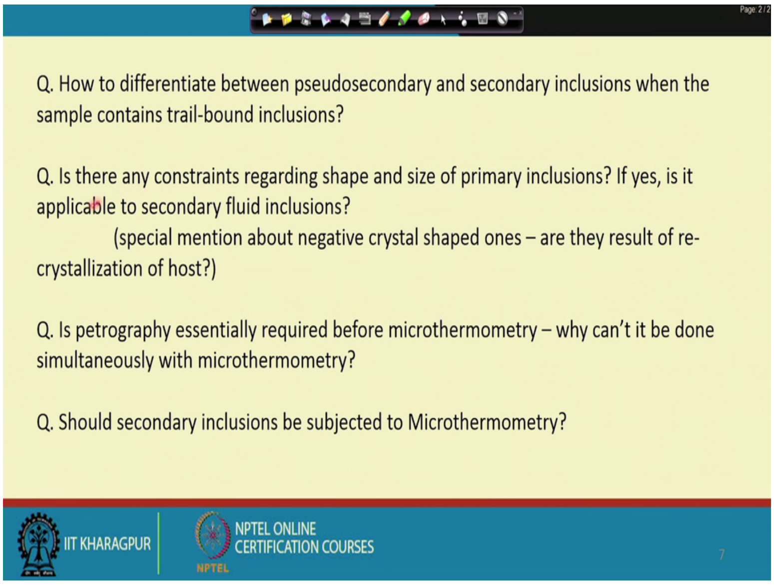

Q. How to differentiate between pseudosecondary and secondary inclusions when the sample contains trail-bound inclusions?

Q. Is there any constraints regarding shape and size of primary inclusions? If yes, is it applicable to secondary fluid inclusions?
(special mention about negative crystal shaped ones – are they result of re-crystallization of host?)

Q. Is petrography essentially required before microthermometry – why can't it be done simultaneously with microthermometry?

Q. Should secondary inclusions be subjected to Microthermometry?

Then, solve the quick questions the how to differentiate between pseudo secondary and secondary inclusions showing the sample contains trail bound inclusions. So, it is a possibly is a good is a relevant question to consider.

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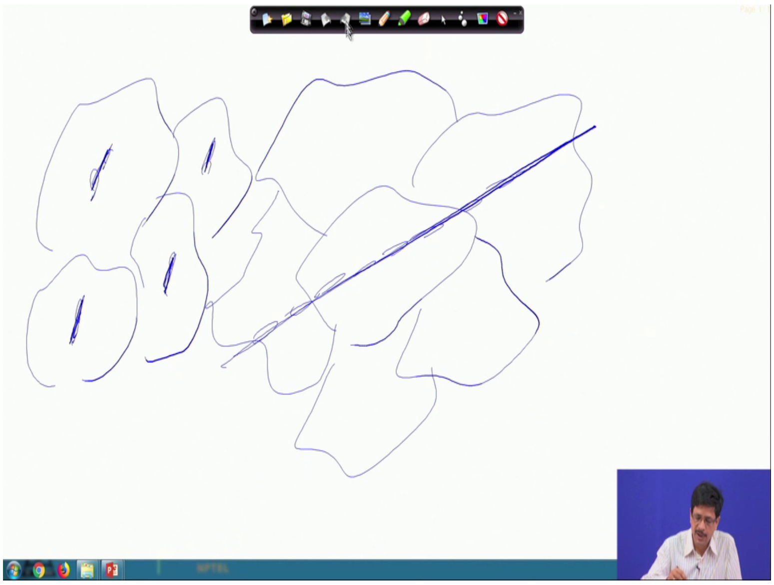

If there are if there are only trail bound inclusion that the only difference that we know that we know that the difference that we if there are many many grains of the host mineral which is present there, then we know that there are the crack which are transgranular and the inclusions which are trapped within this all present within these transgranular crack which are microcracks. They are the once which are how unequivocal interpreted to be secondary of the cracks which are generated after the formation of the host mineral.

