The Evolution of the Earth and Life

Professor Doctor Devapriya Chattopadhyay
Department of Earth and Climate Science
Indian Institute of Science, Education and Research, Pune

Lecture 53

K – Pg extinction: Patterns

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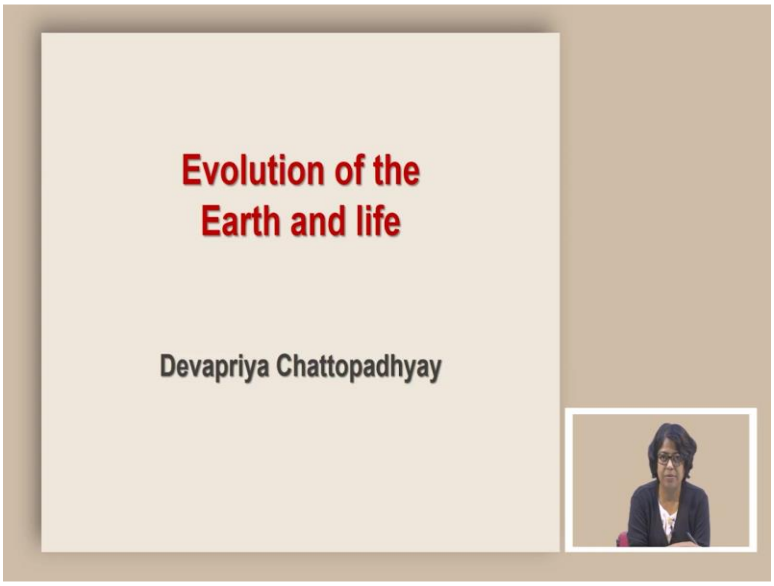

Welcome to the course Evolution of the Earth and Life. Today we are going to talk about one specific mass extinction that took place 66 million years ago.

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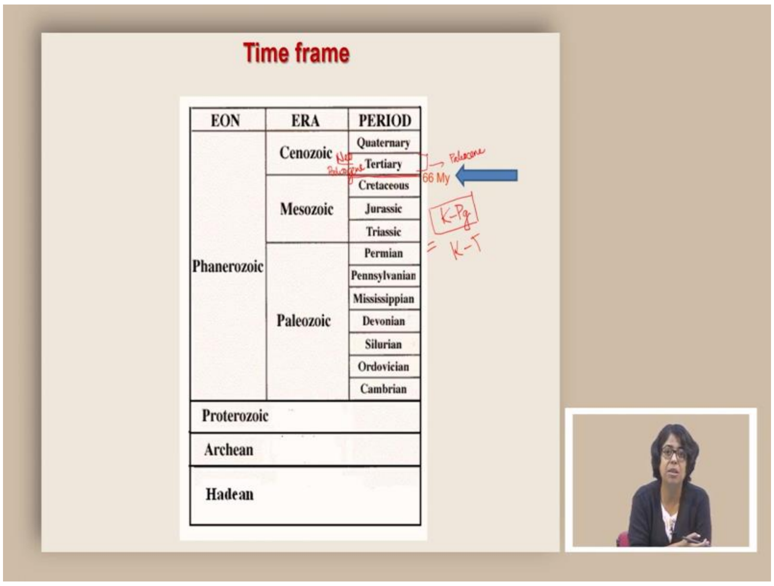

So, the timeline that we are going to talk about is this boundary between Mesozoic and Cenozoic Era. This can also be called the boundary between Cretaceous and tertiary. Now, when we divide the age Tertiary, the first part is called Paleocene. And if we divide it into two parts, then it is called Paleogene and Neogene. Now, because of this, often the Cretaceous and Paleogene boundary is called K-Pg boundary. So, there are two versions that we will often come across in different records.

One is called indicate Cretaceous Tertiary boundary, and the other one is K-Pg, indicating Cretaceous and Paleogene boundary, both of them are technically the same, but today's nomenclature favors this K-Pg boundary are named. And hence, in the rest of the lecture, we are going to use this K-Pg nomenclature.

