Riding the Magma Elevator

Grade Level: 6+

Learner Objectives:

Students will:

- Understand how the subducting plates trigger melting of mantle to form magma
- Identify how gas pressure initiates the ascent of magma into the magma chamber

Setting: Classroom

Timeframe: 20 minutes

Materials:

- Narrative *"Riding the Magma Elevator"*
- Graphic *"Elevator Overview"*
- Graphic *"Level 1—Subduction Zone"*
- Graphic *"Level 2—Basement of Earth's Crust"*
- Graphic *"Level 3—The Magma Chamber"*
- Graphic *"Level 4—Inside the Volcano"*

Vocabulary: Bar, crust, conduit, dike, eruption, granodiorite, lava, mantle, magma, magma chamber, subduction zone, Pascal, vent, volcanic ash, volcanic gases, volcano, volcanologists

USGS
science for a changing world

NATIONAL PARK SERVICE

Living with a Volcano in Your Backyard-An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Examine the processes leading to a volcanic eruption, including mantle melting, magma formation, and magma ascent. During this activity, the students will ride an imaginary elevator from the subduction zone to volcanic vent.

Teacher Background

The query "What triggers a volcanic ***eruption***?" is one of the most common questions pondered by ***volcanologists***. They have explored this question for years and developed some sound theories about the processes at work beneath a ***volcano***. The most common understanding is displayed in the narrative and graphics of this activity.

Sidebar 1: Measures of Pressure

Pressure is a critical factor that influences how volcanoes behave. It is expressed in terms of force per unit area; in English units, for example we measure pressure in pounds per square inch (psi); in metric or SI units, pressure is measured in Pascals, where one Pascal is a Newton of force applied over a square meter of surface area. (An older metric unit of pressure is the bar, which equals 100 kilopascals (kPa)). The pressure of the atmosphere at sea level is roughly 14.7 psi, or 101.3 kPa. Within the Earth, pressure increases with depth due to the weight of rock; the rate of increase is about 100 kilopascals (kPa) per kilometer, or 400 atmospheres per mile. Water vapor and other gases dissolve into the magma because of extreme pressure exerted by overlying and surrounding rocks.

Activity last modified: September 5, 2014

Skills: Inference, discussion, listening

Benchmarks:

See benchmarks in Introduction.

Procedure

1. Use the graphic "***Elevator Overview***" to show the pathway that the "elevator" will be following. Introduce the concept of mantle melting, magma rising into the magma chamber and erupting through the magma conduit.

2. Distribute "***Riding the Magma Elevator***" narrative to every student. For each level, display the appropriate graphic.

3. Read or paraphrase, or ask a student to read the narrative for each level of the magma rising process. At each level, review whether pressure is increasing or decreasing and why.

4. For assessment, at the end of the narrative, ask students for a quick review of what processes occur at each level shown on the graphics.

Adaptations

- Read the text from this activity and have the students draw their own rendition of what magma might look like at each stage.

Extensions

- Create a play in which students act out all the elements and processes involved in a volcanic eruption.
- Direct students to explore Internet–based computer programs that simulate volcanic eruptions. Note the list of selected computer programs in **Internet Resources**.

Assessment

Look for students' recognition of the following concepts: subducting plates trigger melting of mantle to form magma; water lowers the melting of rocks for magma formation; magma rises into Earth's crust and remains in the magma chamber for extended periods of time. Some, but not all magma will move up the conduit to Earth's surface and erupt at a volcano. As the activity progresses, look for evidence that students understand that volcanoes of the Cascade Range originate in this manner, and that volcanoes in similar settings around the Ring of Fire own their origins to the same processes. To assess students' understanding, instruct students to explain the processes as noted in procedure number 4 above.

References

Decker, R., and Decker, B., 1998, Volcanoes: New York, N.Y., W.H. Freeman and Company, 321 p.

Francis, P., and Oppenheimer, C., 2003, Volcanoes: New York, N.Y., Oxford University Press, 536 p.

Kious, J.W., and Tilling, R.I., 1996, This dynamic earth: The story of plate tectonics: U.S. Geological Survey General Interest Publication, 77 p.

Rosi, M., Papale, P., Lupi, L., and Stoppato, M., 2002, Volcanoes: Buffalo, N.Y, Firefly Books, 335 p.

