Evolution of the Earth and Life
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Lecture 8
What are Igneous Rocks?

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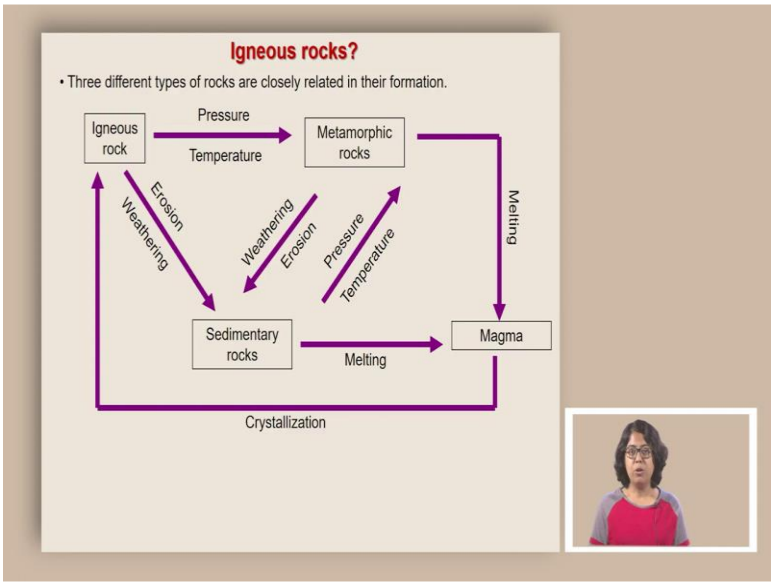

Welcome to the course titled Evolution of the Earth and Life, today we are going to talk about Igneous Rocks, as I mentioned igneous rocks are one of the three types of rocks which are available on the Earth's surface and these rocks, among these rocks igneous rocks are types which are formed from molten rocks, they can be transferred or metamorphosed and form metamorphic rocks, they can also be broken down and form other rocks such as sedimentary rocks.

So, igneous rocks are one of the major sources for development of other types of rocks we have to know a little bit about how these igneous rocks form and we will also try to know something about how many different types of igneous rocks do we find?

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So everything starts from magma, magma are the molten rock that comes from the Earth's interior when it is in the interior and it is not really touching the surface or coming out of the surface then we call it magma but once it reaches the surface then it is called a lava, there are different kinds of rocks, igneous rocks which form at different depth, there are types which form outside the surface when the molten rocks solidifies above the ground in those cases we call them volcanic rock or extrusive rocks.

On the other hand if there are rocks, if there are instances where the molten rock solidifies below the ground, below the surface in those cases we call it an intrusive rock or a plutonic igneous rocks, now if we think about some of the examples we will find that in India we do find a number of rocks which are forming above the ground, one classic example would be the Deccan basalts and those would be called a volcanic igneous rock.

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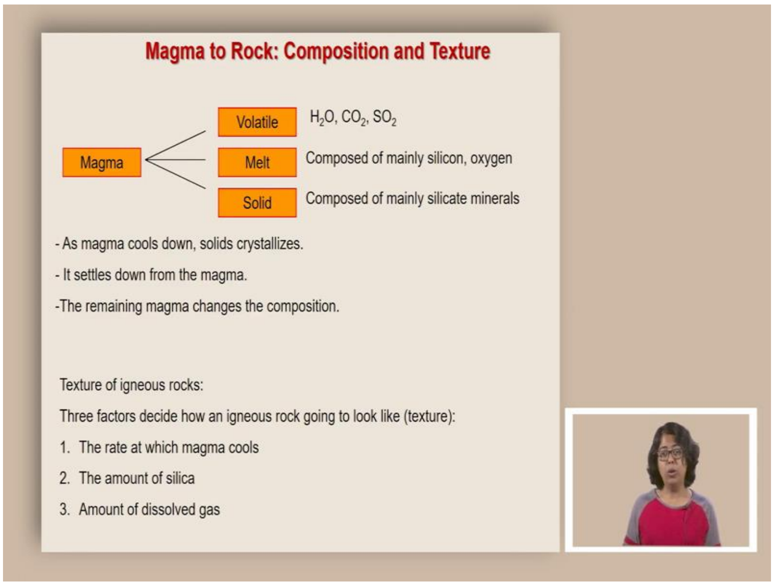

So, when we think about magma it has different components the major components in a magma consists of the solid component the melt component and the volatile component, the solid component is primarily composed of silicate minerals, if you recall some of these discussion about minerals and which minerals are most of the common minerals on the Earth surface as well as Earth's interior at least up to the mantle then it makes perfect sense why these solid part is mostly dominated by silicate minerals.

