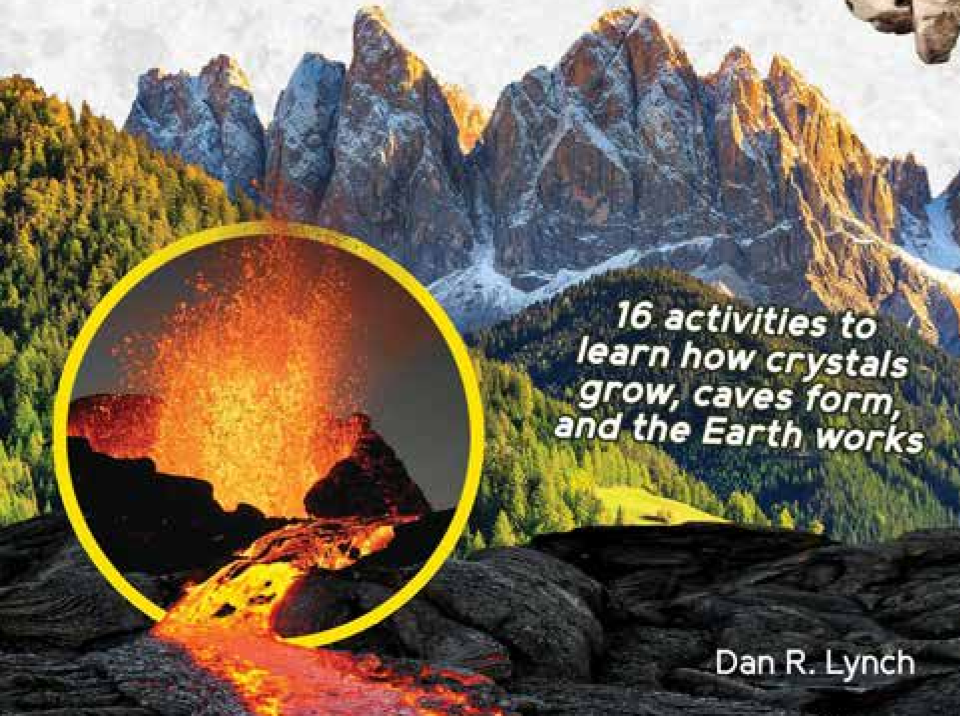
The Earth Book for Kids

An Introduction to Earth Science



16 activities to learn how crystals grow, caves form, and the Earth works

Dan R. Lynch

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An Introduction to Earth Science

Acknowledgments

Dan would like to thank his wife, Julie, for her unending love, support, and patience, and his friends, Emily Dix and Steve Turnbull, for their constant encouragement.

Disclaimer Kids should always be accompanied by an adult when outdoors, and it's your responsibility to recognize, and avoid, the potentially dangerous bugs, insects, plants, or animals in your area. Always be aware of the weather and your environmental surroundings, and stay off private property. Never collect anything unless you're certain you have permission to do so. Rock collecting is not allowed in national parks, on Native American reservations, and in most state and local parks. Collecting Native American artifacts is also illegal on public lands.

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The Earth Book for Kids: An Introduction to Earth Science

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The Earth Book for Kids

An Introduction to Earth Science

Dan R. Lynch

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Table of Contents

Introduction to Geoscience

The surface of the Earth is an exciting patchwork of soaring mountains, deep oceans, and vast plains and deserts. But as amazing as these places are, the science of how they formed is even more incredible! That's because as solid as the ground beneath our feet seems, the Earth is always changing. Inside the Earth, deep underground, it is very hot, and the rocks are soft and move slowly. Everything above them—including us and the ground we walk on—moves with those rocks!

And change is always happening on the surface, too. When it comes to geology, nothing lasts forever—rivers, mountains, and even entire continents move—and they will disappear someday. And by looking at the Earth today and how its continents and oceans fit together, we can figure out what the world looked

like long ago. We can even predict what the planet will look like in the future!

The study of how the Earth and its features form and change is called **geoscience**. Someone who works in geoscience is called a **geoscientist**. There are lots of different kinds of geosciences—some geoscientists study the atmosphere (the air), some study the hydrosphere (the water), and others study the biosphere (how plants and animals interact and evolve). In this book we're going to focus on **geology** (the study of rocks and how they can change) and the **lithosphere**, which is the hard outer layer of the Earth where we find all the mountains, lakes, plants, and animals.

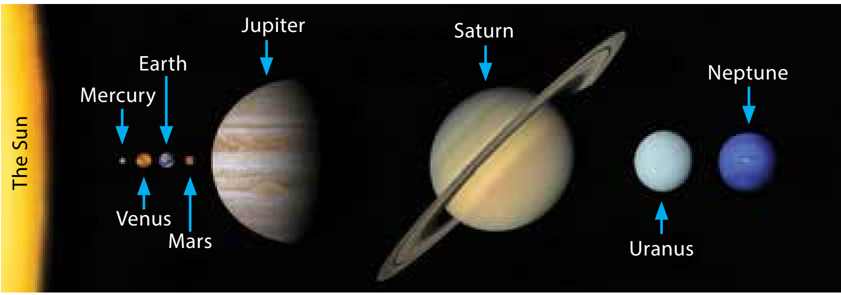
The Earth is a special place, and incredible things happen deep beneath our feet, but you are probably wondering how it all works! We'll talk all about it in this book, but first we need to know: What is the Earth?

The Earth and What It's Made of

What do you think the Earth is made of? You might say that it's made of rocks. And that's true! But rocks are made of mixtures of special chemicals called minerals. When lots of minerals form together in the same space, they grow together to become a rock. But what are minerals made of? To answer that, we have to look a lot closer at the tiny particles that make up minerals and everything else in the universe, including you and me: atoms, elements, and molecules. In this chapter, we'll talk about all the little "building blocks" that make up our world!

What Is the Earth?

Earth is the third planet in our **Solar System**; the first four planets in our solar system are rocky planets; the outer four planets are gas giants (they have atmospheres of thick gas, but not much "ground" to speak of). So far, Earth is the only planet we know of that has life, like plants, animals, and humans. All the planets orbit the Sun, which means they spin around the Sun on an oval-shaped path.



Our solar system. Earth is the third planet away from the Sun. The size comparisons between the planets are true to life, but in reality the planets are much farther apart.

