UNIT 2: WHY WYOMING?

Why does Wyoming have so many natural resources?

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OVERVIEW

Wyoming has an incredibly rich supply of energy resources including coal, natural gas, petroleum, and wind, among others. In this unit, students will understand why Wyoming has such an abundance of energy by exploring origins of each type. They will travel through a brief geological history of Wyoming and focus on the important events that led to the formation of coal, natural gas, and petroleum. They will see how landforms and geological processes create favorable conditions for energy resources through visualizations, demonstrations, and modeling. Finally, students will experience and measure wind speeds to understand the atmospheric and geographic features that make Wyoming’s wind so powerful and reliable. Understanding why we have such abundant resources will lay the foundation for examining specific case studies on energy in the following units.

In the summative assessment, students will apply their understandings of geological history, processes, and formation of energy resources by creating a three-dimensional model of a natural gas, petroleum, or coal formation. They will write a timeline and description of the formation of and current state of the energy resource in this particular location. Small groups for this project will challenge students to collaborate and think creatively to model geologic history.

ESSENTIAL QUESTIONS

- What geological processes have formed fossil fuels?
- How have geological processes influenced energy production in Wyoming?
- Why is Wyoming so windy?

ENDURING UNDERSTANDINGS

- Students will understand the geologic history of Wyoming as it relates to the formation of energy resources.
- Students will understand how certain fossil fuels and renewable energy sources are formed.

DURATION

Seven 45 minute lessons

STANDARDS

Next Generation Science Standards

- Disciplinary Core Ideas
  - Physical Science
  - Earth & Space Science
- Crosscutting Concepts
  - Energy & matter
  - Patterns
  - Scale, proportion & quantity
  - Structure & function
- Science and Engineering Practices
  - Analyzing & interpreting data
  - Using mathematical & computational thinking

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- Constructing explanations & designing solutions
- Obtaining, evaluating & communicating information
- Engaging in arguments from evidence
- Developing & using models
- Planning & carrying out investigations

Wyoming Science Standards
- SC11.1
- SC11.1.5
- SC11.1.7
- SC11.1.8
- SC11.1.13
- SC11.2
- SC11.2.2
- SC11.2.3
- SC11.2.5
- SC11.3

Wyoming Social Studies Standards
- SS12.5.1
- SS12.5.2

Common Core Math Standards
- CCSS.MATH.CONTENT.HSS.IC.B

Common Core Language Arts Standards
- CCSS.ELA-LITERACY.RI.11-12.7

OBJECTIVES

Science and Energy Literacy
- Students will understand that Wyoming has a long, complex geologic past.
- Students will explore geological processes related to formation of coal, natural gas, and petroleum.
- Students will explain factors that make winds so strong in Wyoming.

Community and Place
- Students will analyze geological maps to discover the geological history of their geographic location.
- Students will identify differences in landforms around their school and community.

STEM Careers and Leadership Development
- Students will collaborate in small groups to design a geological model.
- Students will share ideas in discussions.

Applied Problem Solving & 21st Century Skills
UNIT 2: WHY WYOMING?

- Students will demonstrate geological processes through modeling.
- Students will apply scientific method in two lab sessions.
- Students will build and use anemometers to measure wind speed.
- Students will design a model of underground resources.
- Students will apply creativity to their design project.

ASSESSMENT EVIDENCE

Diagnostic:
At the beginning of the unit, students will demonstrate understanding by:
1. Filling out an energy resource chart.
2. Drawing a diagram of what they believe the earth looks like beneath the surface.
3. Visualizing and describing Wyoming’s landscape 65 million years ago.
4. Effectively using wind power to launch and fly kites.

Formative:
During lessons, students will demonstrate understanding by:
1. Filling out an energy resources chart.
2. Completing a porosity and permeability lab worksheet.
3. Participating in discussions and reflections.

Summative:
By the end of the unit, students will demonstrate understanding by:
1. Completing a small group project to design stratigraphic and surficial model of fossil fuel reserves.
DIAGNOSTIC & FORMATIVE ASSESSMENT: ENERGY RESOURCES CHART

*To be completed at the beginning of the unit

Standards:

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<th>Common Core Standards</th>
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<td>CCC - Patterns; Systems &amp; system</td>
<td>ELA-Literacy.RST.11-12.2</td>
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<td>models</td>
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<td>WY Social Studies Standards</td>
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<tr>
<td>SEP - Obtaining, evaluating &amp;</td>
<td></td>
<td>SS12.6.1</td>
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<tr>
<td>communicating information</td>
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<td></td>
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Instructions:

Using the Energy Resources graphic organizer chart in the attached Diagnostic Assessment Resources as a guideline, students should write down as much prior knowledge as possible on coal, oil and natural gas, and wind resources. They may use their concept maps from Unit 1 to assist.
## Diagnostic Assessment Resources

### Energy Resources Chart

<table>
<thead>
<tr>
<th>Coal</th>
<th>Natural Gas</th>
<th>Petroleum</th>
<th>Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What do you already know about each of these energy resources?</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>What is the organic source material, if any, for this resource?</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>What forces or processes influenced the creation of this resource?</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Where would you expect to find this in Wyoming?</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Is this resource renewable or nonrenewable?</strong></td>
<td></td>
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<td></td>
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LESSON 1: ENERGY PRODUCTION IN WYOMING

Standards:

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<td>MATH.Content.HSS.IC.B</td>
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<tr>
<td>SEP - Analyzing &amp; interpreting data</td>
<td></td>
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<td>SS12.5.1</td>
</tr>
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<td></td>
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<td>SS12.5.2</td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>

Lesson Overview:
In this lesson, students will look at energy production trends in the United States and determine how the state of Wyoming fits into the national energy production scene. Students will compare maps showing energy production rankings by state to maps of natural resource reservoirs in order to better understand why Wyoming is one of the top energy producing states in the country. Students will also be able to define an “energy portfolio” as a set of all the energy production methods in the state and discuss how and why an energy portfolio can change over time.