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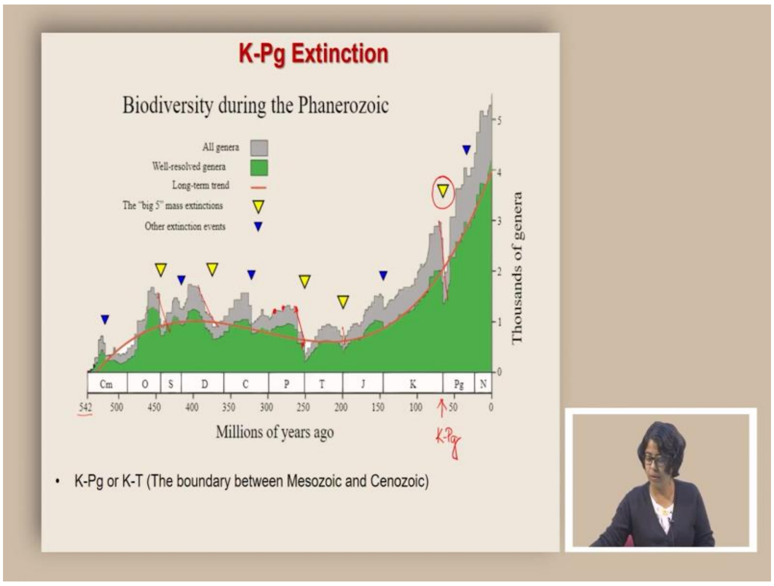

So, as we know that the diversity of organisms changed over time, if you look at the Phanerozoic diversity, starting from Cambrian that is 542 million years ago, it has gone up and down. But overall, the pattern shows an increase, especially since last 200 years. But these changes are this increase is not a monotonic increase. That means that if we take any two subsequent points on this diversity curve, we cannot really see that the curve or that the point which is younger, will show you high diversity.

So, let us take an example, that if we look at this point, and this point, it is true that the older points has lower diversity than the younger points. But then there are points, which are like this, where the older points have high diversity compared to younger points. These are the situation where it is not really an increase in diversity with youngling age, and these are the situations what we are calling an extinction.

So, extinctions are patterns, where groups get wiped out, and none of the representative individuals stay back. So, it is something like the death of a species rather than death of an individual. And we know that there are two kinds of extinction one is a background extinction and the other one is a mass extinction. And if we look at this diversity curve, we will see that there are 5 yellow points and all of these yellow points are indicating a major drop in the diversity pattern and therefore, indicating a major extinction event.

We are going to focus on this particular extinction event, which is between Cretaceous and Paleogene and therefore called K-Pg. Now, why are we studying this one particularly and not any other mass extinction event? The primary reason for that is our understanding of this K-Pg boundary mass extinction is relatively better compared to the other mass extinctions, which are far back in the geologic timescale and hence their records are not the best. This is the youngest of the mass extinction, and they are records are much more complete. And therefore, it is easier for us to understand how it work over time.

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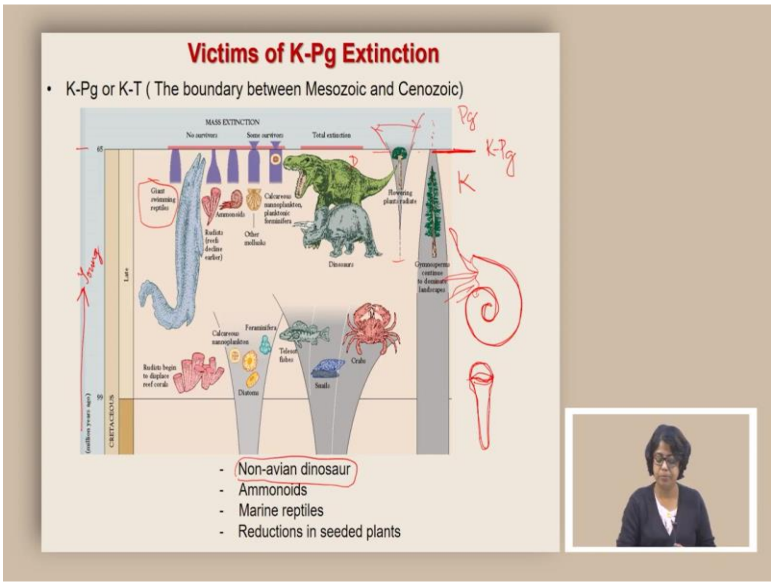

So, let us now try to understand which were the group which got wiped out at this particular boundary. And what we see that there are many groups, which we are familiar with actually got wiped out in this boundary. So, as we are looking at this particular plot, that time is going towards younger age as we are going up and this particular line corresponds to K-Pg. The part above is the Pg and the part below is the K. Now, let us see, what are the groups that were there before.

And if we start, the most prominent one that we can see is a dinosaur and this dinosaur got extinct across this boundary, and we are specifically talking about non-avian dinosaurs. These non-avian dinosaurs are those dinosaurs, which are not bird like are not flying, and therefore, they are called non-avian dinosaurs. These non-avian dinosaurs are very well represented during the Cretaceous and before, but the moment we crossed the K-Pg boundary, we do not find a single representation of this known avian dinosaur.

There are other vertebrate groups also which went extinct around this boundary. And other such thing is the great giant swimming reptiles. During Mesozoic there are multiple types of swimming reptiles and many of them are very, very large, all of them went extinct and this boundary and after this boundary, we do not have a single Marine, swimming reptile, which is large. Apart from these, we also have certain types of fishes, which we do not see very well beyond this point.

