**The Evolution of the Earth and life**
**Dr. Devapriya Chattopadhyay**
**Department of Earth and Climate Science**
**Indian Institute of Science Education and Research, Pune**
**Volcanoes**

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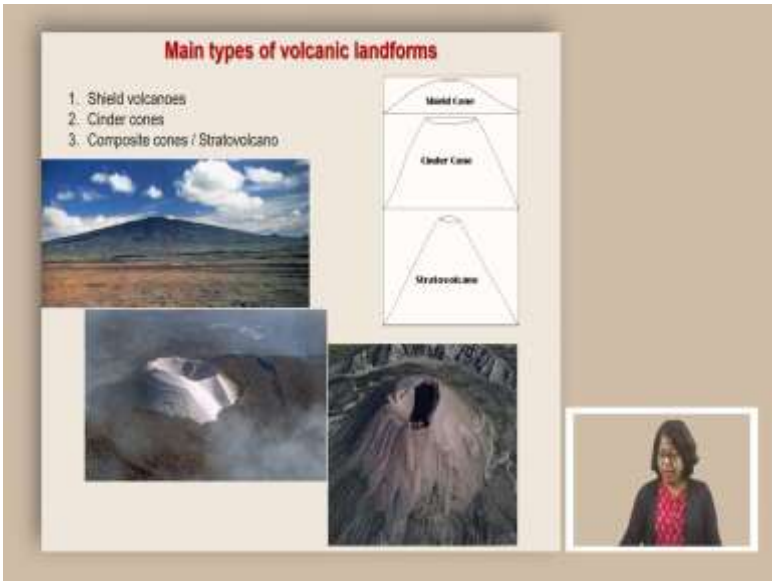


Welcome to the course, evolution of the earth and life. Today we are going to talk about volcanoes. So there are 3 main types of volcanoes. One is shield volcano, the second one is cinder cones and the third one is composite cones or Stratovolcanoes. Today, we will try to understand how each of these types form. And can we say anything about any of these types in terms of their destructiveness.

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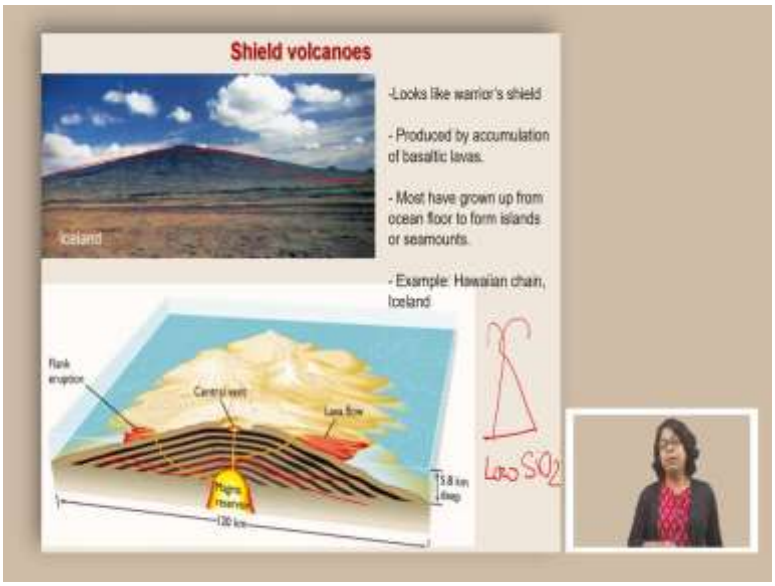

So the shield volcano looks like a warrior's shield. The important thing to notice about this shield volcano is, it is very, very gentle. In fact, if we think about the structure of the shield volcano, it often can be mistaken as not a volcano at all. Because in our mind, often we think of a volcano as a conical to have a conical shape through which eruptions come out. But these shield volcanoes have very gentle slope. And one of the reasons to have this very gentle slope is the composition.

So primarily, these are produced by the accumulation of basaltic lava and the basaltic lava has mafic composition, and therefore it has a low silica percentage. We already talked about how silica percentage contributes to the viscosity. So once we reduce the silica percentage, the viscosity reduces. And once the viscosity reduces, the magma will have higher tendency to flow or it will have low resistance to mobility.

