Chapter 7 Study Guide and Case Studies: Volcanoes

Key Concepts

- Fatal eruptions are on the rise because of population increase and people moving to volcanoes.
- A typical volcano has a crater, a vent and a magma chamber.
- Dissolved gases drive an eruption.
- Rock melts either through decompression or addition of volatiles.
- Active volcanoes currently show signs of activity (seismic, gas emission, eruption).
- Dormant volcanoes are currently not active but erupted in historic times (last 10,000 years).
- A caldera is much larger than a crater and forms after massive eruptions that empty the magma chamber, upon which the roof of the chamber collapses.
- A phreatic eruption occurs when massive amounts of water drive an eruption.
- Five eruption types classify the violence of a volcano and its typical eruptions, from Icelandic type to Plinian type.
- The volcanic explosivity index classifies the violence of individual eruptions, from 0 to 8.
- The Yellowstone eruption about 650,000 years ago is the only known one with a VEI 8.
- The three principal volcanic products are lava flows, pyroclastic debris and volcanic gases.
- Volcanic hazards include lava flows, ash fall, lahars, pryoclastic flows, gas emissions from active eruptions.
- Lahars are volcanic mudflows consisting of pyroclastic debris and water. Lahars can form during eruptions, particularly when the volcano has an ice cap. They can also form during inactive times when heavy rain wash loose debris down the slopes of a volcano.
- Pyroclastic flow (also called volcanic hurricanes) consist of pyroclastic material and extremely hot volcanic gases. Pyroclastic flows can move down an volcano at speeds 300 km/h and are extremely destructive.
- Volcanic hazards during dormant times include erosion and mass movements. Some oceanic volcanoes are capable of massive submarine landslides.
- The top three fatal volcanic hazards are pyroclastic flows, indirect (global impact by massive eruptions that may lead to famine) and tsunami.
- The two principal types of volcanoes are shield and strato (or composite volcanoes). The two principal styles of volcanism are effusive and explosive.
- The three Vs (volumes, volatiles, viscosity) determine the style and vigor of volcanism.

- The type of crust (oceanic vs continental) as well as crustal thickness determines the amount of silica in magma. Silica-rich rocks lead to more explosive volcanism.
- Both silica content and temperature determine the viscosity of magma and lava.
- Magma is found below the surface (intrusive realm) while lava is found above the surface (extrusive realm).
- Silica-rich minerals (such as Quartz) have lower melting temperatures than silica-poor minerals (such as Olivine).
- The geotherm plots Earth's temperature as function of depth (or pressure).
- The two principal processes that melt Earth's rock are decompression (where magma ascends) and addition of volatiles (such as in a subduction zone).

Key Terms

- active, dormant, extinct volcano
- phreatic eruption
- cinder cone
- caldera
- volcanic explosivity index
- lava flows
- tephra
- pyroclastic debris
- ash
- lapilli
- cinder
- lahar
- pyroclastic flow
- fumarole
- tsunami
- shield volcano
- strato volcano
- geothermal activity
- geyser
- viscosity
- effusive eruption
- explosive eruption
- silica content
- magma
- lava
- silicic rock
- mafic rock
- Basalt
- Gabbro
- Rhyolite
- Granite
- instrusive rock
- extrusive rock
- plutonic rock
- melting temperature
- partial melt
- decompression melting
- melting by injection of volatiles
- Cascade volcanoes
- large igneous province

Questions for Review

1. What are the principal features of a typical volcano?
2. What drives a volcanic eruption?
3. How does the ascending magma in a volcano lead to an eruption?

4. Which of the five eruption types describes a particularly benign eruption? Which describes a particularly violent eruption?