Now, let us focus on other groups, non-vertebrate groups. So, among non-vertebrate groups, we know that there are different types of organisms living in the ocean. Many of them have hard skeletons. Among those organisms, one organism was very, very abundant throughout Mesozoic and B are called Ammonoids. These Ammonoids were coiled organisms. They were mollusks, and they were very closely related to squids, and Nautilus.

But these ones were coiled, unlike the squid and octopus that we see today. So, squid and octopus, they represent a group called Cephalopod. And these Ammonoids are also cephalopods. But these Ammonoids were really large. They had a variety of groups, and they also had a very hard skeleton. And we really do not see any of them beyond this boundary. Whereas if we go to Mesozoic throughout Jurassic, Jurassic and Cretaceous, the sea was full of Ammonoids.

The other groups that we see declining and some of them getting extinct are different types of mollusks. So, one particular type of mollusk are these rubies to bivalves again, they look very different. They are very closely related to clams and scallops and oysters. But they look different because instead of typical claim like shape, they looked more like a tube. And they had the top part of it as one lid or one valve and the rest of the tube like appearance is the other valve and they were very good at making hard structures creating reef.

So, unlike the corals, where we see the coral reefs today, these were one of Permanent reef builders during these Cretaceous times, these groups also went extinct right around this mountain, we do not find a single, rudest bivalve beyond this boundary. Now let us focus on the plants. Now among plants, we see a completely different pattern, we find that the gymnosperms were very dominant around this time, and we found many of them going extinct around this time.

So, therefore, the seeded plants are many of the seeded plants went extinct around this time, they were not completely extinct. Therefore, they continued beyond this point, but at a very, very low abundance. On the other hand, the flowering plants, they were not they appeared only in late Cretaceous, and they were not that abundant during this time. But after this extinction, we find that them they are basically radiating or increasing their diversity at a very high rate.

So, there are things which are quite abundant, and they went extinct. There are others which are not that abundant, they survived, and then they started proliferating. One more important thing to remember is this is also a time where there were mammals, those mammals were very small, but they did not go extinct. And they continued beyond this point.

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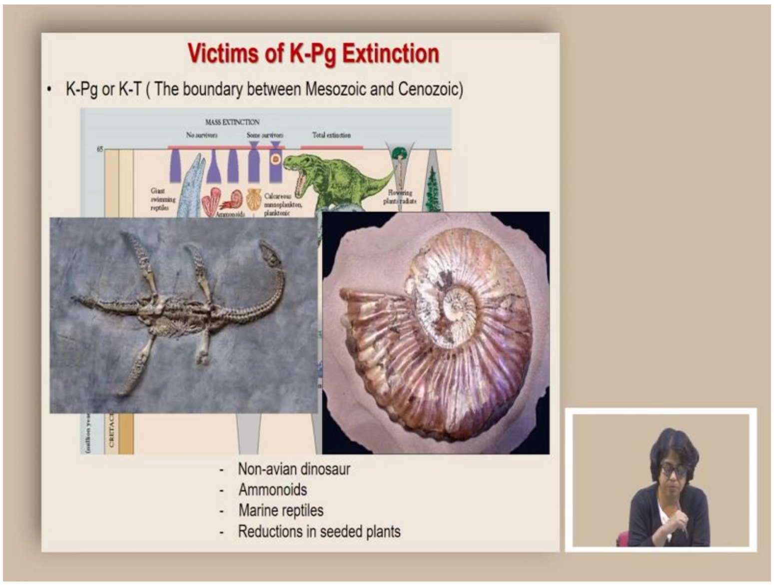

So, this is an example of the Ammonoid that I was talking about. And all of them went extinct beyond this boundary. And you can see the coiled shape of this particular ammonite. The other group that I talked about was this marine reptile. We do not really see such marine reptiles, swimming marine reptiles, which are giants any longer in ocean.

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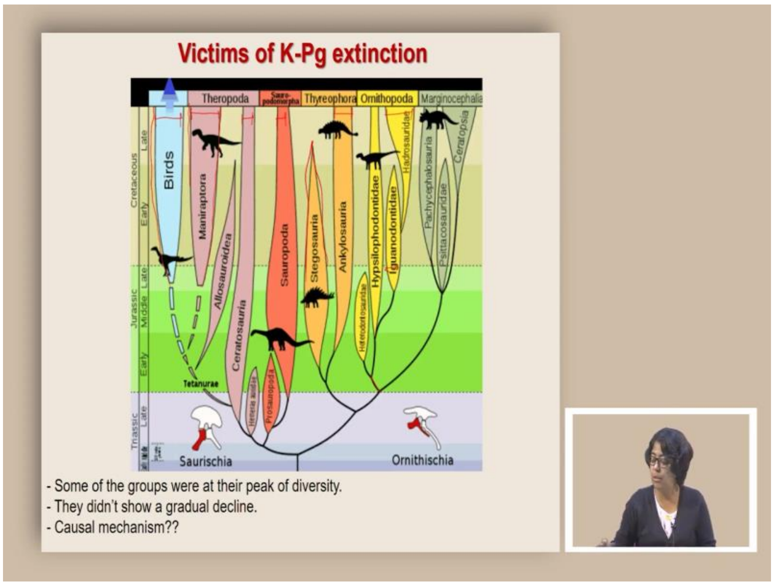

