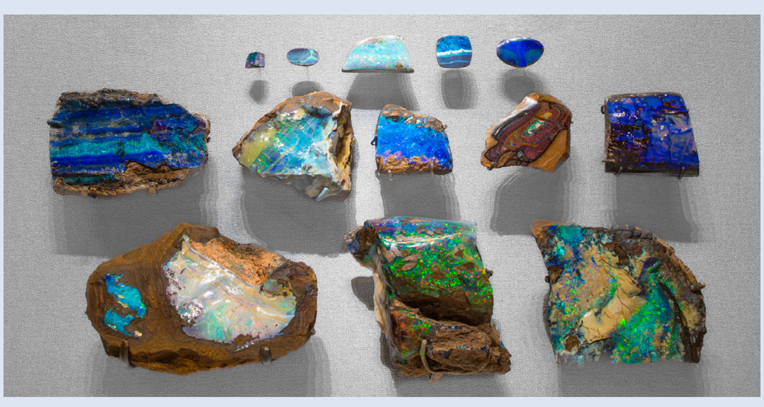
150 YEARS | American Museum of Natural History

Educator's Guide

Mignone Halls of

Gems and Minerals

amnh.org/gems-minerals-educators



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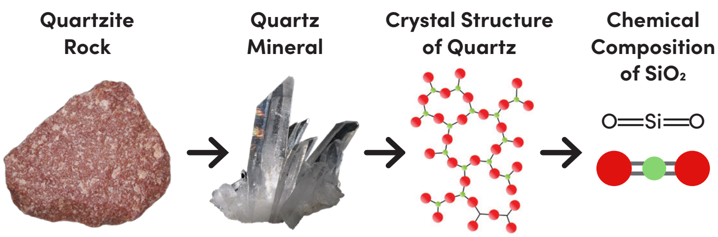
Essential Questions

What are minerals?

Minerals are the building blocks of **rocks**, which make up most of the planet. A **mineral** is a naturally occurring crystalline solid. **Crystals** are made of atoms of one or more **elements**, arranged in orderly, repeating patterns. Scientists classify minerals by their chemical composition: which elements they contain, in what proportions, and the particular patterns by which the atoms of those elements are arranged into crystals. People sometimes fashion minerals into **gems**, durable minerals that have been cut and/or polished to enhance their beauty.



Quartzite rock contains the mineral quartz. Quartz crystals consist of silicon and oxygen atoms arranged in a precise geometry, represented by the chemical formula SiO_2.

The physical, chemical, electrical, and optical properties of minerals depend on their chemical composition and crystal structure. Scientists study these properties by magnifying, crushing, illuminating, scratching, and breaking specimens. The properties of minerals determine how they can be used. For example, diamond and corundum are used as abrasives because they're very hard, while soft and slippery graphite and molybdenite can be lubricants.

How has the number of mineral types changed over time?

The conditions of an environment and the chemicals available in it determine the kinds of minerals that form there. Over billions of years, as our universe changed, so did the variety of minerals. When our universe formed around 14 billion years ago, there were no minerals whatsoever. Over the first few hundred million years, the first stars formed; within them, elements were formed that became the first minerals after the stars exploded. These included diamond, graphite, and forsterite. Nine billion years later, when our solar system formed, more kinds of minerals, such as augite and anorthite, formed along with it. And as our own dynamic Earth began to take shape, increasingly numerous, complex, and diverse minerals began to appear.

Rich in liquid water and home to life, Earth is a special planet. Today, Earth hosts over 5,000 types of minerals. Scientists have identified over 5,500 minerals in our solar system so far. We do not yet know what minerals have formed in distant galaxies and on the Earthlike planets orbiting other stars, but because the same laws of physics operate everywhere, we expect the range to be similar.

How and where do minerals form?

Minerals form everywhere on our planet, from thousands of kilometers deep to the surface and atmosphere. Earth's mineral-forming environments can be grouped as igneous, pegmatitic, metamorphic, hydrothermal, and weathering. Minerals crystallize in these environments when elements react chemically with each other in response to environmental conditions such as changing pressure and temperature. Minerals grow in layers around a starting point or on a surface. Some form in mere seconds, others over millions of years. By analyzing a rock's mineral content and texture, scientists can learn about the conditions under which it formed—and understanding those conditions helps geologists infer the history of Earth. For example, jadeite jade formed at high pressure where oceanic crust was pushed beneath continental crust, while many rubies were forged where continents collided to create mountain chains.

How are minerals important to life?

Studying minerals in rocks helps us understand the greater physical world, including Earth's history and dynamics—and even life itself, because minerals and life are connected. More than 3.5 billion years ago, life on Earth began with single-celled organisms, which relied on minerals for essential ingredients, and perhaps also for surfaces to live on. About 2.4 billion years ago, microbes evolved the ability to photosynthesize. That process released free oxygen over time, which reacted with existing minerals to create thousands of new ones. Then, over 600 million years ago, single-celled organisms began to form new minerals through biological processes. As multicellular organisms evolved, they developed the ability to produce the minerals necessary for growing "hard parts," such as trilobite shells, coral skeletons, squid beaks, or mammoth tusks. These new minerals include those that make up our own teeth and bones. Speaking of bones, minerals are also vital to our understanding of life's history, because without them, there would be few fossils. Most fossils form when minerals replace components of the buried remains of living things, or fill in their shapes or imprints. Besides being partly made of minerals, humans use minerals as resources. We rely on them for many products, including metals, ceramics, fillers, semiconductors, glass, and fertilizer.

What Are the Properties of Minerals?

Physical Properties

Physical properties are characteristics that can be observed or measured without changing the nature of the substance. Hardness, density, cleavage and fracture, and tenacity are all physical properties of a mineral.

Hardness, measured on the Mohs scale, is the degree of resistance to being scratched. Minerals higher on the Mohs scale will leave a visible mark when scraped against those lower on the scale. For example, diamond, the hardest mineral on the scale, with a Mohs hardness of 10, will scratch corundum, which has a hardness of 9, while all the minerals on the scale will scratch talc, the lowest on the scale, with a hardness of 1. The Mohs scale is merely an ordering, not an absolute measure of hardness; corundum, Mohs 9, is twice as hard as topaz, Mohs 8, but only around a quarter as hard as diamond, Mohs 10.

Emery boards are a kind of nail file covered in ground corundum, the second hardest mineral on the Mohs scale (9). Graphite is not only soft (Mohs: 1 to 2), but also slippery, and can be used for lubrication.

Density is the amount of mass packed into a unit volume. If you hold two specimens in your hand that have the same size but different densities, the denser mineral will feel heavier.

Cleavage and **fracture** describe the way minerals break apart. When a mineral's crystal structure creates planes of atoms with weak chemical bonds between the planes, the mineral will tend to break smoothly along those planes, a property called cleavage. Minerals may have three or four directions of cleavage, and the angles between the cleavage planes depend on the crystal structure. If the breakage is irregular, uneven, or curved instead of flat, it is called fracture.

Tenacity describes a mineral's resistance to being deformed—whether it bends (is malleable) or snaps (is brittle), stays bent (is flexible) or springs back (is elastic). Brittle minerals generally have strong internal chemical bonds throughout their structures; in malleable and flexible minerals, some or all of the bonds are weaker.