So, they are the secondary inclusions. And in contrast to that, when we have lots of such grains of the particular inclusion and we see that there are only fractures which are within the mineral grain themselves and have not extending to the grain boundary are not crossing through the translate into the grain boundaries. And there are inclusions within this, then they are the ones which we consider them to be pseudo secondary.

The pseudo secondary essential primary pseudo, so there essentially they formed during the during the during the process of primary growth of this mineral rather than little bit of thought has to be given to it because it might so happened, so one of the situation is that if in one all crystalline aggregate of a single mineral host like quartz. We just see a very stray occurrence of such kind of a fracture or the heel crack only within a just about just about a single grain of the host mineral is showing that.

So, in that case, it could be suspected that it is just a case where they fractious from the fracture it is actually transgranular at just terminated within one grain and that may not actually be a pseudo secondary grain. So, in order to interpret the particular trail to be a secondary, to be pseudo secondary it needs it needs to be consistently represented in. So, the only pointed I could possibly make here is that in order that this, in order that this particular heel crack, the inclusions which are present in that heel crack to be taken as pseudo secondary such kind of heel cracks will present in more than one such grain of the host mineral. That could possibly be one of the ready answer that can be given in this context. So, is there any constant regarding the shape and size of primary inclusions, if yes, is it applicable to secondary fluid inclusions? Of as far as my experience goals of working for, so many, so long a time on fluid inclusions and looking at many diverse types of samples from different geological tenants. I really do not established any relationship between the size that the shape of the inclusions and it is origin being primary or secondary.

There are, there are propositions at the inclusions the reequilibrate or even put. In fact, for example, in a isothermal loading kind of situation or even the inclusions were subjected to hydrostatic pressure condition, the irregular shaped inclusions tend to become more like negative shapes shape or more regular whereas because in some of the photographs which I saw in the very introductory part of the lecture series where we saw that minerals like halite or anhydrate. They do have such dense proper to the extreme, I mean the population almost every inclusion represent in that host mineral is applicative crystal shape. So, there is some control been exerted by the inherent in the in the nature of the crystal there where the mineral where the fluid is being entrapped.

Other than that, there is sometimes it is tail told that in the heel cracks the inclusions or the secondary inclusions tend to attain for a to have negative crystals the regular shape, but this kind of conclusions are very over simplistic. So, is petrography essentially required before microthermometry; why cannot it be done simultaneously with micro microthermometry?

This is actually the answer is a very strong yes, the petrography needs to be done before microthermometry even I would want to suggest. If for the facility is available, then every sample which is being intended to be studied for fluid inclusion first need to be prepared is a normal thin section of a thirty micron thickness, so that the textural characteristic of the host mineral can be known before hand. So, how much over recrystallization is taken place, what kind of defamation features like presence of fandlose extension in the host quartz grain, these kind of features could very well be studied beforehand before a thick section or a vapor is prepared for the same sample prepared from the same sample and the fluid inclusions are examined.

And a thorough petrographic study with different inclusion types the kind of domain in his they represent either in the interior grain or in the grain boundary on the and all this kind of features whether the quartz show some growth zone, primary growth zones all these things will be very clear the once a petrography is done.

So, petrography fluid inclusion petrography is a must before microthermometry. So, trying to are classified inclusion or to do photography while going microthermometry will be very time consuming and also a difficult process a pseudo secondary inclusions be subjected to microthermometry a, the answer is again in depends on the problem that we are actually addressing.

Because sometimes we see that even the heel cracks there are inclusions aqueous mix, aqueous carbonic inclusions which general in entrapment process takes place at higher pressure and temperature conditions. So, generally it cannot be very well generalized that all the secondary inclusions are entrap at temperature pressure conditions which are very low or more surficial deo surface conditions.

Ah as you seen in many metamorphic minerals where the in minerals the garnet, the there are secondary inclusions trails and, but so, even sometimes it would be very even if we are looking at up hydro thermal lower deposit and it is always better to get an idea about the nature of the fluid that were entrapped a secondary inclusion so that to decide whether this would also be integrated into the data to talk about the fluid which actually where responsible of which it to came to play anytime afterwards for any enrichment or any process that took afterward that took place afterwards.