Most of Earth is made up of rock, but depending on where in or on the Earth you look, the rocks can be very different. Rocks on the Earth's surface (the kind you can find and pick up) are cold, hard, and brittle, which means that even though they are very tough,

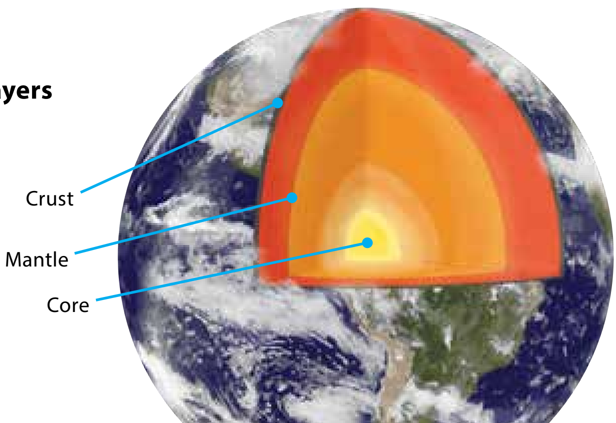
Minerals make up the Earth, and all of the rocks that we see have lots of minerals inside them. When they have enough room to grow, minerals form crystals, which are special shapes that minerals can make. These are crystals of quartz *(say it "kwarts")*, one of the most common minerals of all!

they can break. But many of the rocky areas inside the Earth are very hot—so hot that the rocks can be soft and will bend rather than break! The Earth gets hotter and hotter toward the center, and at the very middle is a core formed of solid metal. The Earth stays hot inside because its rocks are very good at holding in heat and also because gravity inside the Earth and radioactive minerals (special crystals that release energy) make new heat.

If we were able to cut open the Earth, we'd see that it is made of several **layers**. Some layers are hard and others are soft, but they all get hotter as they get closer to the middle of the planet. The layer most important to us is the **crust**, which is the very top layer, on the outside of the planet. It's the coldest and hardest layer. The crust is where all the rocks you've ever seen are found, and it's the layer we live on. But the other layers below it can affect and change how the crust looks—they can even make the crust break and move! We will discuss how all the layers interact later in this book.

The Earth's Layers

If we could cut into the Earth, we could see that it is made of layers.



So now we know that the Earth is formed of rocks that are arranged into different layers, and that each layer is composed of different kinds of rocks. But what are rocks, and what are they made of?

This is a piece of granite, one of the most common rocks in the Earth's crust.

ROCKS AND MINERALS

Rocks and minerals are the materials that make up the Earth, and they can be found anywhere beneath your feet. But what's the difference between them?

Quartz *(say it "kwarts")* is a common mineral that forms pointed crystals. The purple kind of quartz is called amethyst *(say it "am-eh-thist.")*

A **mineral** is a special kind of hardened natural material. Minerals form when certain chemicals combine together and harden. For example, common table salt is actually a mineral called halite *(say it "hay-lite")*. Halite forms when two **elements** called *sodium* and *chlorine* combine together to make a chemical called *sodium chloride*. When sodium chloride hardens, it becomes halite.

A halite crystal

What makes minerals special is that when they harden, they form **crystals**, which have a special shape depending on the mineral. Halite forms crystals shaped like cubes, or blocks. (If you look at table salt through a magnifying glass, you may see little cubic crystals!)

Rocks are also hard, solid, natural materials, but they are made up of mixtures of minerals. Different kinds of rocks can have totally different mixtures of minerals in them. Some rocks have lots of different minerals in them while others have only a few. Sometimes the minerals in a rock are big enough to be seen as spots of color, but in other rocks they may be too small to see.

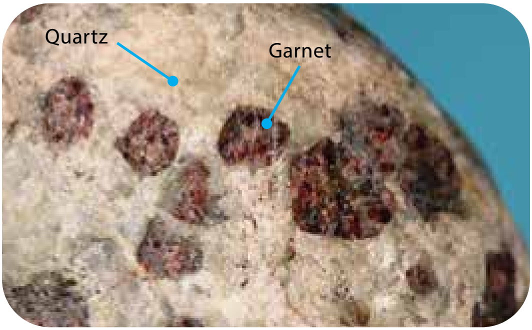
Rocks make up all of the landscape that we can see and are always underfoot. And even if you can't see rocks—say, in a

This is red granite, a type of rock. Each colored spot is a different mineral.

grassy park—that just means they're covered up. If you dig down deep enough, you'd eventually hit **bed-rock**, which is the first layer of hard rock found below all the grass, loose dirt, soil, and mud.

A lot of changes can happen to rocks as they get older. This rock, called gneiss *(say it "nice")*, got its wavy layers after being exposed to lots of heat and weight deep underground.

Minerals form inside rocks, both as *part* of the rock as well as in the spaces and cracks hidden in them. You can find minerals as the little spots of color that are stuck tightly in a rock, but if you're lucky, you'll also find nice mineral crystals hiding in a hole or crack in a rock. When they form inside a hole, they may be found on the walls of an opening, and you might be able to see their full crystal shape.



This is a rock. The red spots are a mineral called garnet, and the white areas are a mineral called quartz. They are formed tightly together in a solid piece, which makes it a rock. The garnet and the quartz are both parts of the rock.

The hole in this rock also contains garnet and quartz. The garnets are the little red crystals and the quartz is the white, glassy crystals. They're the same minerals as in the rock above, but they had more space to form, so we can better see their shapes!

To understand the difference between rocks and minerals, it's helpful (really!) to think of ice cream. Ice cream is made of different ingredients, like cream, sugar, and flavorings. Once the ingredients have been blended together to make ice cream, you couldn't separate them again without melting and ruining the ice cream. Minerals are the same way—the ingredients in them are elements, and you can't easily separate them.

Now, imagine that ice cream is a mineral, and that bananas, chocolate, and nuts are minerals, too. When you mix them together to make an ice cream sundae, that's a lot like different minerals forming together to make a rock! The sundae is like a rock because lots of distinct things combined to make it. But if you wanted to, you could pick out the nuts and still have a sundae.

Of course, a sundae isn't hard and solid like rocks and minerals are, but it is a tasty illustration of how many different parts can come together to make something totally different!

WHAT MAKES A MINERAL?

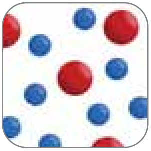
Minerals are made up of certain chemicals that form naturally in the Earth. Chemicals are made of **elements**, which are special materials that are often called "building blocks" because everything is made up of combinations of elements, even you and me! You've probably already heard of many different elements; iron, copper, gold, oxygen, and helium are a few common examples. Elements are made up of **atoms**, which are so small that you need a very powerful microscope to see them. When atoms of different elements come together, they can **bond**, or attach, to each other. When atoms are bonded together in a group, it's called a **molecule** *(say it "mall-eh-cule")*. And when lots of the same molecule come together, they stick to each other and form a larger group. It's a lot like making a small snowball, then rolling it around in the snow to make more snow stick to it, making it larger.