So, often people have thought about this point that more makes a group co extinct. Is it a gradual process. But as we know that mass extinctions often show our very abrupt nature, what it means that it looked as if the groups were doing fine, only for a specific time beyond which it went extinct without any gradual decline in their diversity. And we want to see whether K-Pg extinction also shows some of these things.

So, now we look at these dinosaur group, the large group of Dinosaurian, what we see that many of these started with a narrow branch during early Jurassic, but then they started becoming really wide. And these widening means it is a higher number of species or genera, depending on which level we are counting. When we come to the end of Cretaceous majority of these lines, or these groups are showing the maximum width, which actually tells you that they were doing just fine.

And that does not really tell you that there was any gradual decline, which led to the extinction. For example, this one, it actually shows a gradual decline, but it went extinct long before the K-Pg boundary. If you look at this particular one, it started it started radiating, it actually reached maximum of its diversity. And then it went extinct. The only group which also showed very high diversity and continued are the birds, which we know are actually a part of the overall Dinosaurian group.

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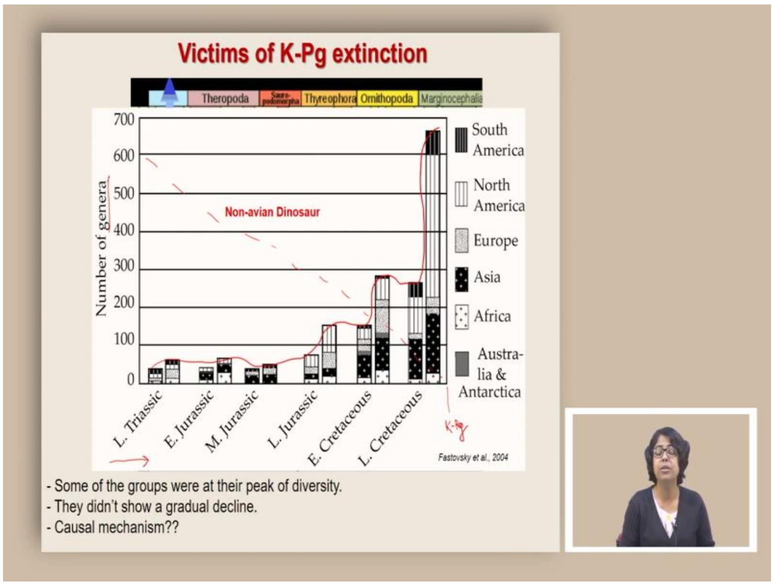

Now, if we specifically look at the dinosaur groups, and look at how they were changing over time, on very, very specific data, what we will see that if you look at these ages, So, this is the K-Pg boundary that we are talking about. And we are coming from older age, then if we combine the number of Genera for non-avian dinosaurs, the total number is actually increasing over time.

So, it is not showing any decline. If it were a decline you would have expected a trend, which is like this, but instead, what we are finding is an increasing trend in the number of general that we have. And that shows that this particular group was not showing any gradual decline before it went extinct. This is another very important clue about what might have happened during K-Pg boundary.

And looking at all these patterns, people started thinking that this might have been a very abrupt event, because of which we do not see any gradual decline. Now, what caused the K-Pg extinction was a debate for a very long time. People observed this abrupt change or abrupt extinction quite a long time ago. But what might have caused it was not clear for a very long time, till a group of researchers started looking for different things, and stumbled upon some interesting patterns.