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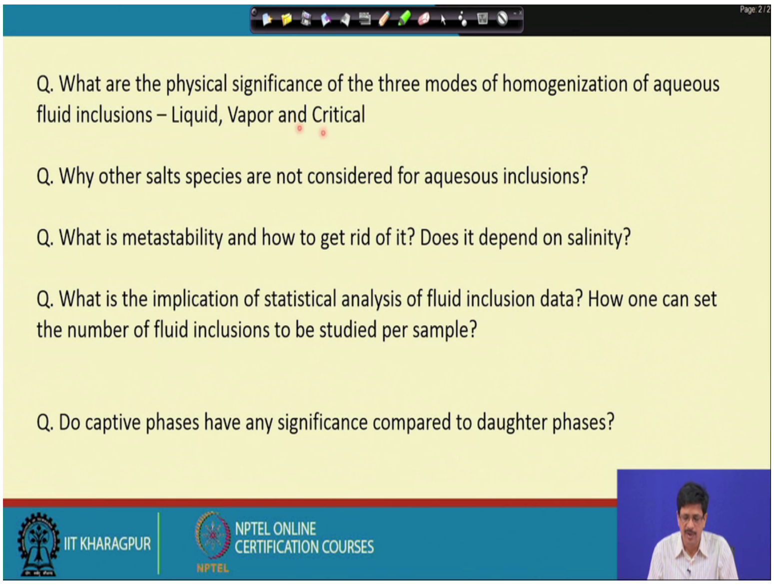

Q. What are the physical significance of the three modes of homogenization of aqueous fluid inclusions – Liquid, Vapor and Critical

Q. Why other salts species are not considered for aquesous inclusions?

Q. What is metastability and how to get rid of it? Does it depend on salinity?

Q. What is the implication of statistical analysis of fluid inclusion data? How one can set the number of fluid inclusions to be studied per sample?

Q. Do captive phases have any significance compared to daughter phases?

So, the three modes of what are the physical significance of the three motion homogenization of aqueous fluid inclusions, liquid and vapor as we know that liquid and vapor inclusions the homogenization if they occur in coeval inclusion they do their of much important implications like deciphering boiling.

Critical homogenization has them too much of any greater significant changes the conditions corresponding to the one that critical temperature of the fluid of that corresponding weight percent of the electrolyte that is present. Why other solves species are not considered for the aqueous inclusion we need to? We need to wait for more better P V T X relationships be established, so that we would possibly not have to express this salinity weight percent Na Cl equivalent. We will be able to explain the salinity indefinite terms of what exactly weight percent Na Cl or K Cl or Ca Cl 2, but you have to wait till we reach that particular size or shape that fluid inclusions study there are lots of areas in which lots of more work and development need to be done.

So, metastability of what is metastability and how to get rid of it; metastability is the lack of response of the inclusions to heating freezing cycles for example, the inclusion does not freeze in, if free cool to temperature almost minus 200 does not homogenize or even after the homogenization the vapor bubble does not come back and or dissolution of a daughter crystal actually the daughter crystal does not again reappear on cooling. So, so many situations could be there all corresponding to metastability. Sometimes, the metastability is taken care of by repetitive cycles of heating and freezing say for example, in one biaqueous biphase inclusion, the temperature of homogenization occur at 200 degree Celsius, but then when the temperature is cool down to almost like even room temperature, the vapor bubble does not reappear. So, even if the if freeze the inclusion and the vapor bubble comes back at a temperature much lower sub zero temperature and again when we heat it, if were able to reproduce the temperature of homogenization, then there is no problem we can always take that homogenization temperature data. But if it homogenization at temperatures wave different from what is the original value, then we know that we are not giving able to reproduce the temperature of homogenization and in that case that inclusion has to be simply discarded and whereas, the metastability does not depend on salinity, but metastability does depend have a lot on the inclusion size.

