Science News
EDUCATOR GUIDE

CNSA/CLEP

March 28, 2020
Rover Peers Beneath Moon's Farside

SOCIETY FOR SCIENCE & THE PUBLIC

SN EDUCATOR GUIDE

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Rover Peers Beneath Moon's Farside

About this Guide

In this Guide, based on the *Science News* article "Rover peers beneath moon's farside," students will explore the moon's geology and learn how to display and interpret data through diagrams. In an activity, students will use their knowledge of Earth's rock cycle to analyze data on rock samples.

This Guide includes:

Article-based Comprehension Q&A — Students will answer questions about the *Science News* article "Rover peers beneath moon's farside" (Readability: 10.1), which details new geologic evidence that could help scientists understand why the lunar nearside and farside look so different. Related standards include NGSS-DCI: HS-ESS1; HS-ESS2; HS-ETS1.

> **Student Comprehension Worksheet —** These questions are formatted so it's easy to print them out as a worksheet.

Cross-curricular Discussion Q&A — Students will explore the value of diagrams, what information they should include and how to draw them. This discussion can be used with any science- or engineering-related article that contains a diagram. Related standards include NGSS-DCI: HS-ESS1; HS-ESS2; HS-ETS1.

> **Student Discussion Worksheet —** These questions are formatted so it's easy to print them out as a worksheet.

Activity: Geologist for a Day

> **Summary:** Rocks found across the world offer clues to geological processes, as well as the history of Earth and the rest of the solar system. In this activity, students will review types of rocks and the rock cycle and will apply that knowledge to interpret data on two rock samples. Related standards include NGSS-DCI: HS-ESS2; HS-ESS1.
>
> **Approximate class time:** 1 class period.

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Article-based Comprehension, Q&A

Directions for teachers: After your students read "Rover peers beneath moon's farside," ask them to answer the following questions.

1. What is Chang'e-4 and what makes it unique?

Chang'e-4 is a Chinese spacecraft that landed on the moon. It is the first spacecraft to land on the farside of the moon.

2. What type of spacecraft is Yutu-2, and how is it different from Chang'e-4?

Yutu-2 is a rover, which means it can travel across the moon's surface. Chang'e-4 is a lander — it is stationary and cannot explore the moon's surface beyond where it landed.

3. What technology does Yutu-2 use to explore the moon? Are there limitations to Yutu-2's technology? Explain.

The rover used radar to collect data on material under the moon's surface. Yes, a limitation of the rover's radar is that it can probe only to a depth of 40 meters.

4. Based on the diagram, what did Yutu-2 find? Be as specific as possible with your description.

Over a distance of about 106 meters, the rover found three distinct layers of material — a top layer of fine soil that extended 12 meters below the surface, a middle layer of coarse material mixed with large rocks that extended 12 meters below the top layer and a bottom layer extending 26 meters below the middle layer. The bottom layer had areas of both fine and coarse materials.

5. What inferences did scientists make based on the finding?

Scientists think the bottom two layers were created from many meteorites and other objects smashing into the moon and displacing material. The top layer of fine soil probably resulted from micrometeorite impacts and temperature shifts. Overall, the layers suggest the farside had a violent history.

6. The author refers to the moon's farside as a layer cake. What type of literary device is this, and why do you think the author uses it?

This is an example of a metaphor. The author likely used this literary device to help readers visualize the farside's distinct layers.

7. What does geologist Daniel Moriarty say is a big question in lunar science? What leads scientists to ask this question?

Moriarty says that a big question is why the moon's nearside and farside look so different.
The moon's nearside has a relatively smooth surface, while its farside is marked with more craters.

8. Were there terms in the story that were new to you? Can you come up with definitions for these terms based on the story?

The terms regolith and ejecta were unfamiliar. Regolith is fine soil. Ejecta is material that is flung away (or ejected), in this case when objects slam into the moon.

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Student Comprehension Worksheet

Directions: After reading "Rover peers beneath moon's farside," answer the following questions.

1. What is Chang'e-4 and what makes it unique?

2. What type of spacecraft is Yutu-2, and how is it different from Chang'e-4?

3. What technology does Yutu-2 use to explore the moon? Are there limitations to Yutu-2's technology? Explain.

4. Based on the diagram, what did Yutu-2 find? Be as specific as possible with your description.

5. What inferences did scientists make based on the finding?

6. The author refers to the moon's farside as a layer cake. What type of literary device is this, and why do you think the author uses it?