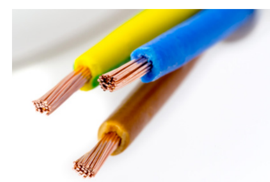
Chemical Properties

A mineral's chemical properties depend on the elements it contains and the strength of the chemical bonds between them. **Solubility** (whether a mineral will dissolve), **fusibility** (whether a mineral will melt at a higher or lower temperature), and solid solution (whether a mineral is a combination of two or more chemical formulas) are all chemical properties.

Salt is highly water soluble at room temperature. When we eat salt, it quickly separates into sodium (NA+) and chlorine (Cl-) ions, and our taste receptors perceive sodium as saltiness.

Electrical and Magnetic Properties

Electrical and magnetic properties depend on how **electrons** move within a mineral. Electrical conductivity refers to how easily electrons pass through a substance, and magnetism refers to how electrons of certain elements spin, sometimes in response to magnetic fields.



Copper is an excellent conductor of electricity. Its metallic bonds allow electrons to move freely.

Optical Properties

Color, streak, luster, and refraction are optical properties. They're consequences of how the mineral interacts with light. Scientists crush a mineral by swiping it across a ceramic "streak plate" to reveal the color of its powder—its **streak**. This can help distinguish between minerals with the same color but different streaks. For example, the black minerals hematite and magnetite have orange (hematite) and black (magnetite) streaks. **Luster** is the way a mineral's surface reflects and absorbs light. For example, the luster of pyrite is metallic, that of quartz is glassy, and that of talc is pearly. **Refraction** is the way light slows and appears to bend, or refract, as it passes through a mineral. Gems cut from minerals with a high degree of refraction, or more light bending, can be especially sparkly.

Iron oxides have a red, orange, or yellowish-brown streak, as seen in cave art.

What Is a Gem?

Gems are minerals with natural beauty—color, transparency, brilliance, iridescence—that have been cut, ground, and polished to enhance their appearance. Some rocks, such as jade or lapis, can also be shaped into gems, as can certain other natural materials, including pearls and amber.

To be used in jewelry, the ideal gem must be hard enough to resist scratching and durable enough to resist breaking. Many minerals, though beautiful, cannot be used as gems because they could not survive being worn.

How Is a Crystal Transformed into a Gem?

It takes skill, and many steps, to transform a rough crystal into a finished gem:

1. The process starts with a rough crystal. This amethyst may look like it has already been cut, but the surfaces are natural crystal faces.

2. Through grinding, rough material is removed until the gem is close to the desired shape.

3. Then the gem is faceted—cut with dozens or even hundreds of tiny faces—to optimize the gem's optical properties. The facets are carefully ground and polished, enhancing the gem's sparkle and beauty.

What Determines Gem Quality?

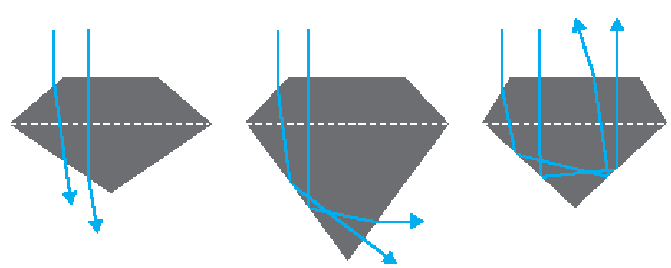
Gemologists use certain properties, some listed below, to determine the quality of a gem.

- **Color:** depth (not too dark or pale), uniformity, fluorescence
- **Clarity:** transparent, translucent, opaque
- **Hardness:** resists scratching (preferably 7+ on Mohs scale)
- **Durability:** resists shattering, cracking, or cleaving
- **Brilliance:** high index of refraction, high luster
- **Special optics:** iridescence (play of colors), cat's eye or star effects

Did you know? Carat. Karat. (Or carrot.)
Carat is the standard unit of weight (mass) for gems—not to be confused with karat, the unit of measurement of gold purity. However, both are based on the carob seed, an ancient measure of weight.

What Is a Facet?

A few minerals are used as gems in their natural crystal form. Most, however, are shaped and polished to bring out their sparkle, brilliant color, or unusual texture. Gems that are transparent are normally faceted: cut with a machine that polishes small, flat windows (called facets) at regular intervals and exact angles. This maximizes light reflected by the stone, highlighting its optical properties and causing it to sparkle. Students can explore the hall to find and observe the visual effects of different types and numbers of facets.



Faceted gems are cut so that light entering from above reflects internally off the lower facets before exiting back through the top.

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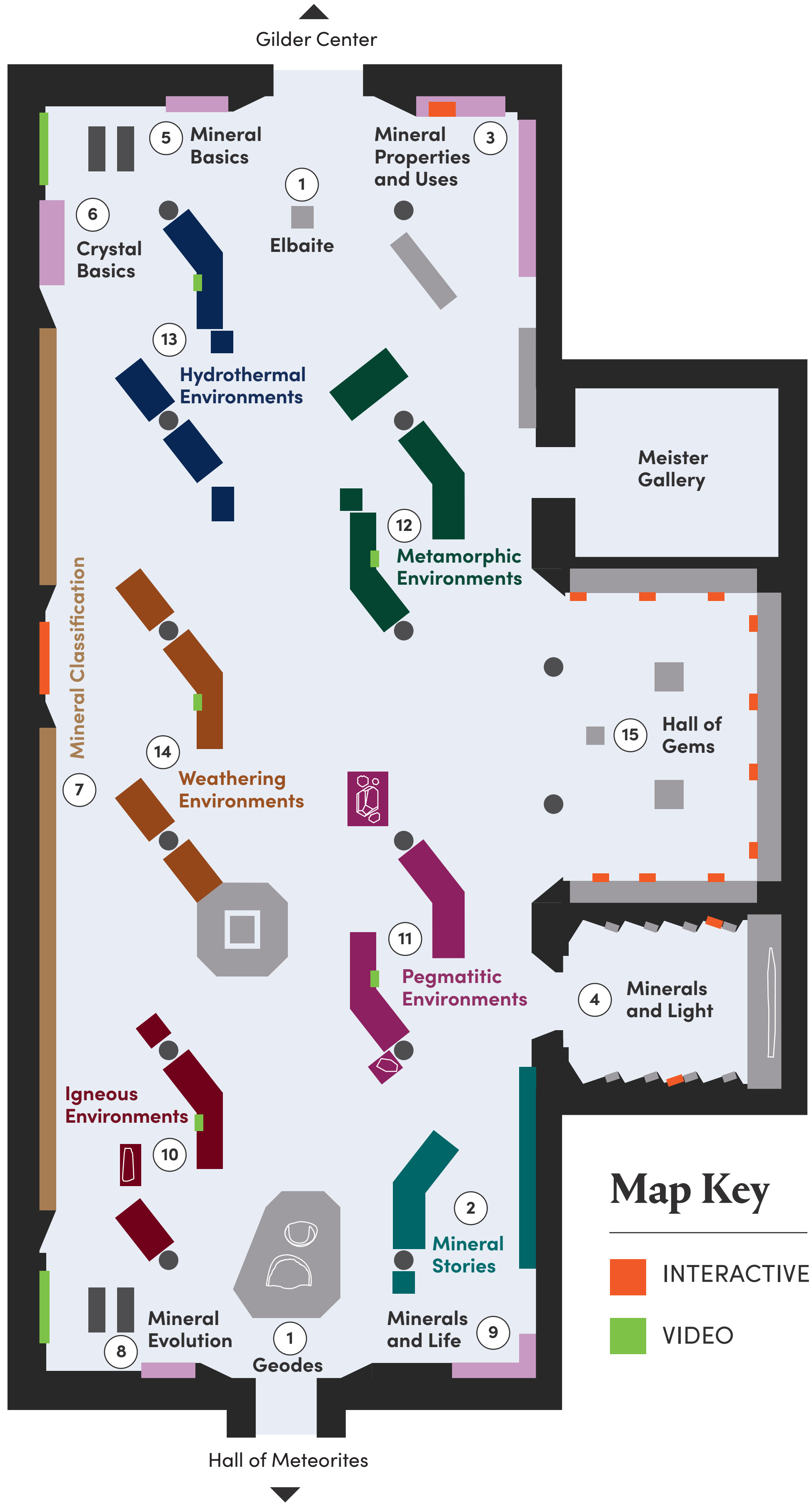


