American Museum of Natural History

Educator's Guide

Allison and Roberto Mignone

Halls of Gems *and* Minerals

amnh.org/gems-minerals-educators

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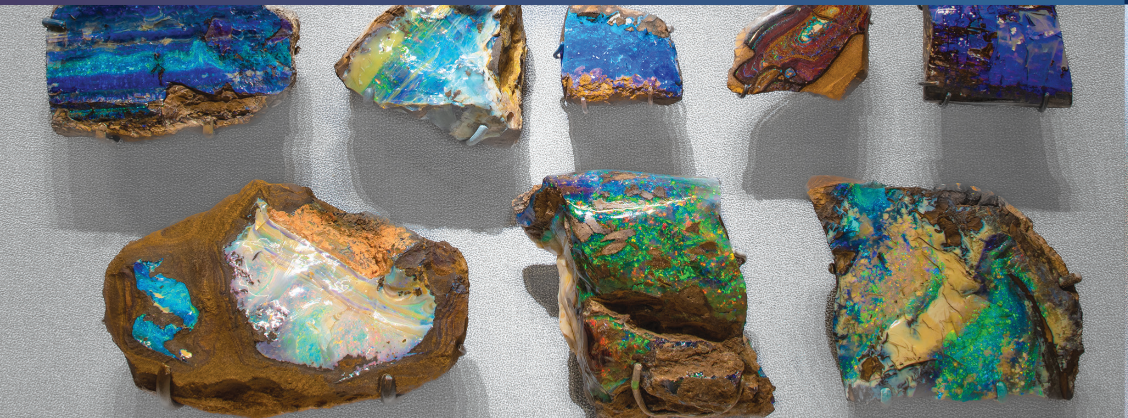
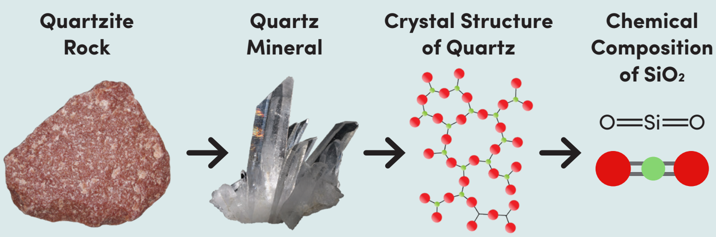


Essential Questions

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.