7. What does geologist Daniel Moriarty say is a big question in lunar science? What leads scientists to ask this question?

8. Were there terms in the story that were new to you? Can you come up with definitions for these terms based on the story?

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Cross-curricular Discussion, Q&A

Directions for teachers:
Search the *Science News* archive to find an article on a topic of your choice that includes a diagram. Some of the answers provided below relate to the *Science News* article "Rover peers beneath moon's farside." Ask your students to read the article, review the diagram and then answer the individual questions below.

Individual questions
1. Describe the diagram included in the article. Explain the different types of information that it contains.

The "Lunar layers" diagram shows a cross-section of the moon's farside down to a depth of about 40 meters. The cross-sectional diagram includes the different types of soil and rocks within a layer and the approximate depth range of each layer. The Yutu-2 rover is also shown on the surface of the moon in the diagram.

2. What is this diagram's purpose? Why do you think the diagram is included in the article?

The diagram is summarizing recent data collected by China's Chang'e-4 lander and Yutu-2 rover. It gives the reader a more efficient way of understanding the data and information that is described in the article's text by representing it visually.

3. Give an example of another diagram you have seen or used. Explain its intended purpose.

Answers will vary and could include scientific or other types of diagrams. Students should clearly state what their diagram explains — whether it's an idea, a process or a system.

Partner questions
With a partner, students should then brainstorm how to define and draw scientific diagrams using the partner prompts below.

4. How would you define a diagram? What is a diagram generally used for?

A diagram is a graphic or image that is created to visually explain an idea, process or system. Diagrams can also be used to organize ideas into categories or define relationships among items.

5. Think about various fields of science — chemistry, biology, environmental science, physics, genetics and so on. What are some examples of scientific diagrams from these fields?

Phylogenetic trees explain how related organisms evolved from common ancestors. Force or free-body diagrams show all the external forces acting on an object and explain the net force on the object. Biochemical cycles of matter, such as carbon, water, oxygen and nitrogen, are used to explain the interconnectedness of Earth's resources and how disturbances can affect an ecosystem. A diagram showing an experimental laboratory setup is often used to explain steps of a procedure. Punnett squares are used to predict possible genotypes from breeding experiments and capture their probability. Molecular diagrams explain how the atoms within a molecule are bonded together and can reveal the molecule's three-dimensional structure.

6. What general steps would you take to conceptualize and draw a diagram? Explain.

To draw a diagram, first define its intended purpose. Determine a level of detail based on that purpose. Outline all of the necessary components and define the relationships among them. Determine how to show the relationships among the components to achieve the diagram's overall purpose. Add symbols, text and units of measurement as needed. Finally, give your diagram a title.

Bonus question

Diagrams and models are related tools that are both used to help explain STEM-related concepts but don't always cover the same breath or depth. Review the questions about scientific modeling from the discussion "Go beyond Mendeleev's model" with students before asking them to answer the question below as a class.

7. What do scientific models and diagrams have in common? How can they be different?

Scientific models and diagrams are both tools that can be used to organize information, often the components of a system, and to help predict and explain a system's behaviors and outcomes. Scientific models are generally simplified, ideal representations of phenomena or big concepts. Models are often corrected over time as new information becomes available. Scientific diagrams are generally used to represent a smaller, well-defined idea, process or system. Scientific models can by represented with diagrams, but diagrams aren't always scientific models. Diagrams require the use of a visual and models can be shown as a visual or explained as a list of components and assumptions. Models can also be physical or mathematical.

Check out the following activities to practice diagramming:

Protective headgear design challenge
Seeing in infrared
Designing soundscapes
Web of changes
Move into a hermit crab's shell
Journey to the center of the Earth
How do neurons form connections
Reduction-oxidation reaction demonstration

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Student Discussion Worksheet

Directions:

After reading the article provided by your teacher and reviewing the diagram, answer the following questions individually.

1. Describe the diagram included in the article. Explain the different types of information that it contains.

2. What is this diagram's purpose? Why do you think the diagram is included in the article?

3. Give an example of another diagram you have seen or used. Explain its intended purpose.

Working with a partner, answer the questions below, which relate to diagrams more generally.