So when these basaltic magmatism lead to a higher contribution of magma to the surface, they tend to move very smoothly without much resistance. As a result, they do not build up and make a very steep cone. On the other hand, they are going to flow very smoothly and create structures which have very gentle slope and it will have a very large spatial dimension.

So most of them grown up from the ocean floor to form islands or sea mounds. Because such kinds of basaltic lava flow, we also encounter in places which are mid oceanic ridges. And if it happens in mid oceanic ridges, we basically end up forming an island, which are basaltic in nature, but there can be without the formation of mid oceanic ridges, there can be other islands also, which are forming in the ocean, and typically developing through the basaltic flow.

Some of them are related to mantle plume. Some of the examples include the Hawaiian chain, and Iceland and all of them do not show you this typical pattern that we have in our mind of a very conical Mountain, which is emanating a lava and magma and erupting in nature. And because of such flows, it is also relatively less destructive, because it flows smoothly. And people are aware of these movements and often they happen quite regularly. And therefore, generally, people do not live very close to them.

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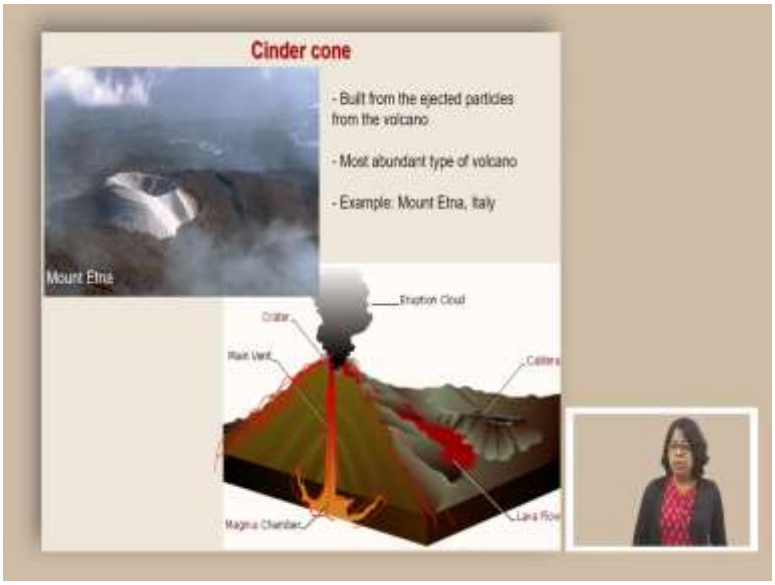


The second type is one of the most unpredictable types. And sometimes it does not even explode more than once are the cinder cones. Now, these cinder cones have kind of a high slope. And the important thing to remember is they will have very uneven surface throughout because they are primarily built from the ejected particles from the volcano. And as we learned that the injected solid particles from a volcano include different types of grain size, starting from the ash, which is fine grained to lapilli, which is slightly larger to bombs and blocks which are really large.

So, the entire flank of these volcanoes would be started with these kinds of solid materials changing in size and therefore, it will have a very jagged margin, when we look at it in the cross section. So, these are telltale signs of a cinder cone. And these are often most abundant type of volcanoes. Their position is not always easily predicted in terms of their plate tectonic position, because the development of these cinder cones are primarily guided by how much explosive material in terms of the volatiles are there so that it explodes. It also depends on what is the composition of the magma.

There can be such cinder cones forming from andesitic volcanism, which are intermediate. It could also happen from other kinds of volcanic material, other kinds of magma composition. So, these cinder cones, although it is very easy to detect in the field because of their jagged margin because it does not always share a single mechanism for its formation. It is not so easy to locate them at priority without observing them. And majority of these cinder cones erupt only once and have very long dormant period or completely blocked by the magma.

So when the magma is rising from the magma chamber, after this one eruption, it forms these cone like structure with jagged margin, but also because it loses its temperature. And without a permanent connection with a plate tectonic boundary, which feeds the magma continuously, the entire part basically solidifies, blocking the entry of the magma for subsequent events. And that is why I am saying that it often erupts just once and then it becomes a dead volcano.

