

9

Volcanoes

Karen Tefend

9.1 INTRODUCTION

How would you like to live on an active volcano? Surprisingly, a lot of people are living on or near active volcanoes, and many more live near volcanoes that are currently considered to be “dormant”, exhibiting a volcanically-quiet period of time over the past 10,000 years, but with the potential to erupt in the future (Figure 9.1). Are they crazy (Figure 9.2)? Maybe some are, but not all volcanoes erupt explosively; for example, the type of volcano that forms the Hawaiian Islands is a type that erupts effusively, with lava running down the sides (flanks) of the volcano (Figure 9.3). Hawaiian citizens are familiar with this style of eruption, and they are also aware that their particular volcano will not erupt explosively. Explosive eruptions are more likely for the volcanoes that make up the Islands of Sumatra and Java (Indonesia); these volcanoes are very dangerous, and yet Indonesia is one of the most densely populated countries in the world. So, it would seem very important to know why some volcanoes



Figure 9.1 | An idyllic setting with rolling fields, crashing waves, and a beautiful snow-capped volcano is pictured.

Author: U.S. Fish and Wildlife Service

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are dangerous, and why others are not. Of the “dangerous” types that are currently dormant, will we have enough of a warning before they erupt? Is it only the eruption that we should worry about, or are there other hazards that we must be aware of? These questions will be addressed in this chapter, along with a few other questions that you might have, such as why volcanoes form in certain locations, especially in relation to plate tectonics, and the association of magma type with volcano type and eruptive style.



Figure 9.2 | A not-so-idyllic photo of a volcano during an explosive eruption is pictured. **Author:** Barry Voight
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Figure 9.3 | Nighttime photo of an erupting volcano; note that this particular volcanic eruption involves the flow of lava down the sides of the volcano, as opposed to the explosive eruption in the previous image, Figure 9.2.

Author: Tryfon Topalidis
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9.1.1 Learning Outcomes

After completing this chapter, you should be able to:

- Relate magma type with plate boundaries
- Understand why most magma crystallizes underground
- Associate volcano form with eruption type and magma type
- Recognize the hazards associated with volcanoes

9.1.2 Key Terms

- Composite volcano
- Dike
- Flood Basalt
- Lahar
- Lava Dome
- Pyroclastic Flow
- Shield Volcano
- Silica Tetrahedron
- Sill
- Viscosity

9.2 MAGMA GENERATION

In the previous chapter on igneous rocks you learned about the concept of partial melting, and in the chapter on plate tectonics you learned about the conditions necessary for mantle rocks to melt; we will review these concepts in this section.

Most magma is generated at the base of the earth's crust; Figure 9.4 is a pressure-temperature diagram similar to the one you saw in the plate tectonics chapter. On the left side of the solid black line (called the solidus) is a region where the temperature is too low for a rock to melt. On the right side of the solidus line is the region where rock will melt.

Notice that the solidus line is not a vertical line going straight down, but is sloped at an angle less than vertical, demonstrating that with increasing pressure the temperature must also increase in order for a rock to melt. Now take a look at the conditions at the base of the crust, at point "X". This rock at "X" is not hot enough to melt; or it can be said that the rock at point X is under too much pressure to melt. To make this rock melt, either the temperature must increase (arrow "a"), or the pressure must decrease (arrow "b"), or we can have both hotter temperature and lower pressure occur simultaneously

(arrow "c"). Regardless of the path taken, we can make this rock X cross the solid line and become magma. The only other way we can make rock X cross the solid line and become magma is to move this line (arrow "d" on Figure 9.4); in other words, change the melting temperature of the rock. This can be done by adding water, which lowers the melting temperature of rock, and now we can make rock X melt without actually having to change the temperature and pressure conditions.

Now let us think of plate tectonics and the types of boundaries that have magma associated with them (Figure 9.5). Tectonic plates that are diverging (or pulling apart), causes the underlying region of the mantle to experience reduced pressure conditions (just like what the cheerleader at the bottom of a pyramid experiences when everyone else jumps off his back). If the mantle is already fairly warm, the decreased pressure may just be enough for magma to be produced (arrow "b" in Figure 9.5). Where tectonic plates are converging (coming together), one of the plates may subduct below the other plate; recall that subduction will only occur if the tectonic plate has an oceanic crust type. This subducting oceanic crust-topped plate will contain minerals that are hydrated (water in their crystal structure), and as the plate subducts, the hydrated minerals will become unstable and water will be released.

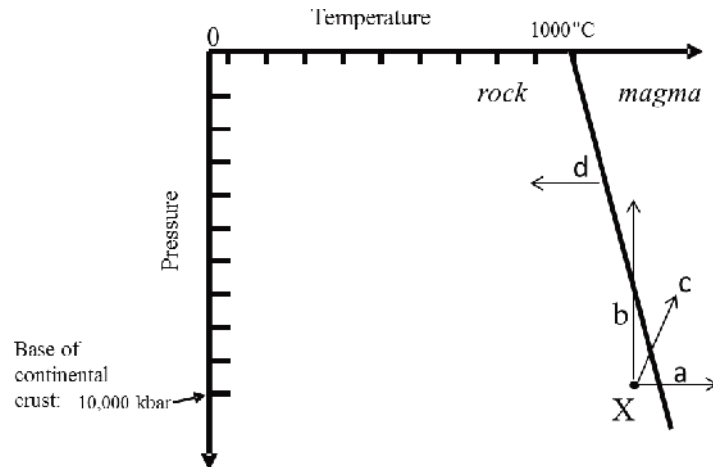


Figure 9.4 | Pressure and Temperature graph of crustal rocks. The line that separates the region of solid versus liquid rock is called the solidus. Note that a rock at point X cannot melt unless one of the following conditions occur: either a temperature increase (arrow "a"), or a pressure decrease (arrow "b"), or any combination of these two changes (arrow "c"), or by adding water to change the melting conditions which shifts the solidus line to the left (arrow "d"). **Author:** Karen Tefend

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This water will lower the melting temperature of the mantle region directly above the subducting plate, and as a result magma is produced (arrow “d” in Figure 9.5). The last way to melt rock is to just increase the temperature of the rock; this particular melting mechanism does not have to be associated with any particular plate boundary. Instead there must be a region known as a hot spot, caused by mantle plumes (arrow “a” in Figure 9.5). Mantle plumes are thought to be generated at the core-mantle boundary, and are regions of increased temperature that can cause melting of the lithospheric region. With the lithosphere broken into several tectonic plates that have been migrating over these plumes throughout geologic time, the resulting hotspot-generated volcanoes can be found anywhere in the world.