Guiding Question:
What is energy production like in Wyoming compared to the rest of the United States?

Duration:
45 minutes

Materials:
Printed out maps of energy production in the United States (See Lesson 1 Resources)

Engage: Interpreting maps
Break students up into groups and have them look at maps of energy production by state for coal, natural gas, crude oil, and wind energy. Ask students to 1) Determine what information the map is trying to communicate, 2) Locate Wyoming, 3) Explain how Wyoming compares to other states in the US, in terms of production of each energy resource. See Lesson 1 Resources for Map Set 1.

Explore: Natural resource reserve maps
Hand out a second set of maps to the students in groups making sure that the maps correspond by energy source. Students who had a coal map from the first set should get a coal map from the second set. Ask them to compare the information on the two sets of maps and use the second map to help explain trends in the first.

The first set of maps indicates that Wyoming is in the top half of energy producing states for a number of resources, while the second set shows the reason why - because Wyoming has a lot of natural resources. There is a lot of overlap between where reserves of natural resources exist and the states that produce the most energy from that resource. See Lesson 1 Resources for Map Set 2.
UNIT 2: WHY WYOMING?

Explain: Wyoming - America’s great energy state
Wyoming is second in the nation in terms of energy production. It is 1st in the nation in coal production, 5th in the nation in natural gas production, and 8th in the nation in crude oil production.

Quick Facts about energy production in Wyoming from the EIA (Source: http://www.eia.gov/state/?sid=WY)

- Wyoming produced 39% of all coal mined in the United States in 2012.
- In 2012, 34 states received coal from Wyoming mines, with 9 states, including Wyoming, obtaining more than 90% of their domestic coal from Wyoming.
- Wyoming accounted for 7.4% of U.S. marketed natural gas production in 2013.
- In 2013, almost 89% of net electricity generation in Wyoming came from coal and about 10% came from renewable energy sources, primarily wind.

Elaborate: Energy portfolios
Introduce the concept of “energy portfolios.” Energy portfolio is a term used to describe the way in which a place (city, state, or country) produces their energy, specifically electricity. An energy portfolio is comprehensive and includes all energy production strategies that utilize energy sources regardless of whether the sources are from renewable energy or fossil fuels.

Using the maps and other prior knowledge about fossil fuels, renewable resources, and energy production in Wyoming, ask students to work in pairs to describe Wyoming’s energy portfolio. After giving students time to describe Wyoming’s energy portfolio, ask them to share back with the class.

Evaluate: Diversifying the energy mix
Read to the class the following point made by the National Academy of Sciences:

“The United States gets 84% of its total energy from oil, coal, and natural gas, all of which are fossil fuels. We depend on fossil fuels to heat our homes, run our vehicles, power industry and manufacturing, and provide us with electricity. Eventually, the degree to which we depend on fossil fuels will have to lessen as the planet’s known supplies diminish, the difficulty and cost of tapping remaining reserves increases, and the effect of their continued use on our planet grows more dire. But shifting to new energy sources will take time.”

Ask students to discuss how diversifying energy production could meet the growing need for energy usage?

Resources:
- Energy Information Administration: http://www.eia.gov/state/analysis.cfm?sid=WY
LESSON 1 RESOURCES

Map Set 1
Source: http://www.energysolution.us/overview2.html

Coal Production by State

Crude Oil Production by State

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Total Energy Production by State

Source: http://www.energysolution.us/US_overview.html
UNIT 2: WHY WYOMING?

LESSON 2: BRIEF GEOLOGIC HISTORY OF WYOMING

Standards:

<table>
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<tr>
<td>CCC - Patterns; Scale, proportion &amp; quantity</td>
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<td>SC11.1.7</td>
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<tr>
<td>SEP - Developing &amp; using models; Analyzing &amp; interpreting data; Obtaining, evaluating &amp; communicating information</td>
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<td>SC11.1.8</td>
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<td></td>
<td></td>
<td>WY Social Studies Standards</td>
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<tr>
<td></td>
<td></td>
<td>SS12.5.1</td>
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</tbody>
</table>

Lesson Overview:
If you turn around 360 degrees in Wyoming, you can look further back in geological time than the depths of the Grand Canyon. Wyoming’s landscape has been stretched and compressed, thrusted up, crushed by ice, and eroded over billions of years to reach its current state. Wyoming’s geologic history is long and complex, but several key periods and events provide insight into the formation of underground resources. In this lesson, students will explore several key events and periods of geologic time to understand the history and formation some of Wyoming’s important landforms.

Guiding Question:
What geologic processes have shaped Wyoming?

Duration:
45 minutes

Materials:
Geologic time cards (Lesson 2 Resources), tape measure

Engage: What lies beneath?
Prompt students to draw what they imagine the crust of the earth looks like, starting from the surface and moving down below an oil or gas field. These diagrams will be revisited at the end of this unit.

Explore: Demonstrating Geologic Time
Set-up: Students will model the scale of geological time using 40 feet of measuring tape (can be scaled to fit classroom space). Use the geology cards in the Lesson 2 Resources that represent important geological events in Wyoming’s history. Each card has an event, a date, and a particular measurement that represents its place in the scale of time (0 feet = formation of earth, 38 ft, 5 in. = present day). For more information on the geologic time scale, see the associated image in the Lesson 2 Resources for details and descriptions.