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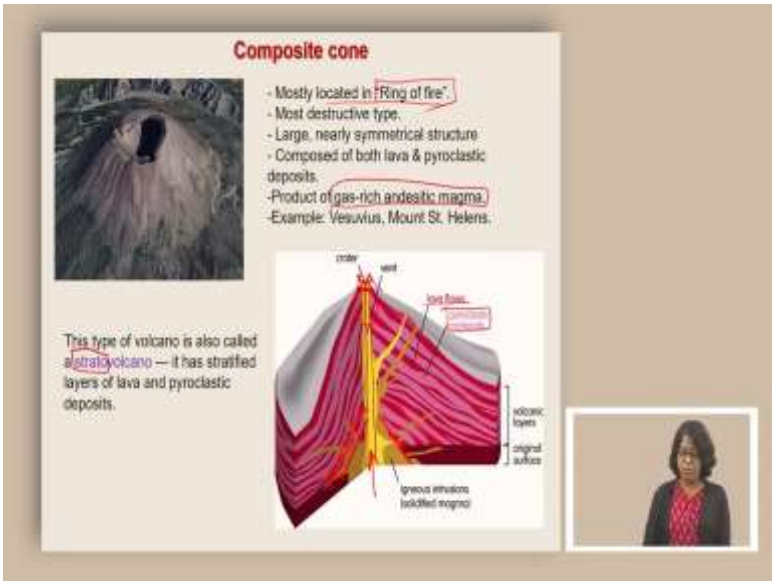


The most complicated and somewhat dangerous type is the third one, which is called a composite cone. And they have a very strong well-established relationship with the plate tectonic boundaries, they are all found in locations with respect to the Ring of Fire. So majority of them are basically along a convergent plate boundary, where these oceanic plates are diving down another oceanic plates forming this ring of fire around Pacific. We also find them in other places where we do see convergent boundaries and this is one of the most disruptive types. They are large and they have a symmetrical structure.

Now, let us take a look at one of the cross section diagrams of this composite cone. So what we see is there is a central vent. And where this vent is appearing at the surface is called the crater. It has this vent through which the magma moves up. But when we look at the flanks, we do see 2 types of material. One is a lava flow, and the other one is pyroclastic material. So often, it is an alternative batch.

Once we see a liquid flow, that is the lava flow. And then it also covered by this pyroclastic material, which can differ in their shape and size, starting with ash flow to all the way to blocks and blocks. And the repeated layer shows that it has a continuous influx of lava of

magma from deep underneath, which keeps on erupting and creating these newer layers. And that tells us that this is one of the types of volcanoes which are not going to be dead right after one eruption.

It also tells us that it is not going to create a very gentle smooth slope simply because we do see these pyroclastic materials. We also see a relatively steeper cone at the beginning, because it often is produced by gas rich andesitic magma. So it has a viscosity, which is not as low as basaltic magma which can flow very smoothly, and therefore would not create a high slope it because of its relatively higher viscosity, it has resistance. And because of this added resistance, it cools off or crystallizes right after it basically erupts.

And it creates a cone which has a steeper slope, and this steeper slope is flanked, it is covered by this lava, which again, do not move farther, making these gentle slopes it becomes a steeper slope, and then it started by this pyroclastic material. And this process continues again and again. It also has gases, which basically creates an explosive nature when it goes up when the magma is rising up. And this gas expands in volume, making giant bubbles, adding to its adaptiveness and explosiveness. And this type of volcano is also called a stratovolcano.

This strato comes from the word stratigraphy or strati graphene, or stratified, or streator, which basically means it has layering. Because there are predictable layering of the lava flow and pyroclastic material, it is also called a Strato volcano. And we are going to focus a bit on this particular type of volcanoes, this composite cone or strato volcano, and we will see a case study of how a Strato volcanic eruption can lead to a complete disappearance of city. And the example that we are going to look at is the eruption of Mount Vesuvius.