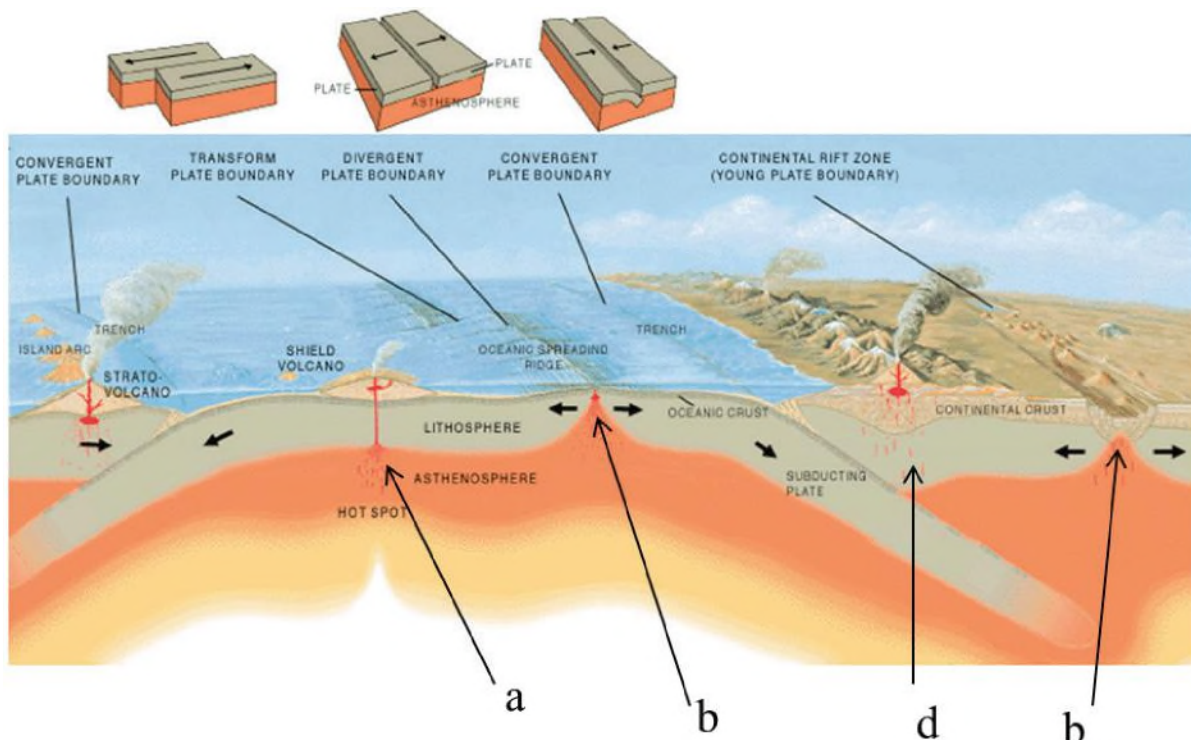


Figure 9.5 | Areas of magma generation at certain plate boundaries (b and d), or within a plate due to a hotspot (a). Arrows a, b, and d correspond to the same arrows as shown in Figure 9.1.

Author: Jose F. Vigil

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9.3 LAB EXERCISE

Part A - Magma Generation and Plate Tectonics

Refer to Figure 9.4 to help answer the questions. The exercises that follow use Google Earth. For each question (or set of questions) paste the location that is given into the “Search” box. When finding your locations in Google Earth, be sure to zoom out to higher eye elevations in order to see all of the important features of each area.

1. Type 19 53 48.36 N 155 34 58.11 W in the search bar on Google Earth, and zoom out to an eye altitude of -615 miles. The magma that resulted in the formation of these islands was generated by what process?
 - a. decreased pressure (arrow “b”)
 - b. the addition of water (arrow “d”, which shifts the solidus to the left)
 - c. increased temperature (arrow “a”)

2. Type 50 16 27.25 N 29 22 05.11 W in the search bar on Google Earth, and zoom out to an eye altitude of -2663 miles. The magma generated at this location is due to:
 - a. decreased pressure (arrow “b”)
 - b. the addition of water (arrow “d”, which shifts the solidus to the left)
 - c. increased temperature (arrow “a”)

3. Type 36 11 46.85 S 71 09 48.03 W in the search bar on Google Earth, and zoom out to an eye altitude of - 2865 miles. The magma responsible for this volcano was generated by what process?
 - a. decreased pressure (arrow “b”)
 - b. the addition of water (arrow “d”, which shifts the solidus to the left)
 - c. increased temperature (arrow “a”)

4. Type “San Andreas Fault” in the search bar on Google Earth; no magma is generated here, because this plate boundary is _____.
 - a. a divergent plate boundary, with decompression melting occurs
 - b. a convergent plate boundary, where water lowers the melting temperature of rock
 - c. a transform plate boundary, where no magma is produced

9.4 MAGMATIC PROCESSES OCCURRING WITHIN THE EARTH’S CRUST

Once magma is generated by one of the mechanisms mentioned earlier (increased temperature, decreased pressure, or by adding water), the magma rises upward through the surrounding rock mainly through pre-existing fractures in the

brittle lithosphere. A lot of magma stops rising upward through the continental crust because it has encountered an area in the crust that has the same density as the magma. This is a natural occurrence when matter is under the influence of gravity: denser material will sink, whereas lower density material will rise upward (think of a lava lamp containing two liquids of different densities). This magma will cool slowly

