**Evolution of The Earth and Life**
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**Lecture 41**
**Origin of Life: Where Did It All Start?**

Welcome to the course of Evolution of the Earth and Life.

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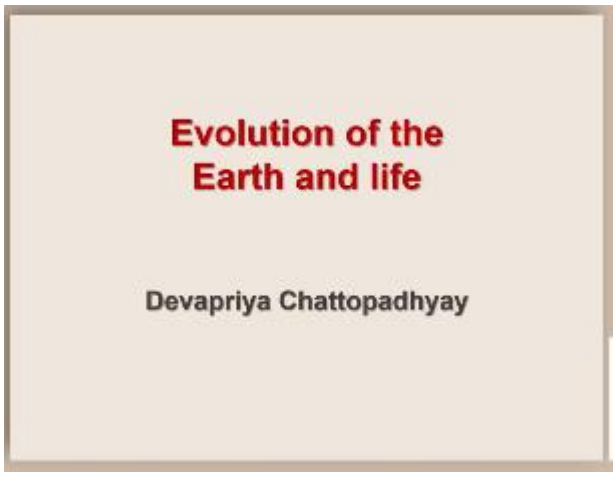


Today we are going to talk about the possible places where the life may have originated. So, the place where life may have originated has perplexed people for quite some time and there are various ideas which were put forward. Many of these ideas have been shown to have some of problems and we are going to discuss those problems as well. But this is a topic of ongoing research and there is no final result in terms of this debate.

We are simply going to cover some of the most prominent ideas in this field and try to understand what are the information that we can take from those. So, one of the ideas where life may have originated was a very unlikely candidate that is outside the Earth.

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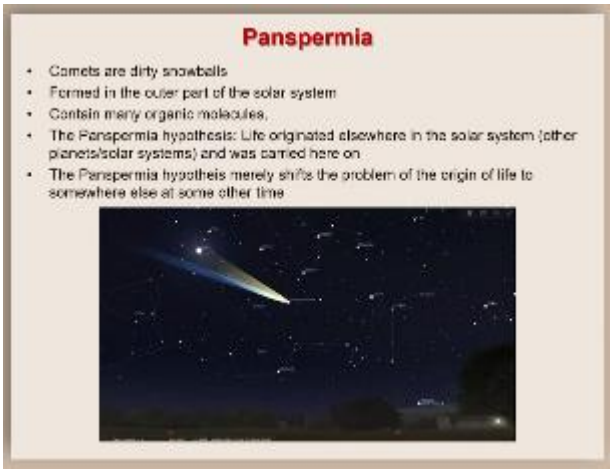


And this is known as Panspermia, so, comets are dirty snowballs that often come close to the Earth and they formed in the outer part of the solar system. It contains many organic molecules and the Panspermia Hypothesis tells that life originated elsewhere in the solar system other planets, other solar system and was carried here on.

Now, the problem with this Panspermia Hypothesis is it simply shifts the problem of the origin of life to somewhere else at some other time. But, it does not really explain why in those planets life may have started.

Now, let us take a look at what kind of evidences are there. So, at the beginning when people started talking about Panspermia it was primarily the comets which often showed development of many organic molecules and some of these organic molecules are important building blocks of life such as amino acids.

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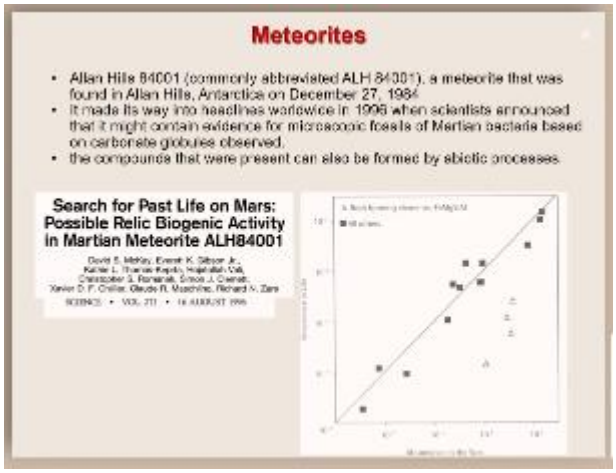


Apart from the comets there are meteorites also and in some of the meteorites there are important organic molecules. One of the very famous meteorite is the Allan Hills 84001.