Hand one card to each student and ask him or her to find the place on the timeline. Once placed, ask each student to share the event and date. Students should notice that in relation to the age of the earth, most biological events happened very recently.

Discussion questions: What do students notice about the period of time between the earth’s formation and first sign of life? How does this activity change your perspective on the earth’s history?
Explain: Important Events in Wyoming’s history

There are several key events in Wyoming’s long geological history that have shaped today’s landscape and influenced the presence of energy resources. The events on the timeline are described in more detail below:

1. 570 million years ago: Sedimentary rocks begin to deposit on Precambrian rock as much of the state is covered by warm, shallow seas. Seas advanced and receded for hundreds of millions of years across the state in different patterns and deposited between 10,000 and 30,000 feet of sedimentary rock.
2. 100 million years ago: Cretaceous Seaway still covers most of Wyoming, depositing “young” sedimentary rocks.
3. 75-50 million years ago: Laramide orogeny uplifts and expands the American west as the Farallon plate subducted beneath the North American Plate. As the plate subducted, it caused a large-scale geological event in which the granitic crust was thrust upward and Rocky Mountains were formed, including many of Wyoming’s mountain ranges.
4. 100,000-10,000 years ago: Glaciers carved mountains and formed rivers.
5. Today: These events created three major physiographic formations: Mountains, Great Plains, and basins. See Lesson 2 Resources for an image depicting the three major formations.

Elaborate: Reading Geologic Maps

Provide geological maps from Wyoming State Geological Survey (http://www.wsgs.wyo.gov/data/gis/Geologic-Map-Wy.aspx). Students should explore the geology of the state using bedrock maps and be able to answer the following questions:

- Where can we find the oldest formations in Wyoming?
- Find Devil’s Tower. When did this form and what kind of rock constitutes it?
- Find Yellowstone. What does its’ colors and ages tell you about its formation?
- Can you view any landforms from your school? How do you think it was formed, how old is the formation, and what constitutes the bedrock?

Evaluate: What geological features are around your area?

Locate local geologic points of interest. Are these features unique or part of a bigger pattern in Wyoming? How can you tell?

Extend: Field Trip

Once students feel comfortable with maps, tie the geological history of Wyoming to your place by taking students on a field trip to a place of interest and explore.

Resources:

- Review rock types with Optional Lesson on Background information
- Large downloadable geological timescales: https://engineering.purdue.edu/Stratigraphy/charts/educational.html
## Lesson 2 Resources

### Geological Timeline Cards

<table>
<thead>
<tr>
<th>Event</th>
<th>Height</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 ft. Formation of the Earth (4.6 B.Y. AGO)</td>
<td>36 ft. 5 in. Modern Insects (140 M.Y. AGO)</td>
<td></td>
</tr>
<tr>
<td>12 ft. 6 in. Oldest Rocks in Wyoming (3.1 B.Y. AGO)</td>
<td>36 ft. 1 in. Great Cretaceous Seaway covers Wyoming (young sedimentary rocks) (100 MY ago)</td>
<td></td>
</tr>
<tr>
<td>25 ft. First single-celled organisms appear (2.5 B.Y. AGO)</td>
<td>37 ft. 8 in. Rocky Mountains Rise in Laramide Orogeny (75-50 M.Y. AGO)</td>
<td></td>
</tr>
<tr>
<td>33 ft. 6 in. Shallow Seas Cover Wyoming (Old Sedimentary Rocks) (570 M.Y. AGO)</td>
<td>38ft 4 1/2 in. Pinedale Glaciation (255,000 - 8,500 Y. AGO)</td>
<td></td>
</tr>
<tr>
<td>35 ft. 2 in. Conifer Forests Flourish (280 M.Y. AGO)</td>
<td>38 ft. 4 15/16 in. Last Ice Age (10-12,000 Y. AGO)</td>
<td></td>
</tr>
<tr>
<td>35 ft. 7 in. Dinosaurs dominate (230 M.Y. AGO)</td>
<td>38 ft. 5 in. Present day</td>
<td></td>
</tr>
<tr>
<td>36 ft. 0 in. First birds appear (190 M.Y. AGO)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Major geologic formations in Wyoming
UNIT 2: WHY WYOMING?

LESSON 3: FORMATION OF COAL

Standards:

<table>
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<tbody>
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<tr>
<td>CCC - Cause &amp; effect: Stability &amp; change</td>
<td>SC11.1.7</td>
</tr>
<tr>
<td>SEP - Developing &amp; using models; Constructing explanations/Designing solutions</td>
<td>SC11.1.8</td>
</tr>
</tbody>
</table>

Lesson Overview:
In this lesson, students will understand the biological and geological processes that form coal. They will understand the unique conditions in which coal formed in Wyoming millions of years ago and be able to identify the type of coal that predominates in Wyoming.

Guiding Question:
What geologic processes lead to the formation of coal deposits?

Duration:
45 minutes

Materials:
Whiteboard to draw "chapters," Geologic timeline, samples of sedimentary rocks

Engage: Land before time
Have students complete a quick-write prompt: Imagine that it is 75 million years ago in Wyoming. What does it look like? Describe what you believe the environment looked like: climate, landforms, water, vegetation, and animals.

Explore: Chapters of coal formation in Wyoming
Revisit geologic time scale (See Lesson 2 Resources for an image of the geologic time scale) with major events and dates (Cambrian explosion, age of dinosaurs, humans, etc. We will be focusing on the times 130-50 MYA: The Cretaceous and Tertiary Periods.