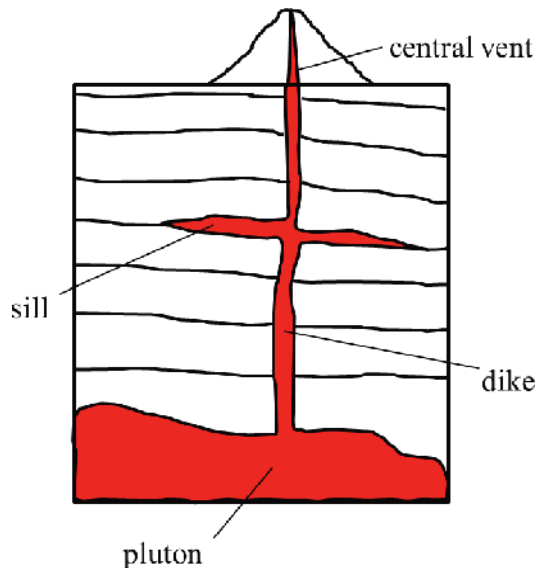


Figure 9.6 | Magma that crystallizes underground will form a pluton, an igneous rock body with a phaneritic texture. Magma can travel further upward through the crust by way of fractures through the rock layers to form a dike or magma may migrate in between rock layers and form a sill.

Author: Karen Tefend

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underground, and crystallize completely into an igneous rock body called a pluton (Figure 9.6). A lot of these plutonic rock bodies are found along our western coast of North America and other areas where magma must move upward through thick crust. Some of this magma may reach the surface either through a fissure or through a central vent in a volcanic structure; as the majority of magma stays underground and crystallizes into plutons, the smaller amount of magma that continues upward towards the surface may eventually crystallize completely within these fissures and become a dike or sill (Figure 9.6). Dikes and sills can be found on the surface of the earth due to uplift and erosion of the surrounding rock layers; sills will be oriented parallel to the surrounding rock layers, but dikes cut across them and are therefore easy to identify on the Earth's surface.

Recall that magma is generated by partial melting of a source rock, and if we refer back to Bowen's Reaction Series (Igneous Rock chapter, or Figure 9.7 in this chapter), we see that minerals have different melting temperatures. If a rock undergoes partial melting, the minerals that melt are those minerals on the bottom of the Reaction Series that are rich in silica (SiO_2) but poor in iron and magnesium. This means that magma generated by partial melting will be richer in silica and contain less iron and magnesium than the source rock (the rock that partially melted). The different magma types (and the solid rock forms that they make) in Figure 9.7 are listed in order of decreasing iron and magnesium, and increasing silica, with ultramafic rocks as the most iron and magnesium rich, and silica poor, and the felsic rocks as the most deficient in iron and magnesium but containing the most silica. Therefore partial melting of a mantle rock, which has an ultramafic composition, will produce a mafic magma; likewise, partial melting of a mafic rock can produce an intermediate magma type, and partial melting of an intermediate rock can produce felsic magma.

There are other ways that felsic and intermediate magmas are produced; for example, magma that is moving upward (ascending) through the crust may melt some of those crustal rocks, which can change the magma's composition. Recall that the continental crust is the lowest density rock type of the earth, of granitic composition, and is quite thick at convergent plate boundaries (see arrow "d" in Figure 9.5); at convergent plate boundaries, magma may have to travel through this thick portion of the continental crust. At any time before the magma is completely crystallized, it can melt the surrounding crust and perhaps end up with a more silica rich composition, therefore an intermediate or even a mafic magma will become more felsic as it travels through the continental crust. Whereas most magma crystallizes below ground, a portion of it does erupt onto the surface of the earth, either as a passive lava flow or under more explosive conditions such as the May 1980 eruption of Mount St. Helens, WA. Whether the style of eruption is passive or active (explosive) depends on the magma composition.

9.5 LAB EXERCISE

Part B - Association of Magma Type with Tectonic Setting

The questions in this exercise demonstrate the control that tectonic setting has on the type of magma produced. For the Google Earth questions, copy and paste the latitude and longitude coordinates into the search bar (or just type them in).

5. A(n) _____ at the Mid-Ocean Ridge, where oceanic plates are diverging and magma is generated by partial melting of the mantle.
 - a. ultramafic magma is produced
 - b. mafic magma is produced
 - c. intermediate magma is produced
 - d. felsic magma is produced

6. Type 19 28 19.70 N 155 35 31.94 W in the search bar on Google Earth, and zoom out to an eye altitude of ~119 miles. This volcano is composed of:
 - a. mafic rocks, because a hotspot partially melted the mantle below the oceanic crust
 - b. mafic rocks, because a hotspot partially melted the oceanic crust
 - c. ultramafic rocks, because a hotspot partially melted the mantle below the oceanic crust
 - d. ultramafic rocks, because a hotspot partially melted the oceanic crust

7. Type 35 35 08.45 S 70 45 08.22 W in the search bar in Google Earth. This volcano formed from an intermediate magma type, because:
 - a. subduction of oceanic crust beneath the continental crust occurs here
 - b. continental crust is subducting, causing magma to form
 - c. a hot spot is partial melting the continental crust
 - d. this is the result of a divergent plate boundary

8. Type 36 40 41.62 N 108 50 17.22 W in the search bar in Google Earth. The dark colored rock that forms a straight line on the surface is most likely:
 - a. a pluton of ultramafic rock
 - b. a dike of ultramafic rock
 - c. a sill of mafic rock
 - d. a dike of mafic rock

9.6 MAGMA COMPOSITION AND VISCOSITY

In the chapter on igneous rocks, you learned that the igneous rock classification is in part based on the mineral content of the rock. For example, ultramafic rocks are igneous rocks composed primarily of olivine and a lesser amount of calcium-rich plagioclase and pyroxene, whereas quartz, muscovite and potassium feldspar are the typical minerals found in felsic rocks (Figure 9.7). We need to re-

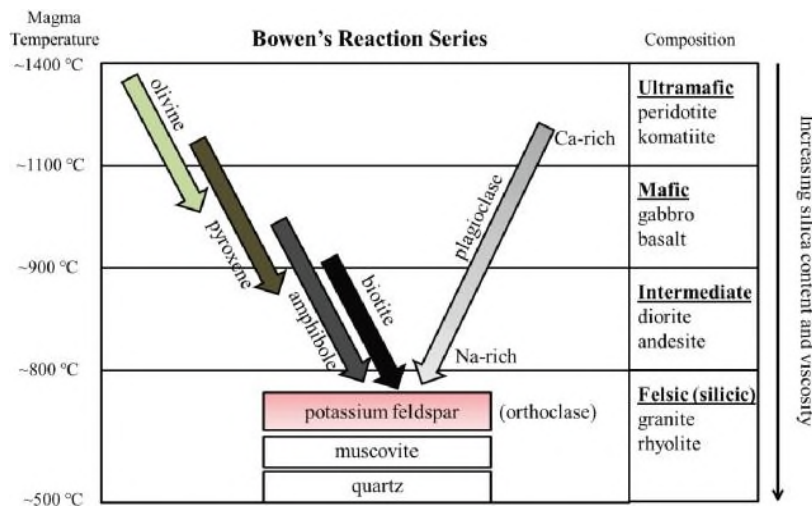


Figure 9.7 | Bowen's Reaction Series, and the magma compositions with the corresponding rock names listed on the right.

