Minerals and Rocks – How and Why Are They Used?

Activity for the Teachers Workshop sponsored by the
Education Committee of the Nevada Mining Association
updated 6 November 2023, including Next Generation Science Standards

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This activity is designed to stimulate students (Grades 6 to 12) to discover why certain minerals and rocks are useful in society, either for their physical properties or for the chemical elements they contain. Each sample in the mineral and rock boxes should be examined; some have obvious properties that are guide to their uses. A good source of information on the uses of minerals and rocks is the U.S. Geological Survey's annual report on *Mineral Commodity Summaries*, which can be found at https://www.usgs.gov/centers/national-minerals-information-center/mineral-commodity-summaries . That report also contains useful information on domestic and international production of many minerals and rocks.

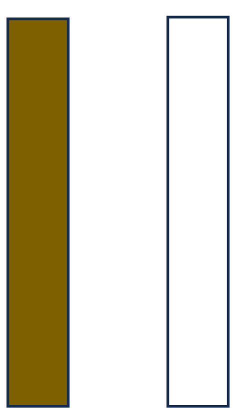
MINERALS

Barite, $BaSO_4$, Number 1 in your Mineral Box, is dense (4.5 g/cm^3), non-toxic, and non-reactive in our bodies and in most natural waters. Those properties make it ideal as (1) a weighting agent in geothermal and oil and gas drilling to prevent blowouts, (2) a weighting agent in bowling balls, and (3) a dense material that shows up in x-rays of the gut (barium cocktails in medical imaging). Barium (Element #56), shows up in x-rays because of its large nucleus. Nevada leads the nation in barite production.

All we need to know for now is that because barite is dense and non-reactive in most water, it can be used to control the pressure during drilling of wells. However, if you have students who are adept at math, see the section below.

Why does barite work as a weighting agent in drilling for geothermal resources or oil?

Water is used to cool the drill bit as its diamond implants grind the rock. Imagine the pressure of a pile of rock compared with the pressure inside a borehole filled with water and rock broken during drilling.



Weight of rock versus water? Which is heavier?

What are some common measures of pressure? **Pressure = Force per unit area**

Pascal (Pa) = 1 Newton (N)/m^2 = 1 N · m^{-2} = 1 kg · s^{-2} · m^{-1}

Newton = 1 kg · m/s^2 = kg · m · s^{-2}. **Force = mass x acceleration**.

Bar: 1 bar = 10^5 Pa. 1 Pa = 10^{-5} bar.

Inches of mercury: 1 inch Hg = 3.385 x 10^3 Pa. 1 Pa = 2.954 x 10^{-4} inch Hg.

Atmosphere: 1 atm = 1.01 x 10^5 Pa = 1.01 bar. 1 Pa = 9.869 x 10^{-6} atm.

1 atm = 29.9213 inches Hg = 760 mm Hg = 14.7 psi.

Pounds per square inch (psi): 1 psi = 6.89 x 10^3 Pa 1 Pa = 1.4508 x 10^{-4} psi

Pressure, P, can be defined as

P = ρGh, where ρ is density (commonly expressed in g/cm^3),
G is the acceleration due to gravity (9.81 m/s^2 at the Earth's surface), and
h is height (in meters).

For example, the pressure at the bottom of a column of water (density = 1 g/cm^3) that is 1,000 meters deep is P = [1 g/cm^3 x 1 kg/10^3 g x 10^6 cm^3/m^3] x [9.81 m/s^2] x [1 x 10^3 m] =

9.81 x 10^6 kg s^{-2} m^{-1} = 9.81 x 10^6 pacscal = 9.81 megapascal
= 98.1 bar
= 96.8 atm
= 1.42 x 10^3 psi = 1420 psi

Typical rock has a density of approximately 2.7 g/cm^3. Therefore the pressure at the bottom of 1,000 meters of rock is P = [2.7 g/cm^3 x 1 kg/10^3 g x 10^6 cm^3/m^3] x [9.81 m/s^2] x [1 x 10^3 m] =

2.65 x 10^7 kg s^{-2} m^{-1} = 2.65 x 10^7 pacscal = 26.5 megapascal
= 265 bar
= 261 atm
= 3.84 x 10^3 psi = 3840 psi

Geothermal and oil wells can be thousands of meters deep; therefore, pressure can be immense.

