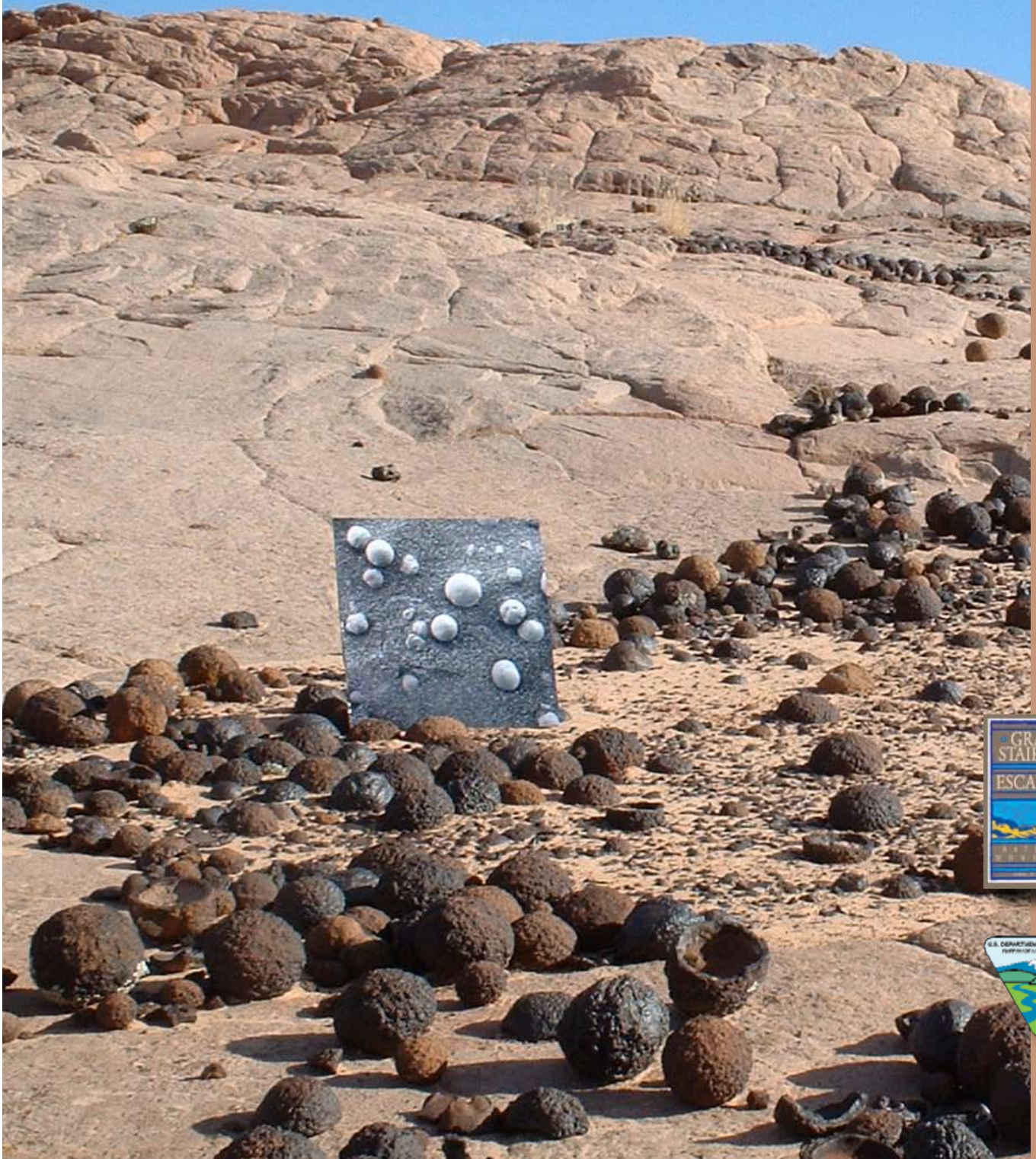


# Moqui Marbles on Mars (How Geologic Research from Earth Helped Solve a Mystery on Mars)

## Teacher Guide

BLM

Grand Staircase-Escalante National Monument



## Moqui Marbles on Mars (How Geologic Research from Earth Helped Solve a Mystery on Mars)

### Grade Level

9-12 and 7-8 (with adaptations)

### Duration

45 minutes or 90 with DVD

### Description

Students learn how geologic research on Earth is being applied to recent discoveries on Mars by examining the chemistry of iron and how iron concretions have formed in the Navajo Sandstone formation of the Colorado Plateau over geologic time.