TIP: Bring Flashlights!

Students can use small flashlights to see how specimens react to beams of light.

1. Geodes and Elbaite

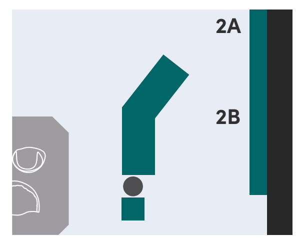
Dramatic signature specimens near the entrances excite curiosity and spark imagination.

"Giant Geodes" and "Extraordinary Elbaite": Students can begin their exploration of the halls with one or more of the specimens located near the two entrances. They can observe the specimens' color, texture, structure, and size, read the panels and note information that stands out to them, such as where the specimens were collected, and surface any questions they have about the specimens. As they go through the hall, students can look for answers to their questions.

This amethyst geode is over 9 feet (2.8 m) tall and weighs around 11,000 pounds (5,000 kg).

This elbaite tourmaline comes from a gem pocket in Brazil. Tourmaline crystals from this pocket are notable for their exceptional quality and distinctive cranberry color.

2. Mineral Stories: NYC and Beyond

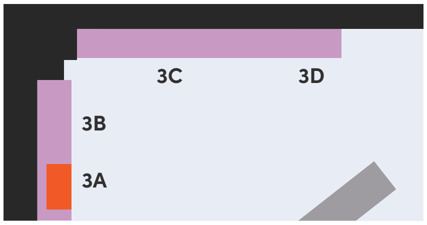


This area of the hall explores the minerals and the clues they provide about the geologic processes that formed the tri-state area as well as selected locations around the world.

2A. "Minerals of New York City" case: The names and borders of the five boroughs of New York City—The Bronx, Manhattan, Queens, Brooklyn, and Staten Island—were assigned by people. But another way to think about the region is by the underlying geology. In this case, students can examine an illustration that shows the different rock formations in the region, read about each borough's geology, and look at examples of rocks found in each borough. Students can also think about and discuss if and how they might reorganize the five boroughs based on geologic history.

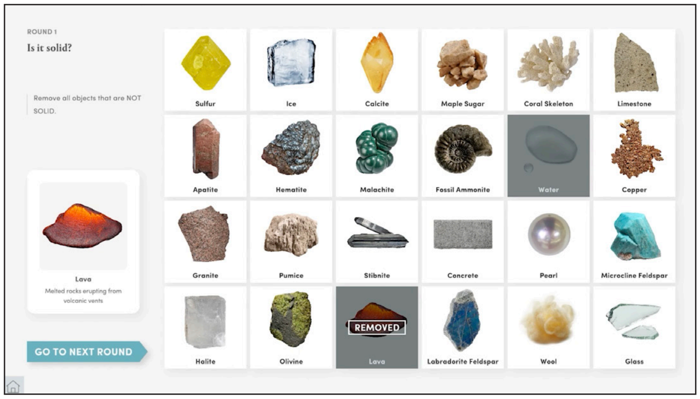
2B. "Iron at New York City's Doorstep," "The Fabulous Gems of Mogok," and "The Tin Islands and the Bronze Age in Europe" cases: Different mineral-forming environments created different types of minerals. Students can explore examples of minerals from three regions—the New Jersey and Hudson Highlands, the Mogok Valley of Myanmar, and western Europe—and learn about their geologic history and how the minerals found there are used by humans around the world.

3. Mineral Properties and Uses



Minerals are all around us, and within us. We couldn't live without them. This area introduces the concept of minerals, their properties, and the ways humans use them.

3A. "What is a Mineral?" interactive game: Through four elimination rounds, students can test their knowledge of the characteristics that make a mineral a mineral.



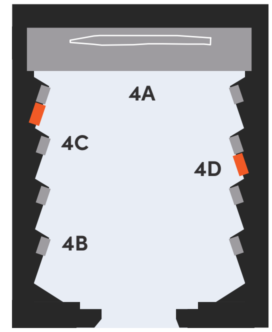
In this game, the four rounds investigate these questions: (1) Is it solid? (2) Is it naturally occurring? (3) Is it entirely inorganic? (4) Does it have a uniform chemical composition and crystal structure?

3B. "What Causes Mineral Properties?" case: Minerals can be hard or soft, impervious or easily dissolved, shiny or matte. Some bend, while others break. Magnets will stick to some and not stick to others. It's all about the mineral's elements—and the chemical bonds between them. Here, students can learn about different types of bonds—covalent, ionic, residual, and metallic—and consider why it is important for scientists to understand the bonds that make up a specific mineral.

3C. Properties cases: These four cases explore the properties of minerals and how understanding those properties allows us to make use of minerals. In each case, students can review the properties and observe the specimens.