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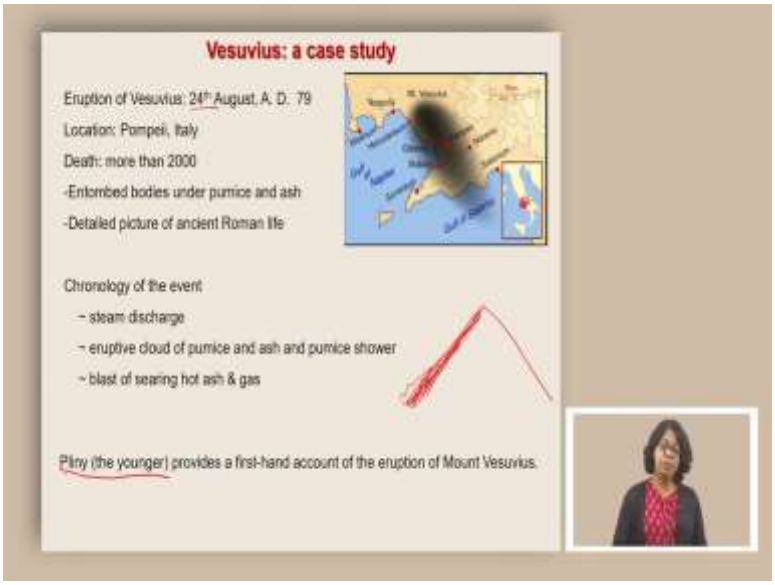


So Vesuvius erupted A.D. 79. So it was a long time ago. And interestingly, we have a very good historic record of this eruption. At the same time, because the structure still exists geologically, we can also deduce the events that took place around that time. And therefore, this led to the development of one of the most well documented case studies of a volcano erupting during human timescale. And what were the subsequent effects of this eruption.

So if we look at the map, and if you focus on Italy, there is this place near Naples in Italy, where Vesuvius is located. And when it erupted at 79 A.D. the nearest town was Pompeii, and Pompeii got buried by this volcanic activity. And it was one of the most prolific towns it was a very popular town at that point of time. And because it got buried by this volcanic activity, after discovery of Pompeii, people could learn a lot about the human history, human culture at that point of time, about these small towns, which was under Roman Empire.

It also tells us something about the geologic events that took place around this time, and we are going to spend some time looking at it. So this eruption of Pompeii led to immediate death of 2000 of its inhabitants. It was a town which was lived by probably 20,000 people. And we still find the intombed bodies under these pumice and ash. And it gives us a detailed picture of ancient Roman life.

So there are 2 sources of information. One is how Strato volcano behaves, and therefore we know that what would be the event once it erupts. And then there is also the description of a historian Pliny the younger, who could escape this volcanism, and while in the sea, he could

still see the volcano erupting, and wrote a detailed description of the account of eruption of Mount Vesuvius or Vesuvio as it is called in Italian.

So according to his description, and our understanding of the volcano, it all started on 24th of August, with a steam discharge, as we know that once the volcano, especially the stratovolcano they become active, the first things that are going to be released out of the magma would be the water vapor because they form giant bubbles. And these bubbles are primarily of water vapor. So with increasing temperature and lack of pressure on the top, it is going to first release a lot of steam. And often these kinds of steam release or volatile (()) (15:49) are called, they kind of make a smoke like appearance. And they are called fumaroles.

The second thing that happened was this eruptive cloud of pumice. So again, very fine ash, and smaller blocks. And all of these are going to be carried by the cloud, and they are going to have a shower. So these fine particles, which ranges to a few microns to somewhere around 5 centimeters, can shower down. And then finally, once this initial part of the volcanic activity is over, then the conduit is experiencing higher pressure because of the expanding volatiles and also the rising magma, it is going to blast and this is the blast, which is going to end up producing a lot of hot ash as well as gas along with the lava flow.

So the lava flow again we are talking about highly viscous lava flow, and therefore the lava flow does not reach very far away. But along with the lava flow, the hot ash and gas will also be getting removed from the volcano and that can travel a large distance. So from the Vesuvius, Pompeii was at a distance of a few kilometers. So the lava immediately did not reach Pompeii, but all these volatile material like hot ash and gas that they traveled and they covered Pompeii. Now, let us recall again the structure of the strato volcano.