Author: Karen Tefend

Source: Original Work

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view the mineral content of these rocks, because igneous rocks are the crystallized result of cooled magma, and the minerals that form during cooling depend on the chemical composition of the magma; for example, a mafic magma will form a mafic rock containing a large amount of the ferromagnesian minerals pyroxene and amphibole, but will not contain quartz (the mineral that is always present in felsic rocks).

Recall that most of the minerals in igneous rocks are silicate minerals, and all of the minerals shown in Bowen's Reaction Series belong to the silicate mineral group. All silicate minerals have crystal structures containing **silica tetrahedron** (a silicon atom linked to four oxygen atoms), and these silica tetrahedra can be linked in a variety of ways to form sheets, linked chains, or a 3-dimensional framework. The lower temperature minerals (quartz, muscovite and orthoclase) have more linked tetrahedra than the high temperature minerals (olivine and pyroxene). Figure 9.8A shows how the silica tetrahedra are linked to form the mineral quartz. Note that this is a 2-dimensional diagram of a 3-dimensional structure, and there are a lot more tetrahedra connected in the area above and behind the typed page. What is important about this figure is what happens to the silica tetrahedra when quartz melts; Figure 9.8B shows that even though the crystal structure is lost (the regularly repeated structure is gone), the tetrahedral links are maintained, albeit distorted. The bonds that link these tetrahedra are strong, and magma temperatures are not high enough to break these bonds. This means that mag-

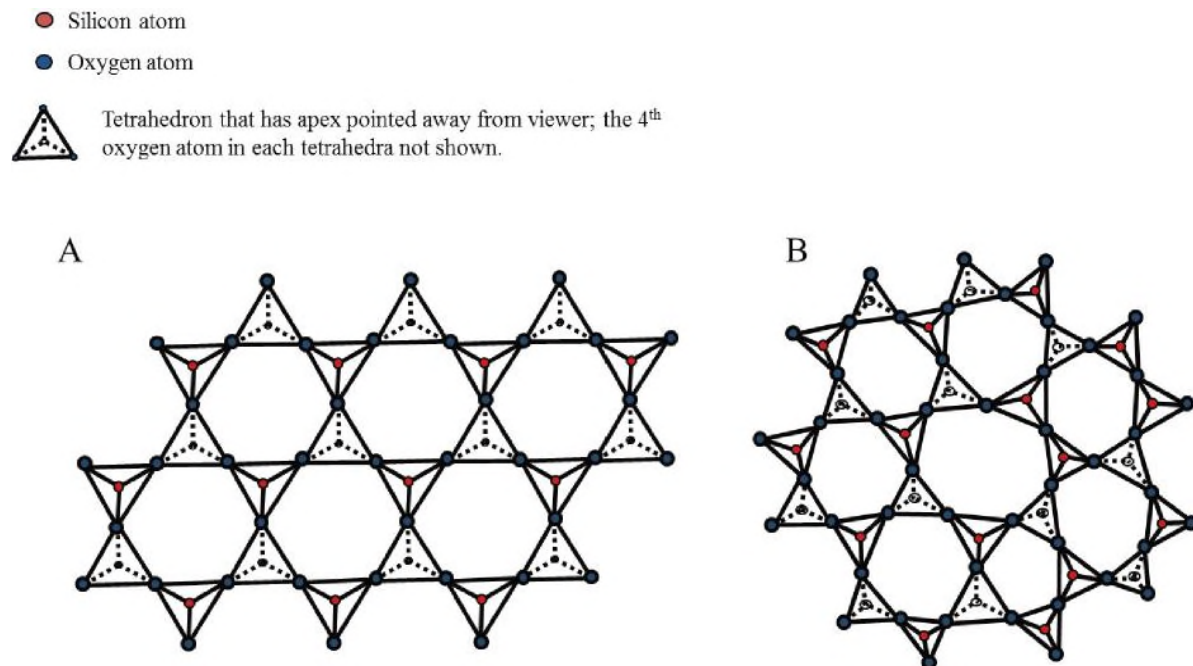


Figure 9.8 | (A) Regular repeated structure of silica tetrahedra in quartz; note that the 4th oxygen of each tetrahedra is not drawn for simpler viewing. These hexagonally arranged tetrahedra are joined to others to form a 3-dimensional framework. (B) shows how the tetrahedra stay linked when quartz melts; the arrangement of tetrahedra is irregular, but the links are maintained.

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mas that can crystallize quartz will have a lot of these tetrahedra linked in the magma, whereas mafic magmas which do not contain enough silicon to crystallize quartz, will instead crystallize minerals that have fewer linked tetrahedra.

Why does the silica content (the amount of linked tetrahedra) of magma matter so much? A large amount of linked silica tetrahedra will result in a magma or lava that is very viscous, meaning that it cannot flow easily (viscosity means resistance to flow). The temperature of a lava also affects the viscosity; think of how ketchup from your refrigerator flows, and how a ketchup stored in your pantry flows; of these two fluids, the colder ketchup has the higher viscosity. In the case of magmas or lavas, the hotter the lava, the easier it flows, and the less silica that is present, the lower the viscosity (see right side of the diagram in Figure 9.7). This means that mafic lavas can flow faster than intermediate or felsic lavas. The silica content of magma affects not only the shape of the volcano, but the style of eruption, or whether an eruption will be a lava that flows, or a magma that blows (up).

