Identifying Igneous Rocks – Video Tutorial Script

Igneous rocks are those formed by the cooling and solidification of magma, or molten rock. As the melted rock cools, new minerals and textures will form based on things like the original magma composition, the addition of any new chemical components from the surrounding rocks, the time it takes to cool, and the temperature and pressures at which it cools. Because there is so much variation in this process, there is a wide variation of igneous rock textures and compositions. When we identify and classify igneous rocks, we are looking for textural and compositional clues in the rock that tell us the story of the original magma formation and its cooling process.

By the end of this learning module, you should be able to list the most common igneous rocks, recognize their textures and compositions, and link them to their formation environment and history.

This pile of igneous rocks contains a wide range of igneous rock compositions and textures and represents a dozen different rock names and histories. This table shows how we classify and distinguish among the variety of igneous rock types by texture and composition. The five columns represent the five basic textures. The four rows, the four basic compositions. As long as you can correctly describe the texture and composition of an igneous rock, you can determine the rock's name AND understand something about its formation history.

Magmas that solidify and cool do so either slowly underground – often taking hundreds to thousands of years – or quickly above ground following an eruption. In the first case, slow underground cooling, there is no eruption. The magmas never reach the surface. Instead they reach an underground magma chamber or insert themselves into cracks or between layers in the rock. Over a long period of time, they cool, and the atoms in the melt bond with each other to form minerals that are most stable based on the existing temperature, pressure, and chemistry. The slow cooling allows for large crystals to form. The texture of these rocks is typically described as **PHANERITIC**, and the crystals are all intergrown and large enough to see with the naked eye.

A subcategory of phaneritic are rocks with unusually large crystals. This texture is called **pegmatitic** and rocks displaying this texture are called pegmatites. Unusually large crystals form when the magma cools slowly AND the magma viscosity is very low, usually through the addition of large amounts of water. This low viscosity, or low resistance to flow, means that atoms can migrate quickly and easily to nucleation sites far away, so single crystals can get to be many inches to sometimes feet long.

In contrast, when a magma erupts as a lava flow, it cools quickly. Atoms don't have time to form large crystals, so the same basic minerals will form, but the crystals will be smaller – too small to see without a microscope. Rocks with a texture of crystals too small to see are called **APHANITIC**.

A few other textures can result when rocks erupt. Sometimes lava flows cool so quickly, especially their outer edges, that they form no crystals, which we call **GLASS**. For a lava flow to form 100% glass it must do more than just cool quickly, it must also have a very high viscosity or resistance to flow. A very high silica content can cause high viscosity, and that can lead to a texture called GLASSY where 100% of the rock is made of glass.

When magmas erupt explosively with lots of gas, lava is thrown through the air – adhering to the gas bubbles. It cools instantly, forming tiny grains of glass, called ash.

Larger blobs of lava thrown through the air with lots of gas within them also cool quickly, WHILE gas is escaping. They form a texture known as **FROTHY** – a combination of solid glass riddled with 50% or more vesicles (holes left by escaping gas). Note: often lava flows will have also cool around escaping gas. Vesicles will also exist in these aphanitic textures. Only when the amount of vesicles is equal to or larger than the amount of rock do we call the texture FROTHY.

If a lot of ash is produced in an explosive eruption, it will settle out of the air and accumulate in piles on the ground. Bits of rock ripped off the sides of the volcano in the explosion might also fall into this pile, along with the frothy bits of lava also thrown out (often called bombs). These deposits can weld themselves together due to their heat, and form a rock with a **PYROCLASTIC** texture. Pyro for their origination from a "fire", and clastic because they are made of clasts or bits and pieces of many different things that were glued together.

Going back to the rock ID table, we see that each of these five textures can be further divided by composition, and based on those two traits leads us to the name of the rock. Compositions are broken up for this simplified rock chart into four main types based on their silica content. Lowest silica (highest iron and magnesium) compositions are called **ULTRAMAFIC**. As silica content increases (and iron and magnesium decreases), we move from ultramafic to **MAFIC** to **INTERMEDIATE** to the highest silica content in **FELSIC** rocks. Note: MAFIC gets its name from its high Magnesium and Iron (Ferric) content. FELSIC gets its name from its high silica and feldspar content. How can we identify the composition of an igneous rock? If we can see minerals, then we can use those to tell us the composition.