So, we have these multiple layers, we always have this layer of the lava followed by pyroclastic material. So we are basically talking about initial phase of the lava flow which gets followed by these development of pumice and other kinds of large blocks of pyroclastic material, and this kind of gets repeated. So let us take a look at how it looks like.

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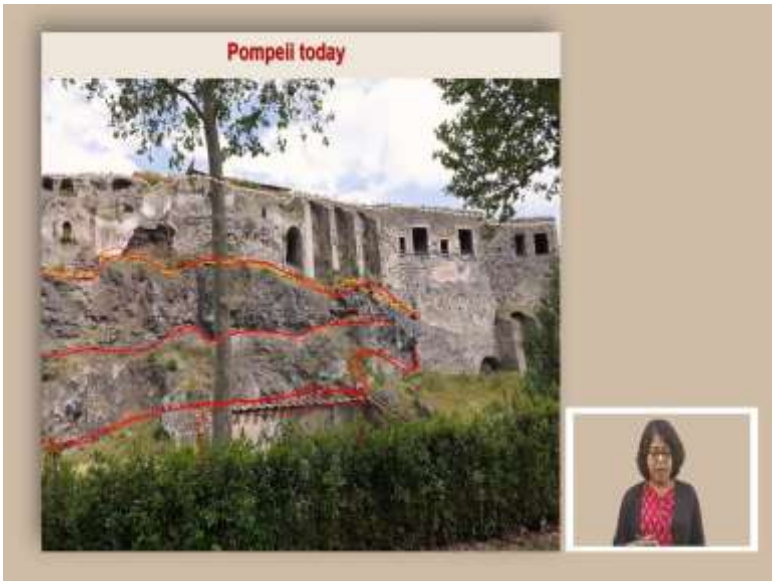


So this is the picture of Pompeii today. So what it shows is some of the structures, some of some of the old Roman structures that you can see right around here, but at the same time, which is interesting to see is that there are different layers of lava. So if I can mark I will see things which starts from here, and there is a lava flow right around here. And then there is a second lava flows right around here. And then there is another lava flow right around here, and so on and so forth.

Now, this city was discovered or excavated out of these lava flow, because it was completely covered by both pumice and ash. And in some parts lava flow. But important thing to recognize is that there are layers of the city, for example, you can see these tiled roofs and the houses underneath the lava flow and also something which is right at the top, which clearly tells you that they have not happened at the same time.

So there are multiple times when it erupted. And you know, houses were destroyed by these flows and it was covered, but people probably did not recognize that and they kept on building the city again and again. And you probably had a proliferating city in the same spot. Now, this lava flow covered parts of the city. But what was more damaging are the other things such as gas discharge, and hot ash and gas. And we are going to see how it looks like.

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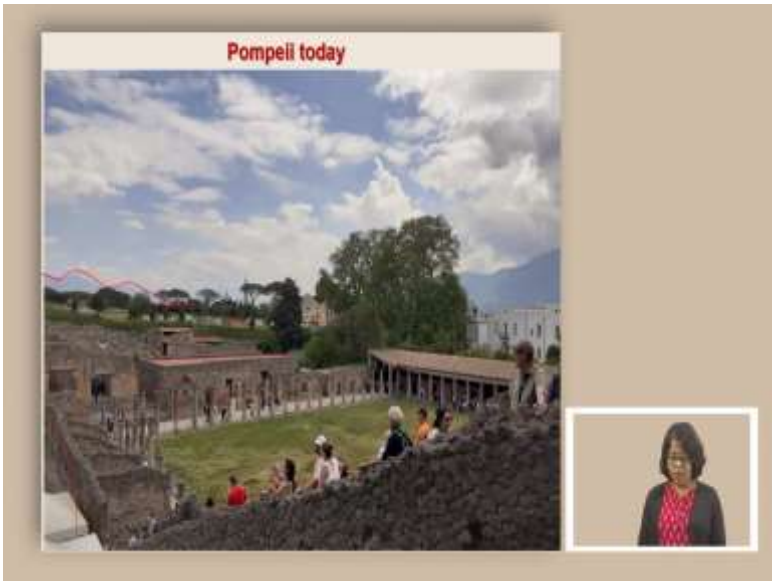


So this is how it looks like after the excavation. So it was a proliferating city. At that point of time, it was a small Roman city where all the amenities were there, there was a theater for watching different kinds of shows, you can see these columns, and they had excellent development of architecture. But at the same time, you can see the background of Vesuvius right around the city, all around the city. And there were ample evidences that even before the Vesuvius actually erupted, there were multiple lava flows, it simply that there were not enough awareness about these repetitive events of volcanism in this area.