The melt on the other hand is composed by mainly silicon, oxygen, so it is not different in terms of composition from the solid as such because the solid component is dominated by silicate minerals whereas the melt still has some silicon and some oxygen, when we look at the volatile part it has other components such as water vapor, carbon dioxide and sulfur dioxide.

Now, the most important part to remember is when a magma cools down these three components change their ratios with time so we do not see the increase in solid within a second it actually increases gradually and there are situations where you do find all these components coexisting together and when the magma cools down, first the solids will crystallize and because it crystallized it is going to change their buoyancy and it is going to settle down from the magma and as a result the remaining magma changes its composition this phenomena is often called a fractional crystallization.

And because these crystals are settling down from the magma from the original melt as the magma cools down its composition keeps on changing and the amount of volatile also changes because some of the volatiles will escape given the required pressure and temperature and because of all of these combination of factors it impacts what kind of igneous rock is going to be formed.

So there are two ways of looking at an igneous rock, one is how do they look like and we call them the texture, the other aspect of igneous rock is what are they made of, what is the mineral composition so using these two factors, one what is the texture and what is the mineral composition we can classify all kinds of igneous rocks. Question is what controls the texture?

So there are three major factors which control how an igneous rock is going to look like, the first one is the rate at which magma cools, the second one is the amount of silica and finally the amount of dissolved gas and they finally decide how a magma is going to behave and also what kind of rock is going to finally form in terms of the texture, so let us first focus on the rate of cooling of the magma.

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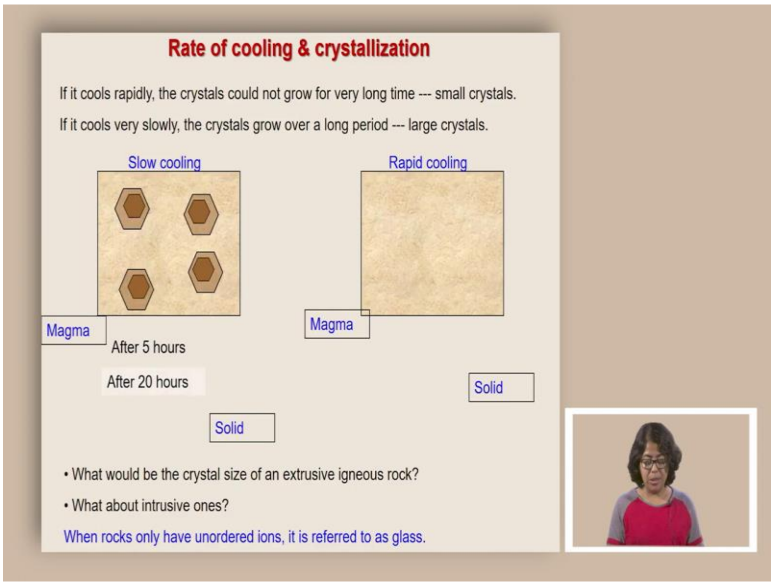