Molecules are very tiny, but under a microscope we can see that each kind of molecule has a particular shape. When many molecules of a certain

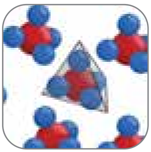
These are crystals of quartz, sometimes called "rock crystal," which is one of the most common minerals.

kind come together and harden, they make a mineral, and the molecules' shapes determine what the hardened mineral will look like. This is how crystals form. A **crystal** is a hardened mineral that gets a special shape from the way its molecules have come together.

Here's an example of how it works, using the mineral quartz *(say it "kwarts")*:

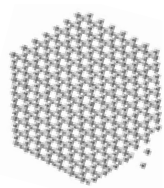


Atoms (tiny particles) of different elements can come together and bond, or stick to each other. In this example, the blue atoms are the element oxygen, and the red atoms are the element silicon. These are the two elements that make up the mineral called quartz.



When oxygen and silicon come together, they bond in the shape of a little pyramid, with four oxygen atoms surrounding one silicon atom. They stick together like this because of each element's special traits. Once they have bonded together, they have become a **molecule**. Molecules of oxygen and silicon make a chemical called **silica**. (We can draw a pyramid around the silica molecules to make them easier to look at.)

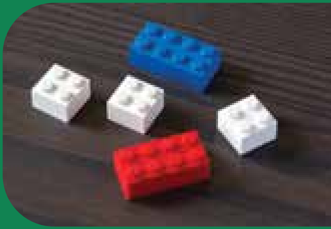
When lots of silica molecules (shown here as little pyramids) come into contact with each other, they begin to bond and build upon each other like a snowball rolled in the snow. The clump of molecules grows bigger in all directions as more molecules join it. But molecules stick together in a very organized way. See how a pattern begins to form?



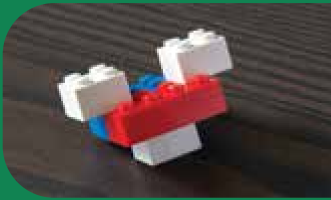
Eventually, when enough molecules have come together and hardened, they become a **crystal**. This illustration shows how a crystal shape can develop when enough molecules have bonded.

This is a quartz crystal viewed from above. See how it has the same six-sided shape as the group of silica molecules above? Even big quartz crystals will have a six-sided shape, all because of the way the tiny silica molecules within them came together.

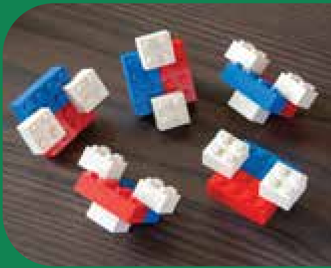
Build Your Own Molecules and Crystals



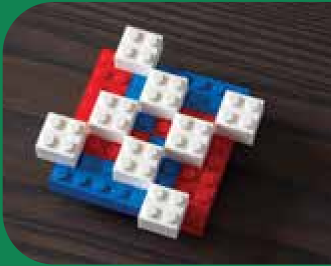
Using toy blocks, you can learn a little about atoms and molecules and even build your own model crystals at home!



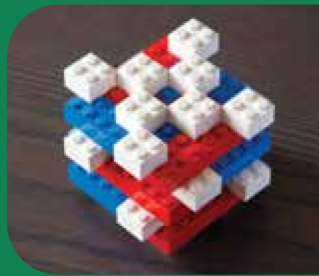
In this activity, we use toy blocks to show how atoms form crystals. Pretend that the blue blocks, red blocks, and white blocks are atoms of three different elements; each color represents different kinds of atoms.



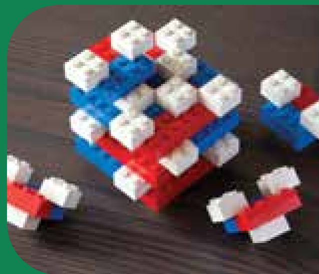
Using these blocks, you can make a small shape with them. This is similar to how atoms bond together to make a molecule! Keep making the same exact shape until you have lots of the same molecules.



Real molecules will start to stick together, and they do so in certain patterns. So you can start putting your toy molecules together, being careful to attach them all the same way. After you've put several of them together, look at the shapes they make. Can you see a pattern beginning to appear? This represents how real molecules stick together in a neatly organized way.



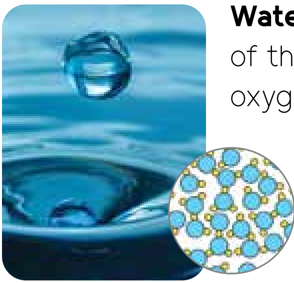
If you keep carefully building the same pattern and add your toy block molecules onto the top and sides of each other, you'll start to see a shape appear. See how this group of toy molecules is making a cube, or a blocky square shape? The molecules themselves aren't shaped like a cube, but when they all come together and build on each other, they start to make a cube. This is a lot like how crystals get their shapes!



This is a real crystal of pyrite (*say it "pie-rite")*, a mineral. Pyrite forms crystals that are shaped like perfect cubes! Pyrite molecules are so small that we can only see them with a powerful microscope. We know that a single pyrite molecule isn't cube-shaped at all, but when many come together, the special traits of their atoms cause them to bond in a blocky shape.

MOVING MOLECULES

Molecules and the atoms that comprise them are always moving. They have energy, and they don't just sit still. Even in rock-solid objects, atoms are vibrating and bouncing off each other all the time. But how much they move is often a matter of how hot they are. The hotter an atom or molecule is, the more it and its neighbors will move and bump each other. The colder they are, the more the stay in place. While molecules themselves are too tiny to see, you can still see how they move around by looking at water.



Water is a natural chemical. It consists of the elements called hydrogen and oxygen. At room temperature, water is a **liquid**, and its molecules are jumbled up and disorganized. There is also enough space between each molecule that they have room to move. So when you put your hand in a bucket of water, the jumbled up molecules are able to bounce around each other to make room for your hand.

As water heats up, its molecules move more and more. And when water gets hot enough, it boils, which means the molecules are moving and jumping around a lot! But boiling water also makes steam. Steam happens when water molecules become so energetic that they bounce away from their neighbors and leave lots of space between them—so much space that they begin to float away into the air. When this happens, we call it **gas**, and steam made from water is a gas.

