Science Education Collection

Igneous Volcanic Rock

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Overview

Source: Laboratory of Alan Lester - University of Colorado Boulder

Igneous rocks are the products of cooling and crystallization of magma. Volcanic rocks are a particular variety of igneous rock, forming as a consequence of magma breaching the surface, then cooling and crystallizing in the subaerial environment.

Magma is liquid rock that typically ranges in temperature from approximately 800 °C to 1,200 °C (**Figure 1**). Magma itself is produced within the Earth via three primary melting mechanisms, namely the addition of heat, addition of volatiles, and decompression. Each mode of melt generation tends to produce specific types of magma and, therefore, distinct eruptive styles and structures.

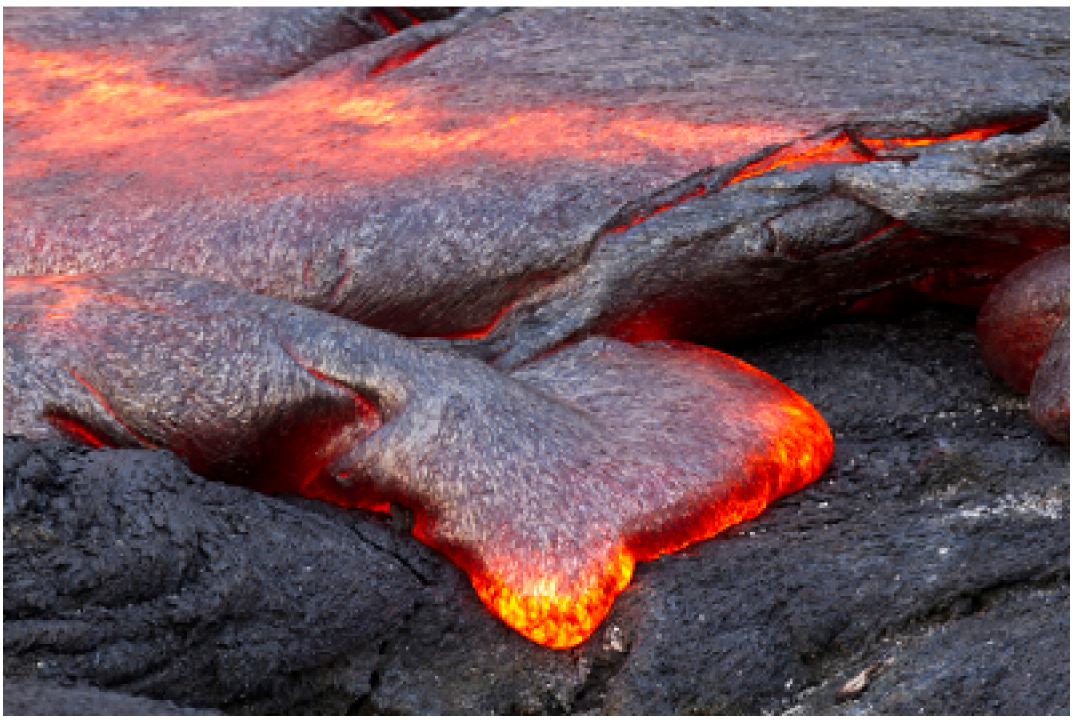

Figure 1. Fresh lava breakout on Kilauea, Hawaii. Lava is the term for magma that is on Earth's surface.

Principles

Heat addition, often linked to hot spots or to the ponding of high temperature melts in the crust, will generate felsic (silica-rich) magmas in continental settings and mafic (silica-poor) magmas in oceanic settings. Volatile addition is the most common mechanism for melt generation at subduction zones and produces intermediate magmas (intermediate silica abundance), typically leading to island arcs or linear volcanic ranges (examples being the Aleutian Islands, the Cascade Mountains (**Figure 2**), and the Andes Mountains). Decompression melting generates mafic magmas and occurs in rift zones. Although rifting can and does occur in continental settings (*e.g.* East African Rift Valley), this is the primary melt mechanism for the mid-ocean ridges that encircle the globe and stretch through the main ocean basins (Atlantic, Pacific, Indian), these being, by far, the dominant zones of magma generation on our planet.

Figure 2. 3,000 foot steam plume from Mount St. Helens on May 19, 1982.
Plumes of steam, gas, and ash often occurred at Mount St. Helens in the early 1980s. On clear days, they could be seen from Portland, Oregon, 50 miles to the south. The plume photographed here rose nearly 3,000 feet above the volcano's rim. The view is from Harry's Ridge, 5 miles north of the mountain.

The type of magma formed in these different settings is linked to the depth of melting, the composition of mantle undergoing melting, and the degree of melting.
In general, oceanic environments and continental rift zones generate basaltic (mafic) melts because of asthenospheric mantle melting.

Typically, felsic magmas form as a result of high percentage melting of continental crust or continental lithosphere; mafic magmas form during melting of oceanic lithosphere or asthenospheric mantle.