### Goals

- Correlate acid-base and oxidation-reduction reactions of iron to rock color and the formation of iron concretions over geologic time.
- Evaluate how research into iron concretions on Earth has been applied to recent discoveries on Mars.

### Academic Content Standards

The following standards are drawn from *Content Knowledge*<sup>1</sup>.

#### Earth/Space Science Standard 3

Understands the composition and structure of the universe and the Earth's place in it.

##### Level IV (Grades 9-12)

##### Benchmark 5

Knows ways in which technology has increased our understanding of the universe (e.g., visual, radio, and x-ray telescopes collect information about the universe from electromagnetic waves; space probes gather information from distant parts of the Solar System; mathematical models and computer simulations are used to study evidence from many sources in order to form a scientific account of events in the universe.)

#### Physical Science Standard 8

Understands the structure and properties of matter.

##### Level IV (Grades 9-12)

##### Benchmark 8

Knows how radioactive isotopes can be used to estimate the age of materials that contain them because radioactive isotopes undergo spontaneous nuclear reactions and emit particles and/or wavelike radiation; the decay of any one

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<sup>1</sup> *Content Knowledge: A Compendium of Standards and Benchmarks for K-12 Education: 4<sup>th</sup> Edition*, Mid-Continent Research for Education and Learning in Aurora, Colorado. <http://www.mcrel.org/standards-benchmarks/>

nucleus cannot be predicted, but a large group of identical nuclei decay at a predictable rate, which can be used to estimate the material's age.

Benchmark 15

Knows that a large number of important reactions involve the transfer of either electrons (oxidation/reduction reactions) or hydrogen ions (acid/base reactions) between reacting ions, molecules, or atoms.

Nature of Science Standard 11

Understands the nature of scientific knowledge

Level IV (Grades 9-12)

Benchmark 3

Understands how scientific knowledge changes and accumulates over time (e.g., all scientific knowledge is subject to change as new evidence becomes available; some scientific ideas are incomplete and opportunity exists in these areas for new advances; theories are continually tested, revised, and occasionally discarded)

Benchmark 4

Knows that from time to time, major shifts occur in the scientific view of how the world works, but usually the changes that take place in the body of scientific knowledge are small modifications of prior knowledge.

## Materials

- *Moqui Marbles on Mars, or How Geologic Research from Earth Helped Solve a Mystery on Mars – Student Activity*
- Journal articles:
  - *On Earth, as it is on Mars?*, by David C. Catling, in the journal *Nature*, June 17, 2004, Vol. 429, ppg. 707-708. Available online at <http://www.nature.com/nature/journal/v429/n6993/pdf/429707a.pdf>
  - *Making a Splash on Mars*, by Charles W. Petit, *National Geographic Magazine*, July, 2005, Vol. 208, ppg 58-77. Available online at <http://www7.nationalgeographic.com/ngm/0507/feature3/index.html>
  - *Roving on the Red Planet*, by Ron Cowen, *Science News*, May 28, 2005, Vol. 167, ppg 344-346.

Or Video

*Welcome to Mars*, Neil Ross, narrator. NOVA production by MDTV Productions for WGBH/Boston, 2005. ISBN 1-59375-246-6. This DVD costs \$19.95, and is available from WGBH at 800-949-8670, or online at <http://www.shop.wgbh.org>

- Computer with internet access
- Video or DVD *Traces in Time*, produced by GSENM

## Objectives

1. Identify chemical reactions of iron that affect the geology of the Navajo Sandstone formation of the Colorado Plateau.