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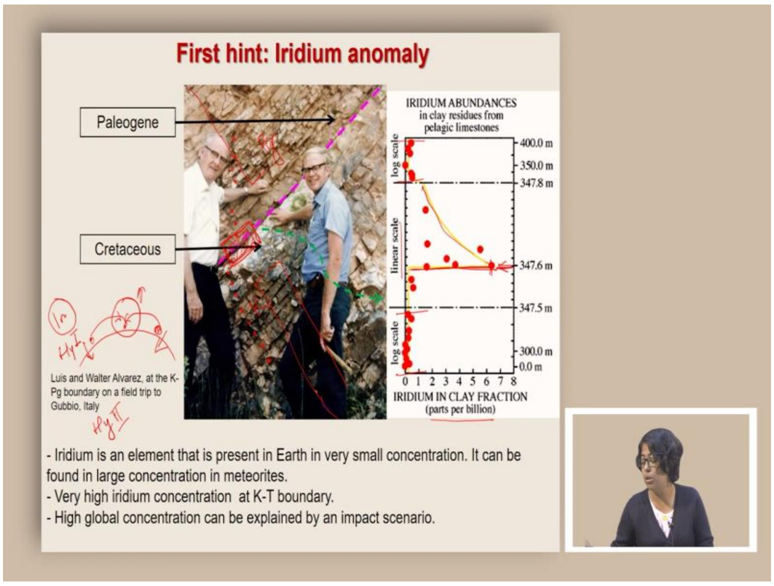

So, this picture shows of Father and Son group, the father was Louis Albers, who was a physicist, and the son was Walter Alvarez was a geologist. They wanted to understand a little bit about a particular element called iridium. And their interest was to address some other question because of which they wanted to check the Iridium concentration across the K-Pg boundary.

In order to do that, they went to a place called Gubbio. It is located in Italy, where you can find these rock layers and the rock layers below this dashed line represents Cretaceous time and the layer above the dashed line represents the Paleogene time. Now, what is this element Iridium. So, this Iridium it is an element and we do not really find it in high concentration on Earth's crust, we only find high concentration of iridium in asteroids, comets and things in the outside in things which are outside the earth.

So, in Extra Terrestrial material, Iridium often shows up in high concentration. There are some iridium which can be deep inside the earth, but it does not really come to the surface and therefore, the overall surficial concentration of iridium on the earth is very low. Now, when they were measuring Iridium across this boundary, they found an interesting pattern. So, what they were doing, they were collecting rock material from all of these points and analyzing their Iridium concentration.

And when they did that, they basically found that as long as they are not looking at this particular point, the Iridium concentration is fairly low. But then if we concentrate on this particular point, which is the boundary and here, we find a really high concentration of

Iridium, it almost looks like this Iridium concentration shot up very highly, and then gradually declined.

So, in order to present the entire thing in one plot, this above part and the part below has been represented in long scale So, that it is collapsed and it requires less space, the same in here, but this part because it is small yet we need to see the detailed measurements, this has been plotted in linear scale and this is the concentration of Iridium, which shows parts per billion because generally the concentration is very low.

Now, what is the observed that the Iridium concentration is very high and it corresponds to this K-Pg boundary layer? They try to explain why this could be the case. One explanation is somehow the concentration of iridium from the entire earth concentrated into this particular place. So, even though there are smaller concentration all over the earth, for some reason, all of them concentrated in one place and thereby increasing the overall concentration.

But if that is the case, then if we do the same measurements globally, we should find a lack of iridium concentration globally, only this part has a high concentration that is one hypothesis. The other hypothesis is if we find that globally, the Iridium concentration for this particular time is always high, and surrounding rocks show lower concentration in time. That means, extra Iridium has been put on the Earth's surface at that particular time. So, that would become hypothesis too. So, their next step was to measure Iridium from all over the world corresponding to this K-Pg boundary. When that was done, it was found that the global concentration was actually very high, right at this boundary.

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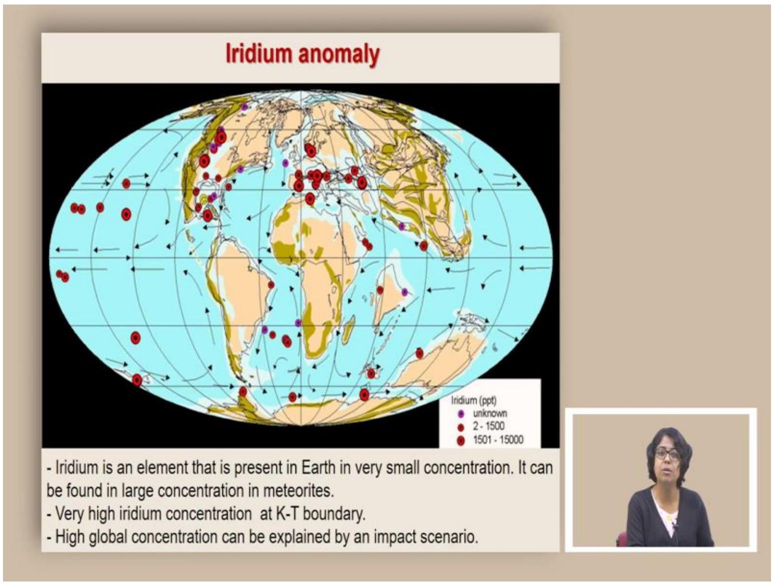