So, that is why we generally avoid inclusions which are less than 5 microns in this maximum diameter, maximum dimension. So, the implication of statistical analysis of fluid inclusion data, how one can set the number of fluid inclusions to be studied per sample? This is a question on which no direct or a straight answer is given.

So, that is different the fluid inclusion data is definitely quantity intense it. So, the number of data has to be such good enough. So that it takes care of the statistics in terms of the distribution in temperature, of homogenization, of the salinity or whatever parameter and sometimes the questions as to how many inclusions to be studied per sample.

So, we do have to believe or take the thing is a random sampling. If we are taking a sample, depending on what is the population if the inclusions are very scares are very and the sample, then definitely the number has to be low, but the inclusions are a lot. So, in that case, we have to see to with that we have to convince our self that you have done the random sampling.

And sometimes, they inclusions occurring in cluster in group do have very close values of salinity and temperature of homogenization. So, in that case taking more data would not be a problem, but sometimes their temperature of homogenizations are little widely different. So, sometimes that becomes a little more time taken to take all the data, but it should be we should convince our self that we have made a random sampling and have taken adequate sample.

So, captive phase do captive phases have any significance compared to daughter phases. The captive phases are the ones which are called the accidental phases which are which did not precipitate from the inclusion fluid that were trapped along with the liquid within the cavity. So, they do not have much of significant, but sometimes if a halite has a is an accidental phase and still keeps a dissolution temperature then the salinity would be overestimated.

But in that case, this situation could be overcome by looking at the population because if the fluid was a was a certain part of time had a certain value of the salinity, then there should be more than one inclusion we should be polyphase at room temperature. If we are only getting a stray inclusion in a population which is polyphase in, rest all are biphase and the suspicion that this daughter phase is this the halite that is there is no a daughter phase, but a captive phase could be stronger.

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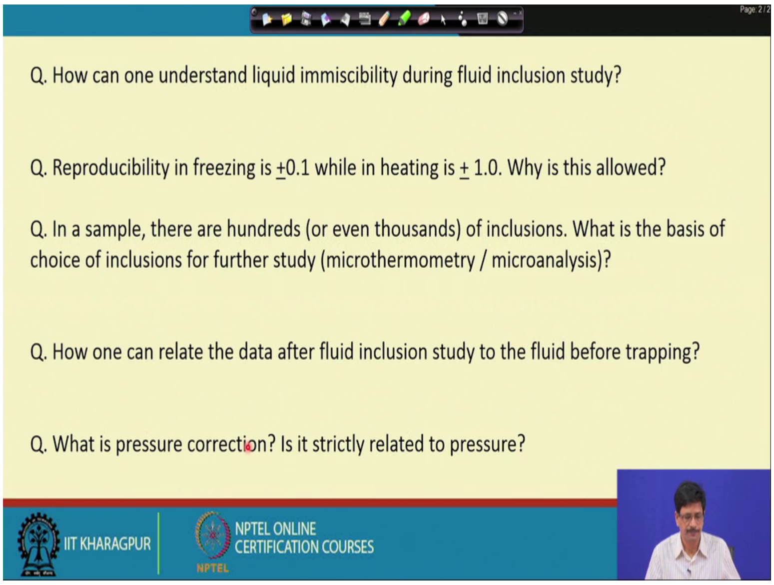

Q. How can one understand liquid immiscibility during fluid inclusion study?

Q. Reproducibility in freezing is ±0.1 while in heating is ± 1.0. Why is this allowed?

Q. In a sample, there are hundreds (or even thousands) of inclusions. What is the basis of choice of inclusions for further study (microthermometry / microanalysis)?