Students need a piece of drawing paper they will fold their paper into 6 squares and labeled 1-6. In each box, students will draw/write the steps of coalbed formation. It helps if there are six steps on the board for students to follow. Each box represents Wyoming during a different time period.

- **Chapter 1**: Early Cretaceous: Warm seaway runs north/south
- **Chapter 2**: Mid-cretaceous: Wyoming is nestled between fold/thrust belt of Western WY and the rise/fall of the seaway as a floodplain. Warm climate. Thick vegetation. Coastal marshes, swamps, delta wetlands. In other words, there was a LOT of water in Wyoming which influenced the entire climate. Wyoming’s elevation was much lower at this time. Because there is so much water, plant material layers in peat beds and does not decompose readily.
- **Chapter 3**: Laramide orogeny: peak 65-50 MYA. Uplift across the state. Seaway recedes as Wyoming rises. Peat beds become compartmentalized in basins.
- **Chapter 4**: Peat beds continue to accumulate as Laramide orogeny continues, finally settling after uplift is complete.
UNIT 2: WHY WYOMING?

- **Chapter 5**: Time. Sedimentation. Geologic processes. Sediment is deposited above peat beds, biological and geological processes, especially temperature and pressure, act on these; alter peat into a carboniferous rock, or a hard fossil fuel called coal. The end result of the chapters is that hundreds of millions of years of organic materials deposited from the western seas is the source of oil, natural gas, and coal in Wyoming.

- **Chapter 6**: Present day: Humans extract coal from thick "seams"

**Explain: Coal Seams**
Coal forms from the accumulation of plant debris, usually in a swamp environment. When plant debris dies and falls into the swamp the standing water of the swamp protects it from decay. Swamp waters are usually deficient in oxygen, which would react with the plant debris and cause it to decay. This lack of oxygen allows the plant debris to persist. In addition, insects and other organisms that might consume the plant debris on land do not survive well under water in an oxygen deficient environment.

To form the thick layer of plant debris required to produce a coal seam, the rate of plant debris accumulation must be greater than the rate of decay. Once a thick layer of plant debris is formed it must be buried by sediments such as mud or sand. These are typically washed into the swamp by a flooding river. The weight of this material compacts the plant debris and aids in its transformation into coal. About ten feet of plant debris will compact into just one foot of coal.

For a coal seam to form, perfect conditions of plant debris accumulation and perfect conditions of subsidence must occur on a landscape that maintains this perfect balance for a very long time. It is very easy to understand why the conditions for forming coal has occurred only a small number of times throughout Earth's history. The formation of a coal deposit requires the coincidence of highly improbable events.

**Elaborate: Distribution of coal in Wyoming**

Ask the students what this explains about the unique conditions that were in Wyoming during the Cretaceous and early Tertiary period - from 130 to 50 million years ago. Have them compare this to their preconceptions of the state of Wyoming they described earlier during the lesson.

**Evaluate: Diagram coal formation**
Draw a diagram explaining how and why coal can occur in seams, making note of important geologic features, processes, and time periods.

**Extension: Field Trip**
If possible visit the University of Wyoming's Geology Museum, with several exhibits dedicated to the environment of Wyoming during the Late Cretaceous. Visit the website and click on "For Teachers" to schedule a tour with the Museum's curator and paleontologist: [http://www.uwyo.edu/geomuseum/](http://www.uwyo.edu/geomuseum/)

**Resources:**
- Wyoming State Geological Survey [website](http://www.wsgs.uwyo.edu/research/energy/coal/Geology.aspx) has a comprehensive explanation of coal formation and its place in Wyoming geological history. There are diagrams illustrating processes and stratigraphy. [http://www.wsgs.uwyo.edu/research/energy/coal/Geology.aspx](http://www.wsgs.uwyo.edu/research/energy/coal/Geology.aspx)
LESSON 3 RESOURCES:
The Story of Coal

We can see that coal can occur in a variety of forms and across a spectrum of properties. But what makes coal types so unique? There are a few factors: Heat, pressure, and time. Here’s a look:

Biological processes:
In ecosystems such as swamps, marshes, and bogs, vegetative matter accumulates as peat. This organic material decomposes very slowly and is supersaturated with water. Slowly, aerobic and anaerobic microorganisms break down plant material in a process called biogenesis. In anaerobic decay of Cretaceous mires, peat underwent “gelification,” resulting in a hydrocarbon gel called “gytta.”

Geological processes:
Heat from surrounding bedrock removes water from the buried material and thermally alters the gel. Heat is a major determinant of coal quality. Generally, exposure to higher heats increases coal’s quality from lignite to subbituminous, bituminous, and anthracite. Most of Wyoming coal is subbituminous. Additionally, older coal, buried deeper in sedimentary layers, has been exposed to higher heats deeper in the crust and holds higher quality than younger deposits. Wyoming’s Cretaceous coal is subbituminous to bituminous, while its Tertiary seams are subbituminous.

Source for formation of coal: Wyoming Coal book

2.20

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CHANGES IN RANK OF COAL

LAB 1: POROSITY

Standards:

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<td>investigations; Constructing</td>
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<td>SC11.2.2</td>
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<td>explanations/Designing solutions</td>
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</table>

Lab Overview:
In this lab, students will conduct an experiment using materials of varying grain sizes to understand that porosity refers to the percentage of spaces or holes (pores) in the rock.

Guiding Question:
What are porosity and permeability and how do they relate to oil and natural gas?