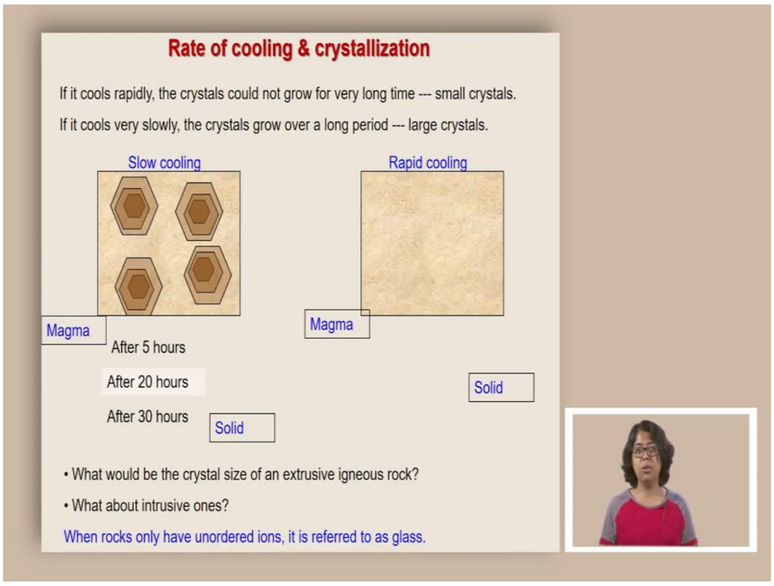

If it cools rapidly then the crystals do not grow for very long time as a result we find very small crystals, on the other hand if it cools very slowly then the crystals grow over a very long time resulting in large crystals so we can think about it in terms of a small cartoon that as magma cools very slowly after five hours you will find these smaller crystals and then after 20 hours these crystals are going to grow larger and become much bigger and eventually if you let it cool for another 10 hours so total 30 hours it will become even bigger. So that means we are talking about a situation where the temperature decrease is very slow over time.

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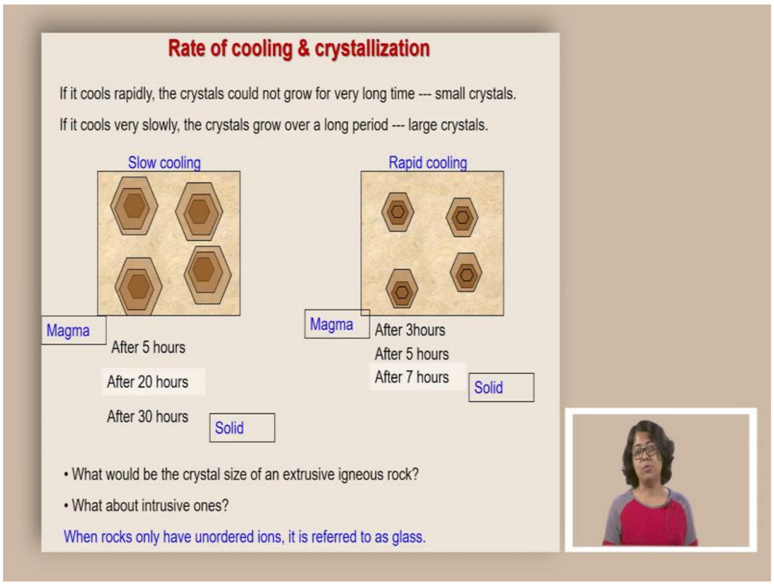

On the other hand if it is a rapid cooling then we are talking about a very short amount of time over which the temperature is dropping quickly as a result we are going to find relatively smaller crystal, now if we can understand in which scenarios these temperature drop is going to be different we can also use these crystal sizes to figure out how a particular rock has formed and researchers realized that temperature profile is quite predictable when we go with depth.

So, if we are talking about very quick cooling it basically means that the magma cooled above the surface or very near the surface where the temperature is much much colder than the interior of the Earth, on the other hand the temperature gradient is much shallower or in other words it cools much more slowly if the magma solidifies inside the or underneath the surface and it never reaches the surface, so what it means that you can expect a difference even crystal size when you are looking at rocks that forms inside versus outside the surface and we just defined the volcanic rock versus plutonic rock based on that criteria.

So now we are going to link it to these volcanic rocks and plutonic rocks, in other words the intrusive rocks versus the extrusive rocks, so if you find a rock where the crystal sizes are very large it generally means that they have undergone slow cooling and hence they were not exposed to the surface conditions when they were cooling and hence you can deduce it to be a part of a plutonic rock or intrusive rock.

On the other hand, if you find very fine crystals that means it cooled very quickly probably above the surface and then we are talking about extrusive rocks or volcanic rocks, if it cools so quickly that it cannot even develop any crystal in those cases it produces a volcanic glass where you do not find any crystal structure.