9.7 LAB EXERCISE

Part C - Magma Viscosity

The following questions address what factors control how fast a magma or lava can flow. The resistance to flow (viscosity) depends primarily on the magma or lava composition, and is also affected by temperature.

9. Intermediate lavas can flow _____ than mafic lavas, due to the ____ viscosity.
- a. slower, higher b. slower, lower c. faster, higher d. faster, lower
10. Let's relate food items to magmas of different viscosity; if we compare how honey and water flow when poured from a container:
- a. then the honey represents felsic magma, and the water represents mafic magma
- b. then the honey represents mafic magma, and the water represents mafic magma.
11. Imagine putting the honey in the refrigerator overnight; will its viscosity be affected?
- a. yes; the viscosity will increase
- b. yes, the viscosity will decrease
- c. no. there will be no change as the composition stays the same

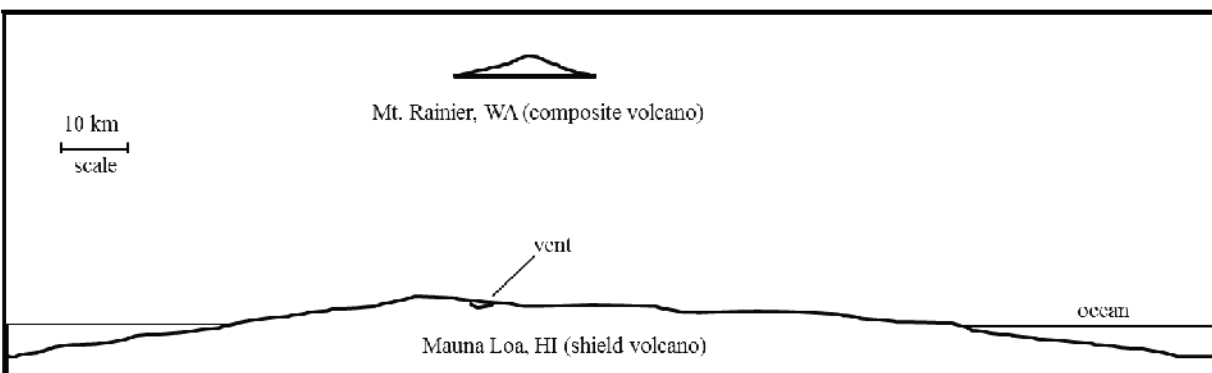
12. Keep the honey in mind while you answer this question: when it is first erupted, basalt lava typically erupts at 1200°C; after flowing away from the vent, the temperature falls, therefore the viscosity of the basaltic lava will:
- a. increase b. decrease c. stay the same

9.8 VOLCANIC LANDFORMS AND ERUPTION STYLES

The size, shape, and eruptive style of any volcano ultimately depend on the magma composition. We will focus mainly on mafic and felsic magmas as intermediate magmas have properties that are intermediate between these two types, and ignore the ultramafic magma as this type no longer forms (due to a cooler earth's interior). As mentioned earlier, mafic magmas are lower in silica and are therefore characterized as having a low viscosity. As mafic magma erupts on to the surface through a central vent (see Figure 9.6, and photo in Figure 9.3), the magma (now called lava) will spread out quite easily due to its low viscosity. Mafic lava flows can travel quite far before solidifying completely, and the type of volcano that forms from mafic lava is called a shield volcano (Figure 9.9). Shield volcanoes are very broad at the base, and have relatively gentle slopes. There are several locations around the world where large amounts of mafic basalt flows are found, without forming a shield volcano: places such as the Deccan Traps in India, Siberian Traps in Russia, and here in the U.S. (Columbia River Basalt Group). Such vast outpourings of mafic lava are called flood basalts, and are believed to be caused by mantle plumes (hotspots), which partially melt the mantle beneath the earth's crust. The mafic magma that is generated by the mantle plume reaches the earth's surface through fractures (fissures) instead of one central vent.

Figure 9.9 also shows a much smaller volcano type, called a **composite volcano**. This volcano also forms from eruptions through a central vent, but the smaller size indicates that any lava that is generated from a central vent did not travel far before solidifying completely, which indicates a more viscous magma,

Figure 9.9 | A comparison of a typical shield volcano versus a smaller,



steeply sloped composite volcano. The size and shape of these volcano types are due to the different types of magma and associated eruption styles. **Author:** Karen Tefend **Source:** Original Work **License:** CC BY-SA 3.0

such as an intermediate or felsic magma type. The term “composite” comes from the layers of lava flows, and the accumulation of ash and other volcanic material produced during a more explosive type of eruption due to the dissolved gases present in the magma (Figure 9.10, and photos in Figures 9.1 and 9.2). It is common to have a certain amount of dissolved gases within magma, and some gases may escape from the magma while still underground, but the most spectacular release of these gases occurs during eruption. The common gases associated with magma are usually water vapor, carbon dioxide, carbon monoxide, and hydrogen sulfide. Mafic magmas erupting onto the surface may form a lava fountain which spurts the magma (now called lava) into the air, where the height of the lava fountain depends on the gas content. However, gases within felsic magmas are not released as easily due to the magma’s high viscosity; as viscous magmas move closer to the earth’s surface, the dissolved gases are under less pressure and large gas bubbles can form. At some point the gas pressure becomes so great that an explosive eruption occurs, and fragmented volcanic material is released. This material can travel great distances along air currents, but enough deposits around the central vent to build up the composite volcano structure. Once the gases are released and the explosive eruptions end, felsic magma may still be extruded onto the surface inside the volcanic crater. This felsic material, now a viscous lava, will flow with great difficulty, and a large amount of the felsic lava will cool completely in the area around the central vent, and may end up “plugging” the vent and forming what is called a **lava dome** (Figure 9.11).