5. What does the volcanic explosivity index (VEI) describe? Can a single volcano have different VEIs?

6. What are the three principal volcanic products?

7. What is the difference between a lahar and a pyroclastic flow?

8. Which are the three most deadly volcanic hazards?

9. Describe how volcanic ash from an otherwise remote volcano can still pose a significant volcanic hazard.

10. Describe the principal differences between a shield and a strato volcanoes?

11. What are the three Vs and how do they impact the style of volcanism?

12. How do crustal thickness and type of crustal rock influence the style of volcanism?

13. What are the two principal factors that control the viscosity of magma? How do they do that?

14. What is the difference between magma and lava?

15. Describe how silica content determines the type of volcanic and plutonic rock.

16. How does silica content in a mineral change its melting temperature?

17. Why is magma typically partially and not fully molten?

18. What is the geotherm?

19. What happens to ascending mantle rock that crosses the geotherm?

20. What are the two principal melting process that melt Earth's rock? Where on Earth do we find them? Give an example for each.

Case Studies

Case Study 1: Arenal, Costa Rica

The 1670 m-high Arenal volcano is a moderately silicic (andesitic) stratovolcano. Arenal Volcano area is an important watershed for the Arenal Lake Reservoir. The reservoir's water is used for hydroelectric power.

Only 7500 years old, Arenal is the youngest volcano in Costa Rica. It erupted unexpectedly in 1968 with a big VEI 3 explosion, when it destroyed the town of Tabacón and killed 87 people. It was the most active volcano of Costa Rica, and in fact one of the 10 most active in the world, until 2010. It had erupted with a Strombolian type, constantly rumbling, peacefully ejecting small tephra and sometimes lava flows. Eco-tourists watched Arenal erupting from a safe distance. Arenal has been dormant since 2010.

Figure C7.1 Mt. Arenal, Costa Rica (source: GVP)

Case Study 2: Mayon, Philippines

2462 m-high Mayon volcano is a stratovolcano on the island of Luzon, Philippines. Mayon is the most active volcano in the Philippines, having erupted over 47 times in the last 500 years. Its last eruption was in March 2019. It has steep slopes (upper slope 35-40 deg). Perhaps not lastly because of its beautiful "perfect cone" shape, Mayon was declared a national park in 1938. The volcano's historical eruptions go back to 1616 when an eruption was first documented by Dutch explorer Spilbergen. Eruptions range from Strombolian to Plinian, the latter making it a dangerous volcano. It is known to produce pyroclastic flows and lahars. Mayon's most violent eruption, a VEI 4 eruption in 1814, killed more than 1200 people and devastated several towns.

Significant eruptions in last 15 years:
July 2006: lava flows and pyroclastic flows (VEI 1) prompted the evacuation of about 100 families. Seismic activity and rising SO_2 emissions prompted alert level 4. Thousands of people were evacuated but some returned by late September, after a 10-day drop in the level of activity (21 Sep 2006 Earthwatch). The level was lowered to 1 by October 25, but a deadly lahar on November 30, fed by Typhoon Durian killed more than 1200 people.

October 2009: Mayon awakened with minor ash explosions. On December 20, 2009, the alert level was raised to 4 because of increased SO_2 releases, seismic activity and an increasing lava flow in the south (VEI 2). Nearly 45,000 people were evacuated, and SO_2 emission increased more than ten-fold by December 25. Tourism also increased ten-fold and some tourists ignored government warnings not to venture into the 8-km danger zone around the summit.

2013/2014: Phreatic eruptions reaching VEI 2 on 7 May 2013 caused the death of five hikers. On 12 August 2014, a 40-m lava dome rose in the summit crater. After emissions of SO_2 and rockfall events a month later triggered a level-3 alert and the evacuation of 12,000 families was planned for the 8-km extended danger zone.

January 2018: a phreatic eruption on 13 January sent volcanic material 2500 m high. About 40,000 people evacuated. Three days later, lava flows reached the 6-km limit of the evacuation zone leading to alert level 4 on 22 January when a Strombolian eruption produced ash plumes and pyroclastic flows. Eruptions reached VEI 2. A day later, lava fountains reached a height of 500 m, every 4-5 h. The evacuation zone was extended to 9 km.