The simplest way to use minerals to characterize the composition of a rock is through **Bowen's Reaction Series**, which does a good job of indicating the minerals one would expect to form from magmas of varying composition. Let's review it briefly. Magmas that form from melting the mantle will be the most primitive and have the lowest silica content and the highest iron and magnesium content. As they start to cool, the first mineral to precipitate – the one that's first stable as a solid at the highest temperatures is olivine. As the magma continues to cool, calcium-rich plagioclase feldspar becomes stable and starts to precipitate alongside olivine. If the magma cooled completely at this point with no more changes (or if it erupted), then you'd have a rock made of olivine and plagioclase, and it would be ULTRAMAFIC in composition. If, however, we let the magma evolve – if we remove the olivines by having them sink to the bottom of the magma chamber and the plagioclase feldspars by having them float to the top or edges of the magma chamber – the composition of the magma would start to change. It would become more silica rich, more water rich, and have less magnesium and iron. Now it would continue to cool until pyroxene began precipitating. Plagioclase feldspar would continue to precipitate as well and perhaps a little more olivine. But basically olivine is on the way out and pyroxene starts to dominate. Plagioclase continues to precipitate abundantly but gradually changes its composition from calcium rich to sodium rich. If a magma of this composition erupted at this point, its composition would be mafic. If, however, we remove the forming minerals from the magma, the composition of the magma will continue to change. It will continue to become more silica rich, more water rich, and lower in magnesium and iron. The next minerals that form as the new magma composition cools are hornblende and then biotite. Plagioclase feldspar continues to form. Pyroxene is on its way out, but as you can see there is SOME overlap. An eruption of this magma produces a rock of intermediate composition. And if we continue this process and remove these minerals and let the magma's composition continue to evolve, we will get a new composition, the highest in silica and water and lowest in iron and magnesium. Cooling this evolving composition allows potassium feldspar to begin forming, as well as muscovite and quartz. Hornblende, biotite, and plagioclase feldspar can also continue forming. An eruption of this magma produces a rock of FELSIC composition. And now you see how identifying the minerals in an igneous rock can help us determine its composition.

What do we do if we can't see any minerals in a rock? We know that the more mafic a rock, the denser it should be. And generally speaking, the darker the color. Felsic rocks should be less dense and lighter in color. As with mineral identification, color is not always the best distinguishing trait, because it can change easily based on small amounts of impurities or gas phases present. So use it only if there are no other helpful identifying characteristic.

So now we know how to determine igneous rock composition, which helps us come up with a rock name, but so what? What does the composition tell us about the rock's formation and history? Let's do a quick review of how and where magmas form. Magmas can form in three different geologic settings: subduction zones, where water squeezed out of the subducting plate drops the melting point of the mantle above it, and causes it to melt. Those magmas rise up and produce subduction zone volcanoes. Where plates are diverging, the crust is thinned, which drops the pressure on the underlying mantle and lowers its melting point, causing it to melt. Those magmas rise to the surface to produce volcanoes along continental rift zones or volcanism along seafloor spreading centers. And where mantle plumes rise from deep within the mantle, large volumes of mantle are melted by addition of heat. These magmas rise to the surface and create large hotspot volcanoes, associated with orders of magnitude more magma supply than the other volcanic settings. All of these original melts of mantle material would be ultramafic in composition, with the same basic major element composition, but variations in minor elements depending upon what part of the mantle was melted to produce the magma. As these magmas rise to the surface, they undergo compositional change or evolution due to two major processes. They can either melt the crust and/or undergo **crystal fractionation** (which we described earlier with Bowen's Reaction Series).

For crystal fractionation to happen, the magmas have to have time and opportunity for slow cooling enroute to the surface, and removal of crystals as they form. That usually means a slow transit (thick crust) and/or low magma supply. Where crust is thin, at seafloor spreading centers or divergent plate boundaries, or where magma supply is high and continuous, like at a hotspot, the most fractionation that occurs prior to eruption is enough to move the composition from ultramafic to mafic. And basalts erupt. A larger travel time with low magma supply provides more opportunity for crystal fractionation. So intermediate and felsic rocks tend to form where magmas rise through thick continental crust like at continental margin subduction zones. The second way to get a magma of a more evolved composition is to melt the crust, which produces felsic magmas. Continental crust has a much lower melting point than mafic magmas, so if large amount of mafic magmas rise up and collect in crustal magma chambers, like they do at the Yellowstone Hotspot, they can cause crustal melting. Those melts can either erupt separately as rhyolites or obsidian domes. Or they can mix with the original mafic magmas and create magmas of intermediate composition. So… when we pick up an igneous rock and identify its composition through its density and mineral content, we are learning something about where the magmas formed and how they moved through the crust. Minor element changes can act as fingerprints giving us a lot more detail on magma formation and evolution. Take a class on igneous petrology to learn more. For purposes of this introductory class, we are simplifying this discussion. When I identify a rock as mafic, I can provide a handful of possible formation scenarios for it and eliminate a few other: it might have been formed as part of a mantle plume or hotspot, or it might have been formed at a seafloor spreading center. If I identify a rock as felsic, it might have formed at a continental subduction zone or at a hotspot region where crustal melting happened. Just like with Bowen's Reaction Series, these models are guides to help us distinguish between various formation settings and compositions. They work most of the time, but they fail to explain everything. For the times when the real world fails to follow our simplified model, we must investigate further.