4. How would you define a diagram? What is a diagram generally used for?

5. Think about various fields of science — chemistry, biology, environmental science, physics, genetics and so on. What are some examples of scientific diagrams from these fields?

6. What general steps would you take to conceptualize and draw a diagram? Explain.

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Activity Guide for Teachers: Geologist for a Day

Purpose: Rocks found across the world offer clues to geological processes, as well as the history of Earth and the rest of the solar system. In this activity, students will review types of rocks and the rock cycle and will apply that knowledge to interpret data on two rock samples.

Procedural overview: After reviewing types of rocks and the rock cycle as a class, students will use their knowledge and additional research to identify two rock samples and determine how they were made. Students will then draw connections between Earth’s geology and the geology of the moon.

Approximate class time: 1 class period

Supplies:
Computer with Internet access
“Geologist for a Day” student activity guide

Directions for teachers:

Review
As a class, review the different types of rocks — sedimentary, igneous and metamorphic — and the rock cycle using the questions below. During the class discussion, have students create a flowchart that describes the different phases of the rock cycle and how they connect.

1. What is the difference between rocks and minerals?

A mineral is a naturally occurring element or compound that has a distinct chemical composition, a crystalline form and predictable physical properties. A rock is a combination of one or several minerals and can include organic matter.

2. What are the key properties of sedimentary, metamorphic and igneous rocks?

Sedimentary rocks are made up of many types of smaller rock fragments and sediments, sometimes in layers. These rocks often contain organic material including fossils and are often formed in or near water or glaciers.

Metamorphic rocks contain minerals that have melted and recrystallized. The original features of the rocks are typically distorted.

Igneous rocks can have various chemical structures depending on the composition of the magma that cools to form the rock, along with what minerals are picked up along the way. The rocks can have small or large crystals depending on how quickly the magma cools.

3. How are sedimentary, metamorphic and igneous rocks related to each other?

Sedimentary rocks are made up of eroded pieces of igneous, sedimentary and metamorphic rocks that are later compacted and cemented together. Metamorphic rocks are made up of sedimentary and igneous rocks that have undergone extreme pressure and/or heating. Igneous rocks are made up of rocks that melted and formed magma and then cooled and solidified, often underneath Earth's surface.

4. Limestone and marble are both made of the same mineral, calcite ($CaCO_3$), yet they have different properties. Why do you think this might be the case?

Limestone and marble are different types of rocks. Limestone is a sedimentary rock generally formed in calm waters from crushed shells and skeletal pieces. Because it is made up of compacted pieces of shell, there are some gaps in its structure, making it porous. Marble is a metamorphic rock typically formed from limestone; under immense pressure and heat, the calcite recrystallizes and locks together, making marble less porous than limestone.

5. Describe how one rock can travel through all phases of the rock cycle.

An igneous rock will be weathered and eroded and the resulting sediments will form layers that will eventually be compacted into sedimentary rock. The sedimentary rock will eventually make its way underground. There, it will become metamorphic rock as it faces extreme pressure and temperatures. Metamorphic rock can melt into magma, cooling into igneous rock under Earth's surface or rising through cracks in the Earth's surface, such as volcanic vents, and cooling there.

Example flowcharts can be found across the Web, including here and here.

Discussion
As a class or in small groups, have students discuss what geologists can learn from studying rock samples.

6. Geologists study different rocks found all over the world. What information can be learned from rocks?

Rocks can offer clues about the history of Earth, such as where water or a volcano was a long time ago. Rocks can also help geologists understand Earth more generally, including its size and interior. Types and extents of rock formations can help geologists to determine where earthquakes may be most likely to strike and to estimate their impacts. Geologists can determine the past locations and movements of glaciers. Knowledge of plate tectonics helps scientists understand which land masses were once connected, and how the land masses are moving today and will move in the future.

7. Most of Earth's surface is covered with sedimentary rock. What can scientists infer from this about the history of Earth?

It is likely that water once covered almost all areas of Earth. That water would have deposited the raw materials for rock and provided the pressure needed to force those particles together. Wind can also create sedimentary rocks, but the scale and extent of the sedimentary rocks on Earth points to water.

8. Metamorphic rocks form deep underneath Earth's surface, where pressure and temperatures are incredibly high. Describe one way that metamorphic rocks can be brought to the surface.