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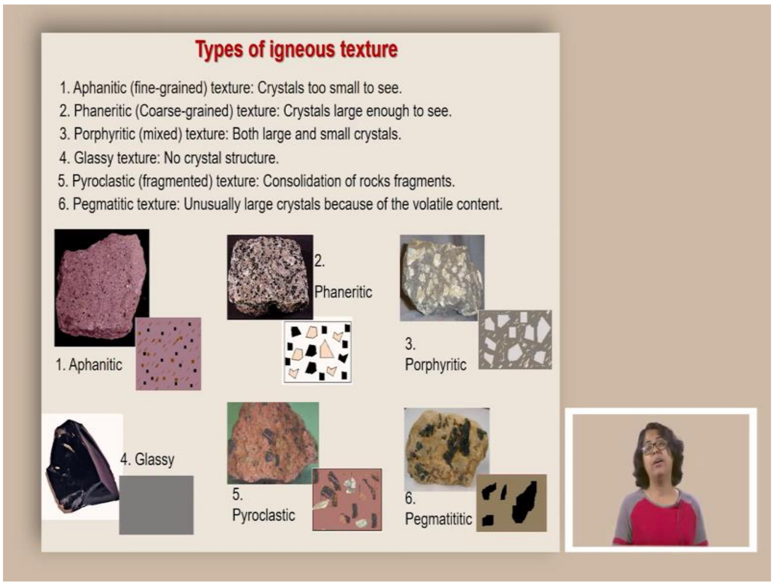

So, as I said that using these texture we can classify a lot of igneous rocks using these textural criteria these are a few examples, so the first one is called and aphanitic texture it means that very very fine grain textures the crystals are extremely small they are small to see, one example of aphanitic texture is given in the slide you can see the rock in the left hand side and in the right hand side there is a corresponding cartoon where you can see the relative size of the crystals. So, the crystal size becomes very clear if you look at the thin section of the rock.

The second one is called a phaneritic texture which basically means it is a coarse grained textures, crystals are large enough to be seen so if you compare the example 1 and example 2 it becomes quite clear that in example one it is very hard to see individual crystals, on the other hand when if we look at the example two we can see these relatively large crystals, the third one is a mixed pattern or porphyritic texture in this case we find a mix of both large as well as small crystal.

So, look at the example of 3 and you will see that there are fairly large crystals but it is sitting in a matrix of extremely small crystals so these kind of mixed crystals are called porphyritic, if there are no crystals then we call it a glassy texture and it might not be very clear if you just look at the rock, generally they are seen as or generally they appear as completely dark rocks in hand specimen and they have a characteristic round shaped fracture we call it a conchoidal fracture but the crystal or the pattern of crystal is not really visible but if you take a section of it and look it under the microscope what you will see that they are devoid of any crystal it is a solid homogeneous mass.

The other last type of texture that we are going to talk about is a pyroclastic texture so this one and another one these are not so common but they often appear in specific environment so example 5 is a pyroclastic texture which basically means it is a fragmented texture and it is a consolidation of different rock fragments so they have not crystallized together per se but they were they came together at a later time and got consolidated.

The last one is something called a pegmatitic texture it basically means that it is a rock with very very large crystals and these large crystals are often crystallized because there were some volatile content and those once the volatile content escaped there are large gaps which were filled through the magma by these very very large crystal so it is quite different from porphyritic in terms of size and also it indicates the presence of volatiles unlike the porphyritic texture. So, with these textural classification it helps us to predict what kind of rocks will have which specific texture depending on partly about their volatile composition and mostly how they have cooled over time.

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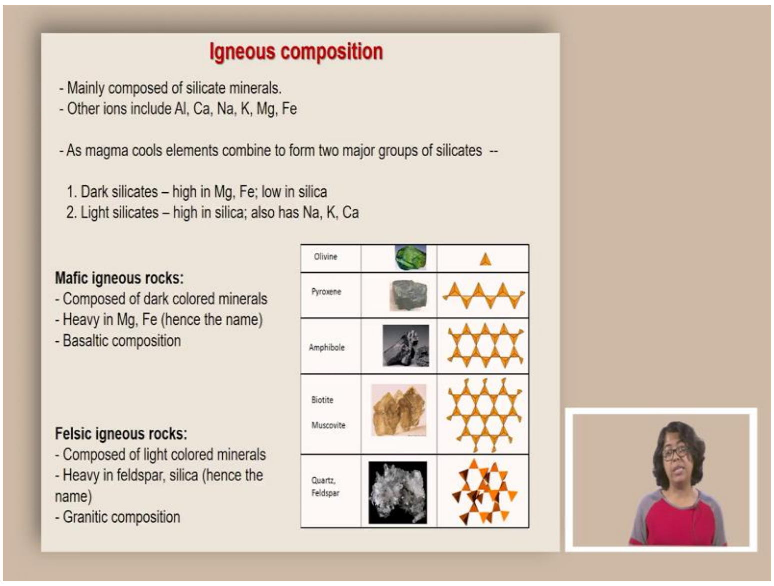

Another aspect of classification is the composition, igneous composition or igneous rock composition is primarily made of silicate minerals but these silicate minerals depending on the silica tetrahedra arrangement there can be other ions including aluminium, calcium, sodium, potassium, magnesium and iron and the proportion of that basically changes depending on which kind of silicate tetrahedra this mineral is made up of.