How is this applied in preventing blowouts?

If the drilling fluid (called "mud") were simply a mixture of water and broken rock, the density of the fluid would be less than that of the rock. To increase the density of the fluid, barite is added, such that

fluid density = ρ(rock) x f_{rock} + ρ(water) x f_{water} + ρ(barite) x f_{barite}, where f_{rock}, f_{water}, f_{barite} and are the fractions of the fluid that are broken rock, water, and barite (measured in units of cm^3 per cm^3 of fluid), such that

f_{rock} + f_{water} + f_{barite} = 1 [*Equation 1*].

To prevent a blowout, the overall fluid density must be at least equal to the density of the rock, and it shouldn't be more than the density of the rock, to avoid pushing the drilling mud into the rock formation. Therefore,

fluid density = ρ(rock) x f_{rock} + ρ(water) x f_{water} + ρ(barite) x f_{barite} = ρ(rock) [*Equation 2*].

Using densities of rock, water, and barite as 2.7, 1.0, and 4.5 g/cm^3, respectively, combining Equations 1 and 2,

f_{barite} = [1.7 x (1- f_{rock})]/3.5

Rewriting Equation 1, f_{water} = 1 – f_{rock} – f_{barite} .

For example, if f_{rock} = 0.5 cm^3 of rock per cm^3 of fluid, f_{barite} = 0.243, and f_{water} = 0.257;
or if f_{rock} = 0.7 cm^3 of rock per cm^3 of fluid, f_{barite} = 0.146, and f_{water} = 0.154.

As drilling progresses, the engineers or geologists monitoring the well need to keep a close watch on the amount of rock in the drilling mud and, therefore, how much barite is needed.

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Fluorite, CaF_2, Number 2 in your Mineral Box, is the primary source of fluorine, which is widely used in the chemical industry (including for refrigerants and polymers), in processing aluminum ore into metal, and in fluoride for the prevention of tooth decay. Our teeth and bones are made in part of the mineral apatite, $Ca_5(PO_4)_3(OH,F,Cl)$. Flouride (F^-) substituted for hydroxyl (OH^-) or chloride (Cl^-) helps to strengthen teeth. Although often occurring as colorful, clear crystals, fluorite is too soft to be considered a gemstone. Its hardness is 4.0 on the Mohs hardness scale.

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Garnet, Number 3 in your Mineral Box, is a group of separate minerals, including

grossular, $Ca_3Al_2Si_3O_{12}$
andradite, $Ca_3Fe(III)_2Si_3O_{12}$
almandine, $Fe(II)_3Al_2Si_3O_{12}$
pyrope, $Mg_3Al_2Si_3O_{12}$
spessartine, $Mn_3Al_2Si_3O_{12}$
uvarovite, $Ca_3Cr_2Si_3O_{12}$

Grossular and andradite commonly form a solid solution (with individual minerals having compositions intermediate between the end members), and almandine and pyrope also commonly form a solid solution. Spessartine is the garnet mineral found in vugs (open spaces) in rhyolite at Garnet Hill near Ely, Nevada. Uvarovite, an emerald-green variety of garnet, is found in some ultramafic rocks (rocks unusually enriched in magnesium and poor in silicon relative to other igneous rocks). With a hardness of approximately 7, garnet is used as an abrasive (in blasting, cutting, and sandpaper). With a somewhat high specific gravity (approximately 4 times as dense as water and denser than many common minerals) and insolubility in water near room temperature, garnet is used in water filtration. When crystals are clear and large enough for faceting, garnets are also semiprecious gemstones.

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Talc, $Mg_3Si_4O_{10}(OH)_2$, Number 4 in your Mineral Box, is used primarily in making paper, ceramics (including automotive catalytic converters), plastics, paint, rubber, and roofing. With a hardness of 1 on the Mohs scale, talc is easily ground to a powder for these uses.

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Feldspar, Number 5 in your Mineral Box, includes a group of minerals that form solid solutions with the following end members:

albite, $NaAlSi_3O_8$
anorthite, $CaAl_2Si_2O_8$
K-feldspar, $KAlSi_3O_8$.