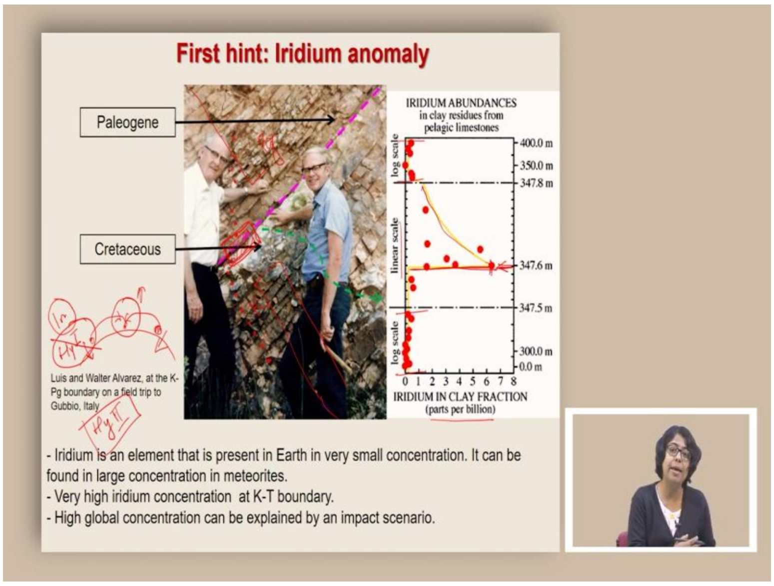

It does not matter from where things were collected. So, the Iridium concentration started showing very very high-level right at that K-Pg boundary all over the globe. So, we cannot really explain the Iridium concentration by hypothesis one, and therefore, the remaining hypothesis is hypothesis two, which means that you are adding extra Iridium to the Earth's surface during this K-Pg boundary.

Now, the question is what can increase Iridium concentration, what can bring extra Iridium on the Earth's surface. And one idea was that it can be an asteroid. So, meteors are these stony or iron stony substances, which are in the extraterrestrial realm. And once in a while you also find them coming close to the Earth often attracted due to gravity. But when they go through the atmosphere, generally they burn, and only a very small piece finally ended up on the Earth's surface.

There can be other situations where these meteorites are really large, they are So, large that it cannot be burned down through the atmosphere, and eventually a significantly large piece of rock hits the earth. In human timescale, it has not happened to the extent of very large substance hitting the Earth. But these are what we call asteroid and in Earth's history, there were a number of events which were caused by such large asteroid impact.

Now, these kinds of asteroids could bring excess your Iridium on the surface of the earth. And that can lead to this increase in Iridium for a specific time. And that is called Iridium anomaly. So, Louis and Walter Alvarez proposed that it corresponds to this kind of a situation in K-Pg boundary.

So, they were proposing that there was an asteroid, which came to the surface hit the surface and thereby contributing a significant portion of iridium and added it to the overall surface. Now, if such a thing happens, then we are talking about a really high impact. Do we have any other evidence of such an impact? And as it turns out, there are separate evidences which also support this hypothesis that there was an impact.

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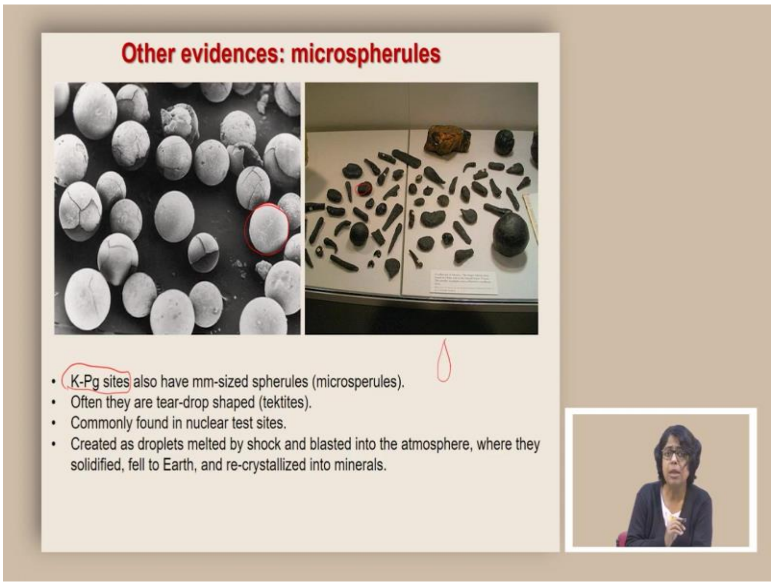

One such thing is called microspherules. These microspherules are very small particles sometimes they are completely spherical. Sometimes they are a bit irregular shape, they can be teardrop shape, all of them form because of very high impact. Sometimes, it is also found in nuclear testing sites because of the extreme heat in a relatively short amount of time. When the because of the blast, when the sentiments go up in the atmosphere, they are still hot.