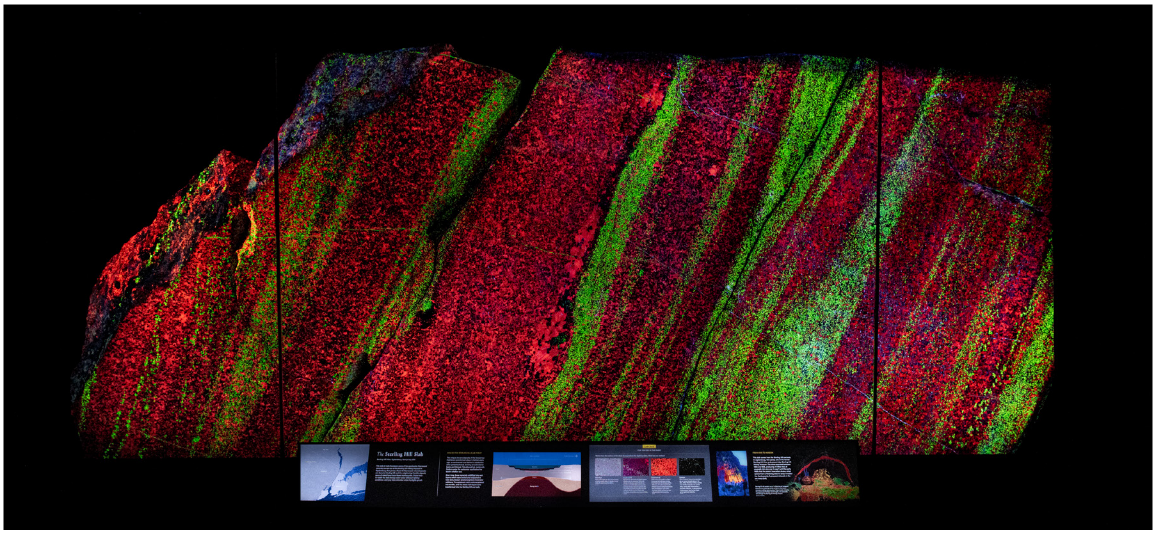
- **Physical Properties:** This case examines how minerals respond to physical forces. The top third of the case focuses on hardness, the middle on cleavage and fracture, and bottom on density.
- **Chemical Properties:** This case explores how minerals behave chemically. It highlights solubility (whether a mineral will dissolve in water) and fusibility (how easily a mineral will melt upon heating).
- **Electrical and Magnetic Properties:** This case examines how electricity moves through minerals (allowing us to light our homes by conducting power to lamps through copper wires, for example) and what makes a mineral a magnet like the magnets on a fridge.
- **Optical Properties:** This case explores a mineral's color, the color of its streak, its luster, its transparency, and how it bends light.

3D. "Our Mineral Resources" case: Students can look for minerals that are used to make everyday objects, such as quartz (glass), albite (ceramics), and trona (baking soda). They can also find out what ores are and why our ability to extract metals from them is so important.



4. Minerals and Light

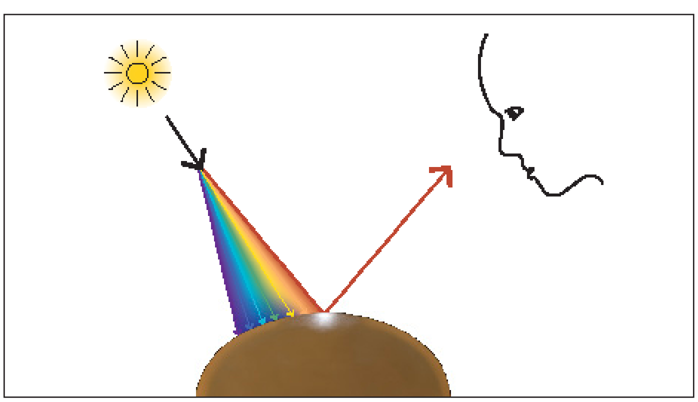
When minerals sparkle, shimmer, shine, or glow, they owe their dramatic appearance to the ways they interact with light. This area explores how minerals can bend, reflect, transmit, and distort light, and the amazing diversity of visual effects that result.



Exposure to ultraviolet (UV) light excites electrons in the minerals. When this energy is released, some falls in the spectrum of visible light and appears as fluorescence.

4A. Fluorescent slab: This large rock specimen showcases a few of the approximately 90 fluorescent minerals found in New Jersey's Sterling Hill Mine. Students can watch the slab change color under different lighting conditions (white light, long-wave UV, short-wave UV, and darkness) and read about what accounts for their observations.

4B. "What Causes Color?" and "How Can One Stone Have Many Colors?" cases: These two cases explore how light interacts with minerals to create effects we perceive as color. The displays include minerals that are always a particular color and those whose color is determined by chemical impurities, and minerals that display more than one color, depending on factors such as the type of light or direction of viewing. Students can look at examples in these cases and also throughout the hall.

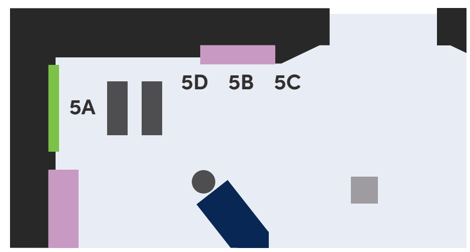


When you shine a light on an object, it absorbs, reflects, and returns certain wavelengths of visible light. Our eyes see the returned wavelengths as color. The variety, hue, and richness of a gem's color is an important factor in assessing its value.

4C. "What Is Play of Color?" and "Why Do Minerals Glow?" cases: These cases contain minerals that display iridescence, or play of color; and those that glow with colors from fluorescence and phosphorescence. Students can read about the difference between iridescence, fluorescence, and luminescences, and then share their observations of these specimens.

4D. Four cases about gems and light: These cases explore the optical properties of gemstones, such as how gems transmit or absorb light, causing them to appear opaque, translucent, or transparent; how gems bend, or refract, light, displaying rainbows; how threadlike substances inside some gems can create eyelike or starlike light displays; and how cutting gems into particular shapes can enhance their beauty. Students can read about the different ways light interacts with gems. They can then observe and compare a mineral that is transparent, one that is translucent, and one that is opaque.

5. Mineral Basics



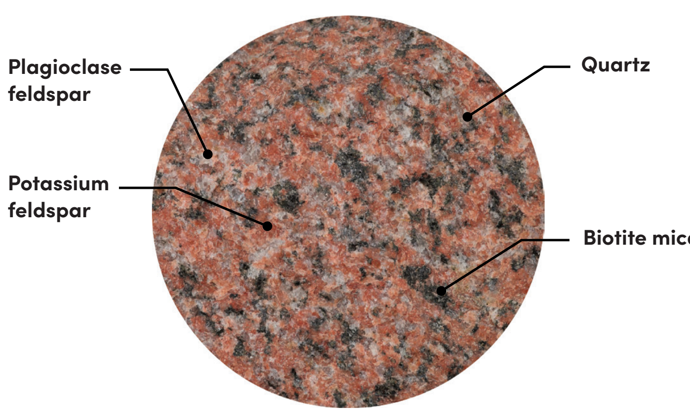
If you look closely enough, even the dullest-looking mineral is a wonder of order. This area explores how atoms bond together in regular patterns to form crystals, how crystals combine to form minerals, and how minerals combine to form rocks.

5A. Video: Students can watch a video to discover how minerals as different as ice and quartz form on Earth, and how to distinguish minerals from the rocks that contain them.

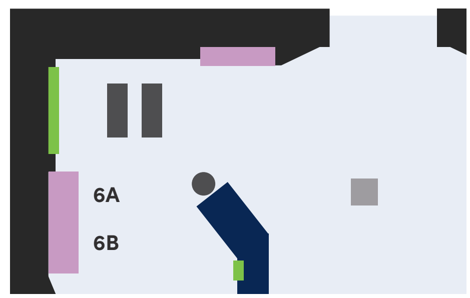
5B. "What Is a Rock?" section (center): A rock is made up of mineral grains. Students can explore the relationship between rocks and minerals by examining a touchable piece of granite rock (#1) to identify the minerals it contains. They can then identify the four minerals (#2–5) that make up granite.

5C. "What Is a Mineral?" section (right): A mineral is a naturally occurring solid with a regularly repeating crystal structure and defined chemical composition. Students can view mineral specimens with different crystal patterns and find their chemical formulas on the panels. They can also examine a specimen that does not meet the criteria for being mineral and discuss what makes this specimen different from those around it.