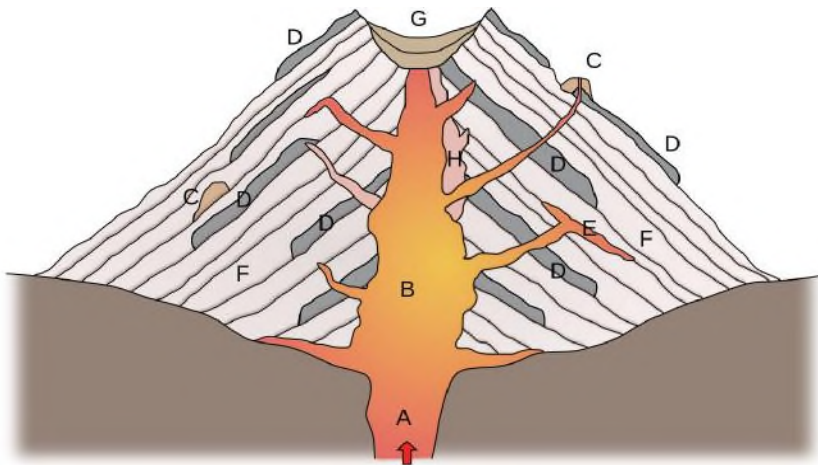


Figure 9.10 | Diagram of a composite volcano. Notice the structure is composed of layered ashflows (F) and viscous lava flows (D). Also of note is the buildup of viscous lava at locations labelled C; these are lava domes. **Author:** User “Woudloper”

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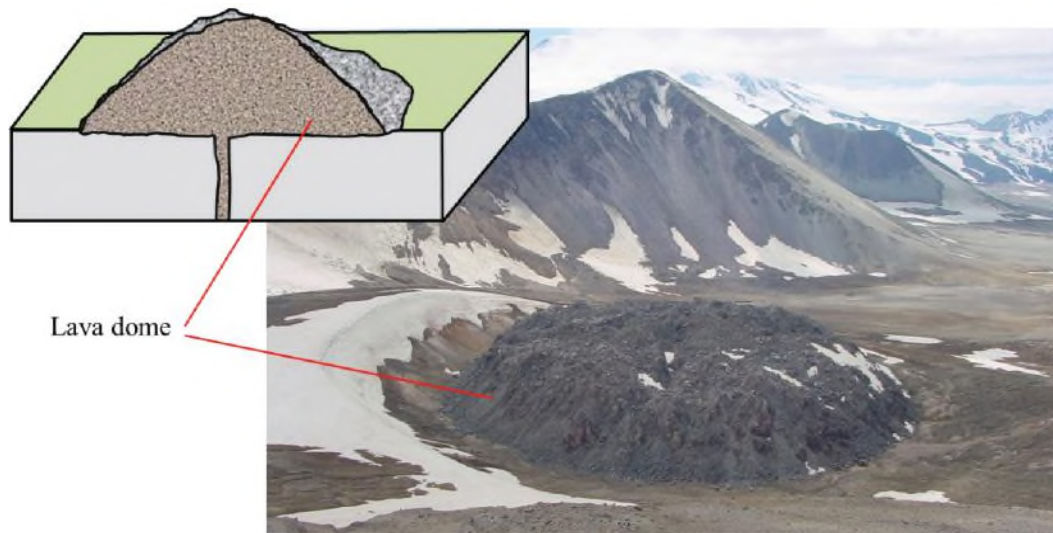


Figure 9.11 | Lava domes are extrusions of viscous lava on the surface of the Earth. The lava does not travel too far from the vent before solidifying completely.

Author: Karen Tefend

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9.9 LAB EXERCISE

Part D - Volcanic Landforms

The composition of a magma or lava may also control what type of volcanic features or landforms are seen on the earth's surface. In this exercise, you will use Google Earth to identify these landforms. Figures 9.9 through 9.11 may help you in this section. For the Google Earth questions, copy and paste the latitude and longitude coordinates into the search bar (or just type them in).

13. Type 43 25 04.18N 113 31 37.38 W in the search bar of Google Earth. Zoom out to an eye elevation of ~90 miles. Based on the size of the area which is dark colored and sparsely vegetated, this region is:
 - a. a basaltic dike
 - b. a shield volcano
 - c. a lava dome
 - d. a flood basalt
14. Click on the nearby photo icon (SW of your latitude/longitude coordinate in Question 13) to view a picture of the area as seen from the ground. This is a picture of:
 - a. a basalt flow
 - b. a felsic dome
 - c. a plutonic rock
 - d. an ultramafic rock
15. How many miles in length is this dark colored feature? (measure the greatest length)
 - a. -8 miles
 - b. -20 miles
 - c. -40 miles
 - d. -50 miles

16. Type 46 12 07.84N 121 31 02.85W in the search bar of Google Earth. This volcano (Mt. Adams) has a lot of snow cover and small glaciers on it, but you can still see the volcanic rock, especially on the eastern flank (side) of the volcano. Zoom in to an eye altitude of ~9000ft to closely examine the rocks on this eastern side of the volcano; do you see any evidence of layering? This volcano is:
- a. a shield volcano
 - b. a lava dome
 - c. a composite volcano
 - d. a large volcanic dike
17. How tall is Mt. Adams, and what is the length of its base (in the widest, N-S dimension)? You will need to zoom out to an eye altitude of ~17 miles to measure the base.
- a. -12,290 ft above sea level, and over 7 miles long
 - b. -11, 890 ft above sea level, and over 4 miles long
 - c. at least 12, 703 ft above sea level, and over 6 miles long
 - d. unable to determine because of the ice
18. Compared to the Big Island of Hawaii (19 53 48.36 N 155 34 58.11 W, or refer to Figure 9.6), which is actually the volcano Mauna Loa, Mt. Adams is:
- a. the same height, but the base is a lot smaller
 - b. the same height, but the base is a lot wider
 - c. smaller in height, and smaller at the base
 - d. smaller in height, but larger at the base
19. Type in 58 15 58.56 N 155 09 35.98 W in the search bar of Google Earth. Examine the shape of this feature by zooming in to an eye altitude of ~3330 ft; use the eye icon in the upper right corner to rotate the view. Now zoom out to an eye altitude of ~7306 ft to see the entire structure and the surrounding area. Based on the size and appearance of this volcanic feature, this is a:
- a. dike
 - b. shield volcano
 - c. lava dome
 - d. flood basalt