This particular meteorite is also cold or abbreviated as ALH 84001. It is a meteorite that was found in Allan Hills of Antarctica around 1984. And this made its way to headlines worldwide when scientists announce that it might contain evidence for microscopic fossils of Martian bacteria based on carbonate globules observed. Now, this is far from being settled the compounds that were present can also be formed from a biological processes.

And therefore, there was a massive controversy of how these kind of globules were formed? Whether, it shows that other planets have life which can form these things or it is simply a biologically produced. And this paper came out in science and it was one of the highly debated paper. One of the important thing is that if you look at the abundance of primary rock forming elements abundance in Sun and abundance in life you are going to see a shift from what you where you are going to see life and known life.

And therefore, this has been taken as one of the evidences when you do the geochemical analysis of various meteorites to say whether there was life or not. But the problem with the studies in meteorites or the studies in comets that finding organic molecules especially in the case of comets finding all organic molecules or amino acids is not enough in terms of saying that there was life.

Because, as we saw from Urey Miller's experiment that those amino acids could be produced under certain conditions even without any biological intervention and there is a long step from forming those amino acids to finally forming self-replicating systems encased by a cell wall cell membrane. And these are things which are important to keep in mind when we think about Panspermia.

And therefore Panspermia in general was rejected simply because it does not really explain about how the transition formed. It could have been very well these transitions these changes from a biological material to biomolecules and then from biomolecules to development of a cell could have happened on the Earth but if these conditions are found in any other place they could have formed probably in those places too.

But we really do not have a concrete evidence to show that outside the Earth we also have a development of these things.

And Allan Hill meteorite study tried to bridge this gap but because some of these compounds were also can be formed by abiotic processes it was not a convincing one.

The second idea of where life could have originated which gained very high acceptance among the scientists especially among geologists was this hydrothermal vents.

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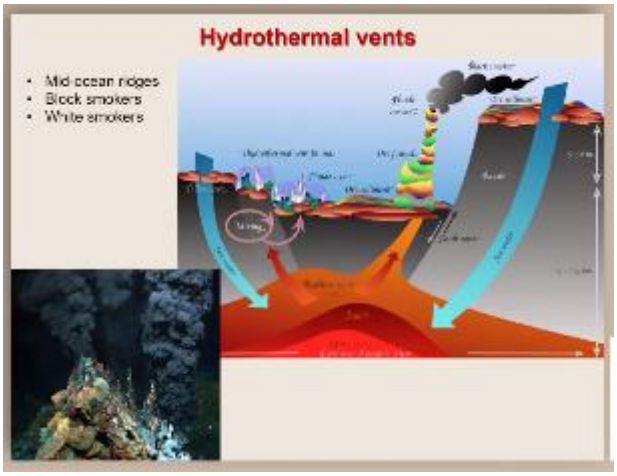


So, let us understand what hydrothermal vents are? Hydrothermal vents are found in proximity to the mid oceanic ridges. These are places where the plates are diverging from each other. So, if you remember the plateauictonic boundaries, there are places where the plates are going away from each other and these are the places where the new ocean floor is being created. And around these places where lava or the magma which is coming from below is very close to the surface they are also very hot. And around these places we find things which are called black smokers and white smokers.

So, these are built ups of these metal rich pipes which are often found because of the high temperature but also because of the high pressure things can be at a state where the boiling point has been elevated to a great extent. So, it is not really boiling but the temperature is very high and that superheated water which is still not completely boiling can take up a lot of metal irons.

And therefore, these things basically contain these metal irons depending on what metal ions are we looking at whether it is a sulphur or phosphorus it can change the colour of the smoke. These can be black or white and according to that it will be called a black smoker or white smoker. What are the other things that we should understand that this is a place of active chemical reaction?