Q. How one can relate the data after fluid inclusion study to the fluid before trapping?

Q. What is pressure correction? Is it strictly related to pressure?

So, how can one understand liquid immiscibility during fluid inclusion study? So, the questions of boiling as well as the unmixing in aqueous carbonic fluid has been discussed. Reproducibility and freezing to point plus minus point one while heating is plus minus one why is it allowed. So, we know that salinity value will vary significantly if the range is more than that and that is also we cannot have may lesser and the lower reproducible 10.1 in freezing cycles where as in a calculation of density and difference of for temperature of one is not going to make the density change the even the 4 place of decimal. So, that is why a plus minus 0.1 is allowed in a sample, there are hundreds of inclusion what is the basis of choice of inclusion for further study.

So, naturally we first go to look at the inclusion workable inclusion in terms of their size and also the shape, the regular shaped once they are going to give us dependable data. So, that could be only the criteria for choice of the inclusions. Sometimes, with the inclusion population is. So, low that we are not actually left with much of choice and we have to take the data on as many inclusions are possible.

How can one relate the data after fluid inclusion study to fluid before trapping? So, there is a actually the isochore and the correction for the pressure correction which comes next what is pressure correction and is it strictly related to pressure. It is actually not related to pressure, but depends on the isochore, the thickness of the slope of the isochore and if we have any other independent estimate of the temperature of pressure, the isochore helps us in getting the value.

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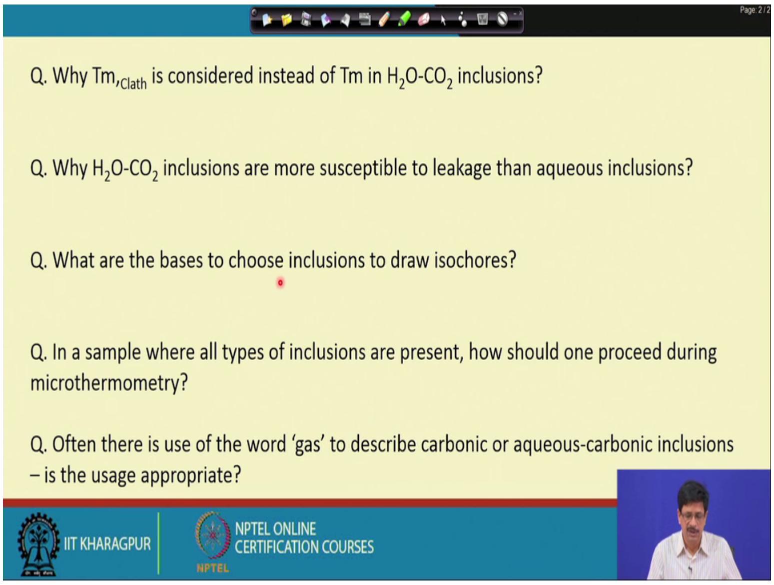

Q. Why $Tm_{,Clath}$ is considered instead of Tm in H_2O-CO_2 inclusions?

Q. Why H_2O-CO_2 inclusions are more susceptible to leakage than aqueous inclusions?

Q. What are the bases to choose inclusions to draw isochores?

Q. In a sample where all types of inclusions are present, how should one proceed during microthermometry?

Q. Often there is use of the word 'gas' to describe carbonic or aqueous-carbonic inclusions – is the usage appropriate?

So, T m Clath rate, why T m Clath rate is considered instead of T m H 2 O 2 T o C O 2 inclusion? So, we know that because most of them many want a lot of water molecule is taken up by carbon dioxide to form the clath rate by the by increasing the salinity apparently. So, T m clath rate will only be used for measure domain the salinity.

Ah H 2 O C O 2 inclusions are more susceptible to leakage because the because the building of a internal pressure which yields which access the yield strength of the host mineral the. So, what the basis to choose the inclusion to draw isochores? So, only when we get coeval inclusions and we know that there could be chances of getting the intersections of the isochore that it is always advisable to draw the isochores.

Otherwise also, like some of the examples which have shown for application to structural geology, there the isochore need to be drawn and in terms of what would be the maximum at the minimum slope value if we get from the at microthermometric data. At that point of time, you know that that represent the range. So, the maximum possible range variation in temperature and pressure, so, the isochore needs is to be drawn.