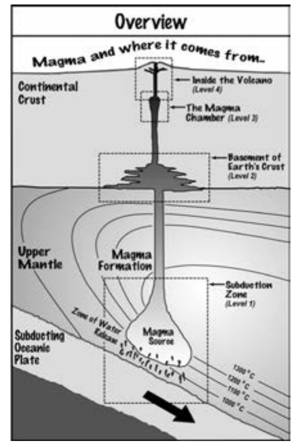
Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Student Page

Riding the Magma Elevator

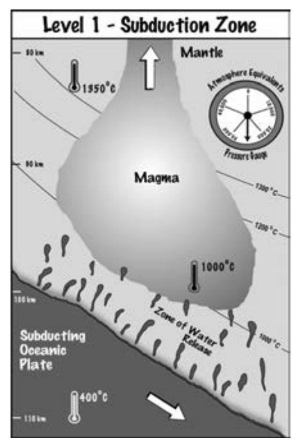
Narrative

Overview



No one has been—nor will likely reach the center of a volcano to examine directly the inner workings of an eruption. However, we can interpret what is going on by using scientific instruments—and a bit of imagination! We'll use an imaginary elevator in this activity to explore four locations crucial to the making of ***magma***: the ***subduction zone*** at **level 1**; basement of Earth's ***crust*** at **level 2**; the ***magma chamber*** at **level 3**; and inside the volcano at **level 4**. We'll make a descent down to level 1, the upper mantle and subduction zone, and then work our way upward to a Cascade volcano on Earth's surface. Put on your hard hats, this elevator's heading down!

Level 1—Subduction Zone



After a hot and dark trip downward, our elevator arrives safely in the upper ***mantle***, just above the subducting Juan de Fuca Plate, 80 to 120 kilometers (50 to 75 miles) below Earth's surface. Looking out our elevator porthole, we view dense ocean floor sediments that have sunk beneath North America. On the way down, we passed through the less dense upper portion of sediments that scraped against the continent and accumulated as great piles of rock—the Olympic Mountains and the Coast Range.

These sediments move quickly—at a speed of approximately 5 centimeters per year (more than 2 inches per year), a rate equivalent to that of your annual fingernail growth! Cold water from the Pacific Ocean helps keep temperatures comparatively cool in the subduction zone—that is, below 400° Celsius (750° Farenheit); however, temperatures here in the surrounding upper mantle are considerably hotter.

Our elevator is well-equipped with temperature and pressure sensors. We note that the pressure is extreme 2.5 gigapascals (GPa). That pressure is 25,000 times greater than pressure exerted by Earth's atmosphere at sea level, and the equivalent of 1.5 million cars stacked one upon the other, and sufficient to make mantle rock flow like road tar exposed to the warm sun. The thermometer indicates an outside temperature of 1,350°Celsius (2460°Farenheit)—sufficiently hot to warm the water within the subducting Juan de Fuca Plate. Water from the subducting slab rises into the mantle rocks. The addition of water to hot mantle rocks causes rock to melt and form magma. This magma begins to rise because it is less dense than surrounding solid mantle rock.

"All aboard," as we head upward to our next stop, the basement of Earth's crust—the Crustal Melting Zone.

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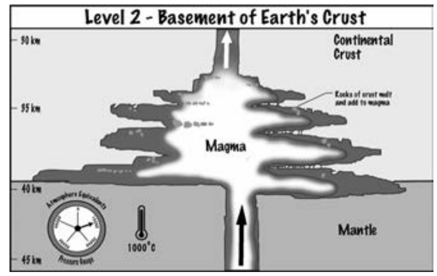
Riding the Magma Elevator

Narrative-continued . . .