There is sea water which is always interacting with the ore sediment that means these are metal rich sediments and it is taking it down and often mixing with the underlying magma chamber. Then there is a fluid which is less than 50 degrees centigrade which is also

interacting here. Then there are ore sediments because they are also precipitating here. There is clay there is basalt which is which forms these pillow lavas.

And again water is going down and therefore, it is also interacting with this basalt. There is enough formation of clay minerals around these places. And together this creates a system where there is enough chemical reactions that are going on. And one of the idea was that these are the places where probably first life appeared. And we will talk about it why we think so.

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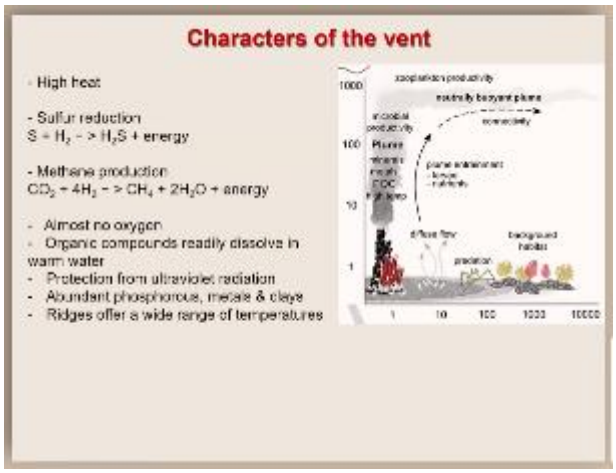


So, let us try to understand the characters of the vent. First of all, it has a high heat. Secondly, it has reactions which are very interesting. First reaction is sulphur reduction it is S plus H2 which creates H2S and then it releases energy. The other one is methane production which basically means it is converting it is interacting between carbon dioxide and hydrogen to make methane water and releases energy. Now, these are the places where these methanogenesis or sulphur reducing bacteria they live and they they can use energy out of these reactions.

So, unlike photosynthesis where the primary source of energy is from the Sun these ecosystems are primarily taking its energy from these chemical reactions. And this is also a place where it is there is no oxygen almost because it is deeper part of the earth. And it does not really get the surficial atmospheric oxygen. As I mentioned that the organic compounds readily dissolve in warm water.

The protection from ultraviolet radiation also comes from this thick layer of water because as we know that the ultraviolet ray although it is very important to form the initial biomolecules as demonstrated by Urey Miller's experiment where these electric discharge or ultraviolet ray

these were key features to develop amino acids. If they continue they basically break down a long chained organic molecule so those are not the best things to happen in a place which is ideal for the origin of life. And therefore, scientists started looking for places where that is not the case.

And in this particular place which is hydrothermal vent or near the hydrothermal vent we have a thick layer of water and therefore, it shields from the ultraviolet rays. There is also abundance phosphorus, metals and clays and these are extremely important component for life. Phosphorus is again an important component for the genetic material.

Metals can lead to these kind of chemical reactions and therefore, they are also important especially in an ecosystem which is primarily deriving its energy from chemical reaction. Clays are important because experimentally it has been shown that often these long chained organic molecules are much more stable when the clays are abundant because, between structures of clays which are loosely sort of bound.

These organic molecules can be resting or trapped which increases their stability. And ridges offer wide range of temperature.

And wide range of temperature means it is a temperature gradient and gradients are always important when we again think about chemical reaction. So, all of these conditions favour hydrothermal vents or the area around hydrothermal vents to be a potential candidate for developing the origin original life or origin of life or the initial biomolecules that probably originated.