Metamorphic rocks can be found on the surface when they get pushed upward by forces below and when weathering and erosion expose the metamorphic rock layers.

9. Sedimentary rocks form in layers. How does the depth of a rock layer help reveal its age?

Because newer materials are deposited on top of existing materials, the deeper a rock is found, the older it generally is. (Though other processes can turn rocks sideways and upside down, obscuring this order.)

10. Intrusive rocks form when magma penetrates existing rock, then cools and becomes a solid before it reaches the Earth's surface. Based on this explanation, which rock is younger, the intrusive rock or existing rock?

Since the magma flows into preexisting rock, the intrusive rock that solidifies must be younger.

Activity
Explain to students that during this activity they will pretend to help a geology lab identify two rock samples, as well as determine the events that caused the rocks to form. If a projector is available, project images of the two samples (linked below) for the students to refer to during their investigation. If a projector is not available, provide color images of the two samples for students to share or open the images on a computer so that students can refer to the images as needed. Note that the URLs contain the type of rock, so you should be careful not to reveal the URLs to students.

Sample 1 (feldspar):
https://www.pitt.edu/~cejones/GeoImages/1Minerals/1IgneousMineralz/Feldspars/KSpar_IrregFractSml.jpg

Sample 2 (granite):
https://dec.vermont.gov/sites/dec/files/geo/images/RxKit/kitgranite.jpg

Provide students with the "Geologist for a Day" student activity guide, which includes the geologist's notes and rock table, as well as access to the Internet for research. The questions below will walk students through identifying the samples' rock types and making inferences about their formation. In the final set of questions, students will make connections between geology on Earth and on the moon.

Student directions:
You are working in a university geology lab for the summer, helping identify the types of rock in samples from dig sites and figuring out how the sample formed. A field geologist asks for your assistance on two new samples. Review the geologist's notes (provided by your teacher) and use them to answer the questions that follow. Your lab has been developing a table of rock types and their characteristics that, though not yet complete, will also aid your efforts.

1. Look at the notes and the pictures of the samples. What other information should be requested from the geologist and added to the notes?

The geologist's notes describe the colors and sizes of the samples but do not include other important information, such as which of the locations marked X sample 2 came from, where the quarry is located, what *the surrounding area is like, how the samples were collected or why these samples or sample locations were chosen.*

2. Based on the geologist's notes, determine the volume of each sample in cm^3. Then use the mass and volume of each sample to find their densities in g/cm^3.

Sample 1:
$v = 2.3$ cm x 3 cm x 1 cm = 6.9 cm^3
$d = m / v = 17.6$ grams / 6.9 cm^3 = 2.55 g/cm^3

Sample 2:
$v = 2$ cm x 2 cm x 1.8 cm = 7.2 cm^3
$d = m / v = 19.8$ grams / 7.2 cm^3 = 2.75 g/cm^3

3. One column on the table is for the "hardness" of the rocks. What is hardness and how is it measured?

Hardness is the resistance of rocks to scratching and is typically measured using reference rocks as a test.

4. The word "silicates" appears several times in the "Material/mineral classification" column of the table. What does this term mean?

A silicate is a mineral that contains molecules of silicon covalently bonded to oxygen with an overall negative charge. The ratio of oxygen to silicon atoms in a negatively charged molecule is greater than 2 to 1.

5. How can several rocks be different types but still have the same material/mineral classification?

The material/mineral classification defines what atoms and molecules are found in the material, but the structural arrangement of these atoms and molecules can be different. For instance, diamond and graphite are both made of carbon atoms, but all of the carbon atoms are covalently bonded in diamond, making it very strong, whereas graphite's carbon atoms are covalently bonded in sheets that are stacked on top of each other, making the sheets able to readily slide off of one another.

6. Before you proceed with your research, you need to fill in some missing details in your table. Research the properties of granite, feldspar, limestone and quartz to add them to the table.

Answers for relevant rows of the table:

Type	Color(s)	Hardness (Mohs)	Identification	Material/mineral classification	Density (g/cm^3)
Granite	*speckled white, gray, tan, red or black*	*7*	*igneous*	*feldspar, quartz, mica, amphibole (silicates)*	*2.75*
Feldspar	*pink or white*	*6*	*mineral*	*silicates*	*2.55*

Limestone	*gray or tan*	*3*	*sedimentary*	*calcite ($CaCO_3$)*	*2.71*
Quartz	*colorless, white, gray or purple*	*7*	*mineral*	*silicates*	*2.65*

7. Based on your table, do you think either of your samples is granite? Why? What could you do to further support your hypothesis?