5D. "What Is a Crystal?" section (left): A crystal's flat surfaces result from the orderly arrangement of its atoms. Students can observe the different faces (sides) of a spinel crystal. In the crystal structure model, students can also observe the bonds that hold together the different elements to form the crystal pattern of spinel.



All granites contain quartz, potassium feldspar, and sodium-rich plagioclase feldspar. Other minerals, like mica or hornblende, may also occur.



6. Crystal Basics

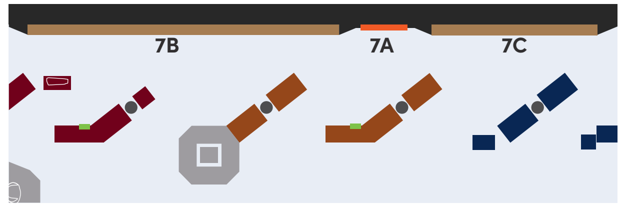
In this exhibit, the larger section on the right explores how crystals can be classified by their geometry; the two sections on the left explore different types of symmetry.

6A. “Crystal Systems” section (right): Crystal systems classify minerals based on the geometry and symmetry of the unit cell—the smallest defining structural unit of a crystal. Though impossible to see with the naked eye, unit cells define most of the traits we observe in larger crystals. Students can touch 3D models of seven unit-cell shapes and examine their corresponding drawings to see how a crystal’s shape is determined by the relative length of its axes—that is, the edges of its unit cells—and by the angles at which its axes meet. Students can also hypothesize about the crystal symmetry of the crystals on display, and provide their reasoning.

Touchable 3D models of crystal shapes

6B. “Twinned Crystals” and “Crystal Symmetry” sections (left, center): The section at the left explores how different minerals can form twinned crystals—symmetrical structures that are incidental, rather than inherent, to the mineral’s crystal shape. The section at the center uses the shapes of pasta to present different kinds of symmetry, from the six-fold radial symmetry of wheel-like ruote (wagon-wheel pasta) to the mirror symmetry of macaroni (elbow noodles); students also can touch various symmetrical objects on the bottom rail to experience symmetry in three dimensions.

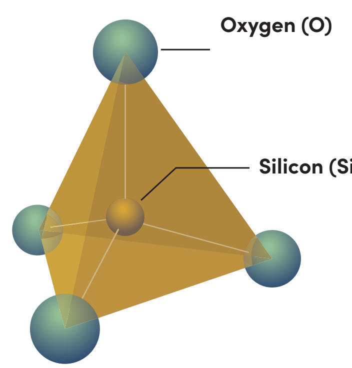
7. Mineral Classification



Minerals are made up of elements; they can be classified by their chemical compositions, as well as by their structures. The large interactive in the middle of this wall allows students to explore the Periodic Table of the Elements, which organizes elements according to their chemical properties. The series of displays to the left of the interactive introduces viewers to ions, or electrically charged atomic units, and their effects on chemical bonds. The displays to the right examine silicate minerals, which are made up of tetrahedra, or triangular pyramids, each comprising four atoms of oxygen (O) and one of silicon (Si), bonded with other elements.

7A. "Minerals are Elementary!" wall interactive (center): The top half of the large screen provides general information about the periodic table, instructions on how to play, and information on how to read a molecule (chemical bond, atom, chemical formula, charge). The bottom half is an interactive area where students can combine different elements to form minerals (double tap to break an element apart and free up more elements).

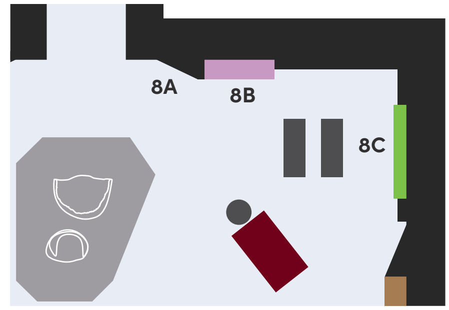
7B. "Classified by Chemistry" wall (left): Scientists created the periodic table to classify and group elements, and it's helpful for understanding the chemical composition of minerals. On either end of this section, students can view a graphic of the periodic table. As they explore the 13 displays, students can use the color coding of the periodic tables on the bottom panels to explore the minerals that result from the different combinations of elements.



Silica tetrahedron

7C. "Classified by Chemistry and Structure" wall (right): Silicates (containing a combination of silicon and oxygen) are the most abundant minerals in Earth's crust. Looking at the wall graphic on either end of this section, students can see how the elements silicon (Si) and oxygen (O) bond to form a triangular pyramid, or tetrahedron with the formula SiO_4. Within each case are different types of silicates categorized by SiO_4 bonding patterns (crystal structure) with specific elements (chemical composition). As they did in the interactive, students can explore the different silicate minerals that result from the different combinations of elements. They can also explore the results of different bonding patterns.

8. Mineral Evolution



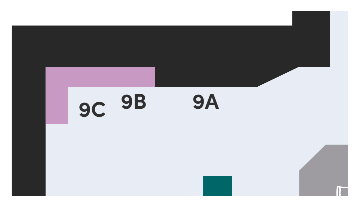
For hundreds of millions of years after the explosive birth of the universe, there were no minerals. Now, billions of years later, there are more than 5,000 mineral species on Earth. Through illustrations, specimens, and a video, this area explores the history of our planet and the minerals it hosts.

8A. Intro panel of Earth's 4.5-billion-year history: Earth's history is marked by changing conditions that allowed minerals to form in ever-greater numbers and an ever-greater diversity. Students can examine this artist's depiction of what our planet looked like from its beginning to today, and consider how the major physical and environmental conditions on Earth changed over time.

8B. "Timeline of Mineral Evolution" display: This spiral timeline illustrates the evolution of minerals since the Big Bang, and the specimens represent the types of rocks and minerals that appeared during different time periods. The spiral is divided into seven time segments, each coded with a different color. Corresponding colors are used as labels to identify minerals that appeared and events that occurred during each time segment. Students can choose one time segment and explore the types of minerals that arose then due to changing conditions.

8C. Video: Students can watch a video to follow the evolution of minerals from the Big Bang to the formation of our solar system and the evolution of life on Earth.

9. Minerals and Life



This area explores the connections between minerals and life: how minerals can replace once-living tissue, forming fossils, and how living organisms can build their own minerals to form materials such as shell and bone.
This tour begins with the observation of a large, touchable petrified wood specimen, followed by specimens in cases that students can use to investigate the connections between minerals and life.

9A. Large petrified wood: This is a slice of a petrified dawn redwood tree that turned to stone after being buried for millions of years in just the right conditions. Students can touch and examine the specimen and share first impressions of what they see, including the hundreds of rings and other markings. They can then share observations of why they think this specimen is no longer part of a tree, but a stone.

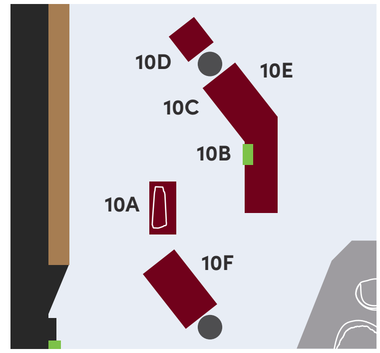
This dawn redwood lived about 35 million years ago in the present-day Cascade Mountains.