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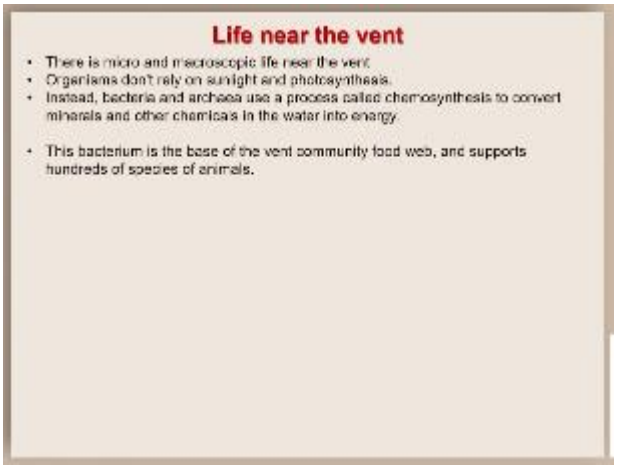


Let us take a closer look at the life near vent that we see today. So, there is micro as well as macroscopic life near the vent even today. Organisms that live there, they do not rely on

Sunlight or photosynthesis instead the bacteria and the archaea that we find in those places they use a process which is called chemosynthesis to convert minerals and other chemicals in the water into energy.

And this is one of the most important points because we know that the initial life was too simple to produce or to take part into complex mechanisms such as photosynthesis. But they still need energy and understanding says that the energy was derived through chemical reactions in a place where these chemical reactions can take place at a very high rate because there is a gradient of temperature there is already free there is a reducing condition and also there is all these metal compounds and other things which are constantly coming out from the inner part.

And this chemosynthesis was one of the major ways how the organisms derived its energy and if we go to the vents today we still see that the ecosystem is dominated by organisms which are taking place into this chemosynthesis.

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The bacterium is the base of the vent community food web and it supports hundreds of species of animals in that place so it has a very interesting ecosystem even today. Now, just to develop a much better understanding of this vent ecosystem we are going to watch a very interesting video.

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The Earth cracks open fluid and minerals spew from the sea floor.

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Water shimmers life abounds.

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We are looking at hydrothermal vents originally discovered near the Galapagos Rift in 1977. Basically a hydrothermal vent is a hot spring produced by underwater volcanoes or tectonic activity.

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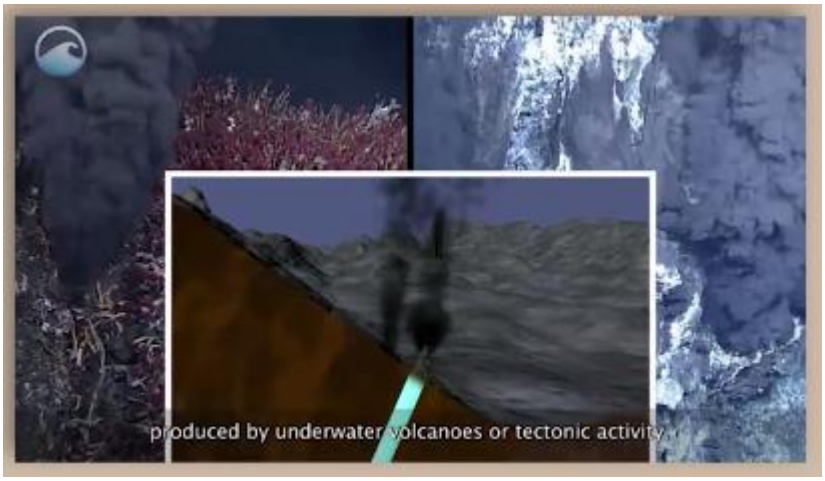


But what is really cool about them is the abundance and assortment of life that exists there. It is not life like we are used to up here on the surface. It is adapted to the dark conditions of the deep ocean. Organisms that live around hydrothermal vents do not rely on sunlight and photosynthesis.

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Instead bacteria and archaea use a process called chemosynthesis to convert minerals and other chemicals in the water into energy.