When water becomes cold enough to freeze, its molecules can't move nearly as much, and they begin to settle down. When they are moving less, they can start to stick together. And when water molecules start to stick together, they do so in an organized way because of the special traits of their atoms. When the water molecules have frozen into place, we call it ice, and ice is a **solid**. And, believe it or not, ice is actually a mineral! It also has crystals. Have you ever taken a close look at a snowflake? Snowflakes have six sides because of how water molecules bond to each other. That means that every snowflake is a water crystal!

But why is all this important when we talk about rocks and minerals? Well, because when rocks heat up or cool down, their molecules move in the same ways!

HOW AND WHERE MINERALS FORM

Now that you know that molecules move around more when they are hot and are able to bond together and form crystals when they cool down, you may be wondering how this happens in the Earth. Minerals can form in many different places and in many different ways, but many result from a similar process.

Hot mineral molecules are energetic and can become mixed in with other kinds of molecules. An example is when you mix table salt into hot water. (Remember that table salt is actually a mineral called halite.) When salt is put into hot water, its molecules spread out and mix in with the water, and the salt disappears. When something like a mineral disappears into water or another substance, that mineral has **dissolved** *(say it "dizz-olvd")*. Its molecules are still there, but they have become separated from each other. When table salt, or halite, dissolves into water, the mixture of salt and water is called a **solution** *(say it "soh-loo-shun")*.

When a solution containing mineral molecules cools off, the mineral molecules stop moving as fast, and they can start to bond together and form a crystal. This is called **precipitation** *(say it "pree-sip-it-ay-shun")* and you can see it at home by dissolving a few scoops of salt in a glass of hot water, then waiting a few days for the water to cool off and dry up. If you're patient, you'll see a crust of salt crystals at the bottom of the cup! They precipitated out of the solution of warm

The Dead Sea in Israel is so salty that when the water dries up, lots of salt crystals precipitate on the shore.

water and salt because the salt molecules were able to bond together as the water dried up.

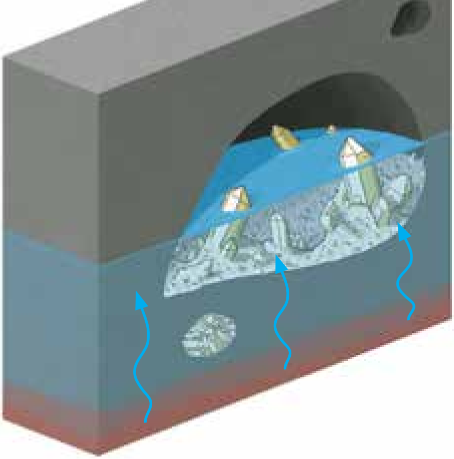
When water inside the Earth is heated up by the hot areas underground, it can dissolve minerals in it. The water can then move around and soak into rocks, and after it cools off, it will leave crystals behind. But how does the hot water move?

When molecules heat up and move around a lot, they leave more space between them, and they spread out from each other. For example, if you have a jar full of liquid water and a same-sized jar full of hot steam, the jar of liquid contains many more water molecules than the jar of steam does. Because the jar of water has more molecules in it, we say that it is more dense than steam; steam is less dense than liquid water. Things that are more dense will sink below things that are less dense, so the hotter water gets, the more it will rise above cooler water. This means that hot water and especially steam will rise above cold water. When you mix hot and cold water, the hot water will rise to the top and the cold water will sink to the bottom. This is called convection *(say it "con-veck-shun")*.

Convection doesn't just happen with water! It happens in air, too. Have you ever been in a hot room and found that it was cooler down by the floor? That's because hot air rises (this is how hot air balloons float up). Convection also happens in the hot, soft rocks inside Earth! That means hot rocks actually float above cold rocks—we'll talk about this a lot more later on.

A lava lamp is a fun way to see convection working. When the "lava" inside is heated up, it rises to the top of the bottle, and when it cools down again, it sinks.

Inside the Earth, convection also makes hot water (often containing dissolved minerals) rise up and soak into the rocks above it. When the water cools off, it precipitates minerals and their crystals in the spaces inside the rock.



When warm water containing minerals rises up into the spaces in rocks, it can cool down and leave crystals behind. This illustration shows water partly filling a hole in a rock and precipitating crystals.

This group of crystals filled a hole in the rock when hot water containing dissolved minerals soaked into it, then dried up.

Not all minerals form in hot water. Some form in red-hot melted rocks! Deep in the Earth where it is very hot, some rocks melt and turn into a thick glowing liquid called **magma**. If magma gets pushed up to the Earth's surface where we can see it, then we call it **lava**. This super-hot melted rock contains tons of dissolved minerals, and when it cools, the minerals precipitate a lot like they do from water! In fact, there are so many dissolved minerals in magma that when they precipitate, their crystals pack together tightly and form a hard, solid mass. Solid masses of different minerals are called **rocks**!

Minerals can form in other ways, too, but precipitation from water or magma is one of the most common ways.

Grow Your Own Crystals

To get a better idea of how hot water full of dissolved minerals can make crystals grow, you can actually grow your own at home!

- Alum in granular or powder form, about 1.5 cups

  Note for adults: Alum consisting of potassium aluminum sulfate is best for this activity (it should specify on the label). Also, be aware that this activity can stain pans and utensils.

- Water, 1.5 cups
- A 1-quart wide-mouth glass canning jar
- A small saucepan
- A stirring utensil
- A piece of string at least 5 or 6 inches long
- A pencil, dowel, or other short stick

Then, with an adult's help, carefully follow these steps:

1. Boil 1.5 cups of water in a saucepan
2. Carefully begin to add the alum powder one tablespoon at a time, stirring to dissolve the alum into the water. This makes a solution.
3. Keep adding alum until you've stirred in about 24 tablespoons. At this point, you will have oversaturated the water and you may see undissolved grains at the bottom of the pan.
4. Carefully pour the hot, alum-rich solution into the open jar.
5. Tie the string to the pencil and place it across the top of the jar, allowing the string to dangle into the solution. Center the string so that it is not touching the jar.

6. Wait 45–60 minutes for crystals to grow. Be careful not to shake or bump the jar as movement can disrupt crystal growth.

7. After 45–60 minutes, carefully lift the string to see what crystals have grown! You may find that one large crystal has grown, or maybe that several smaller ones formed along the string. The longer you leave the string in the water, the larger the crystals will grow. However, if you leave it too long, they may grow so large that they fill the bottom of the jar and you won't be able to get them out.