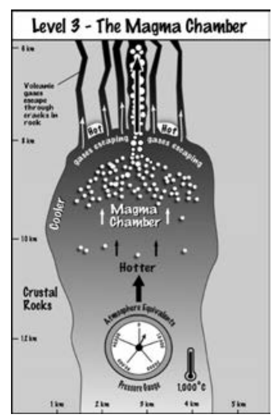
Level 2—Basement of Earth's Crust—Crustal Melting Zone Graphic



The crustal melting zone is 40 kilometers (24 miles) below Earth's surface and is the boundary between the mantle and the overlying continental crust. Our pressure gage shows a pressure of 1 GPa, or 10,000 Earth atmospheres. To our sense of touch, the magma is hot 1,000° Celsius (1,800° Farenheit). Even with oven mitts, you wouldn't want to touch this rock! The rock is pliable, unlike the hard continental crust with which we are familiar at Earth's surface. Rising magma collects at the base of the crust, slowly melting a pathway upwards—perhaps at a rate of 1 meter (3 feet) per year. From our porthole windows we note that the magma rises as a plume of hot rock, completely molten at the plume's center, and partially molten around the edges. This plume of ascending magma melts some surrounding crustal rocks, enabling bits of crustal material to hitchhike upward and form new combinations of elements within the magma.

Now it is time for our elevator to climb upward again. We're headed to the top of the magma chamber.

Level 3—Magma Chamber



We are now at the top of the magma chamber, a zone of partially to completely molten rock. At Mount Rainier, the magma chamber is located approximately 8 to 10 kilometers (5 to 6 miles) below the Earth's surface and extends several kilometers (approximately 2 miles) in width. Why does the magma accumulate here? The upward migration of magma stalls when its density equals that of the surrounding solid continental rock. Here, pressure within the magma chamber approximates 0.3 GP, the equivalent of 3,000 Earth atmospheres, and to the pressure of 180,000 cars stacked one on top of the other! The temperature remains at about 1,000° Celsius (1,800° Farenheit). In the center of the magma chamber the rock is molten and has the consistency of a hot slushy crystal mix. Temperatures and textures vary progressively from the center to the margins; a viscous (mushy) liquid that flows under pressure in the center to cooler solid rock at the chamber's outer edges.

Minerals and still uncombined chemical elements mix and mingle like at a square dance, where atoms change partners and new minerals and element patterns emerge. While the minerals and elements are square dancing, the gases separate from the magma and rise to the top of the magma chamber in search for the quickest and easiest route of escape to Earth's surface.

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Riding the Magma Elevator

Narrative-continued . . .

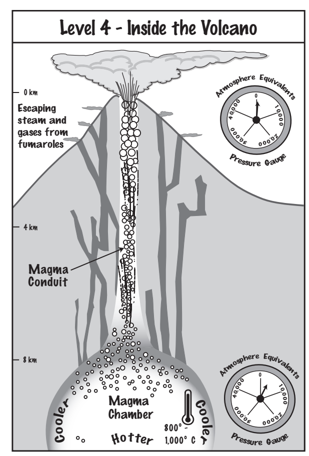
Here the magma rests, often for thousands of years, while it continues to cool, crystallize, form minerals, and receive replenished magma from below. Minerals mix and mingle with crustal rocks. Hot magma remains trapped beneath Earth's surface until the pressure within the magma chamber exceeds the strength of surrounding crustal rocks, forcing a volcanic eruption.

Some magma never makes the journey to the volcano above. It cools and hardens in place, and after thousands of years, the minerals within grow large and form a rock called ***granodiorite***. We see it at Earth's surface today, exposed by erosion.

Our elevator will follow magma as it erupts from the volcano. So hold on, here we go!