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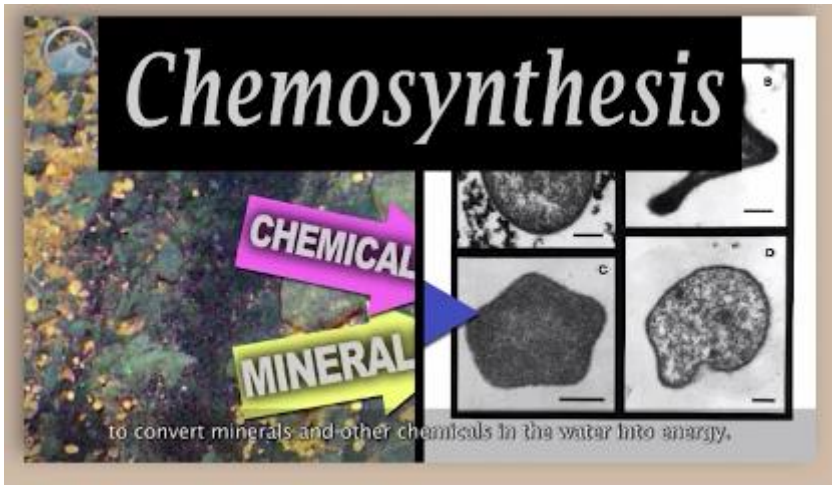


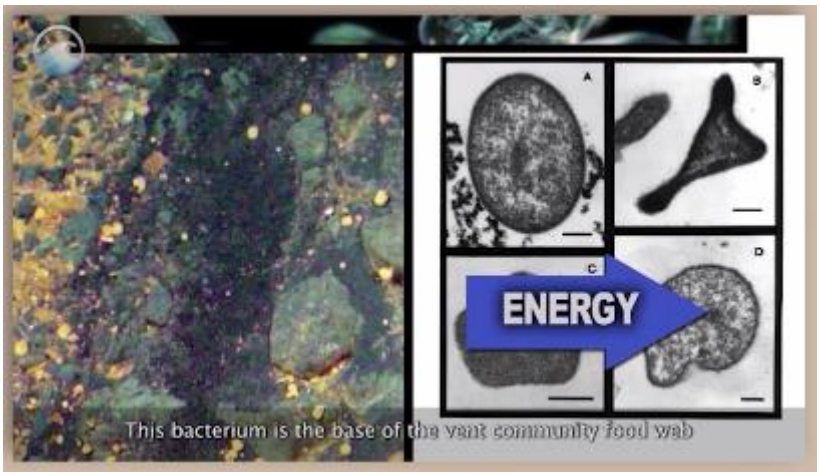


This bacterium is the base of the vent Community Food Web and supports hundreds of species of animals what kinds of animals?

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Well, scientists on the NOAA ship Okeanos Explorer went to the rift in 2011. And here is just some of what they saw Riftia tube worms, also called giant tube worms.

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Which can grow to their full size of almost five feet long in less than two years Bathymodiolus deep sea mussels which are often the first creatures to colonize the vent and are able to survive for a short time after the vent is inactive.

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Serpulid or “feather duster” worms and tevnia tubeworms, which are often the food of choice for vent crabs the top predator of the vent community.

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But it is not all animals down there researchers also saw white flocculent material erupting from the vents like a snow blower an indicator of microbial life beneath the sea floor.

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And of course, there were fresh lava flows, which means the seafloor is continuing to change.

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And that change means there is always more to learn. So, join us as we continue to explore the depths below.

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We would put all the excitement about hydrothermal vents as a potential candidate for the origin of life. It actually has some severe problems when it comes to stability of these organic molecules and how these organic biomolecules can assemble as a cell and eventually propagate in different complex lives. One of the issue was that the concentration in these setups will not be favourable.

What we mean by that when organic molecules build at the beginning there has to be a critical concentration for which there would be competition between organic molecules and eventually development of life.

However, hydrothermal vents are part of open ocean and open ocean even if the development of such molecules happen it will be very easily diluted and there will not be a critical concentration of these long chained organic biomolecules to come together and develop sort

of a community. And that is one of the crucial problems that people have argued against the vents being the origin site of origin of life.

The second problem is that subsequent reactions that is required for sustenance of life includes some of the reactions which require periodic dehydration some things which are required to form peptide bonds which will require desiccation or dehydration.

And in hydrothermal vents which are under a huge column of water and as part of the open ocean it is not possible to have such an area where dehydration reactions can take place. And because of these two major criticisms against the hydrothermal vents now scientists started looking for other potential places which has which satisfies all the qualities of hydrothermal vent but can deal with these two issues.