2. Examine the role iron plays in rock colors and concretions over geologic time.
3. Determine the relationship between iron concretions on Earth and recent discoveries on Mars.
4. Draw conclusions using scientific methodology to synthesize acquired information about iron chemistry.

## Procedures

The video or DVD *Traces in Time* is a great way to introduce students to the Grand Staircase-Escalante National Monument.

1. Step 1 – Starting with *Moqui Marbles on Mars...* and ending with *Oxidation-reduction reactions of iron* (pages 1-2), is a review of acid-base and oxidation-reduction reactions with emphasis on iron. Depending on how familiar students are with these reactions this objective can be done quickly as a class review.

2. Step 2 – *Iron Chemistry* (pages 2-5) presents the effects of iron chemistry over geologic time. This objective again can be completed by individual students or in a classroom presentation.

3. There are two options for Step 3 – *Investigate!* (page 6), the DVD *Welcome to Mars* or articles from scientific journals about research on Mars.

a. *Welcome to Mars* will take 35 minutes to watch if you use the DVD's scene selection and start at section 3, "Mars Geology 101". The entire video takes about 60 minutes.

b. The three different scientific articles range in technical difficulty: "Roving the Red Planet", by Ron Cowen in *Science News* is three pages long with a few photos while "Making a Splash on Mars", by Charles Petit in *National Geographic* is 19 pages with text and amazing photos. Either of these is appropriate for students in grades 7-12.

"On Earth, as it is on Mars?" by David Catling in the journal *Nature* is more technical, though shorter. It can be read by students in grades 9-12, with some "interpretation" of the more technical scientific jargon.

4. Step 4 – *Drawing Conclusions* (pages 7-8) gives students the chance to synthesize the information they have acquired and apply it to six questions.

### Adaptations

This unit can be adapted for use with younger students by working through Steps 1 and 2 as a class before viewing the DVD or reading the scientific articles. Another option is to start with the DVD, which takes 60 minutes in its entirety, and finish with classroom discussions about Step 1 and 2.

## Extensions

*Archaeologic Uses of Moqui Marbles* (page 9) is a short narrative about Moqui marbles and prehistoric cultures in Grand Staircase-Escalante National Monument.

**References**

- Catling, David C., *On Earth, as it is on Mars?*, Nature, June 17, 2004, Vol. 429, p 707-708.  
Available online at  
<http://www.nature.com/nature/journal/v429/n6993/pdf/429707a.pdf>
- Chan, Marjorie A. and William T. Parry, *Rainbow of Rocks, Mysteries of Sandstone Colors and Concretions in Colorado Plateau Canyon Country*, Utah Geological Survey Public Information Series 77, ISBN 1-55791-681-0
- Cowen, Ron, *Roving on the Red Planet*, Science News, May 28, 2005, Vol. 167, p 344-346.
- Petit, Charles W., *Making a Splash on Mars*, National Geographic Magazine, July, 2005, Vol. 208, p 58-77. Available online at  
<http://www7.nationalgeographic.com/ngm/0507/feature3/index.html>

**Assessment**

At the end of this activity students should be able to summarize the following major points:

- Iron concretions provide dramatic evidence of similar geological processes on two sister planets, Earth and Mars.
- They prove that Mars once had more water available than it does today.
- The presence of water prompts the interesting conjecture that some early life forms may have evolved on Mars. But there is no conclusive proof...yet.

**Answer Key****Question 1**

If the Navajo Sandstone not been “bleached” white, becoming the White Cliffs, they might be called the “Red Cliffs” today. An adjoining rock layer, the Kayenta Formation, forms the red cliffs that are called the Vermilion Cliffs. They too are sandstone, but have shale combined with the sand. If you walked along the base of the Vermilion Cliffs, do you think you would find iron concretions? Why or why not?

