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HOT ORIGINS
The ancient history of natural glass

When you think of glass, you would typically think of a material that was produced in a factory, used to make window panes and jam jars. But, as with many human inventions, nature has been ahead of us: glass has been produced on Earth for billions of years. Moreover, Earth's glass factory is still continuing its production in volcanoes worldwide, forming, for instance, a dark glassy rock called obsidian. But other volcanic rocks, and even meteorite craters, also contain large amounts of natural glass.

Apart from volcanoes, there are other ways in which nature can produce glass. Probably the most dramatic way is by means of a meteorite impact. The glass that is produced here is called tektite, and specific examples of tektites have been given their own names. One example is Libyan desert glass from Northern Africa. Another is the moldavite that can be found in the present-day Czech Republic, which has a beautiful green colour. It was formed from a meteorite impact that happened about 15 million years ago. Most other tektites are far less spectacular bits of black glass, which you wouldn't give a second glance if it weren't for their strange shapes.

Additionally, lightning strikes can also produce material that is sintered together with glass, and this is called 'fulgurite'. In a way, it is fossilised lightning, creating intricate branch-like structures where the lightning bolt hit the ground.

Figure 1: This piece of obsidian from Eastern Africa is the most common example of natural glass, a very quickly chilled silicate liquid.

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Figure 2: Moldavite forms during a meteorite impact; the scalloped edge seen here is formed by natural weathering processes.

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Figure 3: Tektites are also glass pieces that result from meteorite impact, and they get their shape as droplets of melt that fly through the air.

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So, what do volcanic eruptions, meteorite impacts and lightning strikes have in common that they all produce natural glass? One necessary ingredient for producing glass is a high temperature and very quick cooling. In volcanic eruptions, magma (molten rock) which typically has a temperature of more than 900˚C, is brought to the surface of the earth, where the temperature is many hundreds of degrees lower, causing very rapid cooling. The temperature of the air around a lightning bolt is even more extreme, in the order of ten thousand ˚C! High temperatures of more than 2000 ˚C are also attained during a meteorite impact, when the kinetic energy of the meteorite is converted to thermal energy upon impact.

Of course high temperatures by themselves are not enough to produce glass: you also need the correct ingredients. For instance, if lightning hits a tree, you just end up with charcoal, not glass. The main ingredient in glass is silica, which is the term used for the element silicon, bonded to oxygen: silicon dioxide (SiO_2). Most people would be familiar with silica, as it is the sole ingredient for the mineral quartz, which can form very pretty crystals. However, there is a very important difference between a mineral and glass: a mineral is a crystalline material, which means that the atoms are arranged in a regularly repeating pattern in three dimensions. The pretty crystals that we see are a result of this ordering. Glass, however, does not have this kind of order – and will therefore not naturally give the nice shapes that crystals have, although we humans can of course pour it into a mould, or change its shape later.

Figure 4: Pumice is formed during a volcanic eruption, and consists of very thin rims of glass around bubbles of volcanic gas.

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If magma cools down very slowly, for instance when it gets stuck in the earth, rather than coming to the surface in a volcanic eruption, all the elements in the melt organise themselves into different minerals, each with their own crystal shape. That is how we end of up with a rock called granite, consisting of quartz and feldspars. But when the magma cools down really quickly, there is no time for the elements to arrange themselves and form crystals. The microscopic structure of glass is similar to that of a melt: a far more messy affair than the regular structure of a mineral.

So in terms of their ingredients (silica, but also quite some aluminium, sodium and potassium) you cannot tell the difference between granite and obsidian. Their very distinct appearance is only a result of the rate in which the melt cooled. Pumice, on the other hand, looks very different from either granite or obsidian, even though it also has the same chemical composition. For pumice to form, the magma must have contained a lot of gas, which formed bubbles, whereby the glass forms the very thin bubble walls. It's a bit like opening a bottle of soft drink after having given it a good shake – and then immediately freezing the froth that comes out of the bottle.

Glasses associated with lightning strikes or meteorite impacts generally have a composition that is slightly

Figure 5: These pieces of obsidian from Greece were probably used as small cutting tools. As they were found in areas where there is no volcanic activity, they testify to the trade of this material during the Stone Age.

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different from volcanic glass, with more iron and less sodium, and even more silica than obsidian. However, the composition depends on the exact material that was struck by the meteorite or the lightning bolt. Large parts of the earth are covered by silica-rich rocks or sediments (sand, mud, clay…), so there is a good chance that this will be involved. The colour of the glass is related to the chemical composition: the moldavites, with their pretty green colour, have a lower iron content than most other tektites, which are black. Obsidian, on the other hand, looks black because it contains microscopic inclusions; if you look at a very thin piece of obsidian, you can see that the glass itself is actually very light in colour.

Figure 6: Snowflake obsidian forms when the glass starts to devitrify, forming clusters of crystals.

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It has been known for a long time that glass has special properties, which stem from the fact that it is not a crystalline material: it doesn't have any preferred direction in which it breaks. This characteristic has been exploited by early humans, who used obsidian to make sharp-edged tools such as knives. Obsidian was thus a very valuable material, and there is evidence that it was traded over hundreds of kilometres as early as 20 000 years ago. Interestingly, this material is being used again nowadays for some surgical procedures instead of metal scalpels.

Although glass is very durable if we compare it to other natural materials like wood or cotton, it's actually not a really stable substance: over time, it will start to devitrify, whereby it forms tiny crystals. This will generally give it a dull appearance, although a quite attractive example is the so-called snowflake obsidian, which contains clusters of white crystals. However, devitrification is a rather slow process, and we can still find bits of glass in rocks that are 3.5 billion years old.

So, it is somewhat humbling to realise that with the 'invention' of glass circa 5 000 years ago, humans were simply imitating what nature had been producing for billions of years already.

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