9B. Fossil specimens: Much of what we know about what lived in the past comes from studying fossils, which form when the remains of living things are buried and their shapes, imprints, or hard parts are preserved. Often, that happens because minerals formed around or replaced once-living tissues. Without minerals, we would know much less about the history of life. Students can explore the two cases and then, using a specimen from these cases or using the petrified wood, share how wood became a fossil.

9C. "How Does Life Make Minerals?" case: Over 600 million years ago, single-celled organisms began making biominerals—inorganic minerals formed through biological processes. Students can discuss functions of biominerals.

10. Igneous Environments

Igneous minerals and rocks form from molten rock. When molten rock cools, it solidifies. Both the chemical composition of the molten rock and the cooling environment—fast or slow, deep down or at the surface—determine what types of igneous rock form and what minerals they contain. These rocks and minerals are our main source of information about the inner workings of our dynamic planet.



This curated tour begins with a visit to a large, touchable rock, followed by visits to cases that explore the formation and varieties of igneous rocks and minerals.

This orbicular granite comes from Western Australia, an ancient piece of continental crust that began forming about 2.7 billion years ago.

10A. "An Oldie but Goodie" specimen: Igneous minerals crystallize from molten rock, which is called magma when it's churning below Earth's crust, and lava when it's flowing at the surface. Students can touch this large rock and share their observations of its size, mineral grain size, texture, colors (light vs. dark), and patterns. Tell students that observations such as those they shared are clues to a rock's history, including where it formed, and its composition.

10B. Video and "How Magma Becomes Solid" case: Minerals take time to crystalize, so magma from the same source can form different minerals and rocks, depending on where and how quickly it cools. In this animation, students can get an overview of how magma flows toward Earth's surface. Then they can look at nearby displays for examples of the igneous minerals and rocks.

10C. "Cooling Above and Below" case: The minerals and texture of an igneous rock are clues to its history. Finer-grained rocks with hard-to-distinguish crystals solidified rapidly from lava (extruding magma) on or near Earth's surface. In contrast, larger rocks with easily recognizable crystals grew slowly and solidified from magma deep in Earth's crust. The "Look Closely" callout panel highlights local geography in New Jersey. Students can compare the textures of a basalt (small, hard-to-distinguish crystals) and a diabase (medium-sized, easily visible crystals) and infer which one cooled faster and where they came from. Then students can use the "Anatomy of a Volcano" diagram to help them envision where the other rocks in the case formed.

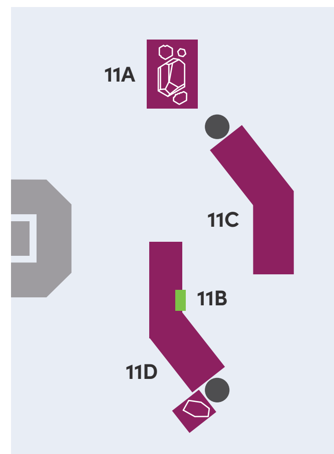
10D. "A Stone That Shimmers" specimen: When the labradorite feldspar in this tall column cooled, it separated into submicroscopic layers with different chemical compositions. These layers bend light differently, scattering it and causing iridescent colors. Students can shine flashlights on different parts of the column to observe the vivid colors that appear and to look for the individual crystals of feldspar that make up the rock.

This pillar of labradorite rock comes from a large body of anorthosite, a type of igneous rock, in Madagascar.

10E. "Light and Dark" case: The colors of minerals in an igneous rock often indicate the chemical composition and origin of the parent magma. In the "Look Closely" callout panel, students can compare the colors of three rocks and read the label to see what the rocks' colors indicate about their composition and origin. Referring to the chart on the bottom panel, students can learn how geologists classify igneous rocks, such as those on display, based on their mineral content and texture.

10F. "Ore Today, Gone Tomorrow" and "Minerals for the Modern World" cases: Because minerals in cooling magma crystallize at different rates, igneous rocks can form layers of ores rich in materials such as precious metals and rare earth elements necessary for modern technology. In these two cases, students can see how these important ores formed and find out about the properties and uses of the elements they contain.

11. Pegmatitic Environments



Pegmatites are a special kind of igneous rock characterized by large—occasionally enormous—interlocking crystals, sometimes of unusual minerals containing rare elements. Large crystals typically mean that magma cooled slowly, allowing crystals to grow for a long time, but pegmatites are rule breakers. High concentrations of water and certain chemical elements in their magmas allow them to solidify rapidly, sometimes in just a few days. Water also allows pockets to form where minerals can grow unimpeded as large, well-defined crystals. Pegmatites are a source of minerals for gemstones, industry, and rare-element ores.

This curated tour begins with a visit to a spectacular display of gigantic beryl crystals, followed by a video and cases that explore how pegmatites form.

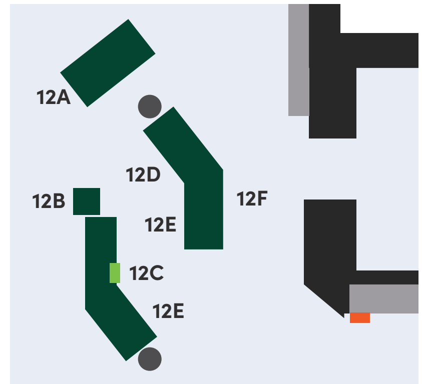
11A. "Behemoth Beryls" specimens: Pegmatites are sources of enormous individual crystals, such as the large beryls on display—each a single crystal. Students can observe the crystals' size and shape (hexagonal prisms), count the number of sides, and hypothesize how the crystals might have formed and grown so big.

11B. Video and the "Large Crystals and Unusual Textures" and "What Big Crystals You Have" cases: In this animation, students can get an overview of how water and chemical elements in magma enable the growth of large crystals and distinctive textures. Then students can look at the cases on either side of the video to observe the size and shape of the crystals, as well as the visual appearance of their texture. Students can hypothesize about the crystal system and symmetry of these crystals.

11C. "Simple Pegmatites" and "Complex Pegmatites" cases: Both simple and complex granitic pegmatites contain quartz and feldspars, but only complex pegmatites include minerals rich in rare elements such as lithium and beryllium. Students can compare the minerals in the two cases and read the labels to find out what makes them different and how the elements they contain affect their uses.

11D. "The Fabulous Tourmaline Family" case: Tourmalines commonly form in pegmatites because pegmatitic magma can concentrate boron, an essential component of tourmaline. Tourmalines come in a wide variety of crystal shapes and colors, as demonstrated by those on display. In the "Look Closely" callout panel, students can focus on one particular tourmaline specimen to examine its color zones and read about the clues these color zones provide about the changing composition of the crystallizing fluid.

12. Metamorphic Environments



Metamorphic rocks all had previous "lives." The minerals in the original rock were formed under one set of conditions, but were then subjected to different degrees of heat, pressure, and abundance of water in Earth's crust. They responded to the change by transforming to become minerals stable under the new conditions. Metamorphic rocks and minerals record the history of Earth.