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Once it was covered, it also gave us a very good understanding of how the light was at that point of time. The most important thing was these kinds of entombed bodies. So in the initial

time when the steam discharge happened, unfortunately, many of the residents did not take it very seriously. They basically thought it was just a hot air, which was everywhere, and they did not pay attention, although they could see according to Pliny description that Vesuvius is from Vesuvius you can see these clouds which are going up and gases which are coming out, but they simply thought that they are safe. At the second phase, when the raining of ash and some of the pyroclastic material started to happen.

Even then, some of the residents fled. But other stayed there simply because they thought they had very strong roofs. And, in fact, it was true that the roofs were quite well structured, and they did not buckle or they did not fall off at the beginning. And in terms of some of the residents who were moving around, they thought it simply ash which are very fine, and it almost looked like gray ice fall from the cloud.

Then it was also mediated with some of the pyroclastic material, which ranged in size by 5 centimeters. So 5 centimeter diameter fall of pyroclastic material is not enough to kill a person and therefore some of them did not pay attention, but the important thing to recognize it, it went on for the entire day. As a result, these roofs had a thick pile of the position of these ash as well as pyroclastic material. As a result, it started to collapse. When it started to collapse, it was too late.

So by the time this ash and pyroclastic material shower was over, after one and a half days, the residents even when they were entrapped because of the collapsing roof. They could not go anywhere, because it was followed by this discharge of hot air accompanied by some of the lava flow. So that is when many of these residents died immediately, but then they were buried under this fine ash. And this fine ash accompanied with some of these hot gas discharge killed them, their bodies were entombed and later because of rain, the rain water mixed with this ash made a perfect cementing material.

So what that means the entire body got covered by a material which is very fine and which hardened like cement. So during excavation, the researchers understood that if this is the structure of the entire ash layer, some of the places are hollow, because they could tap on it and it will sound slightly different. And they realized by breaking some of the places that there were gaps there were empty places, those empty places were created because those bodies were entombed, but eventually those bodies decayed, leaving behind a perfect gap which resembles the body.

So later, the researchers started filling these voids by pouring cement. And that made these kinds of casts. And this is only one example of the cast. But there are plenty of casts. And some of these human casts are showing fine facial expressions too. And in majority of these casts, it is showing that they are trying to hide, or they are trying to save their head. And pretty much all of them are telling you that when they were covered by ash, they were still alive, and they were still trying to protect themselves.

So apart from these bodies, the entire town was also buried under these ash, which was later excavated. So we know how the roads were, how the town was built, how the structure of the houses were, around the road, how people got entertained in large arenas. And it also shows us just looking at the structure of the roads, as well as the number of residents and number of houses, that there was a considerable traffic jam. In those roads of Pompeii.

They were using the horse carts, but there was only one road kind of going through the city. And with the number of residents with the number of houses around, it was, it was must be a very busy city. There were also glimpses of lifestyle of local residents, where there are individual houses with preserved and there were murals around the houses, which shows how they painted their houses and things like that. So the Pompeii's past, especially during Roman time got preserved because of the activity of a strato volcano. And it also shows us what the different stages are of a volcano erupting, especially the strato volcano.

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But unfortunately, the volcanoes are still there today. And we know that these volcanoes may erupt again, at some point of time. So this is a clip of the Pompeii city today with the

backdrop of Vesuvius, which may still affect it. So finally, it is important to look at the volcanoes and try to understand how it is going to evolve in future.