Level 4—Inside the Volcano

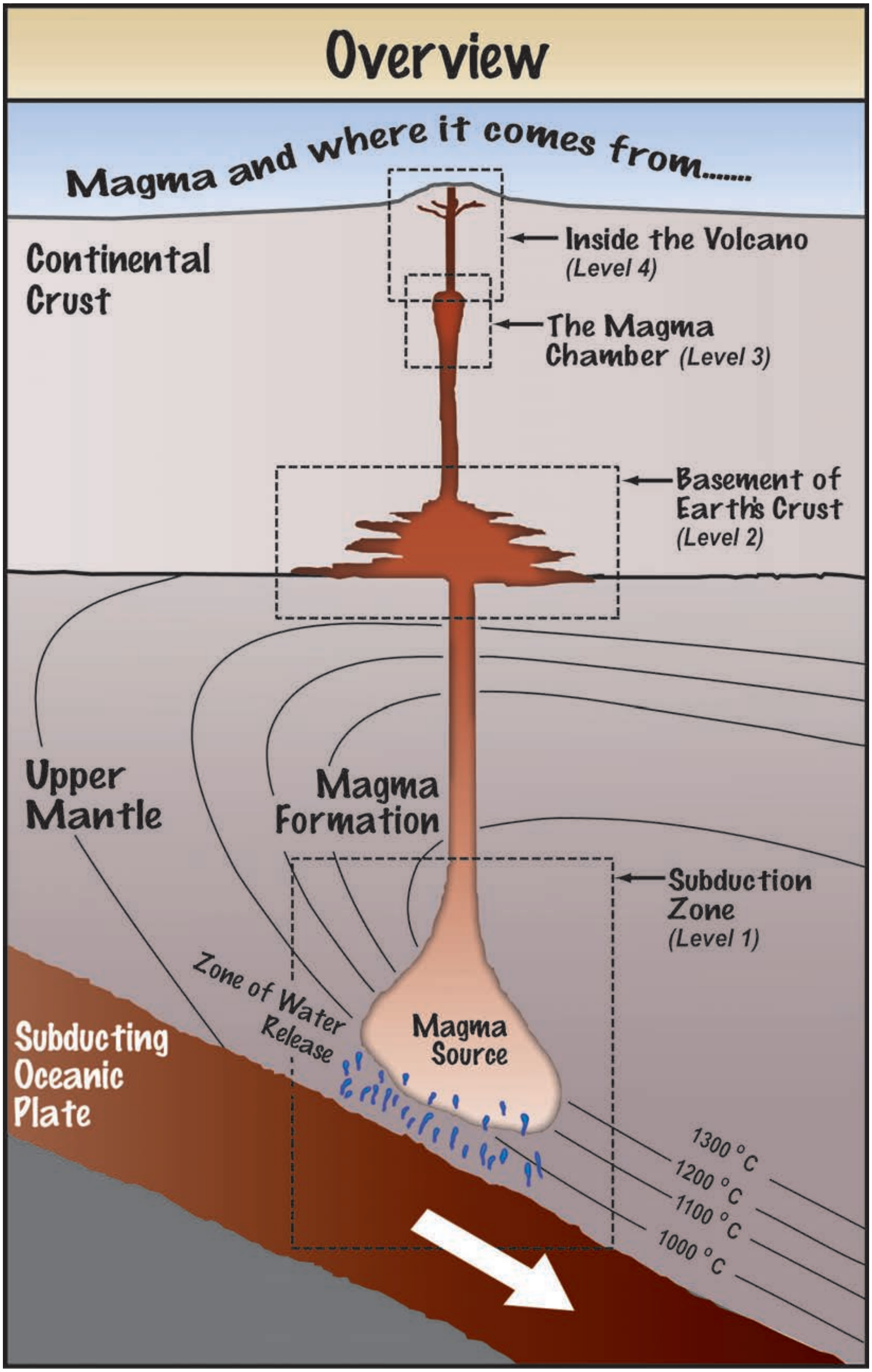
When pressure in the magma chamber is sufficient, magma forces open a narrow pathway that extends up to the Earth's surface, called a ***conduit***. During non-eruptive times, the conduit is filled with solid rock and debris from previous eruptions, which traps debris, ***volcanic gas*** and magma like a cork in a bottle. This conduit acts as a superhighway for magma erupting from the volcano. Magma can reach speeds of 50 to 100 meters per second (160 to 300 feet per second) as it rushes upward.