Figure C7.2 Mt. Mayon, Philippines (source: GVP)

Case Study 3: Stromboli, Italy

Mt. Stromboli is located in the Tyrrhenian Sea (part of the Mediterranean Sea) west of Italy. It is 2,700 m high, from seafloor to the summit, but reaches only 926 m above the sea surface. It is one of eight Aeolian Islands that form a volcanic arc north of Sicily. About 500 people live in two towns (Stromboli and Ginostra) on the 11.5 km^2 island.

Stromboli has been erupting nearly continuously for the last 2000 years. Minute to moderate explosions usually produce small amounts of pyroclastic material but effusive eruptions in 2002, 2003, 2007 and 2013/14 produced small lava flows. Because of its small, frequent and continuous activity, Stromboli attracts many tourists. Spectacular incandescent nighttime explosions identify Stromboli as the "lighthouse of the Mediterranean". An unusually large, VEI 2 eruption in the late afternoon on 3 July 2019 killed a hiker.

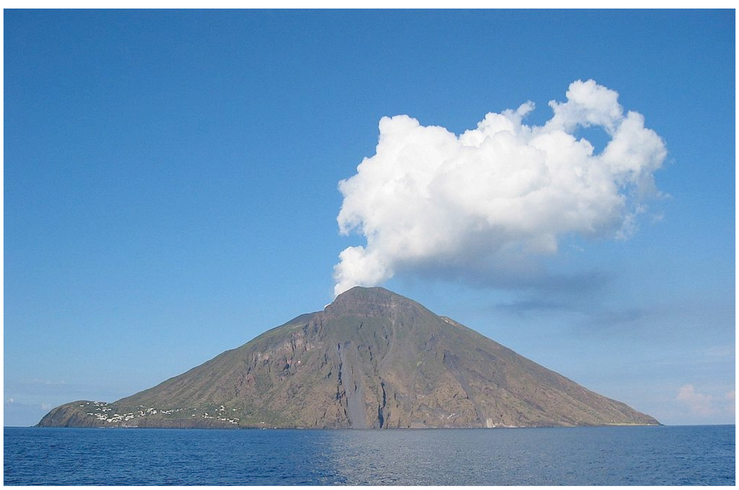

Figure C7.3 Mt. Stromboli, Italy (source: Wikipedia)

Case Study 4: Rabaul Volcano, New Britain Island, Papua New Guinea

688-m high Rabaul is a violent volcano on the tip of the Gazelle Peninsula in Papua New Guinea. Its most prominent feature is a caldera, with hills of pyroclastic material around it (Rabaul is described as a pryoclastic shield). The town of Rabaul is located within the caldera. The northeast end forms a broad sheltered harbor. Tourism is a major source of income. Several vents surround the caldera and make up Rabaul, with Tavurvur bringing most devastating eruptions over Rabaul. The vents can erupt at the same time. In 1937 Vulcan and Tavurvur erupted together, killing more than 500 people. A twin eruption in 1994 forced the temporary abandonment of Rabaul, with its airport destroyed. The new airport, 50 km to the southeast experiences occasional closure after ash eruptions from Tavurvur.

In October 2006, a large, sustained Vulcanian eruption produced a 5-km-high eruption column and thunder and lightning. Windows rattled and doors slammed from semi-continuous air blasts. Windows in the observatory, 12 km away, blew out from shock waves. The eruption grew to sub-Plinian status throughout the day when thick ash plumes reached 18 km altitude. Ashfall affected the entire Gazelle Peninsula. This eruption was a VEI 4.

Tavurvur was last active with a VEI 3 eruption in August 2014.