Duration:
45 minutes

Materials:
Marbled cake, core samples of Berea sandstone (available from the University of Wyoming), bucket of sand, bucket of gravel, bucket of sand and gravel, Waste material buckets (3), three 1,000-mL graduated cylinders or plastic tubes, one 500-mL graduated cylinder, Stopwatches Porosity and Permeability Lab Worksheet (See Lab 1 Resources)

Engage: Core Sample Demonstration
Revisit the Diagnostic Assessment from Lesson 1: "What Lies Beneath?" What mental model do students have of underground energy sources? Tell students that today they will explore geological properties - porosity and permeability to better understand oil reservoirs.

Explain to students that trying to 'see' what is beneath the surface of the Earth is one of the jobs of a geologist. Core samples can be taken and analyzed to determine the likely composition of the Earth's interior. Now, show students the cake (marbled). Ask them to predict what the cake looks like on the inside. Then, insert a plastic straw to demonstrate the purpose of a core sample. Show students the sample - and then explain that this is similar to the process that geologists use to extract core samples.

Explore: Measuring porosity
This lab demonstrates important characteristics of reservoir rocks: porosity and permeability. Porosity is the presence of tiny spaces (pores) in rock that hold oil or gas. Permeability is a characteristic that allows the oil or gas to flow through the rock. See the attached Lab 1 Resources for a diagram describing porosity and permeability.
To demonstrate, fill each of the cylinders halfway with one of the materials. Take about 500 mL of water, get ready with the stopwatch, and then pour the water into each of the cylinders timing how long it takes for the water to get to the bottom. Record the results with the Porosity and Permeability Lab Worksheet in the Lab 1 Resources. This exercise can be done with one cylinder by emptying the cylinder into a waste bucket and repeating the process with each of the other materials.

**Explain: Permeability and porosity**
Permeability is the ability of fluids to travel through porous rocks. If a petroleum well is to be successfully produced, the reservoir must have porosity, permeability and pressure to move the oil and natural gas to the well bore. Geologists look for porosity in core samples and permeability of the ground to help predict where oil and natural gas reservoirs are most likely.

**Elaborate: Cap rock**
What if the substrate is more like clay? Hypothesize and test how fast water would permeate through clay. Because clay has very low permeability and porosity, water will move slowly or not at all. Clay in this experiment functions like cap rock in an oil or gas reservoir that naturally functions to keep the resources locked underground.

**Evaluate: Permeability, porosity, and reservoir formation**
Discuss the following questions: How is porosity the formation of oil and natural gas? What does this tell you about the bedrock under certain parts of Wyoming?

**Resources:**
LAB 1 RESOURCES

Diagram of porosity and permeability

Permeability and Porosity Worksheet

Measuring Permeability

1. Fill one graduated cylinder with 350 mL of gravel, one with sand, and one with a gravel and sand mixture.

2. Pour 100 mL of water into each material. Record the time (in seconds) it takes water to reach the bottom of the beaker.

3. Measure the height in centimeters of the cylinder from the bottom to the 350 mL mark. Use these figures to determine the flow rate in centimeters per second (cm/sec).

4. Repeat for the other two cylinders and record your data in the chart below.

<table>
<thead>
<tr>
<th>Material</th>
<th>Height (cm)</th>
<th>Time (s)</th>
<th>Flow Rate (distance (cm)/ time (s))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravel/Sand Mix</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Measuring Porosity

1. Empty the wet materials from your graduated cylinders into the waste buckets. Refill each beaker with 350 mL of the materials: gravel, sand, and gravel/sand mixture.

2. Fill a graduated cylinder with 100 mL of water. Slowly pour the water into the first beaker, until it reaches the top of the gravel. Record exactly how much water was poured into the beaker.

3. Determine how much water has been added to the sediment in order to fill up all of the pore spaces. (350 mL - remaining water) = volume of pore space

4. Calculate the porosity of the materials using this formula: 
   Porosity = (pore space volume/total volume) x 100

5. Repeat for the other two sediments and enter your data in the chart below.

<table>
<thead>
<tr>
<th>Type of Material</th>
<th>Remaining water volume (mL)</th>
<th>pore space volume (mL)</th>
<th>% porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(total volume - remaining water volume)</td>
<td>(pore space/total volume)</td>
<td>(pore space/total volume)</td>
</tr>
<tr>
<td>Gravel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravel/Sand Mix</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discussion Questions:

1. Which material was most porous? Place the following sedimentary rocks in order from highest to lowest porosity/permeability: shale, sandstone, mudstone

2. Why is porosity in rock layers important to oil and natural gas accumulation?

3. How does grain size influence the velocity and permeability of sediment? How do you think this affects how oil flows?

4. Why is it important to understand porosity and permeability when drilling for oil?
LESSON 4: FORMATION OF PETROLEUM AND NATURAL GAS

Standards:

<table>
<thead>
<tr>
<th>Next Generation Science Standards</th>
<th>WY Science Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCI - Earth &amp; Space Science</td>
<td>SC11.1</td>
</tr>
<tr>
<td>CCC - Patterns; Energy &amp; Matter;</td>
<td>SC11.1.7</td>
</tr>
<tr>
<td>Stability &amp; Change</td>
<td>SC11.1.8</td>
</tr>
<tr>
<td>SEP - Construction explanations/</td>
<td></td>
</tr>
<tr>
<td>Designing solutions;</td>
<td></td>
</tr>
<tr>
<td>Engaging in arguments from</td>
<td></td>
</tr>
<tr>
<td>evidence</td>
<td></td>
</tr>
</tbody>
</table>

Lesson Overview:
In this lesson, students will understand the biological and geological processes that form petroleum and natural gas. They will understand the unique conditions in which oil and gas formed in Wyoming millions of years ago.