I think that sample 2 is granite because it has a density of 2.75 g/cm^3 and is white with specks of black. I could get more evidence by testing the hardness of the sample to show it has a Mohs hardness of 7.

8. Based on your table, what do you think the identity of sample 1 is? Why? What could you do to further support your hypothesis?

I think that sample 1 is feldspar because it has a density of 2.55 g/cm^3 and is white. I could get more evidence by testing the hardness of the sample to show it has a Mohs hardness of 6.

9. Does it make sense that these two materials would be found in the same quarry? Why or why not?

It does make sense that these two materials would be found in the same quarry. They are both made of silica, which is a molecule made from silicon and oxygen. Granite is made when a variety of minerals including feldspar and quartz are put under tremendous pressure and temperatures.

10. Based on your knowledge and any necessary research, how did these rocks form?

Feldspar is a mineral formed from quickly crystallizing magma. All types of feldspar are aluminosilicate minerals, meaning they contain silicon, aluminum, oxygen and either potassium, sodium or calcium. Granite is an igneous rock that is made from a variety of minerals in slowly cooling magma, including feldspar and quartz.

11. What can you infer from the relative depths of the two samples? How may this relate to your understanding of how the two samples formed?

Because the granite sample was found at a greater depth, the feldspar sample was presumably deposited after the granite sample was formed. That suggests the granite sample is older than the feldspar sample. The feldspar could have formed as an intrusion after the granite had formed, in which case it would still be younger than the granite.

Geology of the future

After completing your work, you get a new message from the geologist. She notes that the rocks are not from a quarry on Earth, but from a quarry on the moon! Read a bit about the geology of the moon in "Rover peers beneath moon's farside." Consider how this new information might change your understanding of the rocks and their formation by answering the following questions.

12. Some quick research suggests that moon rocks brought back from the Apollo missions were igneous. Why might it make sense that the moon rocks were igneous when most of the rocks on Earth's surface are sedimentary?

Sedimentary rocks are formed by the compaction and cementing of eroded particulate matter together. Unlike Earth, the moon has very little atmosphere, resulting in almost no wind on the surface. The moon also has no liquid water. Since strong forces from moving water and high surface winds are absent on the moon, it is unlikely the moon's surface has many sedimentary rocks.

13. How do the rocks on the moon's farside (the side facing away from Earth) and the nearside differ? What might that suggest about the moon's history?

The farside of the moon is mostly covered in regolith, according to the Science News *article, created when smaller impacts break up the rock on the surface. The nearside is covered in smooth floodplains. Perhaps larger impacts melted the rock on the nearside, or magma erupted from beneath the moon's surface and covered existing craters.*

14. Oxygen and silicon are the two most common elements found on both Earth's and the moon's surfaces. Based on the new information, could your identification of the samples still be correct? Why or why not?

Yes, my identifications could still be correct. The moon is primarily made from igneous rock and both feldspar and granite are igneous. Both samples are rich in silica, which is made of silicon and oxygen.

15. Why would geologists compare rocks from Earth and the moon? Why might geologists be interested in rocks from other planets?

Geologists study and compare rocks from Earth and the moon to understand the internal structure of the moon and to understand how it was formed. Comparing samples and data from across the solar system can also offer clues to solar system formation.

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Activity Guide for Students: Geologist for a Day

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You are working in a university geology lab for the summer, helping identify the types of rock in samples from dig sites and figuring out how the sample formed. A field geologist asks for your assistance on two new samples. Review the geologist's notes (provided by your teacher) and use them to answer the questions that follow. Your lab has been developing a table of rock types and their characteristics that, though not yet complete, will also aid your efforts.

1. Look at the notes and the pictures of the samples. What other information should be requested from the geologist and added to the notes?

2. Based on the geologist's notes, determine the volume of each sample in cm^3. Then use the mass and volume of each sample to find their densities in g/cm^3.

Sample 1:
v =
d =

Sample 2:
v =
d =

3. One column on the table is for the "hardness" of the rocks. What is hardness and how is it measured?

4. The word "silicates" appears several times in the "Material/mineral classification" column of the table. What does this term mean?