And finally, they crystallize within a very short amount of time creating these kind of micro schedules. And if they are slightly larger, when they drop down, they take this shape of our teardrop and therefore, you can get a variety of shapes. So, they are either the circular one spherical ones are called micro spherules. Sometimes you also get things which are called Tektites.

These are very common in these kinds of impact sites, we can create them in nuclear sites today, during nuclear testing, they basically we present these droplets, which are created by the shock and blasted in that atmosphere, then quickly cooling down. Interestingly, many of these K-Pg sites contain a large number of these micro spherules. Often, they are also these Tektites shaped. So, this supports the idea of an impact and a shock.

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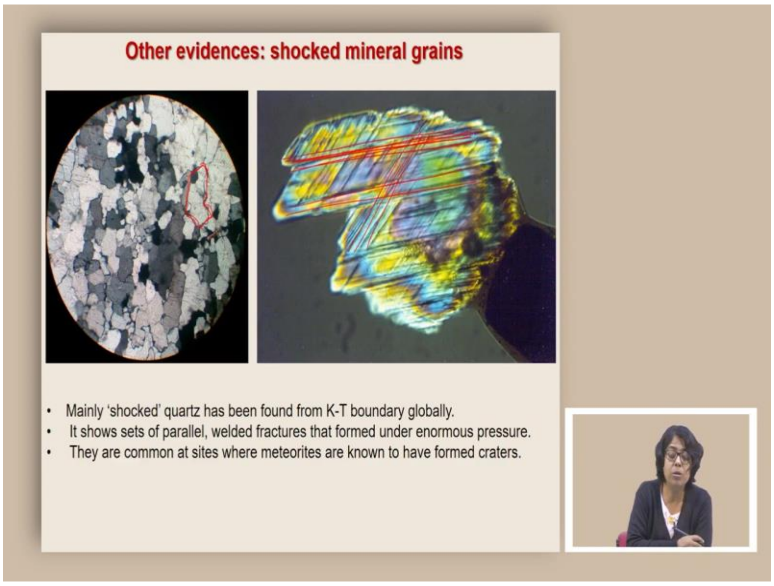

This is not just one evidence, and other evidence comes from a mineral grain and the mineral name is quartz. So, quartz if we make a thin section of this quartz and look at it under microscope, it looks something like this. It is fairly white to grayish colorless in appearance, and unless the section is very thick, and therefore it is showing some abnormality, it is not going to show any significant color.

The other important point is if you look at these structure of the quartz, you are not going to see any very specific orientation, what we call cleavage. Now, the quartz that has been discovered from some of these places associated with K-Pg boundary, they show these interesting color patterns. And you also see some of these striations.

And again, our understanding comes from these nuclear sites, which subject the sediments around to a very high degree of shock metamorphism and resultantly we find quartz grains which show colors. So, it changes their optical property chose colors as well as things like weak planes aligned in a particular direction or cleavages. Now this again, we started finding the shocked quartz started finding from K-Pg boundaries. So, this also supports the idea that there was an impact.

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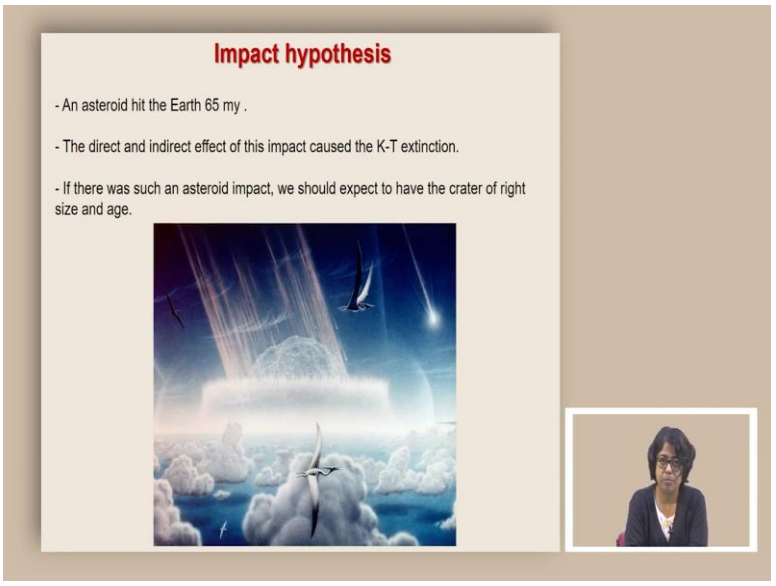

So, according to Alvarez, Louie and Walter Alvarez, the Earth was hit by a large asteroid 65 million years ago, that was their original idea. Now, the ages have been revised. And we know that it could range between 65 to 66 million years ago. But around that time, the Earth was hit by a large asteroid. And because of this asteroid impact, there were some direct effects that changed the atmosphere and indirect effects which are relatively long-term effect, which also impacted the atmosphere.