Figure C7.4 Rabaul Volcano, New Britain Island, Papua New Guinea (source: GVP)

Case Study 5: Examples that even "remote" volcanic activity can be hazardous

Airplane flying through Ash Clouds:
Mt. Redoubt in Alaska is relatively remote and is located near the southern end of Cook Inlet, about 200km southwest of the city of Anchorage. It has erupted only few times in

recorded history. On Dec 15, 1989, a Dutch KLM Boeing 747 jumbo jet was on its way from Amsterdam to Tokyo. It had about 250 people on board and was at cruising altitude (about 10 km) when it encountered an ash cloud of the erupting volcano. The ash clogged all four engines which lost power and the plane started a dramatic 12-min descent to 4km altitude, only 1.5 km above the mountains. The engines started up again only after the 18th attempt before the pilot could land the plane safely in Anchorage. The damage to the engines was $18 Mio.

Unfortunately, such incidents are quite common and the pilots have, in general, no warning time. Examples include an equally terrifying encounter of a 747 with an ash could during the 1982 eruption of **Mt. Galunggung, Indonesia** (7.5-km descent). There also all 4 engines shut down. During the 1991 **Mt. Pinatubo, Philippines** eruption, 17 flights were affected. Officials now work with scientists on an early-warning system in the Alaska region for polar flights to Eastern Asia. Recent studies suggest that weather satellites from space that could track these clouds can discriminate weather clouds from ash clouds (NB: clouds from large forest fires are also a significant hazard though the hazard from these fires has a different effect).

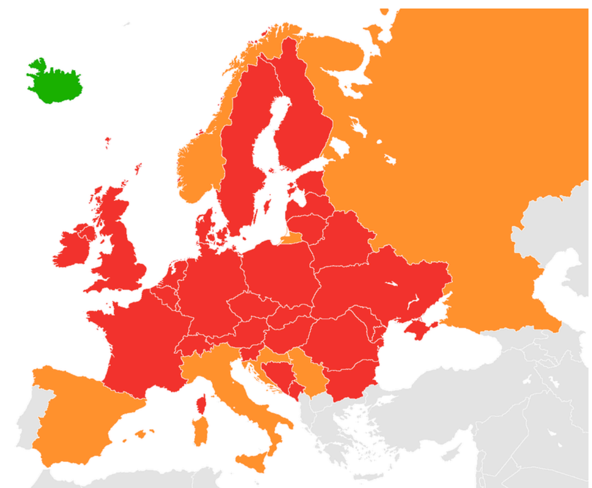

Figure C7.5 Complete (red) and partial (orange) closure of airspace to flights unde instrument flight rules (IFR) on 18 April 2010 following the 14 April eruption of Eyjafjallajökull, Iceland. (source: Wikipedia)

In March 2010 **Eyjafjallajökull, Iceland** sprang to live with eruptions from fissures. Glacial meltwater contributed to subsequent eruptions ten times larger (VEI 4), ejecting massive amounts of ash several kilometers into the atmosphere. Due to prevailing winds, the cloud shifted eastward leading to air traffic warnings that culminated in a week-long (16-23 Apr) disruption of air traffic and closure of airspace in western Europe in April. By 21 April 95,000 flights were cancelled, leading to economic losses in the billions ($1.7B to airlines alone). Sporadic closures followed, including two days in May in Ireland and UK but also as far south as Spain. People as far as Kenya were impacted because Kenyan farmers could no longer ship and sell their roses and other flowers on the European market. Citing visually clear skies, Irish Airline Ryanair initially ignored the volcanic hazard warning but later admitted that volcanic ash found its way into their engines[1]. The closure of the European airspace by the EU presidency was contested by some airlines arguing that the warnings were based on conservative modeling estimates[2]. But Finnish Air Force F-18 were damaged even during short test flights, molten glass was reported on F-16 NATO jets, and Royal Air Force training flights were suspended after damage to their Eurofighter Typhoon aircraft.

(1)http://news.bbc.co.uk/2/hi/uk_news/northern_ireland/8672663.stm
(2)https://en.wikipedia.org/wiki/Air_travel_disruption_after_the_2010_Eyjafjallaj%C3%B6kull_eruption