Map

Getting Started

1. Geodes and Elbaite
2. Mineral Stories: NYC & Beyond

Mineral Properties

3. Mineral Properties and Uses
4. Minerals and Light

Mineral Fundamentals

5. Mineral Basics
6. Crystal Basics
7. Mineral Classification

Mineral Evolution and Diversity

8. Mineral Evolution
9. Minerals and Life

Mineral-Forming Environments

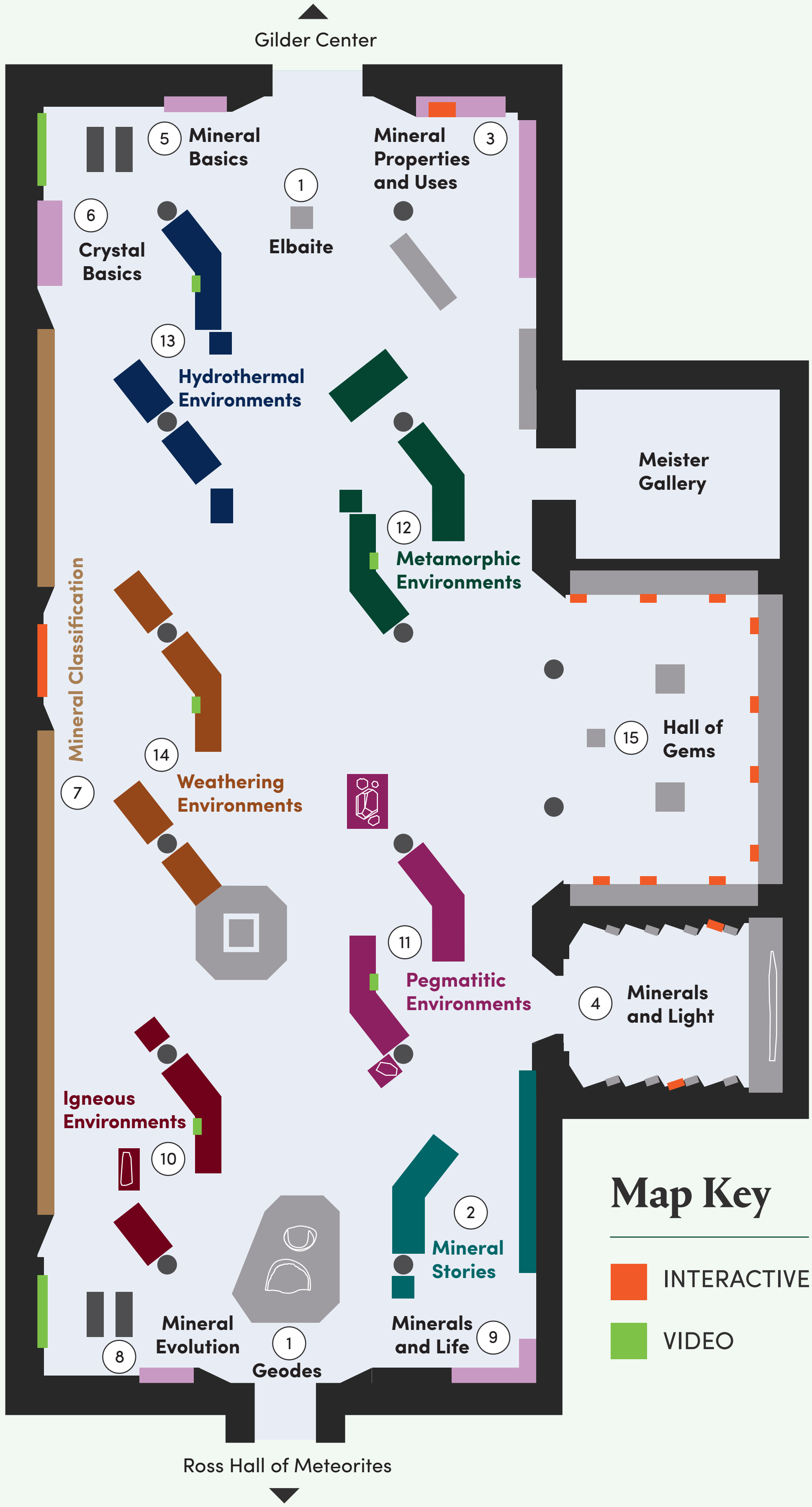
10. Igneous Environments
11. Pegmatitic Environments
12. Metamorphic Environments
13. Hydrothermal Environments
14. Weathering Environments

Gems

15. Hall of Gems

TIP: Bring Flashlights!

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



Map Key

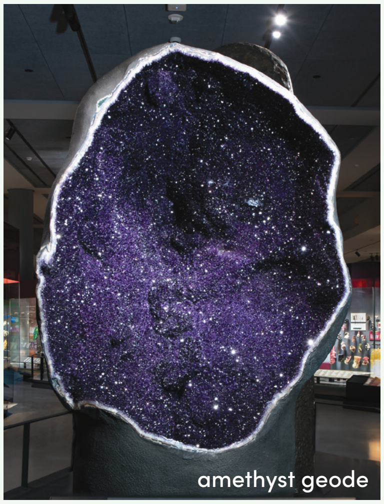
INTERACTIVE

VIDEO

Teaching in the Mignone Halls

1. Geodes and Elbaite

Dramatic signature specimens near the entrances excite curiosity and spark imagination. Students can examine them and speculate about how they formed.



amethyst geode

2. Mineral Stories: NYC and Beyond

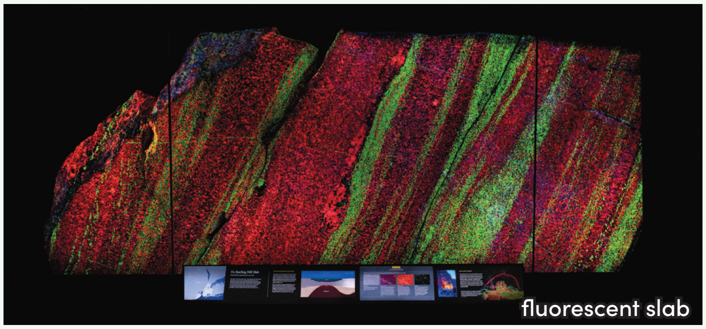
Students can look for clues about the geologic processes that formed the tri-state area as well as selected locations around the world.

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. First, students can play an interactive game to find out what characteristics define a mineral. Next, they can explore nearby displays to learn about the physical, chemical, electrical, magnetic, and optical properties of minerals, and the different types of bonds that cause these properties. Finally, they can look for minerals that are used to make everyday objects.