This curated tour begins with visits to observe two large specimens, one touchable, followed by a video and displays about different kinds of metamorphic rocks.

12A. Amphibolite slab: Over a billion years ago, igneous rock was buried 20 miles (30 km) below the surface and was transformed by extreme heat and pressure into this amphibolite slab containing large garnet crystals. Students can touch and observe this specimen and postulate how it formed. Throughout the hall, they can also explore some of the many examples of garnet, a mineral that is stable at high pressures and temperature.

This 14,5000-pound (6,577-kg) slab of amphibolite contains giant garnets. It comes from Gore Mountain in upstate New York.

12B. "Tumbling Tourmalines" case: These large black tourmalines, also known as dravites, grew near the boundary of two colliding microcontinents in what is now Western Australia. Along the boundary, buried sediments reacted with fluids under pressure and permitted the growth of large tourmaline crystals. Students can observe the patterns of the white plagioclase crystals within the larger black dravite crystals and speculate about the conditions that caused the crystals to appear so dense and tightly packed together.

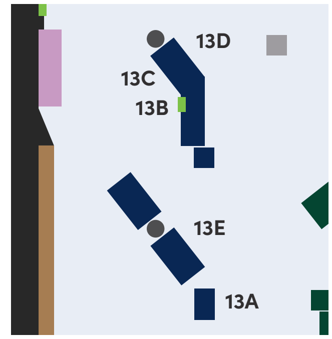
12C. Video and "Reacting to Changing Conditions" case: In this animation, students can get an overview of how pressure and temperature increase with depth, creating the right conditions for different minerals to form at different depths. Then they can look at the case to the right to learn about diffusion, a process by which minerals in metamorphic environments can exchange chemical elements with nearby minerals.

12D. "Recording the Dynamic Earth" case: Different pressure and temperature conditions allow distinct assemblages of minerals to form. On the wall, students can examine specimens arranged according to facies (assemblages of minerals that form for a particular rock composition at different temperature and pressure).

12E. "Metamorphism Great and Small" and "When Magma Meets Carbonates" cases: Changes in temperature, pressure, or fluid abundance can all cause rock to undergo metamorphic alteration, and these changes can occur at vastly different scales. On a small scale, hot magma can alter the rock it touches, a process called contact metamorphism. On a larger scale, entire mountain ranges can press down on rock and alter it, a process called regional metamorphism. In the first case, students can look at the "Metamorphism at Different Scales" graphic to learn about these two different types of metamorphism. In the other case, they can examine the "Stewed Carbonates" graphic to find out about a specific, economically valuable type of contact metamorphic rock known as skarns.

12F. Jade case: Jade is a tough and dense material, valued throughout human history by cultures around the world, that was once formed into blades and hammers and now is more commonly made into decorative objects. Students can observe the colors and patterns in this rock in the "Look Closely" callout to learn how the vein of white and lavender jadeite may have formed. They can also look at the other objects in this case to see how people use jade.

13. Hydrothermal Environments



The word **hydrothermal** comes from the Greek for water (**hydro**) and hot (**thermos**), and heat and water are the stars of the show in this environment. Hot water dissolves minerals, then flows through pores and fractures in rocks, transporting the minerals' components. As the water cools, it deposits these components in empty spaces, where they form new minerals.

This curated tour begins with a visit to a spectacular specimen of spiky stibnite crystals, followed by a video and cases that explore how hydrothermal minerals form.

13A. Stibnite specimen: This mineral—with hundreds of large bladelike crystals—grew in a large underground cavity. Students can observe the crystals' shape, size, and direction of growth, then look at the diagram and hypothesize how they might have formed.

Weighing almost half a ton, this stibnite from southeastern China is one of the largest on public display in the world.

13B. Video: In this animation, students can get an overview of how hydrothermal minerals form when water, heated by magma, circulates through cracks in rock; the water transports dissolved materials, which crystallize into minerals in the cracks as the water cools.

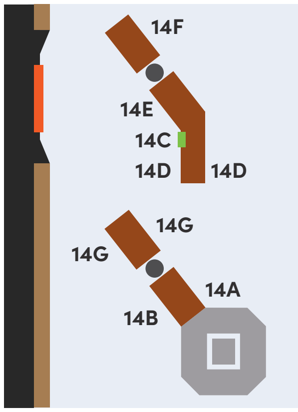
13C. "Veins and Pockets of Crystals" case: Earth's brittle crust fractures as its dynamic interior moves, making cracks and cavities where minerals can form. In the "Look Closely" callout, students can examine a stibnite and a celestine specimen and compare the directions of their crystal growth to infer whether the crystals formed a mineral vein or pocket. Students can then explore other examples of veins and pockets to see if they recognize similar growth patterns.

13D. "How Water Transports Minerals" case: Water is an excellent solvent. Its molecules have positively and negatively charged sides, which can disrupt the chemical bonds in many minerals, dissolving them. A mineral's solubility depends on the strength of its chemical bonds as well as the temperature and composition of the fluid. In the "Look Closely" callout, students can examine a specimen that contains both white calcite and purple amethyst quartz to see how the the order of mineral layers gives a clue to the differences in the two minerals' solubility.

13E. "The Many Colors of Fluorite" case: Fluorite, a common mineral deposited in veins, fractures, and cavities by hydrothermal processes, forms in many colors. Students can observe the wide range of colors and identify examples that owe their color to chemical impurities, exposure to radiation, or defects in the crystal structure that trapped atoms of rare-earth elements.

14. Weathering Environments

Earth is always changing. As rocks and minerals become exposed at its surface, the weathering process changes them through exposure to air, water, ice, and life. Weathering is often accompanied by erosion, or the transportation of weathered materials by flowing water, wind, ice, and gravity. Weathering counteracts Earth's dynamic building processes and, over billions of years, has produced the clays, soils, and salts critical to the survival of life on Earth—including our own lives.



This curated tour begins with a visit to a giant, colorful specimen of blue azurite and green malachite, followed by an overview video and cases exploring the weathering processes and the minerals that result.

This stone block weighs about 7,200 pounds (3,300 kg). It contains about 3,400 pounds (1,500 kg) of copper—enough to wire about 17 single-family homes with electricity.

14A. "The Singing Stone" specimen and "Our Colorful Planet" case: This massive block of blue azurite and green malachite is an example of the colorful minerals that can form underground when enriched groundwater flows downward, exposing metal sulfide deposits to oxygen and other agents of weathering. Students can examine the colors, patterns, texture, and porosity of this rock and share their thoughts about how it may have formed. In the "Our Colorful Planet" case, students can see other bold and vibrant rocks that formed in the oxidized zone.

14B. "An Enriching Process" case: These minerals formed when water containing dissolved gases trickled downward through rocks containing sulfide deposits, forming three distinct layers, or zones. Students can examine the illustration of the zones, then look for examples of minerals formed in each zone.

14C. Video: Students can watch this animation to get an overview of how rainwater, which is slightly acidic, moves downward from the surface, seeping through soil and rock and carrying away dissolved elements, which react with rocks further down to form new minerals.