5. How can several rocks be different types but still have the same material/mineral classification?

6. Before you proceed with your research, you need to fill in some missing details in your table. Research the properties of granite, feldspar, limestone and quartz and add them where appropriate on your rock table.

7. Based on your table, do you think either of your samples is granite? Why? What could you do to further support your hypothesis?

8. Based on your table, what do you think the identity of sample 1 is? Why? What could you do to further support your hypothesis?

9. Does it make sense that these two materials would be found in the same quarry? Why or why not?

10. Based on your knowledge and any necessary research, how did these rocks form?

11. What can you infer from the relative depths of the two samples? How may this relate to your understanding of how the two samples formed?

Geology of the future
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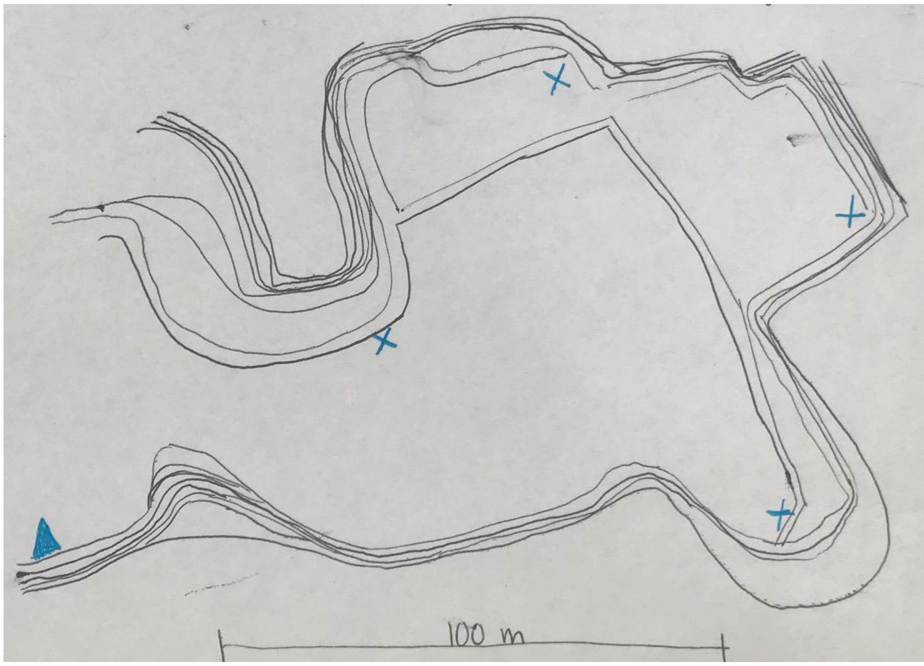
14. Oxygen and silicon are the two most common elements found on both Earth's and the moon's surfaces. Based on the new information, could your identification of the samples still be correct? Why or why not?

15. Why would geologists compare rocks from Earth and the moon? Why might geologists be interested in rocks from other planets?

Geologist's notes

<u>Granite Quarry—May 27, 2019</u>
Small eastern corner of the quarry.
Arrived at 9 a.m., weather conditions are calm with clear skies, temperature is 18° C (65° F).
Team consists of two graduate students and myself.
Discussed mine operations with the quarry manager.
Drew map and started working.



Marked the map with location of samples: Δ for sample 1, X for sample 2.
Samples have been submitted to the lab for analysis.

Sample 1: white sample
Mass is 17.6 grams
Size is 2.3 cm by 3 cm by 1 cm
Found at 3 meters deep

Sample 2: white/light gray sample
Has small black spots
Size is 2 cm by 2 cm by 1.8 cm
Mass is 19.8 grams
Found at 15 meters deep

Rock table

Type	Color(s)	Hardness (Mohs)	Identification	Material/mineral classification	Density (g/cm^3)
Amphibole	green or brown	5.5	mineral	silicates	2.90
Diamond	colorless	10	mineral	carbon (C)	3.51
Granite					
Feldspar					
Graphite	black or gray	1	mineral	carbon (C)	2.26
Gypsum	colorless	2	mineral	calcium sulfate ($CaSO_4$)	2.96
Limestone					
Marble	white	3	metamorphic	calcite ($CaCO_3$)	2.71
Mica	black	2.5	mineral	silicates	2.88
Quartz					

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