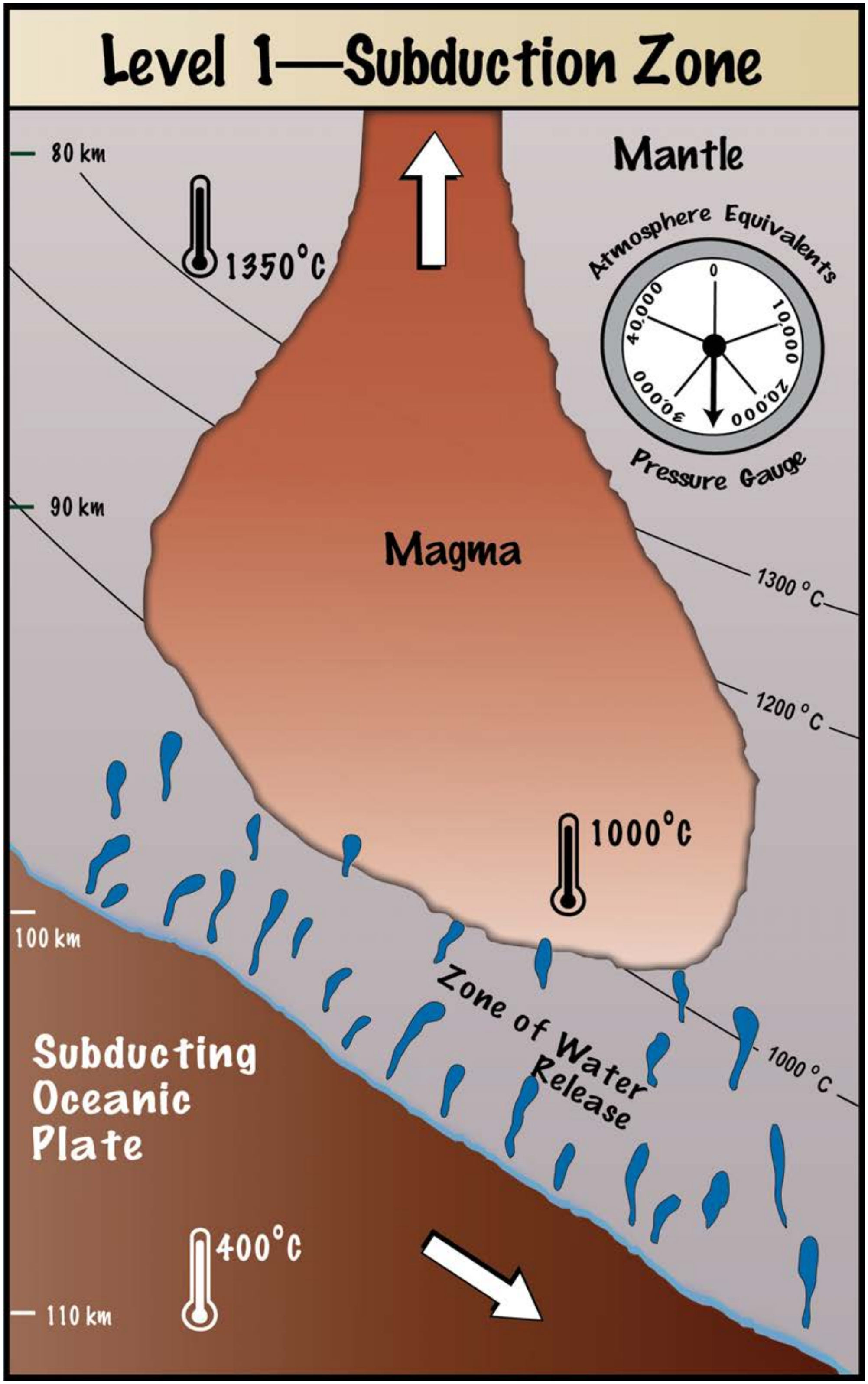


It takes only a few minutes for magma to rush from the magma chamber to the ***vent*** of the volcano during an explosive eruption, a distance of 8 to 10 kilometers (5 to 6 miles). Gas-rich magma escapes first, often blasting surrounding magma into billions of shards of ***volcanic ash***. ***Lava*** then squeezes or flows from the vent. The conduit sometimes overflows, and magma squeezes into cracks within the volcano forming ***dikes***.