Let's look at the science happening:
alum powder, like salt or sugar, will dissolve in cold water, but only a little. Cold water won't hold very much dissolved alum in it. But if you heat up the water, a lot more will dissolve in it. When the water starts to cool down, it can no longer hold the dissolved alum, which begins to clump together and harden. This is called precipitation, and as it precipitates, it starts to crystallize. The crystals form on the string because they can stick to the string better than they can to the jar.

SECONDARY MINERALS

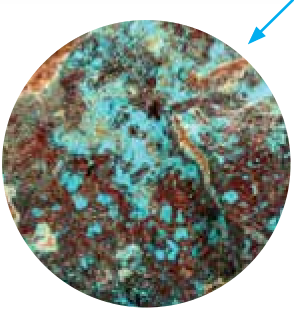
Not all minerals form when they precipitate out of water or magma. Some minerals form when older minerals lose molecules. As older minerals are affected by weather, especially by rain and water, molecules can be separated from them. As water carries those molecules away, they can then bond with other, totally different molecules. New minerals can form as a result, and they can look completely different from the older mineral that provided the molecules! These are called **secondary minerals**, and they can form right on top of the older mineral or far away from it.

Copper is a good example. Copper is an element that forms naturally as a mineral. It is a reddish-orange metal. But when water and other chemicals carry away and change its molecules, lots of secondary minerals can form. And many of copper's secondary minerals are very colorful! If you've ever seen a copper penny with some blue or green crust on it, those are secondary minerals! Secondary minerals can form right on top of copper in nature, too, or inside the rocks around the copper.

This is a natural piece of copper. It doesn't look very coppery, does it? That's because it's coated in lots of secondary minerals. All of the blue, green, and dark reddish-brown spots are different minerals that grew on top of the copper.

Copper can produce many secondary minerals, and lots of them are colorful! Here are a few examples:

Copper



Chrysocolla

Cuprite

Malachite

COMMON AND IMPORTANT MINERALS

The minerals here are some of the most common ones on Earth, and all of them help form the makeup of many different kinds of rocks. You'll find these as mineral grains inside rocks:

Quartz *(say it "kwarts")*
Quartz is one of the most common minerals on Earth, and you can find it just about anywhere. It is very hard, white or clear, glassy, and forms six-sided crystals. It is most abundant as the little white spots in rocks like granite.

Feldspars *(say it "feld-spars")*
There are many different kinds of feld-spar minerals, and they are all closely related. They are very common, espe-cially in **igneous** (page 33) rocks. They often grow blocky, light-colored, opaque (not see-through) crystals, but they are most common as the tan or gray spots in rocks like granite.

Micas *(say it "my-kas")*
There are lots of different kinds of mica minerals, but all of them form as very thin, flaky crystals. Mica minerals are often very shiny, too, so if you ever find a speckly rock with lots of shiny "glitter" spots, those are usually mica minerals.

Amphiboles *(say it "am-feh-bowls")*
Amphibole minerals are a group of closely related minerals that are usually dark in color and often have a fibrous texture, almost like the texture of wood. Amphibole minerals are most often seen as the dark spots in light-colored rocks like granite.

Pyroxenes *(say it "pie-rock-seens")*
Pyroxene minerals are a group of minerals that are usually dark (often black) in color and have a glassy shine to them. They are most common as black shiny spots in dark rocks like gabbro.

Olivine *(say it "olive-een")*
Olivine is a glassy, green mineral that helps build dark-colored rocks like gabbro. It is pretty common inside rocks, but it is usually so small that you need a magnifying glass to find its grains.

Calcite *(say it "kal-site")*
Calcite is a very common mineral that is soft, glassy, translucent (it lets some light through it), and can form both as pointy crystals or as blocky crystals. It is common in sedimentary rocks like limestone.

WHAT'S IN A ROCK?

Rocks are made up of mixtures of different minerals all tightly packed together. Each kind of rock has a different mixture of minerals in it, and if the mixture changes, it becomes a different type of rock. Some rocks are **coarse grained**, which means that they have lots of colored spots and speckles that you can easily see. In coarse-grained rocks, each spot of color is a mineral grain that grew to a large size, and each different-colored grain is a different mineral. Granite is a good example. But other rocks are **fine grained**, which means that their minerals didn't grow very large at all. Some fine-grained rocks have mineral grains so small that you can't easily see them, and the rock will look like it is a solid color without colored spots.

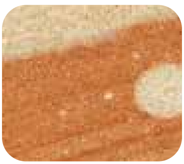
This colorful rock is red granite. Each different colored spot is a different mineral. Here are four of the main minerals in granite and what they look like when they form on their own as crystals.

THE THREE MAIN TYPES OF ROCKS


Granite (felsic)


Gabbro (mafic)

Igneous rocks *(say it "ig-nee-us")* are rocks that formed from magma or lava (melted rocks) either deep inside the Earth or on the Earth's surface after a volcanic eruption. Igneous rocks that formed inside the Earth are called **intrusive**, and ones that formed on the surface are called **extrusive**. All igneous rocks come in two main types: **felsic** *(say it "fell-sick")*, which are usually light-colored, and **mafic** *(say it "may-fick")*, which are usually dark-colored.


Sandstone

Sedimentary rocks *(say it "sed-e-ment-air-ee")* are formed when little grains of material, like sand or mud, stick together and harden. This usually happens underwater in wide, flat formations called **beds**.


Gneiss

Metamorphic rocks *(say it "met-a-morf-ik")* formed when older rocks are squashed by lots of weight, heated by the hot Earth, or both. The heat and pressure can change the rock and turn it into a new type of rock. Metamorphic rocks can begin as igneous, sedimentary, or even other metamorphic rocks.

Inside Our Earth

Our planet Earth is an incredible place, and even though it is billions of years old, it's still changing! Earth has several layers, and the closer they get to the middle of the planet, the hotter the layers are. This means that deep below our feet, it is so hot that even solid rocks become soft and can even melt. And when the rocks are soft, all of the weight piled on top of them makes them move very slowly. These things are happening all the time, and they can make mountains grow taller, break huge rocks, and even move the continents around the world! From the crust to the core, in this chapter we'll talk all about what's inside our Earth.