And in doing so the other place other geologic setup which is emerging to be one of the most prominent potential candidate of a place where life originated is a continental pool.

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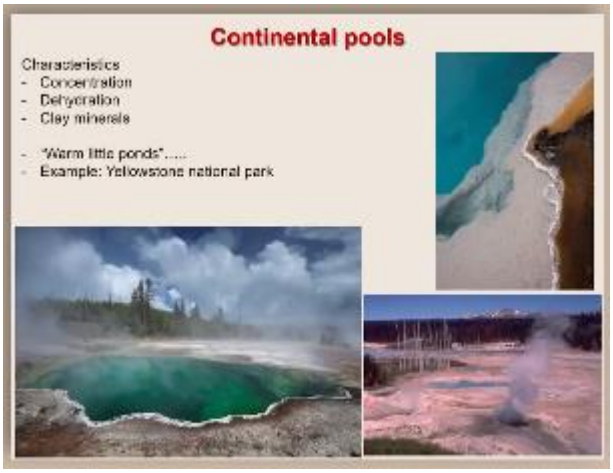


It is also called a continental worm pool. So, what are these things? As we know that there are continents and often even inside continent there can be a plate boundary along these plane boundaries there can be divergence.

So, that means lithosphere here is very thin and the heat is coming up so and the magma is very close to the surface.

What it does? Often it heats up the underground water it could also happen if its enclosed vicinity with the sea water there can be tidal pools where during the tide it comes up and because of the vicinity of these lithospheric layer or the close to the magma chamber they can

be heated up. So, there can be tidal pools also or there can be situations of groundwater heating up.

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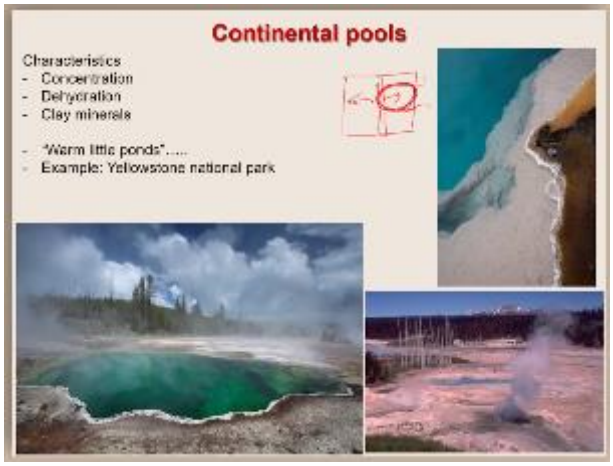


Now, what happens if it actually acts like that. So, if it is a tidal pool then the composition of that water is the sea water. It also has a thickness in terms of the pool and therefore, it also saves those molecules first formed molecules from the ultraviolet ray. This because we are still talking about rocks interacting with the water so this will also have clay formation around this is hot because of the underneath close proximity of the magma and therefore there is a temperature gradient.

This also has clays, this has metals, this also supports chemosynbiuses in addition to that because they are relatively smaller pools sometimes even connected pools. It is not as vast as ocean and therefore, if some organic molecules form here it will not be diluted in the entire ocean. It is still part of this small pool and there is a possibility of building up a critical concentration of these biomolecules which solves the problem of the concentration that we have seen was an issue for the hydrothermal vents.

The second issue was the dehydration, now these pools are typical places where desiccation also happen because of evaporation and therefore, there would be places at the rim of the pool at the sides of the pool where there would be places where it is constantly evaporating but it is not part of the deeper part of the pool.

And therefore, there would be cycles of desiccation during the day and it will also be inundated by regular tidal movement and therefore it will have these cycles of desiccation and non-desiccation. This is an ideal situation for creating some of these reactions which

require at least periodic desiccation or periodic dehydration. And as I mentioned that they also have clay minerals.

Now, the question is that do we have any such place in the world today that we can observe? And the answer is yes, there are number of Continental Rifts where we can observe this one of the example is Yellowstone National Park in the U.S, where there are these continental thermal geysers where the water often converts to vapour and comes off.