Guiding Question:
What geologic processes lead to the formation of oil and natural gas reservoirs?

Duration:
45 minutes

Materials:
Play dough (enough for each student to have 3-4 colors)

Engage: Pre-assess Natural Gas and Petroleum Formation
Think-pair-share: How do you think natural gas and oil formed? With a partner, discuss and come up with an idea using your knowledge from Wyoming's geological history to support a claim.

Watch this short video (~2 minutes) on Oil and Natural Gas formation - https://www.youtube.com/watch?v=0PrSZMOChWU. Ask students to assess their own understanding of oil and natural gas formation by comparing their earlier guesses with the description in the video. What was different or the same? Is anything surprising?

Explore: Modeling rock formations with playdough
Use playdough to model the compressional stresses that form synclines and anticlines. Directions for modeling these geologic formations are in the Lesson 4 Resources, or watch this reference video: http://www.youtube.com/watch?v=LmBeqAQKvJ0)

Explain: Anticline/syncline formations unearthed!
Synclines and anticlines are folds in rock that result from compressional stress in the earth's crust. Compressional stresses fold the rock into wave-like formations called synclines and anticlines. The crest of a wave refers to the highest point of the wave, and the trough refers to the lowest point. Anticlines are folds in which each half of the fold dips away from the crest. Synclines are folds in which each half of the fold dips toward the trough of the fold. Anticlines appear to form an "A" shape or a frown shape, and synclines form the bottom of an "S," or a smile.

Formation of Pinedale Anticline: Millions of years ago, massive river systems ran through the Anticline area depositing more than 5,000 feet of sand and sediment. Over time, these deposits
became over-pressured, gas-charged and buried by at least 9,000 additional feet of sediment. This process resulted in the deposition of more than 5,000 gross feet of gas-rich, but highly discontinuous sand sediments in parts of the area. The gas was trapped by the formation of an anticline – an arch of stratified, dense rock in which the layers bend downward in opposite directions from the crest (similar to an upside-down bowl). In Pinedale, the Anticline formed during the Cretaceous Age trapping gas at depths of 7,000 to 20,000 feet.

Anticlines, like the Pinedale Anticline in Sublette County, are favorable locations for oil and natural gas exploration due to their dome-like structure.

**Elaborate: Oil and Natural Gas Reservoirs**

Anticlines are one of several types of oil traps. Oil traps are formations in which oil and natural gas collect as they seep up from source rock, the source of organic material. See the image in the [Lesson 4 Resources](#) that shows a general oil trap. Oil and gas travel up through a porous and permeable reservoir rock until they are “trapped” beneath an impermeable cap rock.

Other common oil and gas traps are described in the [Lesson 4 Resources](#).

**Evaluate: What makes an oil or natural gas reservoir?**

Conclude with a think-pair-share and/or individual in-class and/or take-home synthesis prompt: Synthesize information from the porosity lab with the formation of anticlines and synclines. How is porosity related to anticlines and synclines and the formation of oil and natural gas? Based on the concepts we explored today, how do you think geologists are able to identify areas that are rich in fossil fuels?

**Resources:**

- Western Interior Seaway graphics: [http://eas.unl.edu/~tfrank/History%20on%20the%20Rocks/Nebraska%20Geology/Cretaceous%20Webpage/Timescale/Timescale.html](http://eas.unl.edu/~tfrank/History%20on%20the%20Rocks/Nebraska%20Geology/Cretaceous%20Webpage/Timescale/Timescale.html)
- Paleogeography resources: [http://www.scotese.com/K/t.htm](http://www.scotese.com/K/t.htm)
Lesson 4 Resources

Modeling Anticline/Syncline Formation

1. Students will take playdough and flatten 3-4 colors into small sheets. Students should arrange the colors into layers representing strata. Following the law of superposition in geology, older sedimentary rock should be on the bottom, and each younger layer should be placed on top of the last.

2. Next, ask students to imagine that over time, the weight of rock and the precipitation of minerals such as silica from groundwater cemented rock together. Students should press down on their play dough models, slightly altering the shape of the rocks.

3. Explain that due to forces within the earth’s crust, compressional stress from two sides toward the center of a rock alters the rock further, causing it to fold into waves.

4. Students should put pressure on the two sides of their playdough models to form a wave-like structure (they may have to shape it). These waves represent synclines and anticlines. Anticline formations include the layers that sit at the top of the wave, and synclines include layers that sit in the trough of the wave.

5. As wind and water erode away layers over time, the surface of the formations can expose older sedimentary layers. Students can model this by using an index card to cut across top of model at an angle. New colors of playdough should become exposed.

http://www.radford.edu/jtso/GeologyofVirginia/Structures/GeologyOfVAStructures4-2e.html

http://www.radford.edu/jtso/GeologyofVirginia/Structures/GeologyOfVAStructures4-2e.html
This figure shows good places under the earth to try and find petroleum oil and natural gas.


LESSON 5: WILD, WINDY WYOMING!

Standards:

<table>
<thead>
<tr>
<th>Next Generation Science Standards</th>
<th>Common Core Standards</th>
<th>WY Science Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCI - Earth &amp; Space Science</td>
<td>ELA-Literacy.RI.11-12.7</td>
<td>SC11.1</td>
</tr>
<tr>
<td>CCC - Patterns; Cause &amp; effect</td>
<td></td>
<td>SC11.1.7</td>
</tr>
<tr>
<td>SEP - Analyzing &amp; interpreting data</td>
<td></td>
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</tbody>
</table>

Lesson Overview: This lesson is designed to engage students in one of Wyoming's most powerful natural forces: wind. Students will explore wind by going outside and using kites to demonstrate the dynamics of the wind. They will also be introduced to the factors that influence the strength and reliability of wind in Wyoming, laying the groundwork for Wyoming's important role in wind energy development.