14D. "Weathering Changes and Forms Minerals" and "Weathering Environments" cases: Exposure to air, water, and ice can alter minerals chemically, and physical forces can break them down into sediment. In the smaller case, students can observe specimens that have been transformed by eight different kinds of weathering processes, and in the larger case they can examine specimens to look for signs of weathering.

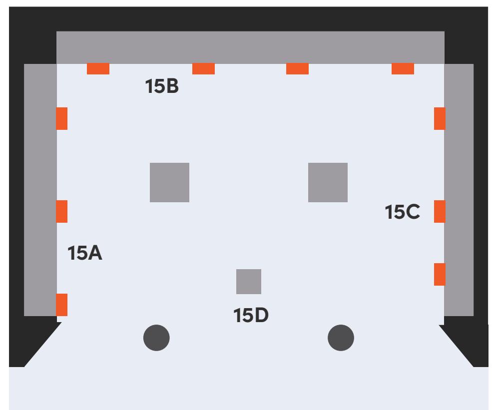
14E. "Settling into Place" case: Minerals at the surface weather differently, depending on properties such as cleavage, solubility, and toughness. They break into grains of different sizes and weight, which are transported by wind, water, ice, and gravity, sometimes accumulating into sorted deposits. Students can observe examples of what rocks and minerals might look like after they've weathered. In the "Look Closely" callout, students can compare the grain sizes of two samples of gold for clues to whether they traveled by wind or water. They can observe an example of a diamond and hypothesize about why it has not broken down.

14F. "Growing Up, Down, and Sideways" case: Dramatic examples of weathering form in areas of limestone or dolostone bedrock. The carbonate minerals in these rocks dissolve easily in groundwater, leaving behind caves, and then recrystallize from dripping water, resulting in formations called speleothems. These can include toothlike spikes that hang from cave ceilings (stalactites) or grow from floors (stalagmites). Students can look at specimens and imagine how they may have formed.

14G. "Salt and Survival" and "From Solution to Sediment" cases: Halite, or table salt, is necessary for our bodies to survive and function. Students can read about how salt forms and its importance to humans; then they can look at different kinds of salt. In the case on the other side, the "Look Closely" callout features two mineral specimens that crystallized as water evaporated in a sandy environment. Students can compare the shapes of the two specimens for clues to their crystal shape.

15. Hall of Gems

Gems are minerals that have been cut, ground, and polished to enhance their appearance. This hall includes examples of gems from around the world. Touch screens in front of cases provide close-up views and data about each specimen. As students explore this area, they can apply their knowledge of mineral properties, mineral-forming environments, and the interaction of light and minerals to understanding which minerals get used for gems and why. Below are highlighted stops.

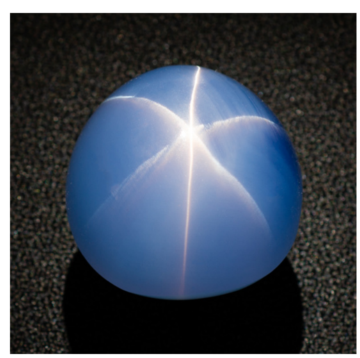


15A. "Rough and Cut Gems" and "Synthetic and Treated Gems" cases: To transform minerals into ornaments, people have developed methods to shape and polish them. People have also figured out how to manufacture synthetic versions of minerals that have the same composition, structure, and properties as the corresponding minerals. In these two cases, students can first read about how minerals are transformed into gems. Students can also learn how some gems are made in a lab and not from minerals, and then—from their knowledge of mineral properties and mineral formation—think about how this is possible.

15B. Quartz and ruby cases: Some minerals, like topaz and diamonds, have the same name as their gemstones. In other cases, the same mineral can give rise to different gemstones because its color varies. Students can observe the quartz case and the ruby case to see examples of this. For example, purple quartz is called amethyst, and yellow quartz is called citrine. Throughout the hall students can look for other examples of minerals giving rise to different gemstones.

15C. Birthstones: Students can explore this case to identify their birthstone and note any facts about birthstones that have varied across time and culture. They can also look for their birthstones throughout the hall.

15D. Star of India: This famous 563-carat blue sapphire, along with the other sapphires and rubies in this case, displays a floating, starlike pattern caused by tiny fibers of the mineral rutile, which reflect incoming light. Students can move their heads to watch the stars move in the Star of India and other examples of star corundum in this case. They can visit the exhibit of star stones and cat's-eye stones in the nearby Minerals and Light room to learn more.



The Star of India is just over 563 carats, making it the largest gem-quality star sapphire known.

Come Prepared Checklist

- ☐ **Plan your visit.** For information about reservations, transportation, and lunchrooms, visit amnh.org/field-trips.
- ☐ **Read the Essential Questions** in this guide to see how themes in the halls connect to your curriculum. Identify the key points that you'd like students to learn.
- ☐ **Review the Teaching in the Halls** sections for an advance look at what your class will encounter.
- ☐ **Download activities and student worksheets** at amnh.org/gems-minerals-educators. Designed for use before, during, and after your visit, these activities focus on themes that correlate to the standards.
- ☐ **Decide how your class will explore the halls:**
  - You and your chaperones can facilitate the visit using the Teaching in the Hall sections.
  - Students can use the worksheets and/or maps to explore the hall on their own or in small groups.

Correlation to Standards

A Framework for K–12 Science Education

Scientific and Engineering Practices • Asking Questions • Developing and Using Models • Analyzing and Interpreting Data • Obtaining, Evaluating, and Communicating Information • Constructing Explanations

Crosscutting Concepts • Patterns • Cause and Effect: Mechanisms and Explanations • Scale, Proportion, and Quantity • System and System Models • Structure and Function

Disciplinary Core Ideas • ESS1.A: The Universe and Its Stars • ESS1.C: The History of Planet Earth • ESS2.A: Earth Materials and Systems • ESS2.C: The Roles of Water in Earth's Surface Processes • ESS2.E: Biogeology • ESS3.A: Natural Resources • PS1.A Structure and Properties of Matter • PS1.B Chemical Reactions • PS4.B: Electromagnetic Radiation

Glossary

crystal: a naturally occurring, symmetrical solid with flat surfaces, like a cube, a prism, or even a snowflake. Crystals are made of atoms arranged in an orderly, repeating pattern.

density: the amount of mass packed into a unit volume. A gold nugget is heavier than a piece of quartz of the same size, because gold is denser than quartz.

deposit: an accumulation or concentration of minerals laid down by a natural process, such as gravity or the movement of water, wind, or ice

element (chemical element): matter composed of a single type of atom. Few elements are found in an uncompounded, pure form. The periodic table is the classification of the chemical elements.

fracture: the tendency to break along rough or curved surfaces

gem: a mineral that has been cut and/or polished to enhance its beauty

mineral: a natural solid with a crystal structure and a specific chemical composition

mineralogy: the study of minerals, or what mineralogists—including crystallographers, mineral physicists, and crystal chemists—do

Mohs Scale of Hardness: a system for determining the resistance of a mineral to being scratched, with 1 being the softest (talc) and 10 the hardest (diamond)

rock: a naturally occurring solid made of one or more minerals. Rocks make up most of Earth's crust.

sediments: small fragments of mineral or rock that are broken off, carried, and deposited by wind, water, or ice

CREDITS

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