But there is also a pool and these pools have a number of bacterial community some of them are extremely primitive and more often than not they show these chemical reactions that we associate with the initial condition.

So, now these continental hot pools or warm pools are one of the most prominent candidates for the places where life may have originated and it is interesting also because this was one of the ideas of Darwin when he pondered upon where life must have been originated.

He talked about probably life originated in a place of warm little ponds and then proliferated from there and it resembles very closely to what we see today especially in terms of the continental hot pools.

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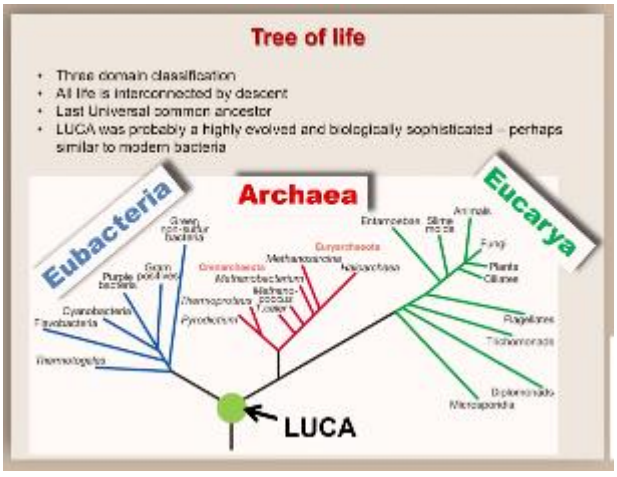


Now, once we know a little bit about where it originated then the next question is how it originated and how did it look like when it originated? So, when we look at the life of today we can broadly subdivide it into three domains.

And all of life is interconnected by the descent, that also shows that this idea that all life that we see today originated from a single source is actually validated. And the single source is now called the Last Universal Common Ancestor in short Luca. Now, what was the nature of

Luca when it was first originated. Luca was probably a highly evolved and biologically sophisticated organisms perhaps smaller to similar to modern bacteria.

But, we do not really have any fossil record of Luca because we are still talking about a single cell. But these factors that there are commonality between life all kinds of life that we see today on the earth starting from their genetic material to their structure in the cell it all points to that all of us have the same common ancestor and all of us basically originated from the single point. And Luca was that single point which is the last universal common ancestor.

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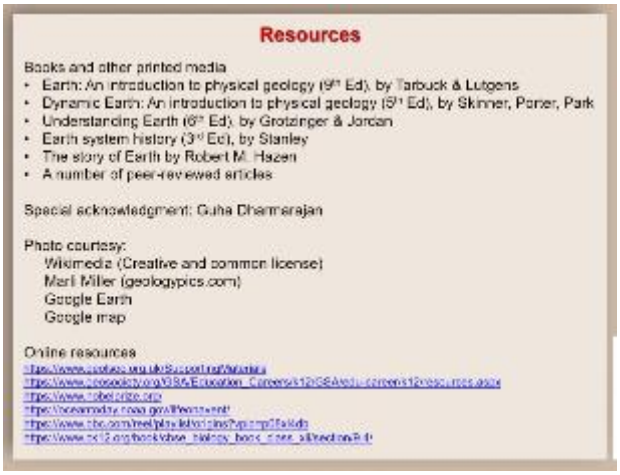


So, in summary today we learned what were the probable sides of the appearance of life. We learned about Panspermia and why that does not solve the question of where life originated and how? We also learned about hydrothermal vents and why some of the conditions in hydrothermal vents favour the idea of origination of life in on the Earth but at the same time we learned about the concentration issue as well as problems of conducting dehydration reactions in hydrothermal vents which are the major criticisms against hydrothermal vents as being potential sites for origin of life.

Then we learned about the continental warm pools or geysers these are the most accepted ideas about where life may have originated. And once life originated it originated from a single point which we are calling the Last Universal Common Ancestor or Luca. Here are some of the resources that I used for this lecture.

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Here is a question for you to think about. Thank you.