Guiding Questions: What is wind? What factors influence wind in Wyoming?

Duration: 45 minutes

Materials:
Kites, plastic bags and dowel rods or printer paper and bamboo skewers, crepe paper for streamers, layers/outerwear, white board/markers, notebooks, internet, materials in anemometer lesson

Engage: Exploring wind with kites
Bring kites to class, or ask if any students have kites at school. Alternatively, have students construct a simple kite pattern. Go outside, split students up into pairs - preferably at least one person per group has flown kites before. Before giving kites to students, ask them these questions: What conditions allow kites to fly? What are some tactics for launching and flying your kite? Ask students to make observations while flying kites to be able to expand on their explanations.

Students will break into pairs or groups of three with one kite each, and spend 15-20 minutes learning how to fly their kites, maneuvering the kites in the air, running and launching kites.

Explore: Visualizing wind direction
Attach a few streamers approximately 2 meters in length along the length of the kite string. When kites are in air, students should be able to see subtle differences in wind direction at different heights.

Explain: What is wind, and how is it created?
First, ask students to think-pair-share: What do you think causes wind to occur? Students take one minute to hypothesize what causes wind to occur, share with a partner, then share with the group.

Bring a small white board or drawing surface outside and draw a diagram of how wind is created (see Lesson 5 Resources). Wind is the product of movement of air from high pressure to low pressure, similar to diffusion. The sun heats the land unevenly (based on topography), causing air in some areas to warm faster than others. The warmer, lower pressure air rises, and the cooler, higher
pressure air rushes to fill the space resulting in wind. Wind formation is demonstrated in this video: http://www.redorbit.com/news/video/education_1/1112801902/what-is-wind/

Elaborate: Wild, Windy, Wyoming
Here in wild, windy, Wyoming we are lucky enough to have some of the windiest areas in the nation. The wind covering the state flows mainly from the Pacific, with a small amount flowing south from Canada. We have seasonal changes in wind. In winter, sustained winds of 30-40 mph are common in windy basins, with gusts of 50-60 mph. (See Lesson 5 Resources for seasonal wind maps of the U.S. - Darker blue are stronger winds. Winter has strongest winds). Ask students why they think winter has the strongest winds?

Evaluate: Wind patterns and flow
Ask students what other features might help strengthen wind in Wyoming? Think about topography, temperature differentials, latitude, elevation, etc. See the Lesson 5 Resources for more information on the effects of topography on wind speed.
What causes wind?

Differential heating: The atmosphere does not absorb solar radiation equally from the equator to the poles. This differential heating of the earth influences global-scale wind patterns.

Coriolis Effect: Pressure systems on the earth are dynamic, and move due to the Coriolis Effect. In the northern hemisphere, the rotation of the earth causes falling objects to curve westward. It also causes high pressure systems to turn clockwise and low pressure systems counterclockwise. The Coriolis Effect is affected by the friction of rough land. However, the Coriolis Effect is most directly observed at high altitudes, not on the surface, and causes the jet stream.
Topography: Topography causes land to heat at different unevenly.

**Valley and Slope Winds**

![Daytime](https://www.meted.ucar.edu/dot/media/graphics/valslope.jpg)

- **Upslope wind**
- **Downvalley wind**
- **Downslope wind**

![Nighttime](https://www.meted.ucar.edu/dot/media/graphics/valslope.jpg)

The COMET Program

https://www.meted.ucar.edu/dot/media/graphics/valslope.jpg

**Seasonal Wind Maps**

![Winter Wind Map](https://www.meted.ucar.edu/dot/media/graphics/valslope.jpg)
UNIT 2: WHY WYOMING?

Images retrieved from: NREL Wind Energy Resource Atlas of the United States
http://rredc.nrel.gov/wind/pubs/atlas/maps.html#2-6

DRAFT – August 2015
LAB 2: MEASURING THE WIND

Standards:

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<th>Common Core Standards</th>
<th>WY Science Standards</th>
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<td>SC11.2</td>
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<td>CCC - Scale, proportion &amp; quantity; Structure &amp; function</td>
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<td>SC11.2.2</td>
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<tr>
<td>SEP - Analyzing &amp; interpreting data; Using mathematical &amp; computational thinking; Obtaining, evaluating &amp; communicating information</td>
<td></td>
<td>SC11.2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SC11.2.5</td>
</tr>
</tbody>
</table>

Lab Overview:
In this lab, students will build on their understanding of wind energy by practicing measuring wind speed with various types of tools. They will build anemometers to measure wind speed and convert from rotations per minute to miles per hour and use the Beaufort scale to estimate wind speed. Students will compare the tools for accuracy and reliability of measurement.

Guiding Question:
How do meteorologists measure wind speed?

Duration:
45 minutes

Materials:
Dixie cups, straws, pencils, push pins, tape, Beaufort charts, digital anemometers (if available)

Engage: Measuring with the Beaufort Scale
Beaufort Scale was developed by Sir Francis Beaufort of the Irish Royal Navy in 1805 to estimate wind speed based on observation on land or sea. It is still used across the world when issuing maritime advisories. Use the Beaufort scale in the Lab 2 Resources to determine the Beaufort number of the wind in your area today.