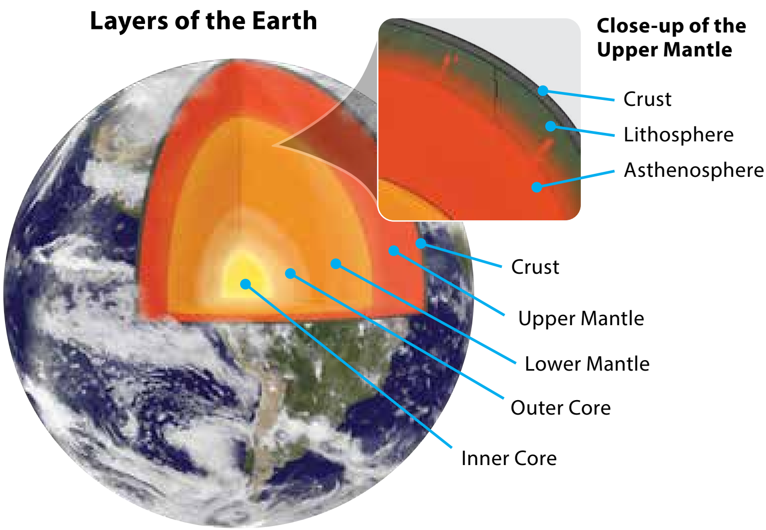
Layers of the Earth

The Earth is made up of different layers, and each layer is hotter than the layer above it. The top layer, on the outside of the planet, is called the **crust**. The crust is the layer that all the plants, animals, and people you know live on top of. It is made up of cold, hard rocks. All of the mountains, valleys, plains, and other landforms you've ever seen are part of the crust. But the crust is thin (compared to the mantle and the core), and it is affected and changed by the layers of the Earth found below it.

The next layer down is called the **upper mantle**. Even though it's too deep to see, it's still one of the most important layers because it can cause lots of changes to the crust above it. It is divided into two parts: a warm, thinner upper layer called the **lithosphere** *(say it "lith-oh-sfeer")* and a hotter, thicker lower layer called the **asthenosphere** *(say it "as-theen-oh-sfeer")*. The lithosphere is hard and rigid and made of dense rocks. But the asthenosphere is so hot that the rocks there are soft and can move slowly when weight presses on them, a lot like warm candle wax. And just like water in a bathtub, hotter rocks in the asthenosphere rise upward and cooler rocks sink downward because of convection. This means that the asthenosphere is always moving and hot rock is rising.

The inside of Earth isn't just old, cold rock—it's hot and always moving! Volcanoes offer us a tiny glimpse inside our amazing planet, but there's a lot more going on beneath our feet!

Below the upper mantle is the **lower mantle**, which is very hot but is still hard and solid because it's too deep and the pressure is too great for rocks there to melt. And at the very center of the Earth is the **core**, which is composed mostly of iron! The core is divided into two parts: the **outer core**, which is so hot that the metal is in a molten liquid form that swirls around, and the **inner core** which is even hotter but is so deep and under so much pressure that it stays a solid ball of metal.



But how do all of these layers interact to make mountains and oceans? And why are some layers soft and some stay hard? Let's take a closer look at how the Earth's layers work.

INSIDE THE EARTH: HEAT AND PRESSURE

It is very hot inside the Earth—so hot that it can melt rocks!—but not all of the Earth's hot layers are soft. So why do the rocks in some hot layers get so soft that they can flow and move like hot wax while the rocks in other deeper layers are even hotter but stay solid?

We've all seen an ice cube or candle melt, but what is actually going on when that happens? When solid materials like rocks are heated, the molecules within them start to move more and more the hotter it gets (see page 20 to review how heat makes molecules move). Eventually the high heat makes the molecules move so much that they can't stick together anymore and they get very disorganized. This causes the rock to soften, which is called **melting**.

Pressure is the force that squeezes and crushes something when weight is put on top of it. If you have ever dived to the bottom of a swimming pool, you probably felt the weight of the water above you pushing on your body, especially in your ears—that feeling is the pressure of the water. The same thing happens inside the Earth, but millions of times stronger! The weight of the rocks in the crust and upper mantle is so heavy that they create very high pressure that squeezes and pushes down on all the layers below them.

Convection in the Kitchen

Hot liquids, like water and magma, have more energy than cold liquids. That means that hot liquids have a lot more space between their molecules than cold liquids do. This makes hot liquids less dense, so they rise above cold, denser liquids. This is called **convection**, and it happens inside the Earth with hot, soft rocks and magma. But hot water will rise, too, and with an adult's help, you can use it to see how convection works.

1. **Fill a small Pyrex glass or measuring cup with water and add some blue food coloring. Stir until the water is dark blue, then put it in the refrigerator for an hour or two. (You could put it in the freezer to speed it up, but be careful not to let it freeze! Freezing could break the glass.)**

2. **After the blue water has chilled and is very cold, have an adult help you heat up a big glass container of hot water. (Adults: make sure to use a Pyrex bowl so that the high temperature doesn't**

crack the glass.) Don't boil the water—it doesn't need to be that hot—but getting it very hot will help this activity work better.

3. Next, have an adult slowly and carefully tip the cold blue water into the container of hot water. Be careful not to pour it too quickly or splash it, otherwise the water will mix up too much and you won't be able to see the convection happening.

4. Can you see how the cold blue water sinks right to the bottom of the bowl of hot water? Even though it's all just water, the cold water sinks below the lighter hot water.

5. After all the cold water has been slowly poured in, take a look: the bottom of the bowl will have more dark-blue cold water and the top will have more clear hot water. Later, when the water is all the same temperature, the color will be more evenly mixed.