Plagioclase (a solid solution between albite and anorthite, with relatively minor amounts of K) is the most common mineral in many igneous rocks. Mafic (magnesium- & iron-rich) rocks (extrusive basalt and intrusive gabbro) contain plagioclase that is rich in Ca, whereas felsic (feldspar-rich) or silicic (silica-rich) rocks (extrusive rhyolite and intrusive granite) contain plagioclase that is rich in Na. Felsic rocks also contain K-feldspar minerals (**orthoclase** or **microcline** in intrusive rocks and **sanidine** in extrusive rocks). **Adularia** is a K-feldspar that precipitates from hydrothermal fluids, which are often associated with gold and silver deposits. The high-temperature K-feldspars commonly contain significant amounts of Na and smaller amounts of Ca. Because Na- and K-rich feldspars have lower melting temperatures than many other minerals, they are used as a flux (helping material melt) in making glass, pottery, and ceramic tile.

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Gypsum, $CaSO_4{\bullet}2H_2O$, Number 6 in your Mineral Box, is used primarily in making wallboard (sheetrock). The process involves grinding gypsum to a powder and heating it to form plaster of Paris:

$CaSO_4{\bullet}2H_2O$(gypsum) + heat = $CaSO_4{\bullet}\frac{1}{2}H_2O$(plaster of Paris) + $^3/_2H_2O$(water)

The plaster of Paris is then combined with water to form a slurry that is spread onto long sheets of paper and capped with another sheet of paper. The reaction is reversed:

$CaSO_4{\bullet}\frac{1}{2}H_2O$(plaster of Paris) + $^3/_2H_2O$(water) = $CaSO_4{\bullet}2H_2O$(gypsum) + heat
(an exothermic reaction, which is why molding with plaster of Paris creates heat).

Within less than an hour, gypsum crystallizes, and the wallboard is cut to standard-sized sheets.

Large, clear crystals of gypsum (selenite) are collected for sale as mineral specimens. These crystals, like the one in your Mineral Box, can't be easily ground to the powder used in making plaster of Paris, because they break along the cleavage planes. Fine-grained gypsum (alabaster) can be easily carved, because it is soft (hardness of 2 on the Mohs scale). Gypsum is also an additive in some cements.

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Calcite, $CaCO_3$, Number 7 in your Mineral Box, is the mineral in limestone. As the name implies, it is used to make lime, CaO, by heating:

$CaCO_3$(calcite) + heat = CaO(lime) +CO_2(gas).

Lime has many industrial uses. Mixed with materials that include Al_2O_3, SiO_2, and smaller amounts of $CaSO_4$ and Fe_2O_3, lime makes cement. After water is added to cement powder, it begins to crystallize a variety of synthetic minerals, some of which can be found in metamorphic rocks. Cement is the binder that is used with aggregate (crushed rock, gravel, or sand) to make concrete.

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Magnetite, Fe_3O_4, Number 8 in your Mineral Box, and **hematite** (Fe_2O_3) are the primary minerals in iron ore. To make iron metal (Fe) or steel (iron combined with carbon plus other metals, such as nickel and manganese), iron in these minerals needs to be reduced, typically in a blast furnace. Magnetite is named for Magnesia, Greece (a locality for lodestone, crystals that are large enough to be natural magnets). The term magnet comes from the mineral, not vice versa. Magnetite has a black streak (when powered), whereas hematite has a red streak. Most of the red colors of rocks are due to hematite.

In the near-surface environment, oxygen in air (O_2) or dissolved in groundwater oxidizes magnetite to form hematite or goethite (FeOOH) through reactions such as the following:

Fe_3O_4 (magnetite) + ½ O_2 (oxygen in air or water) = 3 Fe_2O_3 (hematite)

2 Fe_3O_4 (magnetite) + ½ O_2 (oxygen in air or water) + 3 H_2O (water) = 6 FeOOH (goethite)

To make metallic iron, the oxidized iron (Fe^{2+} and Fe^{3+}) in ore minerals must be reduced, typically with either carbon (C) in coal or carbon monoxide (CO) through reactions such as:

Fe_3O_4 (magnetite) + 2 C (carbon in coal) = 3 Fe (metallic iron) + 2 CO_2

Fe_3O_4 (magnetite) + 4 CO (carbon monoxide gas) = 3 Fe (metallic iron) + 4 CO_2

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Muscovite, $KAl_2[AlSi_3]O_{10}(OH)_2$, Number 9 in your Mineral Box, has excellent cleavage, making it ideal, when fine-grained and ground to a powder, for use in joint compounds, oil-well-drilling additives, paint, roofing, and rubber products. Large crystals (sheet mica) are used in electrical and electronic equipment. The other common mica is **biotite**, which is a solid solution between **annite**, $KFe(II)_3[AlSi_3]O_{10}(OH)_2$, and **phlogopite**, $KMg_3[AlSi_3]O_{10}(OH)_2$. It is typically found in igneous rocks.