Explore: Build an Anemometer
Take anemometers outside to measure wind speed by counting rotations of cups and converting from rotations per minute to miles per hour. Track the number of rotations the anemometer makes per minute and use the circumference of the anemometer to help determine wind speed. See the Lab 2 Resources for a diagram or visit http://www.ext.colostate.edu/energy/k12/wind-lesson.pdf for instructions and a worksheet:

**Alternative:** If school has a commercial anemometer like a Kestrel, compare commercial anemometer to student-built anemometers. How similar or different were the measurements? What are some variables that might influence this difference if you found one?
**UNIT 2: WHY WYOMING?**

**Explain: Calculate wind speed**
Anemometers like this homemade one and commercial ones use revolutions per minute to help determine wind speed and are used by many scientists including meteorologists, atmospheric scientists, and environmental engineers.

**Elaborate: Prevailing winds**
In Wyoming, the prevailing wind can blow from the SW to the NW, depending on the area. Check out this cool map of the country to see how wind flows across the nation today: [http://hint.fm/wind/](http://hint.fm/wind/)

Forecasts and collection points of wind flow provide the data for this map. Zoom in and out to look closely at Wyoming. What is the prevailing wind today? Look in the archives to see wind data from super-storms like Hurricanes Katrina and Sandy, etc. Ask students if they can identify any landforms that may be influencing the wind. Where are winds the highest? Where are they the lowest?

**Evaluate: Comparing technologies**
Compare Beaufort and homemade anemometer results. Which is more accurate? Why? What are the appropriate uses for each wind measurement strategy?

**Resources:**
- NREL US wind map, link to WY wind map: [http://www.windpoweringamerica.gov/wind_maps.asp](http://www.windpoweringamerica.gov/wind_maps.asp)
- Climate of WY: [http://www.wrcc.dri.edu/narratives/WYOMING.htm](http://www.wrcc.dri.edu/narratives/WYOMING.htm)
- Coriolis effect: [http://www.csun.edu/~psk17793/ES9CP/ES9%20factors_affecting_wind.htm](http://www.csun.edu/~psk17793/ES9CP/ES9%20factors_affecting_wind.htm)


UNIT 2: WHY WYOMING?

LAB 2 RESOURCES

Beaufort Scale

<table>
<thead>
<tr>
<th>Beaufort number</th>
<th>Wind Speed (mph)</th>
<th>Seaman's term</th>
<th>Effects on Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Under 1</td>
<td>Calm</td>
<td>Caim; smoke rises vertically.</td>
</tr>
<tr>
<td>1</td>
<td>1-3</td>
<td>Light Air</td>
<td>Smoke drift indicates wind direction; vanes do not move.</td>
</tr>
<tr>
<td>2</td>
<td>4-7</td>
<td>Light Breeze</td>
<td>Wind felt on face; leaves rustle; vanes begin to move.</td>
</tr>
<tr>
<td>3</td>
<td>8-12</td>
<td>Gentle Breeze</td>
<td>Leaves, small twigs in constant motion; light flags extended.</td>
</tr>
<tr>
<td>4</td>
<td>13-18</td>
<td>Moderate Breeze</td>
<td>Dust, leaves and loose paper raised up; small branches move.</td>
</tr>
<tr>
<td>5</td>
<td>19-24</td>
<td>Fresh Breeze</td>
<td>Small trees begin to sway.</td>
</tr>
<tr>
<td>6</td>
<td>25-31</td>
<td>Strong Breeze</td>
<td>Large branches of trees in motion; whistling heard in wires.</td>
</tr>
<tr>
<td>7</td>
<td>32-38</td>
<td>Moderate Gale</td>
<td>Whole trees in motion; resistance felt in walking against the wind.</td>
</tr>
<tr>
<td>8</td>
<td>39-46</td>
<td>Fresh Gale</td>
<td>Twigs and small branches broken off trees.</td>
</tr>
<tr>
<td>9</td>
<td>47-54</td>
<td>Strong Gale</td>
<td>Slight structural damage occurs; slate blown from roofs.</td>
</tr>
<tr>
<td>10</td>
<td>55-63</td>
<td>Whole Gale</td>
<td>Seldom experienced on land; trees broken; structural damage occurs.</td>
</tr>
<tr>
<td>11</td>
<td>64-72</td>
<td>Storm</td>
<td>Very rarely experienced on land; usually with widespread damage.</td>
</tr>
<tr>
<td>12</td>
<td>73 or higher</td>
<td>Hurricane Force</td>
<td>Violence and destruction.</td>
</tr>
</tbody>
</table>

SUMMATIVE ASSESSMENT: MODELING GEOLOGICAL FORMATIONS

*To be completed at the end of the unit.

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<td>SC11.1.7</td>
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<tr>
<td>CCC - Patterns; Systems &amp; system models</td>
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<td>SC11.1.13</td>
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<td>SEP - Developing &amp; using models;</td>
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<td>WY Science Standards</td>
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<td>Stability &amp; change</td>
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<td></td>
<td>SS12.6.1</td>
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Instructions:

**Setting:** In a galaxy far, far away on a planet exactly like earth, lies land with an underground secret. Because of the unique geological and ecological events in the planet’s long history, there are resources buried deep beneath the surface.

**Students' task:** Design a geological formation of natural gas, petroleum, or coal. Each student should build a three-dimensional model of an energy resource showing both surficial and underground stratigraphy. The model should tell a story. In addition, students should create a geological timeline and story of the events that created this landscape, including ecological activity that was eventually altered to form oil, gas, or coal.

Resources