*For the most part the Kayenta formation is not bleached or a big marble former because it is more shale and not as porous or permeable.*

**Question 2**

Why is water so important to the search for life on Mars?

*“...all life, as we know it, requires water.” Without water, simple life forms could not have developed on Mars or Earth.*

**Question 3**

Why did NASA scientists target the rover to a site on Mars with lots of hematite?

*Hematite (Fe<sub>2</sub>O<sub>3</sub>), an oxide of iron, forms in a water solution. So if hematite is present, then at some time in the past water must have been on Mars too.*

**Question 4**

What did Steve Squyres mean by his phrase “blueberries in a muffin”? If you need a little help with this, try looking at the following images online:

<http://www.jpl.nasa.gov/missions/mer/images.cfm?id=1057>

<http://www.jpl.nasa.gov/missions/mer/images.cfm?id=743>

<http://www.jpl.nasa.gov/missions/mer/images.cfm?id=647>

*He meant that the hematite spheres were randomly scattered in the rock, just as blueberries are distributed in a breakfast muffin. That, or else Steve was getting hungry.*

### Question 5

Compare Utah concretions (Moqui marbles) to Mars concretions (blueberries).

#### a) How are they alike?

- Both Moqui marbles and “blueberries” accumulate at the surface.
- Both form within porous sedimentary rock.
- Both are produced through iron-rich fluid chemistry.
- Both require water during their formation process.

#### b) How are they different?

- Utah’s concretions are mostly quartz sand cemented by hematite.
- Martian concretions are more purely hematite, crystalline, and gray in color.
- Martian concretions contain high levels of sulfate salts, suggesting they formed in evaporating brine. Utah marbles have little sulfur.
- During the formation process, the Martian fluid was more acidic.
- The Utah fluid was more reducing and hydrocarbon-rich.

### Question 6

Iron is not the only atom important in fluid chemistry on Mars. What other important element is represented by the symbol (S)?

*Sulfur*

## Vocabulary

<b>Cenozoic</b>	Belonging or relating to the most recent era of geologic time, covering the period from the present to about 65 million years ago, during which modern plants and animals evolved.
<b>Concreted</b>	A mass formed when particles coalesce, or concrete together.
<b>Emancipated</b>	Freed from constraints or restrictions
<b>Fissures</b>	Long narrow cracks or openings, especially in rock.
<b>Formations</b>	Unit of rock consisting of a succession of strata or an igneous intrusion.
<b>Goethite</b>	Hydrated iron oxide [FeO(OH)]
<b>Hematite</b>	A mineral that is an important iron ore and occurs as black, brown, or red crystals or in a massive uncrystallized form, often in very large deposits (Fe <sub>2</sub> O <sub>3</sub> ).

Hopi	Native North American people of northeastern Arizona.
Iron Concretions	Natural spherical forms and other shapes formed in porous media (like sandstone) when certain iron compounds precipitate.
Jurassic	The period of geologic time during which dinosaurs flourished and birds and mammals first appeared, extending from 200 million years to 145 million years ago.
Oxidize	<ol style="list-style-type: none"><li>1. To react or cause a chemical to react with oxygen. For example, in forming an oxide.</li><li>2. To lose electrons, or to cause a chemical element or compound to lose electrons.</li><li>3. To form an oxide coating or to cover something with an oxide coating.</li></ol>
Permeable	When solids, liquids, gases, or magnetic fields are able to pass through.
Pigment	<ol style="list-style-type: none"><li>1. Compound added to give something, such as paint or ink, its color.</li><li>2. Compound in plant or animal tissue that gives it color.</li></ol>
Porous	Permitting the movement of fluids or gases through it by way of pores or other passages.
Reduced	To undergo, or cause a substance to undergo, a chemical reaction in which there is a gain in hydrogen or a loss of oxygen.
Sandstone	Sedimentary rock made up of sand particles, mostly quartz, bound together by a mineral cement, along with some feldspar, mica, and rock debris.
Shale	A dark fine-grained sedimentary rock composed of layers of compressed clay, silt, or mud.