Magma Viscosity and Explosivity

Viscosity and volatile content are the primary controls on magmatic explosivity. Highly viscous felsic magmas with high volatile contents are likely to produce the most explosive eruptions. In contrast, highly fluid (low viscosity) and low volatile content mafic magmas (*e.g.* basalt) will generally produce the most quiescent eruptions.

Volcanic Products

When magma escapes from a volcanic edifice, there are a variety of possible products, including lava and pyroclastics.

Quiescent eruptions allow for magma to pour off the side of the volcano, or outwards from fissures. These are called lava flows. Lava flows rarely travel at velocities greater than a few kilometers per hour. As such, they can result in structural damage, but rarely cause loss of life.

More explosive eruptions will result in mixtures of magma, rock, and gas to be ejected from the volcano. Collectively, this ejected material is termed "pyroclastic." Pyroclasts can come in a range of sizes from ash (very fine grained material, <2 mm, and often of submicroscopic grain sizes) to lapilli (2-64 mm), to tephra, and bombs (>64 mm).

In some cases, a highly fluidized pyroclastic eruption, containing hot fragments, liquid droplets, and thick gases, will mobilize and move as a rapid mass off the side of a volcano. These events are termed pyroclastic flows (**Figure 3**). They can be on the order of 1,000 °C, and travel at velocities in the range of 100-600 km/h. These are, without doubt, one of the most dangerous volcanic products.

Two experiments are presented that relate to the principles of volcanic rock formation. The first experiment demonstrates a key principle of volcanic layering: subsequent deposition of lava and the principle of superposition. The second experiment is a variant on the frequently used baking soda and vinegar in a bottle explosion. Although very simple to perform, it shows several important aspects of volcanic eruptions.

Procedure

1. CO_2 Volcano

1. Fill a plastic container with a thin neck (a 16-oz. soda bottle for instance) about half-full with warm water.
2. Bury the bottle beneath modeling clay or dough, leaving just the neck (opening) of the bottle exposed, simulating the structure of a volcano.
3. Add a few drops of dishwashing liquid (in order to make the liquid frothy and likely to produce bubbles).
4. Using a folded piece of paper as a funnel, add 4 teaspoons (approximately 15-20 mL) of baking soda.
5. Gradually add red vinegar to the plastic container. If using a 16-oz. soda bottle, add 8-10 oz. of vinegar. Add the vinegar to the container until it begins to effervesce.
6. If desired, cork the container for a “violent eruption” or leave it uncorked for a more quiescent eruption.

2. Lava Layering

1. Warm paraffin on a hot plate so it becomes a viscous fluid.
2. Take a thin section of cardboard, and bend in to form bends and troughs of various shapes. Pour the liquid paraffin onto the inclined cardboard surface. As the paraffin flows over the uneven surface it will form a layer of varying thickness, as would be seen in a real lava flow.
3. After the paraffin has cooled and solidified, repeat the process two or three times, in order to simulate successive lava flows.

Results

1. CO_2 Volcano

During the CO_2 experiment, some of the material will flow outwards like a lava flow. The frothy nature of the flow is reminiscent of lava that is charged with volatiles. Most volcanic eruptions are linked to volatile loss. Those that are particularly explosive will have considerable volatile emanations. If the container is corked, then the initial eruption will involve pyroclastic-type material that is ejected into the air above the volcanic edifice.

2. Volcanic Layering

With the volcanic layering experiment complete, note that the layers thin with distance from the magma source. This is a phenomenon that would be commonly seen in volcanoes. It can also be seen that subsequent layers can partially melt the underlying layer. The principle of superposition can also be observed in the demonstration, where older layers are found on the bottom, younger layers atop.

Applications and Summary

Volcanism and associated rocks are of great interest to geologists. Not only do volcanic eruptions pose a threat to nearby communities, it is important to recognize that they can also lead to scenic landscapes, and positively influence soil and agricultural productivity.

Recognizing volcanic rocks in the field, linking them to specific eruptive styles, and ascertaining regions of past activity are part of fundamental geologic assessments for regions in which people live and/or work. Volcanic rocks can be indicators of past eruptive activity. The types of volcanic rocks present can also be used to evaluate the severity and explosivity of past eruptions. Understanding the potential types of eruptions (*e.g.* lava flows (**Figure 1**), ash, pyroclastic flows (**Figure 3**)) that might occur in a volcanic region are a crucial part of developing mitigation strategies.

Figure 3. Pyroclastic flows sweep down the flanks of the Mayon Volcano, Philippines, 1984.

Volcanic layering can also be a window into a “page-by-page” history of a region. Volcanic layers can contain information about past climate, environment, and even life. In particular, volcanic layers are relatively easy to date (unlike sedimentary layers) using isotopic dating techniques. Therefore, volcanic layers are useful time-markers in geologic investigations.