To identify and name an igneous rock, all we need is to correctly characterize its texture and its composition. Let's get started by separating all these rocks into five piles related to our five textures: phaneritic (100% of crystals big enough to see without a hand lens), aphanitic (most of the crystals are too small to see), frothy, pyroclastic, and glassy.

Notice from the table that rocks with a pyroclastic texture are called **VOLCANIC TUFF**, regardless of their composition. However, we will find them more often in the FELSIC or high-silica composition. Why? Remember, high silica means high viscosity. It also means higher gas content. The higher the gas content, the more likely an explosive eruption. And the higher the viscosity, the harder time the gas has escaping the magma, so the more likely it will collect within and allow pressure to build. This rock is pyroclastic because we see chunks of rocks, crystals, and pumice pieces in a matrix of ash. So this rock is a tuff.

Here are two rocks with a frothy texture. According to the table, the frothy texture is separated into two rock names – SCORIA for the mafic or low-silica composition rocks and **PUMICE** for the intermediate or felsic rocks. How do you tell the difference? Not only is the scoria darker than pumice, it's also denser. In fact, pumice is so low in density, it floats on water. So this must be the scoria, and this the pumice.

The glassy texture, as we already mentioned, is only felsic in composition. The name of this glassy rock is **OBSIDIAN**.

Here we have three rocks that are aphanitic. You'll notice that they all seem to have SOME crystals big enough to see, but most, the groundmass, is rough and has no visible crystals. It's hard enough to say it's not ash, like in a tuff. So we can say this groundmass is cooled lava, hardened with tiny crystals too small to see or identify. How do we determine composition? If we're lucky enough to have some **phenocrysts** in the rock – perfectly formed crystals that formed slowly when the magma was at depth before it erupted – we can use those phenocrysts to determine composition. For example, this rock has phenocrysts of hornblende. Presence of hornblende in such high abundance means intermediate composition. So this rock is an andesite. Because it also has phenocrysts, it's a special kind of aphanitic rock known as a **porphyry**. And we name the rock a hornblende **ANDESITE** porphyry. Porphyritic rocks are always named first with their dominant phenocryst, followed by the compositional aphanitic name, ending with the name porphyry.

This dark dense rock has some clear phenocrysts. It's hard to tell what they are, but the color of the rock being so dark, and the density so high, suggests the rock is mafic. Therefore these phenocrysts are probably plagioclase crystals. And the name of the rock is a plagioclase feldspar **BASALT** porphyry.

That leaves us with this last rock, which has a pinkish groundmass and large quartz phenocrysts. Quartz is found only in felsic rocks. That makes this rock a quartz **RHYOLITE** porphyry.

On to the phaneritic rocks. We can start by lining them in by color, from lightest to darkest. Let's see if that helps. Color is a good guide, but we must corroborate with additional information. Also, how do we fit in the pink rock and the green one? Because phaneritic rocks have crystals big enough to see, we should be able to line these up next to Bowen's Reaction Series and identify the minerals. The green rock is made up 100% of green, glassy minerals. What are they? Olivine. A rock made entirely of olivine must be ultramafic, so that means this rock is **PERIDOTITE**.

The pink mineral in this rock looks just like potassium feldspar, and that means it must be felsic in composition. Phaneritic felsic rocks are called **GRANITE**. But this rock is ALSO granite. Why different? Remember: potassium feldspars can be pink or white. This rock is dominated by the pink variety, but it also has some quartz, some biotite, and some hornblende. This rock is dominated by the white variety of potassium feldspar, but also has some muscovite, biotite, and quartz.

That leaves these two rocks which look very similar and differ mostly in darkness. If we line these up next to the Bowen's Reaction Series, we can see (or estimate) that this rock is made of pyroxene and plagioclase (mostly pyroxene because mostly dark), and this rock is made of hornblende with greater amounts of plagioclase. It's hard to SEE the difference between pyroxene and hornblende when the crystals are this small. A microscope would help. But in this case we can use the relative darkness of the rocks to guide us. So this rock is the mafic one, and it's called **GABBRO**. And this rock is the intermediate one, so it's **DIORITE**.

So let's line up all these rocks in the order of the rock chart, with the phaneritic texture on the left, aphanitic next, then glassy, then frothy, then pyroclastic. Ultramafic composition is at the top, followed by mafic, then intermediate, then felsic. Starting on the right, we have Tuff, Scoria, Pumice, Obsidian, and the rest. How do we remember these names? A mnemonic that can help you remember the rest of these names is "Pretty Good Diet Granola BAR." Starting with the ultramafic phaneritic rock and working down, we have "pretty" peridotite, "good" gabbro, "diet" diorite, "granola" granite, "BAR" – basalt, andesite, rhyolite.

Remember: learning the names of igneous rocks tells us exactly how the magmas cooled and what level of evolution the magmas had experienced (based on their composition). So the texture and composition are the clues we read to determine the history of the rock, and that corresponds to its name.

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