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Pyrite, FeS_2, Number 10 in your Mineral Box, is a mineral commonly associated with gold deposits. Much of the gold in the deposits near Carlin, Nevada occurs with arsenic in pyrite, not as separate gold grains but in solid solution in the pyrite. In the shallow parts of the deposits, where pyrite was oxidized (by rain water or groundwater), gold occurs as microscopic particles. These gold deposits were missed by the 49ers who crossed Nevada on their way to the gold fields in California, because the gold particles are too small to be collected by panning. Pyrite crystals are prized as mineral specimens.

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Quartz, SiO_2, Number 11 in your Mineral Box, is the dominant mineral in sand dunes, beaches, sandbars, and sandstone. With a hardness of 7 on the Mohs scale, it is ideal for sandpaper and abrasives. It is a common aggregate in concrete. When rounded (through erosion by stream flow, wind, or waves), it makes excellent sand for hydraulic fracturing in oil and gas fields (frac sand). Clear and colorful varieties can be semiprecious gems or collector's items, including:

amethyst, purple
smoky quartz, black, gray, or brown
citrine, yellow
rose or pink quartz, pink
prasiolite, green
rock crystal, clear .

Chalcedony or cryptocrystalline quartz includes agate and petrified wood. Synthetic (cultured) quartz, which is free of fluid or other inclusions, is used in electronics.

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Sulfur, S, Number 12 in your Mineral Box, is used primarily to produce sulfuric acid, which has many industrial uses, including the production of fertilizer from phosphate rock. Most of the sulfur consumed today comes as a byproduct of petroleum refining and natural gas production.

ROCKS

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Rhyolite tuff, Number 1 in your Rock Box, is one way that rhyolite (the chemical equivalent of granite) occurs. Tuff formed by being violently erupted as ash, usually from a caldera. It commonly contains crystals (of feldspars, quartz, and other minerals), rock fragments, and pumice that was flattened by the weight of overlying ash. Others forms of rhyolite include obsidian (volcanic glass), pumice (glass with abundant holes), perlite (hydrated glass), and solidified/crystallized lava flows, domes, and shallow intrusions. Rhyolite tuffs are the common dimension stone for the building blocks of cathedrals in Mexico. Rhyolite makes light-weight aggregate for use in paving roads and as architectural aggregate (with shades of pink and gray). Pumice is also used as light-weight aggregate and as stone to wash jeans. When heated to drive off the trapped water in perlite, it expands to make insulation and plant-growing material. To many geologists, **rhyolite is the most interesting rock**. It is commonly associated with ore deposits of gold, silver, beryllium, lithium, tin, and fluorite.

Common igneous rocks include the following, arranged by decreasing silica (SiO_2) content.

	Felsic or silicic			Mafic	Ultramafic
Extrusive/ Volcanic	**Rhyolite**	Dacite	Andesite	Basalt	Komatiite
Intrusive	Granite	Granodiorite	Diorite	Gabbro	Peridotite

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Granite, Number 2 in your Rock Box, is commonly mined for dimension stone. Because most minerals in granite (plagioclase, K-feldspar, quartz) are hard and insoluble at normal temperatures, polished granite withstands wear well enough to be used in countertops. These properties also make it ideal for structural building stone, facings on buildings, gravestones, and steps. Granite is also used as crushed stone. The polished stone industry uses the term "granite" for any intrusive igneous rock or metamorphic rock that contains dominantly hard minerals and "marble" for any metamorphic rock that is soft, including true marble.

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Shale, Number 3 in your Rock Box, is used in the production of cement as a source of Al_2O_3 and SiO_2, because shale is composed primarily of fine-grained clay minerals. One of the most common clay minerals is kaolinite, $Al_2Si_2O_5(OH)_4$. Shale is a clastic sedimentary rock. Clastic rocks are defined on the basis of the sizes (diameters) of the dominant clasts or grains in the rock.