So, as magma cools the elements combine to form two major types of silicates, the first one is called the dark silicate and these dark silicates include the minerals which are primarily Olivine, Pyroxene, Amphibole they are darker in colour and if you look at their silica tetrahedral structure they are primarily independent or a chain structure double chain structure things like that and these dark silicates are generally high in magnesium and iron and they are low in silica and because of that they are basically called the rock that they make they are basically called a mafic igneous rock.

Mafic because they are rich in Mg and Fe and using that letters it is called mafic, they are composed of coloured minerals and they have high proportion of Mg and Fe and they have relatively less amount of SiO_2 because if you look at the silica tetrahedral arrangement towards the top of this diagram you basically see more involvement of other ions, other metal ions but as you are going down with the series towards the lower part the silica tetrahedra is getting balanced by other silica tetrahedra and this shearing increases increasing the relative proportion of silica.

So, the other type of light silicates when they are making the rock it is called a felsic igneous rock, felsic because again it is primarily composed of minerals such as feldspar and silica and therefore they are called felsic, on a broader scale these mafic igneous rocks are also called to have basaltic composition because basalties are typical example of that whereas felsic igneous rocks are called to have granitic composition because granite is one of the most common examples of such felsic igneous rocks.

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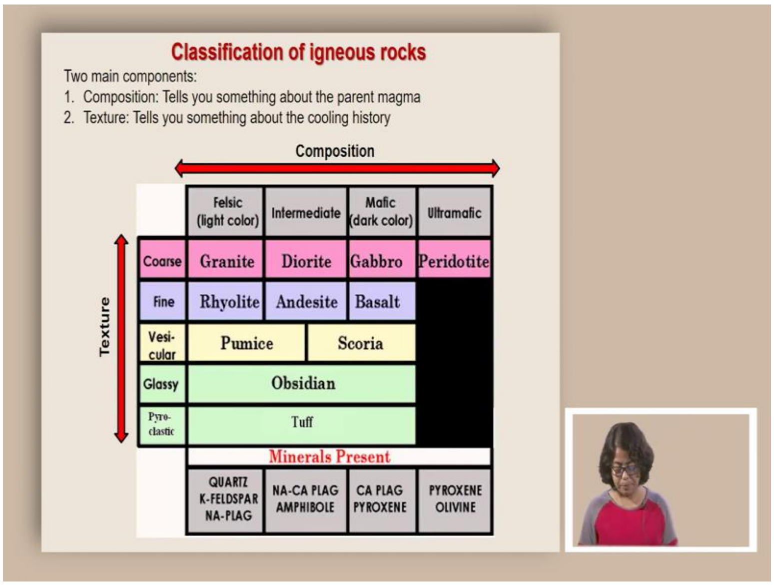

So, now we are going to combine the texture as well as composition to have some of the nomenclature of igneous rocks and these are some of the very common igneous rocks that we find on the Earth, one example of it which is extremely common is granite, so if we look at granite it says that it is coarse and it is also falls under felsic so it has to be something where you can see the crystals and the overall colour would be a light in nature.

On the other hand, if we go towards the other extreme we will find something like peridotite which means it is extremely dark coloured, it is ultramafic but it can still have a texture which is coarse, please remind yourself that these texture is telling you something about the cooling history on the other hand the composition is telling you about the parent magma from where they have crystallized.