And a combination of these things led to the wide scale collapse of the ecosystem and caused the extinction. So, this was the hypothesis that the algorithm put out. However, one major issue was that although this was a hypothesis, which explained the extinction of various groups, and their support of this impact, in the form of shocked quartz and microspherules as well as Iridium anomaly, it was still not clear that exactly where it hit, and do we find a crater for these kinds of impacts.

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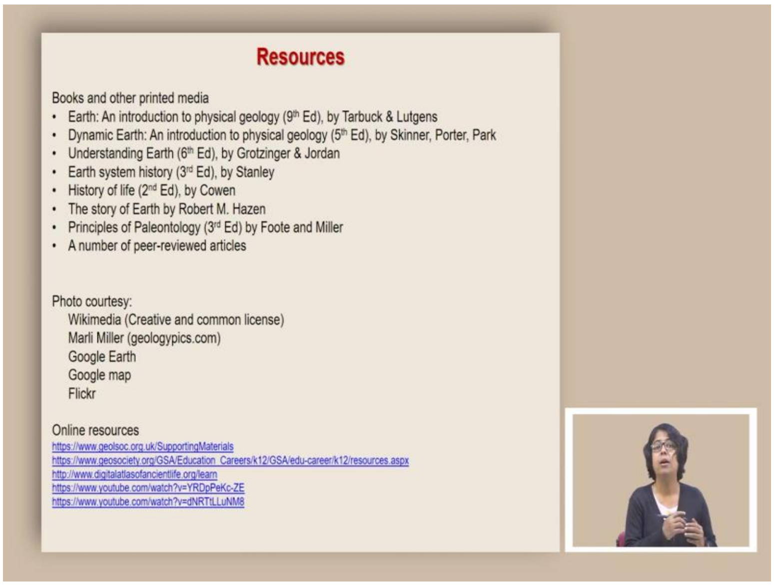

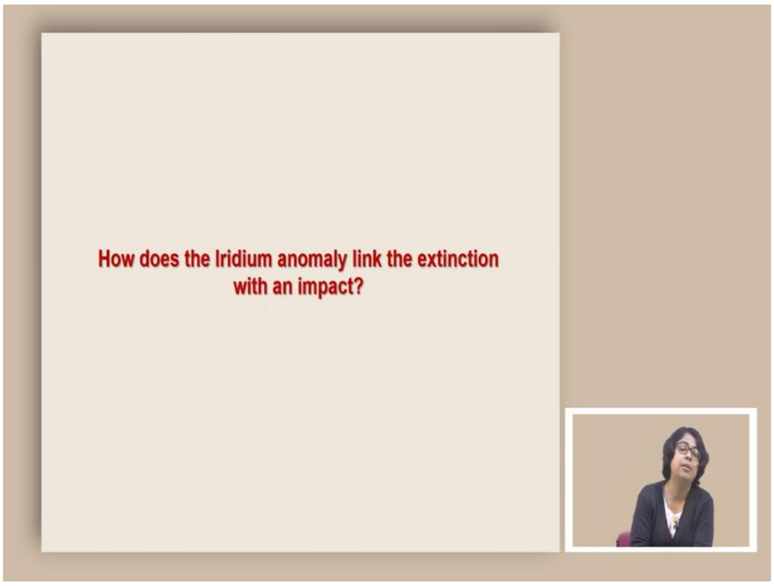

So, in summary, today, we learned about one of the major mass extinctions the youngest one, which is called a Cretaceous Paleogene mass extinction, this Cretaceous Paleogene mass extinction or K-Pg extinction caused the extinction of a number of groups among vertebrates. It includes non-avian dinosaurs, large varying reptiles. Among the invertebrate groups, it wiped out Ammonoids, rudest, bivalves. Many other microorganisms, which can secrete their shells among plants, it also changed because it did not impact the flowering plants.

On the other hand, the total number of seeded plants started to reduce because of this extinction. Now, the reason for this extinction was proposed by Louis and Walter Alvarez, where they found an interesting Iridium anomaly during this K-Pg boundary, which was global in nature, and they interpreted it to be a result of an asteroid impact. The asteroid impact was also supported by findings off microspherules from the K-pg site, as well as the shocked cowards both of these things are often produced in nuclear sites.

And using all these supports. The algorithm proposed this impact hypothesis, which argues that there was a large asteroid which impacted the earth 66 million years ago, and changed a global change in atmosphere as well as in the ocean, which finally led to the extinction of these diverse groups, which were all ways which were often at the height of their diversity. These are some of the resources that I used for this slide. And here is a question for you to think about. Thank you.