Grain size (mm)	clay	$^1/_{256}$	silt	$^1/_{16}$	sand	2	pebble	64	cobble/boulder
Sedimentary rocks	**shale**		siltstone		sandstone		conglomerate		
	mudstone & mudrock								
Metamorphic rocks	slate/phyllite		schist/quartzite				metaconglomerate		

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Conglomerate, Number 4 in your Rock Box, is sometimes used for crushed stone needed in construction and road building. However, if there are many cobbles or boulders in the rock, it is not ideal for such use.

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Schist, Number 5 in your Rock Box, is a metamorphic rock that breaks into irregular plates. It is mined to make crushed rock used in construction.

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Gneiss, Number 6 in your Rock Box, is a metamorphic rock in which the minerals in the original sedimentary (or igneous) rock have recrystallized, often to form other minerals, such as garnet. Gneiss that contains abundant hard minerals (quartz, feldspars, garnet, magnetite, etc.) is mined for dimension stone and makes beautiful countertops.

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Basalt, Number 7 in your Rock Box, is the most abundant volcanic rock, making up the bulk of oceanic crust. It is mined for crushed rock. Scoria, a variety of basalt with holes formed by escaping gas (mostly H_2O and CO_2) is mined from cinder cones and sold for architectural aggregate and charcoal grills.

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Quartz diorite, Number 8 in your Rock Box, is mined for dimension stone. It is intermediate in composition between diorite and granodiorite. Geologists have lots of names for rocks.

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Sandstone, Number 9 in your Rock Box, is used as crushed rock and dimension stone. When friable (easily broken apart into sand grains), it is used for glass making, frac sand, and sand traps in golf courses. The **Nevada State Rock** is sandstone, named for the Jurassic Aztec Sandstone, which crops out in Red Rock Canyon and Valley of Fire in Clark County. The red color of much of the Aztec Sandstone is from coatings of hematite, Fe_2O_3, on the sand grains, and the orange colors are from coatings of goethite, FeO(OH), two minerals with oxidized iron, Fe^{3+}. Some Aztec Sandstone is cemented well enough with quartz to be cut and polished for facings on walls inside buildings. Mars is red because of hematite.

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Limestone, Number 10 in your Rock Box, is one of the most common rocks that is crushed for use as aggregate. Its other main use is in the production of lime and cement [see Calcite]. Some limestones are hard enough to be polished and used for flooring; other limestones are mined and cut as dimension stone. Limestone is composed predominantly of calcite. A similar-appearing rock is dolomite, which is composed of the mineral dolomite, $CaMg(CO_3)_2$.

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Quartzite, Number 11 in your Rock Box, is metamorphosed sandstone. More compact than sandstone, quartzite is often used for paving stones. Composed mostly of quartz, the rock withstands weathering and erosion well. It is also used for crushed stone and in the steel industry.

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Marble, Number 12 in your Rock Box, is metamorphosed limestone. The calcite crystals in limestone are generally microscopic. Metamorphism, particularly at high temperature, has recrystallized the calcite, making the crystals visible with the naked eye. Marble is used for carving into statues and is cut and polished as dimension stone.

Because of its softness (calcite's hardness is 3), marble is easy to carve with steel tools (hardness of 5 to 6), but, for the same reason, marble makes poor kitchen countertops. Because rainwater is acidic, marble weathers easily. The reaction can be described as:

$CaCO_3$(calcite) + $2H^+$(in acidic rainwater) = Ca^{2+}(dissolved in water) + H_2O (water) + CO_2(gas).

This is the same reaction that occurs when vinegar or other acid is placed on calcite; it fizzes from the CO_2 gas. Granite (the intrusive equivalent of rhyolite), therefore makes much better gravestones than marble. **Let's hear it for rhyolite!**

The polished stone industry uses the term "marble" for other soft rocks, including serpentinite, a green rock composed primarily of one or more of the **serpentine**-group minerals, typically antigorite, $Mg_3Si_2O_5(OH)_4$. Serpentinite forms from the metamorphism of ultramafic rocks that contain abundant olivine, a solid solution of forsterite (Mg_2SiO_4) and fayalite (Fe_2SiO_4). Metamorphism of iron in olivine yields magnetite (a common mineral in serpentinite). The reaction produces hydrogen gas, which has been known to occur naturally in limited commercial quantities:

$3Fe_2SiO_4$ (in olivine) + $2H_2O$ (water) = $2Fe_3O_4$ (magnetite) + $3SiO_2$ (silica) + $2H_2$ (gas)

Serpentine rarely contains quartz, because metamorphism of the forsterite component of olivine consumes silica:

$3Mg_2SiO_4$ (in olivine) + SiO_2 (silica) + $2H_2O$ (water) = $2Mg_3Si_2O_5(OH)_4$ (serpentine)

Antigorite is a platy variety of serpentine. Another mineral in the serpentine group is chrysotile, also $Mg_3Si_2O_5(OH)_4$, which occurs as fibrous crystals, asbestos. The amphibole group of minerals also includes asbestiform varieties.

Serpentine is the California State Rock. Olivine is one of the first minerals to crystallize in basalt. It can sink to the bottom of a basaltic magma chamber that forms at ocean ridges, thereby forming a peridotite layer in the oceanic crust. Serpentinite that formed from the metamorphism of peridotite presumably was thrust onto California along subduction-related faults.

Rocks rich in serpentine or olivine are being considered for carbon sequestration (CO_2 capture from a power plant, cement plant, or from the atmosphere, followed by storage to decrease the amount that enters the atmosphere and contributes to global warming). The chemical reactions involved create solid carbonates, magnesite ($MgCO_3$) and siderite ($FeCO_3$):

Mg_2SiO_4 (in olivine) + CO_2 (gas) = 2 $MgCO_3$ (magnesite) + SiO_2 (quartz)

Fe_2SiO_4 (in olivine) + CO_2 (gas) = 2 $FeCO_3$ (siderite) + SiO_2 (quartz)

$Mg_3Si_2O_5(OH)_4$(serpentine) + $3CO_2$(gas) = $3MgCO_3$(magnesite) + SiO_2(quartz) + $2H_2O$(water)

These reactions involve large volume increases, which make them impractical for underground injection of liquid CO_2 under pressure into formations of basalt or ultramafic rocks. Injection of CO_2 into deep, porous and permeable sedimentary formations, however, is being done for carbon capture and storage and for enhancing recovery of oil.

Uses of Minerals and Rocks - Next Generation Science Standards* – High School

Disciplinary Core Ideas

HS-ESS3 Earth and Human Activity - ESS3.A: Natural Resources

- Resource availability has guided the development of human society. (HS-ESS3-1)
- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2)

Science and Engineering Principles

Using Mathematics and Computational Thinking

Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS- ESS3-3)
- Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-ESS3-6)

Crosscutting Concepts

Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS3-1)

Systems and System Models
When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-ESS3-6)

Stability and Change

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS- ESS3-3),(HS-ESS3-5)
- Feedback (negative or positive) can stabilize or destabilize a system. (HS- ESS3-4)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

- Modern civilization depends on major technological systems. (HS-ESS3-1),(HS- ESS3-3)
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS- ESS3-2), (HS-ESS3-4)

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NOTE: The example of using the mineral barite to prevent blowouts in oil & gas or geothermal wells employs algebra in the design of the drilling fluid.

*The Nevada Academic Content Standards for Science (NVACSS) are based on the Next Generation Science Standards and include ESS3.A – Natural Resources.

Uses of Minerals and Rocks - Next Generation Science Standards* – Middle School

Disciplinary Core Ideas

MS-ESS3 Earth and Human Activity - ESS3.A: Natural Resources

Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geological processes. (MS-ESS3-1)

Science and Engineering Principles

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6-8 builds on K-5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the student's own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (MS-ESS3-1)
- Apply scientific principles to design an object, tool, process or system. (MS-ESS3-3)

Crosscutting Concepts

Cause and Effect

- Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. (MS-ESS3-3)
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS3-1), (MS-ESS3-4)

Stability and Change

- Stability might be disturbed either by sudden events or gradual changes that accumulate over time. (MS-ESS3-5)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ESS3-1), (MS-ESS3-4)

The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (MS-ESS3-2), (MS-ESS3-3)

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NOTE: The chemical reactions for making lime from the calcite in limestone or in making iron for steel can be discussed in terms of positive and negative consequences (with release of CO_2).

*The Nevada Academic Content Standards for Science (NVACSS) are based on the Next Generation Science Standards and include ESS3.A – Natural Resources.