4. Minerals and Light

When minerals sparkle, shimmer, shine, or glow, they owe their dramatic appearance to the ways they interact with light. This room explores how minerals can bend, reflect, transmit, and distort light, and the amazing diversity of visual effects that result. Students can start with this room's centerpiece, a spectacular fluorescent slab, then examine the cases at the left to see how light interacts with minerals to create colorful effects: iridescence, fluorescence, and phosphorescence. Then they can explore the cases on the right, which demonstrate the optical properties of gemstones.



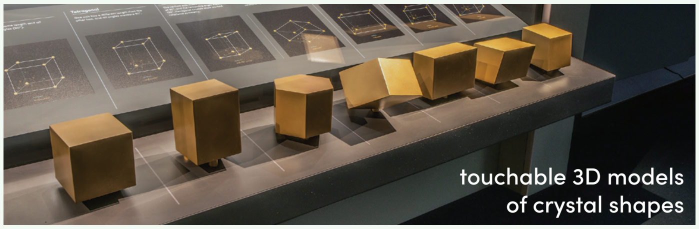
fluorescent slab

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. Students can watch a video to see how minerals as different as ice and quartz form on Earth, then examine the displays to understand the differences between a rock, a mineral, and a crystal.

6. Crystal Basics

Students can find out how crystals can be classified by their geometry and explore different types of symmetry.



touchable 3D models of crystal shapes

7. Mineral Classification

Minerals are made up of elements; they can be classified by their chemical compositions, as well as by their structures. Students can play with the large interactive in the middle to explore the Periodic Table of the Elements, which organizes elements according to their chemical properties. Next, they can view the series of displays to the left of the interactive for an introduction to ions, or electrically charged atomic units, and their effects on chemical bonds. Then they can view the displays to the right to explore the effects of these bonds in 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.

8. Mineral Evolution

For hundreds of millions of years after the birth of the universe, there were no minerals. Now, billions of years later, there are more than 5,000 mineral species on Earth. Students can examine art and specimens and watch a video to find out about the history of our planet and the minerals it hosts.

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. Students can observe a large, touchable petrified wood specimen, and then investigate the connections between minerals and life by examining specimens in nearby cases.

Download the online guide to access the full Teaching in the Mignone Halls, with expanded content for each of the 15 sections: amnh.org/gems-minerals-educators

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. Students can touch and observe a large granite rock, then visit cases that explore the formation and varieties of igneous rocks and minerals.

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. Students can observe a spectacular display of gigantic, touchable beryl crystals, then watch a video and examine cases that explore how pegmatites form.

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. Students can observe large garnets in a huge touchable slab of amphibolite, then watch a video and examine displays about different kinds of metamorphic rocks.

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. Students can observe a spectacular specimen of spiky stibnite crystals, then watch a video and examine cases that explore how hydrothermal minerals form.

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. Students can observe a giant, colorful specimen of blue azurite and green malachite, then watch a video and examine cases that explore the weathering processes and the minerals that result.


stibnite

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 the 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.

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.

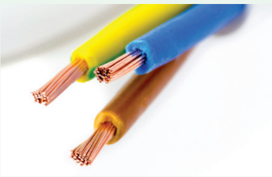
Chemical Properties

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?

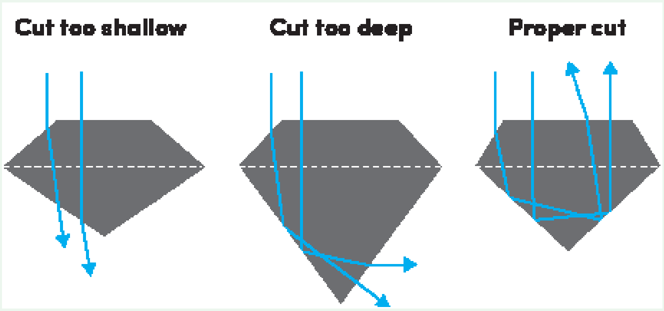
Gemologists use certain properties, some listed below, to determine the quality of a gem.

- **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.

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 Mignone Halls** section for an advance look at what your class will encounter.
- ☐ **Download student worksheets** at amnh.org/gems-minerals-educators. Designed for use during your visit, these worksheets will help students explore natural phenomena 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 Mignone Halls section.
  - Students can use the worksheets and/or maps to explore the halls 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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PHOTO CREDITS

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