In a sample where all types of inclusions are present, how should we proceed during the microthermometry? As it also I told this point in the introductory session that you should better to go for the pure carbonic inclusion first freezing followed by the freezing of the aqueous carbonic inclusion to take data for the carbonic component, then go want to relocate the aqueous then the aqueous biphase inclusion salinity, then relocate them to get the temperature of homogenization, then go on to the aqueous carbonic inclusions to take their final homogenization temperature. Because most of the cases, they might leak and they make they may also make the other aqueous inclusion leak because the temperature is high.

So, often there is used of the word gas to describe carbonic or aqueous carbonic inclusions the it is possibly it is not that very correct because they are not present in the gaseous form we can see them very clearly the present in the liquid form with the pressure corresponding to the liquid vapor homogenization equilibrium.

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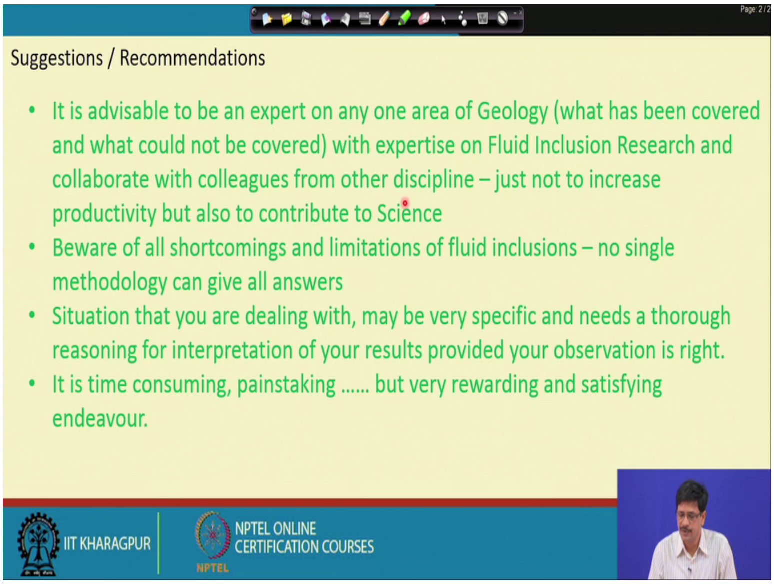

Suggestions / Recommendations

- It is advisable to be an expert on any one area of Geology (what has been covered and what could not be covered) with expertise on Fluid Inclusion Research and collaborate with colleagues from other discipline – just not to increase productivity but also to contribute to Science
- Beware of all shortcomings and limitations of fluid inclusions – no single methodology can give all answers
- Situation that you are dealing with, may be very specific and needs a thorough reasoning for interpretation of your results provided your observation is right.
- It is time consuming, painstaking …… but very rewarding and satisfying endeavour.

So, it is advisable to be an expert on in anyone area of geology with expertise on fluid inclusion and to collaborate with experts of other disciplines, not just to increase the productivity just to also to contribute to science. So, collaboration with other experts being a fluid inclusion expert is always more advisable and definitely makes a very good better combination.

So, one should beware of all the shortcomings and limitations of fluid inclusion because no single mythology can be all the answers to the problem that we pose in terms of the geological problem. With the situation that you are dealing with maybe very specific and needs a very thorough reasoning and interpretation of your own results provided your observation is rights.

So, in this in this case, you need not have to be same or what exactly identical to what you get in some other locality because your situation may be very specific and unique and only thing is that you have to take enough care that you have your data of the observations are right. Because it is sometimes saying that wrong interpretation is something on which the science are raw expertise wrong observation actually damages is damaging to science.

So, fluid inclusion is time consuming is painstaking, but is finally, at the end of it is rewarding and satisfying endeavor and as we know that a lot more of work to be done to make this particular field even much more useful and the definitely want to look for the they that fluid inclusions are able to be utilized to solve geological problems in much bigger way. So, thanks a lot and all those who have registered for the writing, the final end semester exam and they and examination in the end of this particular course, all the best wishes to them.

Thank you.