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So, let us look at how it looks like today. So when we look at today, from the crater, to away from the crater, we see the ocean and we also see a sprawling neighborhood of a lot of people who are living there, and then we are going to look at the crater itself. So when we look at the crater itself, of Vesuvius, this is how it looks like. So we are looking at the crater which goes deep down, and it is filled up, it is actually completely closed, but then we actually see these fumaroles we actually see gas escaping structure.

So, it is possible that in future, it may still erupt, because it still is active in some sense, because you can see the gases coming out of it. If you are walking down there, you can also smell the sulfur and right next to it, we have a sprawling neighborhood. So there are different places in the earth where you see people living with very, at very close proximity to the volcanoes, and they understand the risk and still the volcano flanks or the age of the volcanoes are often very rich in minerals and therefore they are agriculturally, very important and therefore, it is not always possible to move people because they are places of really good agriculture.

So, in summary, what we learn today, we understood different types of volcanos, and where can we find each type with respect to the plate tectonic boundaries? What kind of eruption can we expect in each type? That is something we also learned. Finally, we learned a little bit about one specific eruption that happened in the past, which was documented by humans, as well as the structure of the volcano.

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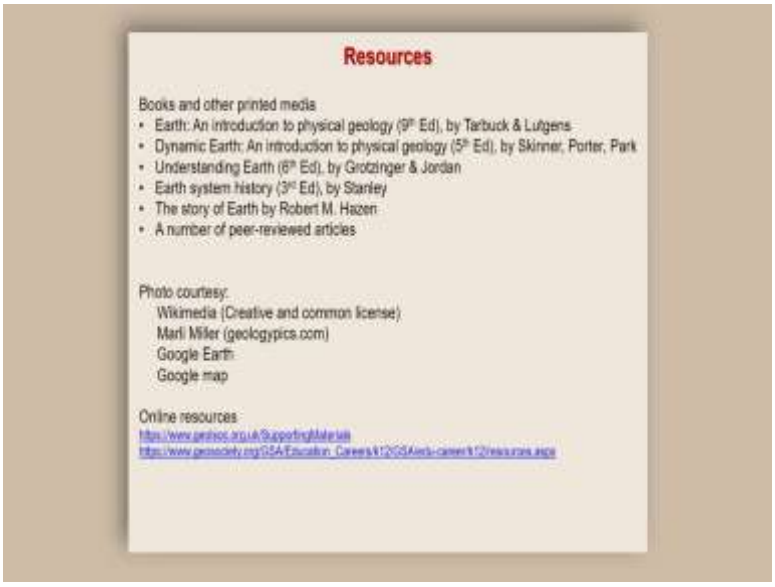

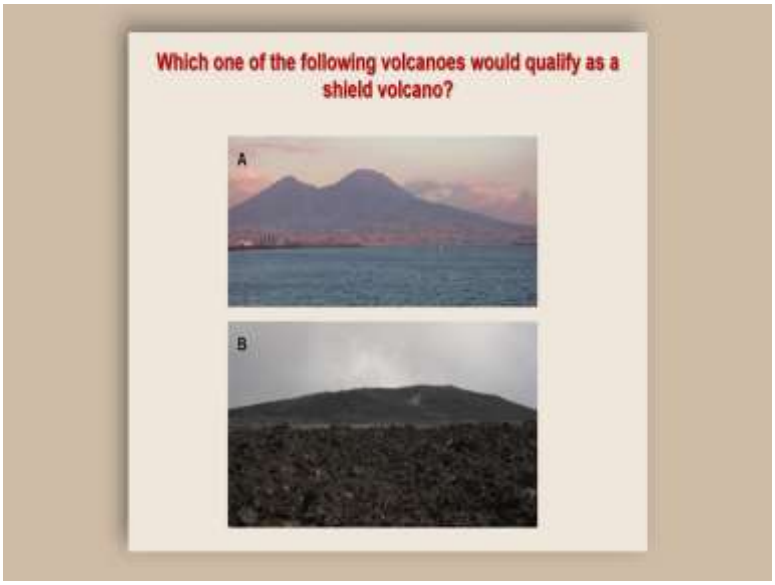


Here are some of the resources that are used for this lecture. Here is a question for you to think about. Thank you.