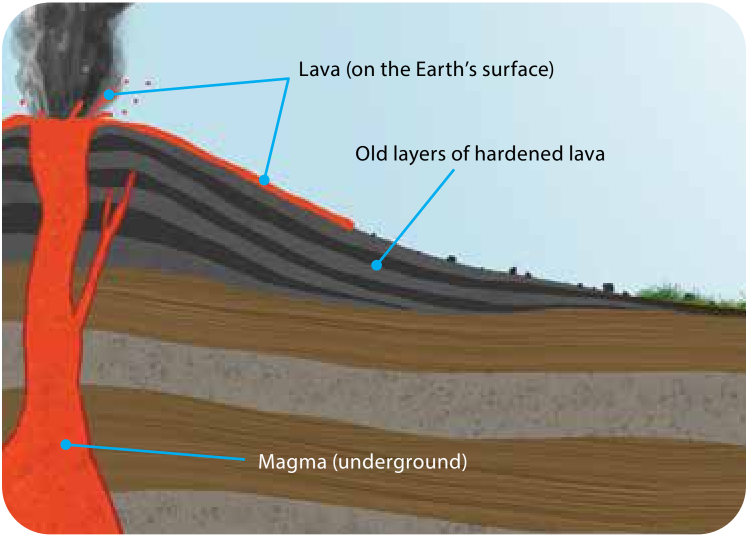
INSIDE THE EARTH: MAGMA AND LAVA

Most of the hot rock in the asthenosphere is soft, like warm wax. But when it rises to where there is less pressure, it can melt entirely, and it is called **molten rock**, which acts like a liquid. Molten rock that is deep inside the Earth is called **magma**, and it can stay hot for a very long time. Sometimes magma is pushed up through openings in the Earth's crust to where we can see it. These openings are called **volcanoes**, and some volcanoes are like tall mountains and others look like a crack in the ground. When magma is pushed out of a volcano, we call it an **eruption**, and when magma has been erupted onto the Earth's surface, then we call it **lava**. Lava cools very quickly when it is exposed to air; it quickly turns into solid rock.

While high heat usually makes the molecules in rocks move around, very high pressure can actually push on the molecules so hard that they stay locked in place. So even though the heat makes them want to wiggle around, they can't because the pressure is too high. That's why some layers of the Earth are still solid even though they are very hot!

We will be talking about magma, lava, and volcanoes all throughout this book, so remember what these terms mean!

Inside a volcano



The volcano in the photo below is in Iceland, and it erupted lots of lava onto the Earth's surface which quickly cooled to form black rock. Also, notice all the steam and gas coming out of the volcano, too.

Hot and Cold Rocks

To get an idea of how heat within the Earth can make rocks so hot that they become soft, try this:

1. Have an adult help you get some small blocks of wax. (Adults: blocks of paraffin wax are often sold in grocery stores alongside canning supplies.) Wax is a solid and is a little bit soft at room temperature. When wax gets really hot, it can melt, and when it is really cold, it becomes very hard. This is a lot like how rocks can become softer or harder depending on how hot they are.
2. Place one block of wax in the freezer for a couple hours.
3. Place another block in a jar or bowl of hot tap water. You can place the wax in a plastic baggie to keep it dry, and then float the baggie in the hot water. Let the wax warm up in the hot water for 10–15 minutes.
4. Take the block of wax out of the freezer and feel how it compares to how it did when it was at room temperature. Does it feel harder? If you drop it, or gently hit it with a hammer, it will shatter because it has become harder and more brittle as it got colder. This is a lot like the cold, hard, brittle rocks you find on the Earth's surface.

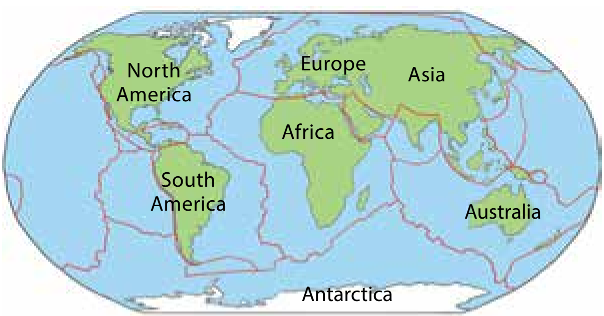
5. Next, take the warmed wax out of the hot water and the plastic baggie and see how it feels compared to the cold wax. The warm wax will feel much softer and you may be able to push into it with your fingers. If you try to hit it with a hammer or drop it on the floor, the warm wax won't break but it will dent or deform. That's because it has become softer and less brittle as it warmed up. This is similar to what happens to rocks deep in the Earth; they have become hot, but they are under too much pressure to melt and become magma.

To see how high pressure can slowly change the shape and form of softened rocks, try this:

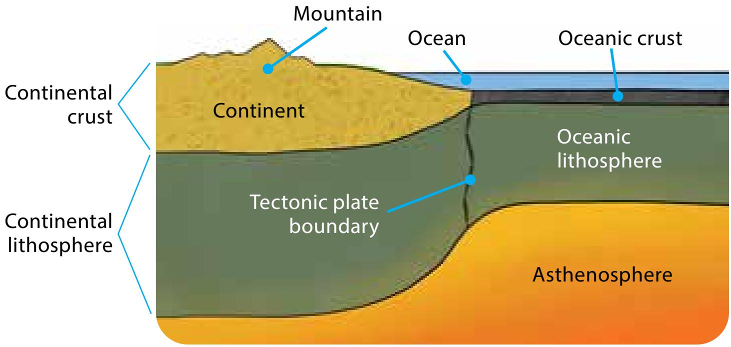
Cover the wax with a paper towel. Then put the warm wax on a hard, flat surface and balance a heavy, flat weight (like a stack of books) on top of it. Let it sit for a while until the wax cools. If the wax was warm enough, it will slowly begin to flatten. The wax is soft, but not melted, so the weight is able to compress it—just like rocks inside the Earth!

TECTONIC PLATES: HOW THE CONTINENTS MOVE

As solid as the ground may seem, the surface of the Earth (the crust) is always moving very slowly. But how? Remember that the lithosphere is the hard, top portion of the upper mantle (see page 36), and the Earth's crust sits on top of it. But the lithosphere is not one solid piece. It is broken up into several huge pieces that fit together like a giant puzzle. These pieces are called **tectonic plates** and they are always moving because of the hot, soft asthenosphere below them. In the asthenosphere, hot rock rises and cooler rock sinks, and that motion makes the tectonic plates above it move around slowly. Tectonic plates can bump into each other; some get pushed on top of others, some get forced below others, and some just slide past each other. And in all cases, the crust above them moves along with them. The places where plates meet each other are called plate **boundaries**, and it is along the boundaries where lots of changes in the Earth's crust happen, like where volcanoes form and earthquakes occur.



The red lines are the boundaries where the major tectonic plates meet.



THE DIFFERENT CRUSTS AND PLATES

Not all tectonic plates are the same. The thickest tectonic plates are found beneath the continents, so we call those the **continental lithosphere**, or continental plates. Between the chunks of continental lithosphere are areas of thinner lithosphere—those are found beneath the oceans, so they are called **oceanic lithosphere**, or oceanic plates. The **continents** are the big landmasses that make up our world, and they are only found on top of the thick continental lithosphere; they are made primarily of lighter weight felsic rocks, which we call **continental crust**. But the crust found at the bottom of the oceans, just above the oceanic lithosphere, is made of very dense, heavy, mafic rocks; we call it **oceanic crust**. The oceanic crust is very thin compared to the continental crust, but is actually heavier! All of these differences in thickness and weight of the lithosphere and crust means that they all move and interact differently.