9.10 VOLCANIC HAZARDS

When comparing the two volcano types, shield and composite, it is obvious that although the shield volcanos are more massive (see Figure 9.9), they are far

less dangerous to the population than the smaller composite volcanoes. Shield volcanoes produce basaltic lavas that may fountain at the vent, due to gases, but end up flowing passively down the flanks of the volcano (Figures 9.3 and 9.12). Other than property damage, anyone living on or near a shield volcano is not likely to perish due to a volcanic eruption. This is not the case for the composite volcanoes; explosive eruptions produce a lot of volcanic fragments, called pyroclastic debris or tephra, that range in size from dust and ash to large blocks (or bombs) of volcanic material (Figure 9.13). Pyroclastic debris at first travels high up into the atmosphere into an eruption column, which then spreads outward along with the prevailing wind direction, but during the explosive phase of the eruption, the central vent widens as the rocks around the vent are also blown during the eruption; this widening of the vent results in less upward momentum of the eruption column. As a result, the pyroclastic material travels down the flanks of the volcano as a **pyro-clastic flow**, a very dangerous mixture of hot volcanic material and noxious gases.



Figure 9.12 | Photo of a lava fountain, caused by gas release from a mafic magma.

Notice the mafic lava flows down the sides of this structure.

Author: G. E. Ulrich

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Although pyroclastic flows are extremely dangerous, most deaths associated with composite volcanoes are from mudflows, called **lahars**. Many composite volcanoes are capped by snow and ice, and even a small eruption can result in meltwater running down the sides of the volcano. This water can easily erode the ash and other volcanic debris on the flanks of the volcano and result in a fast moving slurry of mud and larger material such as trees and boulders. Lahars move swiftly through river channels and can endanger any town or city that is built in the low lying areas downstream from the volcano (Figure 9.13). Lahars can also be generated by large amounts of rainfall in the area. Several ancient mudflow deposits are

recognized in the Cascade area of Washington and Oregon. Because of the proximity of major cities and many towns in the vicinity of these dormant volcanoes (and the recently classified “active” Mt. St. Helens), volcano monitoring systems are in place. For example, seismic activity is monitored, as earthquakes are generated by the upward migration of magma beneath the volcanic structure, and GPS technology is used to monitor any changes in slope, as magma may push the sides of the volcano outwards and increase the angle of the volcano’s slope. Also monitored are the stream valleys on the volcano to detect lahars that can happen at any time, regardless of the active or dormant status of a composite volcano.

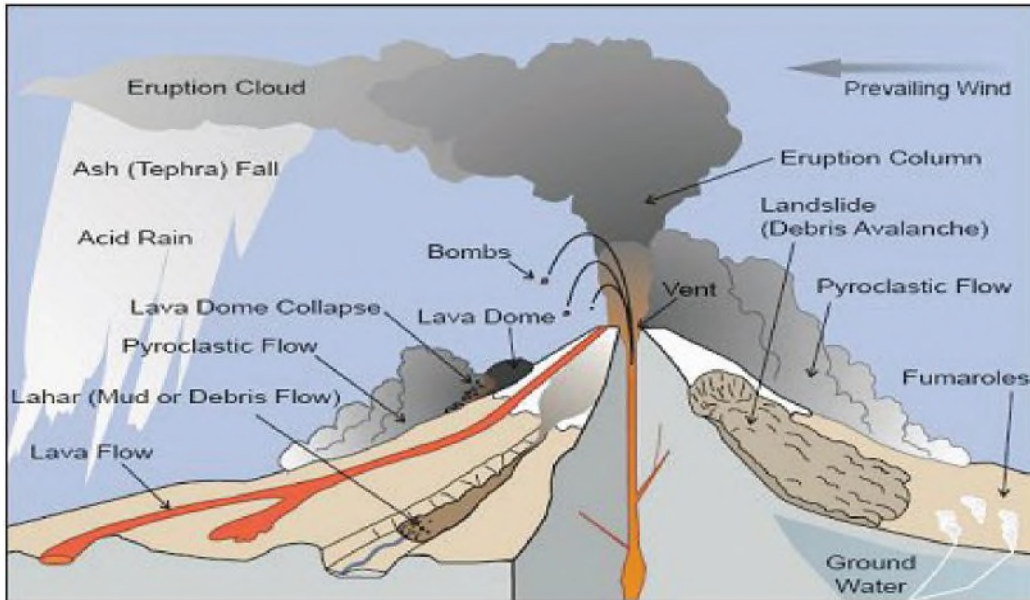


Figure 9.13 | Diagram demonstrating the hazards and other features associated with composite volcanoes.

Author: volcanoes-42325.wikispaces.com

Source: Volcanoes-42325

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9.11 LAB EXERCISE

Part E - Volcanic Hazards

Potential hazards associated with certain volcanic types can be identified using topographic maps or aerial photographs. In this exercise, we will use Google Earth.

20. Type Mount St. Helens, WA in the search bar in Google Earth and examine the crater at an eye altitude of ~26,000 ft. Based on the appearance of the crater:
 - a lahar removed the north side of the volcano
 - a pyroclastic eruption removed the north side of the volcano
 - a lava dome grew so large that it is higher than the north side of the crater
 - a glacier has eroded the north side of the crater

21. Type Mount Rainier, WA in the search bar in Google Earth. The Carbon River flows from the north part of Mount Rainier (fed by meltwater from the Carbon Glacier on the flank of the volcano). At an eye altitude of ~20,000ft, follow the course of the Carbon River, past the town of Carbonado and stop at the town of Orting. Based on the locations of these two towns, which do you think is in danger from a lahar?
- a. Both are in danger of lahars
 - b. Carbonado, because it is closer to Mount Rainier
 - c. Orting, because it is in a low lying area along Carbon River
 - d. Neither one is in danger because Mount Rainier is dormant

9.12 STUDENT RESPONSES

1. Type 19 53 48.36 N 155 34 58.11 W in the search bar on Google Earth, and zoom out to an eye altitude of ~615 miles. The magma that resulted in the formation of these islands was generated by what process?
 - a. decreased pressure (arrow “b”)
 - b. the addition of water (arrow “d”, which shifts the solidus to the left)
 - c. increased temperature (arrow “a”)