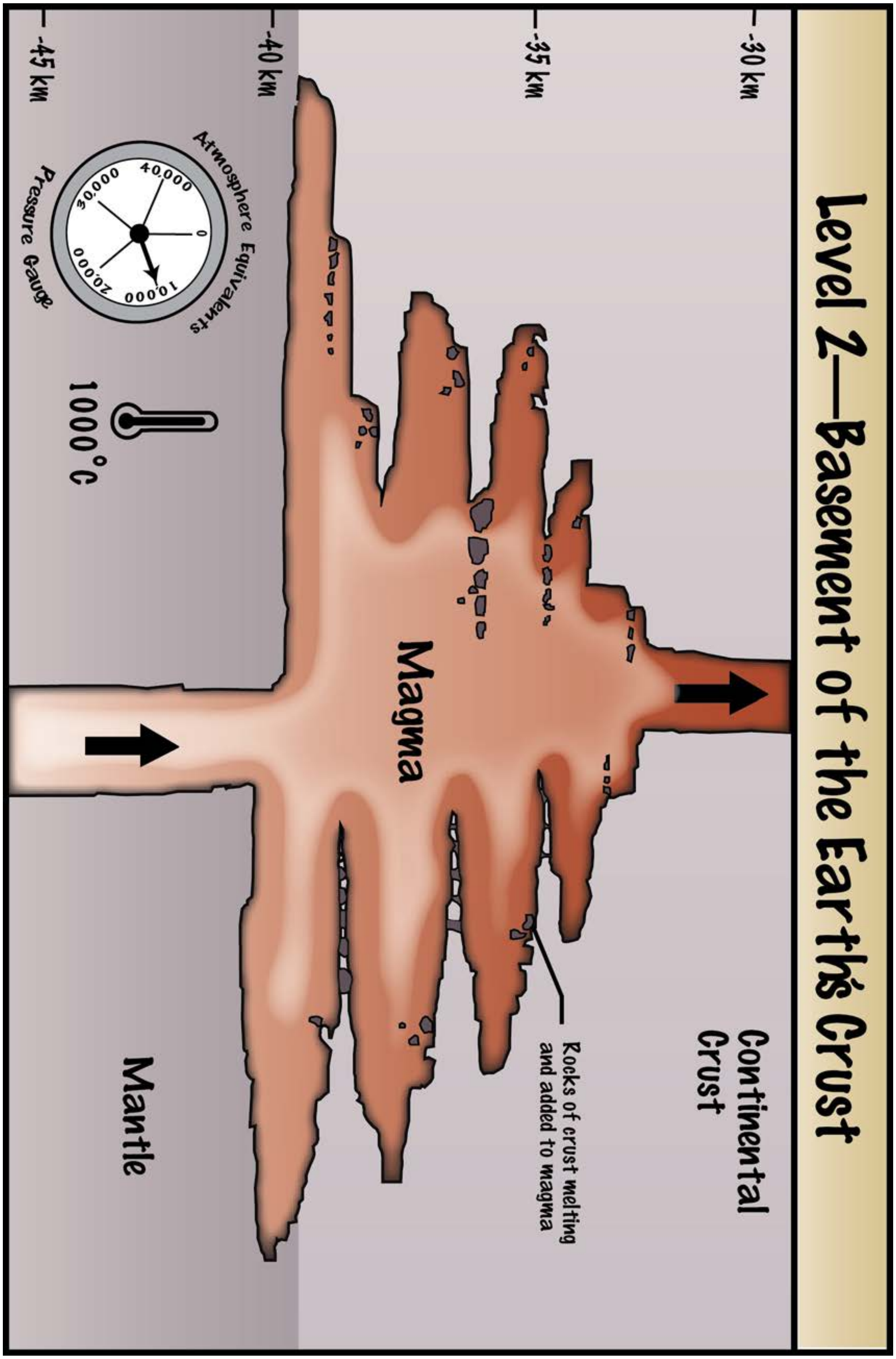
Hold on, because we are about to explode out of the volcano along with lava, ash, and gases. Here we go!

To learn what happens after an eruption, move on to **Soda Bottle Volcano** and Chapter 2 activities of this guide.