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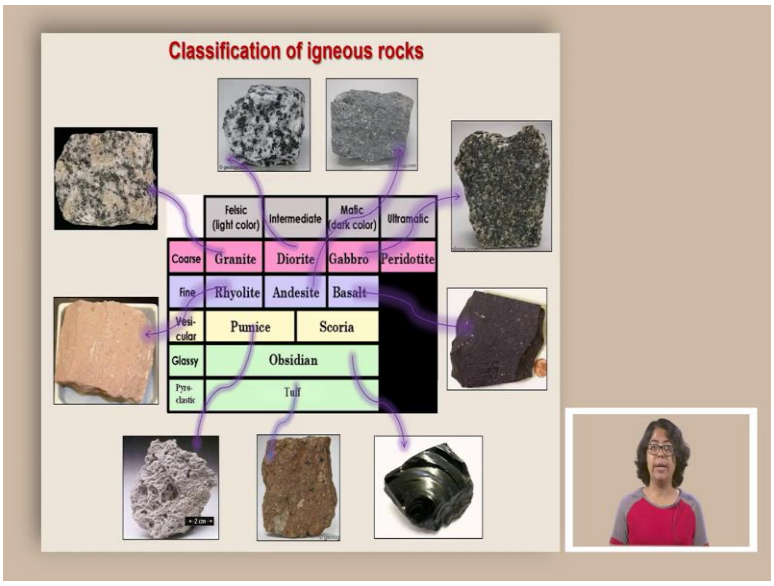

So, these are some of the examples of very common igneous rocks and their names, so if we go from the first one it is a pyroclastic rock where things have been bound together in a later process and there is a big variation in the grain size one of the example is a tuff, another one where there is lot of vesicles or in other words there are a lot of gaps or hollow spaces because of the volatile escape structure and one example of it is pumice and another one if it is a very dark one it is a mafic composition but still you have such volatile escape structures these are called scoria.

And then we have volcanic glass and these volcanic glass are generally called obsidian, they do not have major crystal forming, let us take a look at the granite and in the granite we do see large crystals relatively large crystals or coarse grained and it is generally light colored and this is a typical example of granite, now if we go to slightly more towards mafic composition then we find some a rock which is called diorite again the crystal size does not change but it contains relatively more magnesium and iron compared to granite.

Then if we go to rocks such as gabbro it is much darker in colour and finally peridotite will look very very dark but in this series the grain size really does not change, on the other hand if we basically compare rocks like gabbro and basalt both of them are darker in colour and compositionally they are not very different but if you look at their grain size they are quite different, in basalt we do not see individual crystal grains whereas in gabbro we do find individual crystal grains showing that this must have had a slower cooling history compared to this one.

So, this classification of igneous rock is very important because it tells us something about their cooling history as well as the overall composition, the moment we utter a name and therefore it is important to have a general understanding of this classification scheme and to have an idea of what the common igneous rocks look like.

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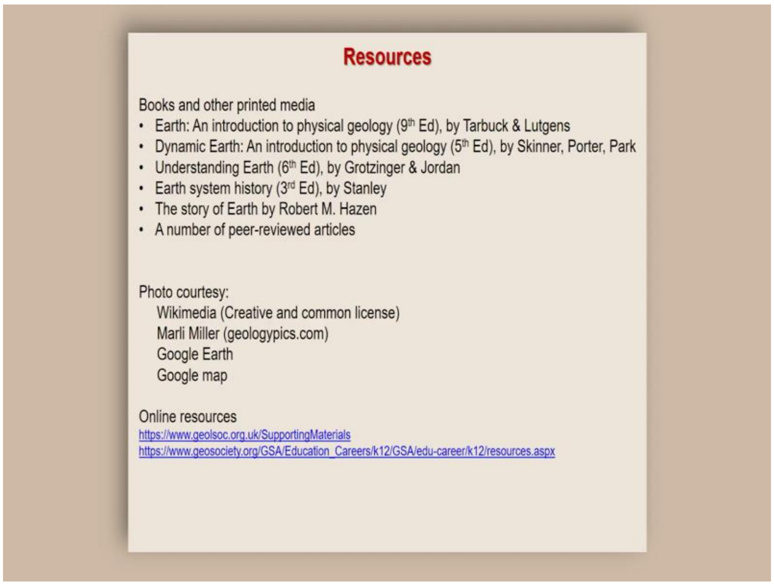

So in today's class we learned what is an igneous rock, we also learned what are magma and what are the main ingredients that you can find in a magma, we learned how crystallization and rate of cooling are related and where you can find large crystals versus small crystals, using all of these composition as well as the crystal structure the size of the crystals it is possible to differentiate a number of types of igneous rocks and that is how the igneous classification is done using this classification you can name rocks and also by hearing the name of our igneous rock you can immediately tell something about their composition as well as their crystal size. These are some of the resources that I used for the lecture, here is a question for you to think about. Thank you.