TYPES OF TECTONIC PLATE MOVEMENT

The lithosphere is divided into sections called tectonic plates, and they sit on top of the hot asthenosphere. But the asthenosphere is thicker and denser than the lithosphere, which means the tectonic plates are actually floating on top of it. It's a lot like putting sprinkles on top of Jell-O—even though the gelatin is soft and the sprinkles are hard, the sprinkles won't sink into it on their own because they aren't dense or heavy enough. Since the heat of the asthenosphere keeps its hot soft rock moving around, the tectonic plates floating above it go along for the ride.

Tectonic plates can move in a variety of different ways, and a lot can happen at the plate boundaries where they meet, depending on how thick and heavy the plates are and which direction they're moving. Here we will look at the most common plate movements.

This is the San Andreas Fault in California as seen from an airplane. This long canyon is actually the boundary between two tectonic plates. These two plates are sliding past each other (transform movement) which makes earthquakes common here.

Glossary

asthenosphere: the bottom layer of the upper mantle. It is very hot and the rocks there are soft and flow slowly; above it is the lithosphere, which is cooler, harder, and thinner

atom: the smallest piece of an element; everything is made up of atoms that are bonded, or attached, to each other; atoms by themselves are too small to see without a very powerful microscope

basin: a low area, often bowl-shaped, where water can collect

bed: sedimentary rock over great amounts of time

bedrock: the first layer of hard, solid rock beneath the soil, dirt, and plants

chemical: a chemical is a special material that is made up of just one type of molecule; water is an example of a chemical

continent: the major landmasses that make up the dry land found on Earth; our continents include North America, South America, Europe, Asia, Africa, Australia, and Antarctica

convection: the movement of hot materials rising and cold materials sinking; this happens because hot materials are lighter and rise to the top

crust: the hard, brittle, cold outermost layer of rock on Earth; we live on the crust

crystal: a solid shape formed when a mineral hardens; each mineral has a certain crystal shape determined by its molecules.

dissolve: when something comes apart and disappears into a liquid; sugar dissolves into water because the water makes the sugar molecules separate

element: the different material "ingredients" that make up all things; elements include things like iron, copper, gold, oxygen, hydrogen, and carbon; elements are called the "building blocks" of our world

eruption: when lava and gas is released from a volcano

extrusive rocks: igneous rocks that cooled and hardened quickly on the Earth's surface

fault: a break in a rock or rock formation caused by tectonic plate movements and/or pressure on the rock

gas: a substance that can rise and float in the air because its molecules are very far apart; steam is a gas

igneous: rocks that are formed when magma or lava cools and hardens

intrusion, or intrusive magma: a mass of hot magma that has forced its way upward into the lithosphere or crust

intrusive rocks: igneous rocks that cooled and hardened slowly deep inside the Earth

landform: a feature of the Earth's surface that is distinct and different from other nearby features; for example, a high mountain and a nearby low plain are different landforms

lava: hot, melted, liquid rocks that have reached the Earth's surface

liquid: a substance that can flow and change shape depending on its container; liquids are made up of jumbled up molecules without much space between them; water is a liquid

lithosphere: the top layer of the upper mantle. It is warm, but mostly solid and hard; below it is the asthenosphere, which is hotter and thicker

magma: hot, melted, liquid rocks that are hidden deep inside the lithosphere

mantle: the largest layer inside the Earth; it is very hot and partly made up of softened rocks; it is divided into two parts: the upper mantle and lower mantle

metamorphic: rocks that formed when older rocks were compressed by high pressure, heated up inside the Earth, or both

mineral: a natural material formed when certain chemicals harden; minerals form as crystals inside rocks

molecule: groups of atoms that have bonded or attached to each other in a certain order

plate boundary: the line where two tectonic plates meet; at a boundary, one plate may go below the other, they may spread apart from each other, or they may scrape past each other

pluton: a large intrusion of magma that cooled to form one solid mass of igneous rock

precipitation: when a solid material forms from a solution, such as when the solution dries up

rift: a gap between tectonic plates that grows wider as magma rises between them; when a rift becomes big enough, it can become a sea

rock: a hard, solid material made up of mixtures of minerals that formed together in a tight mass.

sedimentary: rocks made up of sediments that have settled and hardened together

sediments: small particles of broken up rocks, minerals, or living things; sand, clay, and skeletons are examples of sediments

solid: a substance that is hard and does not easily flow or change shape; solids are made up of molecules that are tightly packed together, often in a particular pattern or shape; ice is a solid

solution: a liquid that has a dissolved material in it; when you dissolve sugar in water, the mixture of sugary water is now a solution

tectonic plates: the huge pieces of the lithosphere that fit together like puzzle pieces; they are found beneath the continents and oceans, and they move slowly because of the movement of the asthenosphere below them

volcano: an opening in the Earth's crust that lets lava and gases rise and spill out onto the Earth's surface

PHOTO CREDITS

continued from page 2

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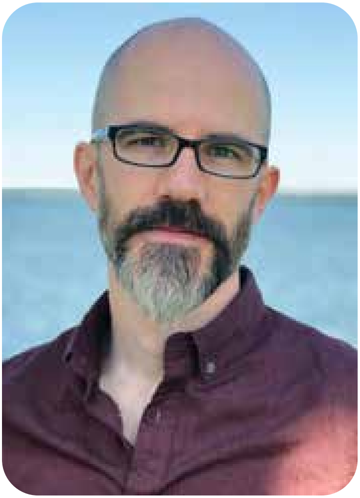
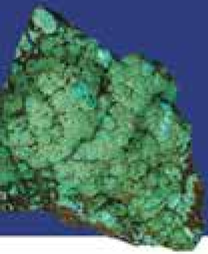


About the Author

Dan R. Lynch grew up in a rock shop where he learned how to identify rocks, minerals, and fossils from a young age. Since then, he's written over 20 books about rock and mineral identification, with a special focus on agates from his home region of northern Minnesota and Lake Superior. He has always loved the natural world, especially all of its wonderful little details that most people don't pay any attention to and the amazing science behind them. With his children's books, he hopes to spark young readers' curiosities in both the rocks beneath their feet and the ones beyond the horizon. Dan currently lives in Madison, Wisconsin, with his wife, Julie, and their cat, Daisy.



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