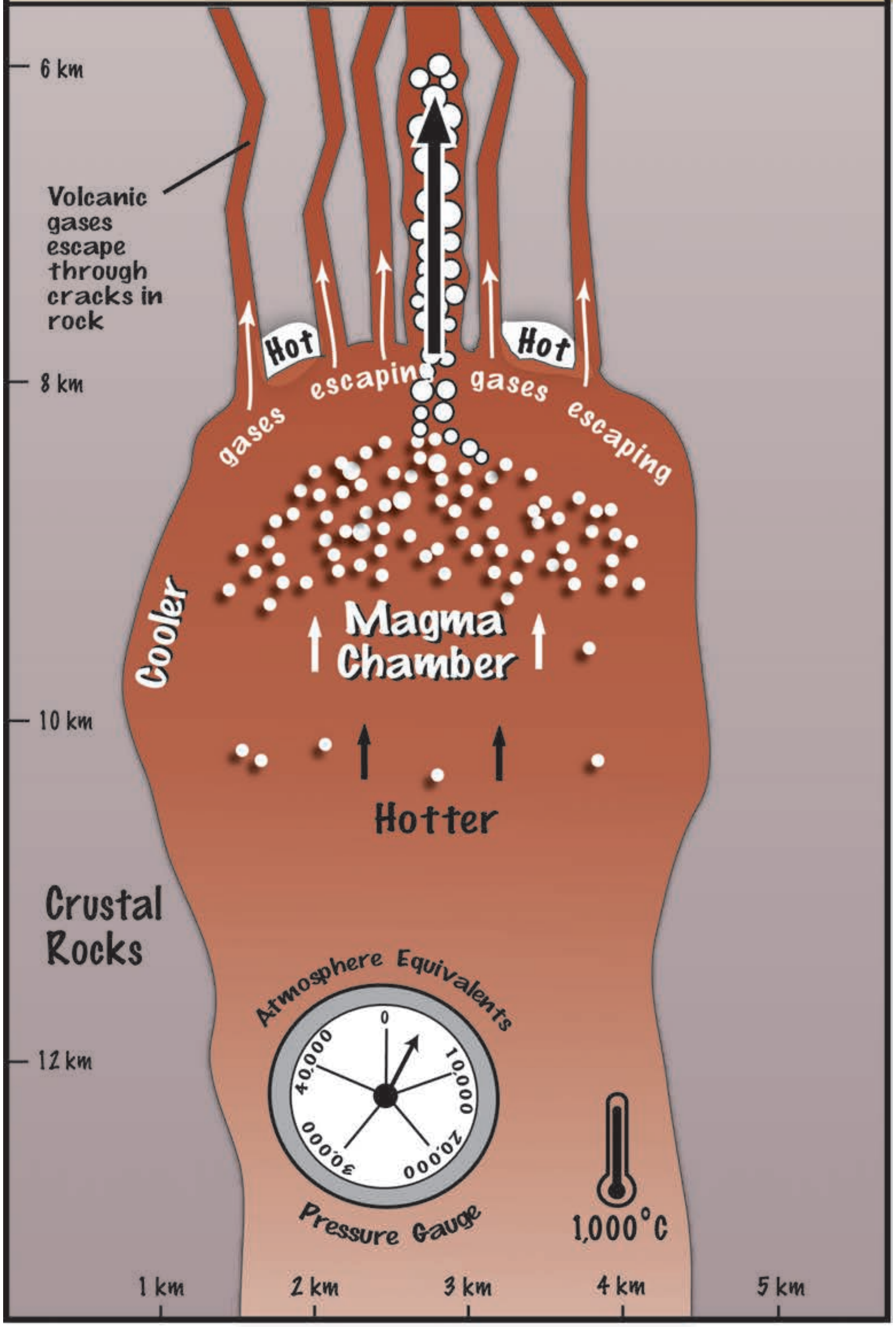

Overview
Magma and where it comes from.......
Continental Crust
Inside the Volcano (Level 4)
The Magma Chamber (Level 3)
Basement of Earth's Crust (Level 2)
Upper Mantle
Magma Formation
Subduction Zone (Level 1)
Zone of Water Release
Magma Source
Subducting Oceanic Plate
1300 °C
1200 °C
1100 °C
1000 °C



Level 1—Subduction Zone
80 km
1350°C
Mantle
Atmosphere Equivalents
0
10,000
20,000
30,000
40,000
Pressure Gauge
90 km
Magma
1300 °C
1200 °C
1000°C
100 km
Zone of Water Release
1000 °C
Subducting Oceanic Plate
400°C
110 km


Level 2—Basement of the Earth's Crust
-30 km
-35 km
-40 km
-45 km
Continental Crust
Rocks of crust melting and added to magma
Magma
Mantle
Atmosphere Equivalents
40,000
30,000
20,000
10,000
0
Pressure Gauge
1000°C

Level 3—The Magma Chamber



Level 4—Inside the Volcano