2. Type 50 16 27.25 N 29 22 05.11 W in the search bar on Google Earth, and zoom out to an eye altitude of ~2663 miles. The magma generated at this location is due to:
 - a. decreased pressure (arrow “b”)
 - b. the addition of water (arrow “d”, which shifts the solidus to the left)
 - c. increased temperature (arrow “a”)

3. Type 36 11 46.85 S 71 09 48.03 W in the search bar on Google Earth, and zoom out to an eye altitude of ~ 2865 miles. The magma responsible for this volcano was generated by what process?
 - a. decreased pressure (arrow “b”)
 - b. the addition of water (arrow “d”, which shifts the solidus to the left)
 - c. increased temperature (arrow “a”)

4. Type “San Andreas Fault” in the search bar on Google Earth; no magma is generated here, because this plate boundary is _____.
 - a. a divergent plate boundary, with decompression melting occurs
 - b. a convergent plate boundary, where water lowers the melting temperature of rock
 - c. a transform plate boundary, where no magma is produced

5. A(n) _____ at the Mid-Ocean Ridge, where oceanic plates are diverging and magma is generated by partial melting of the mantle.
 - a. ultramafic magma is produced
 - b. mafic magma is produced
 - c. intermediate magma is produced
 - d. felsic magma is produced

6. Type 19 28 19.70 N 155 35 31.94 W in the search bar on Google Earth, and zoom out to an eye altitude of ~119 miles. This volcano is composed of:
- mafic rocks, because a hotspot partially melted the mantle below the oceanic crust
 - mafic rocks, because a hotspot partially melted the oceanic crust
 - ultramafic rocks, because a hotspot partially melted the mantle below the oceanic crust
 - ultramafic rocks, because a hotspot partially melted the oceanic crust
7. Type 35 35 08.45 S 70 45 08.22 W in the search bar in Google Earth. This volcano formed from an intermediate magma type, because:
- subduction of oceanic crust beneath the continental crust occurs here
 - continental crust is subducting, causing magma to form
 - a hot spot is partial melting the continental crust
 - this is the result of a divergent plate boundary
8. Type 36 40 41.62 N 108 50 17.22 W in the search bar in Google Earth. The dark colored rock that forms a straight line on the surface is most likely:
- a pluton of ultramafic rock
 - a dike of ultramafic rock
 - a sill of mafic rock
 - a dike of mafic rock
9. Intermediate lavas can flow _____ than mafic lavas, due to the viscosity.
- slower, higher
 - slower, lower
 - faster, higher
 - faster, lower
10. Let's relate food items to magmas of different viscosity; if we compare how honey and water flow when poured from a container:
- then the honey represents felsic magma, and the water represents mafic magma
 - then the honey represents mafic magma, and the water represents mafic magma.

11. Imagine putting the honey in the refrigerator overnight; will its viscosity be affected?
- yes; the viscosity will increase
 - yes, the viscosity will decrease
 - no. there will be no change as the composition stays the same
12. Keep the honey in mind while you answer this question: when it is first erupted, basalt lava typically erupts at 1200°C; after flowing away from the vent, the temperature falls, therefore the viscosity of the basaltic lava will:
- increase
 - decrease
 - stay the same
13. Type 43 25 04.18N 113 31 37.38 W in the search bar of Google Earth. Zoom out to an eye elevation of -90 miles. Based on the size of the area which is dark colored and sparsely vegetated, this region is:
- a basaltic dike
 - a shield volcano
 - a lava dome
 - a flood basalt
14. Click on the nearby photo icon (SW of your latitude/longitude coordinate in Question 13) to view a picture of the area as seen from the ground. This is a picture of:
- a basalt flow
 - a felsic dome
 - a plutonic rock
 - an ultramafic rock
15. How many miles in length is this dark colored feature? (measure the greatest length)
- 8 miles
 - 20 miles
 - 40 miles
 - 50 miles
16. Type 46 12 07.84N 121 31 02.85W in the search bar of Google Earth. This volcano (Mt. Adams) has a lot of snow cover and small glaciers on it, but you can still see the volcanic rock, especially on the eastern flank (side) of the volcano. Zoom in to an eye altitude of -9000ft to closely examine the rocks on this eastern side of the volcano; do you see any evidence of layering? This volcano is:
- a shield volcano
 - a lava dome
 - a composite volcano
 - a large volcanic dike

17. How tall is Mt. Adams, and what is the length of its base (in the widest, N-S dimension)? You will need to zoom out to an eye altitude of ~17 miles to measure the base.
- 12,290 ft above sea level, and over 7 miles long
 - 11, 890 ft above sea level, and over 4 miles long
 - at least 12, 703 ft above sea level, and over 6 miles long
 - unable to determine because of the ice
18. Compared to the Big Island of Hawaii (19 53 48.36 N 155 34 58.11 W, or refer to Figure 9.6), which is actually the volcano Mauna Loa, Mt. Adams is:
- the same height, but the base is a lot smaller
 - the same height, but the base is a lot wider
 - smaller in height, and smaller at the base
 - smaller in height, but larger at the base
19. Type in 58 15 58.56 N 155 09 35.98 W in the search bar of Google Earth. Examine the shape of this feature by zooming in to an eye altitude of ~3330 ft; use the eye icon in the upper right corner to rotate the view. Now zoom out to an eye altitude of ~7306 ft to see the entire structure and the surrounding area. Based on the size and appearance of this volcanic feature, this is a:
- dike
 - shield volcano
 - lava dome
 - flood basalt
20. Type Mount St. Helens, WA in the search bar in Google Earth and examine the crater at an eye altitude of ~26,000 ft. Based on the appearance of the crater:
- a lahar removed the north side of the volcano
 - a pyroclastic eruption removed the north side of the volcano
 - a lava dome grew so large that it is higher than the north side of the crater
 - a glacier has eroded the north side of the crater

21. Type Mount Rainier, WA in the search bar in Google Earth. The Carbon River flows from the north part of Mount Rainier (fed by meltwater from the Carbon Glacier on the flank of the volcano). At an eye altitude of ~20,000ft, follow the course of the Carbon River, past the town of Carbonado and stop at the town of Orting. Based on the locations of these two towns, which do you think is in danger from a lahar?
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