AGU GIFT: The Science of Fracking

Presenter Bios

Daniel Birdsell (Daniel.Birdsell@colorado.edu) is pursuing a PhD at the University of Colorado in Civil Engineering. He studies environmental impacts of oil and gas development in the subsurface such as the migration of hydraulic fracturing fluids and the geo-mechanical impacts of Class II disposal wells. He helped teachers in Colorado develop a curriculum for teaching about ecosystem services focused on oil and gas development. Daniel holds a B.S. in Chemical Engineering from the University of New Mexico.

Lisa Gardiner (lisagard@ucar.edu) leads K-12 curriculum development and teacher professional development at the UCAR Center for Science Education. She holds a PhD in Geology from the University of Georgia and an MFA in Nonfiction Writing from Goucher College. She has worked in diverse education settings from universities to nature centers and farms. In her current role, she creates educational experiences for classrooms, blogs, websites, museum exhibits, interactives, and books and instructs teacher PD workshops and online courses.

Katya Hafich (Katya.Hafich@colorado.edu) splits her time at University of Colorado Boulder between coordinating the education and outreach program at the AirWaterGas Sustainability Research Network, and coordinating K-12 and community outreach programs at the CU Boulder Office for Outreach and Engagement. She's a recovering biogeochemist, and now works with K-12 teachers, community groups, and faculty on global issues of climate change and hydraulic fracturing.

Tori Hellmann (tori.hellmann@d51schools.org) is a science teacher at Palisade High School in Palisade, Colorado where she has taught Geophysical Science, Biology, Honors Biology, Zoology, Botany, AP Environmental Science and IB Biology. She is also the advisor for the MESA club, which involves STEM activities and competitions in Colorado. Previously Tori taught middle school science at Holy Family Catholic School in Grand Junction, Colorado. She holds a master's degree in science education from Montana State University and a bachelor's degree in elementary education K-8 from Northern Arizona University. Her interest in science began at Colorado State University where she majored in watershed science. This past summer Tori was a Teacher-in-Residence with the AirWaterGas project, developing science curriculum about the impacts of oil and gas development.

Greg Lackey (gregory.lackey@colorado.edu) is a PhD candidate at The University of Colorado, Boulder. His primary research interest is the multiphase transport of stray methane away from leaky oil and gas wellbores. Greg is also very interested in environmental education. He spent two years working as a teaching resident assistant for the Sustainability and Social Entrepreneurship Residential Academic programs at the University of Colorado. He has also been a part of the education and outreach team for the AirWaterGas Sustainability Research Network.

The Rock Porosity Experiment

Introduction
Students will investigate the porosity and permeability of rock formations that may hold oil, gas, and water.

Credits
Lesson developed by Tori Hellmann, UCAR AirWaterGas Teacher-in-Residence with support from science advisor Jessica Rogers. Adapted from The Absorbancy of Rock from the SEED Science Laboratory Activity Library.

Grade level
6-10

Time Required
Teacher Prep Time: Approximately 15-20 minutes
Class time: One ~90 minute block period

Learning Goal
Students will be able to relate the physical properties of permeability and porosity of rock formations to the amount of water, oil, and natural gas held in these formations.

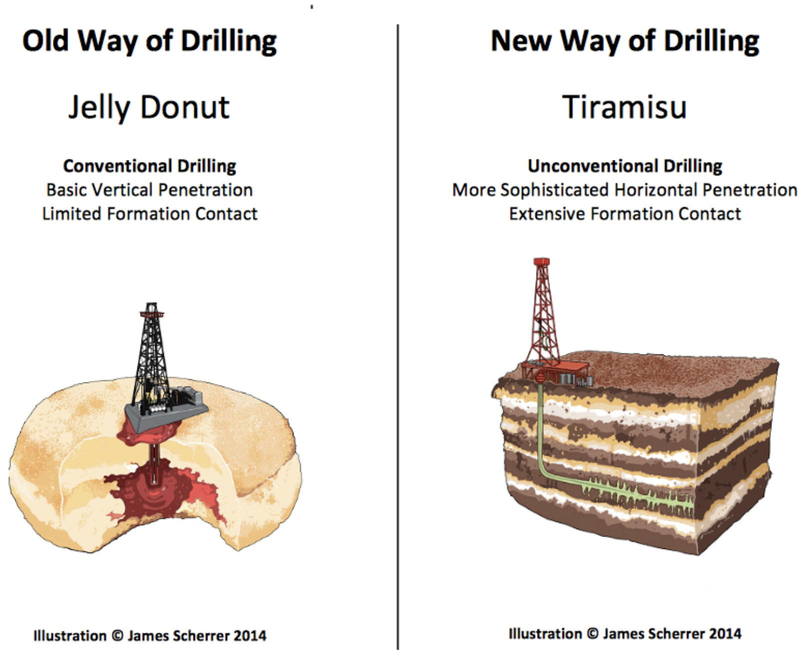
Standards
Next Generation Science Standards
HS-ESS3-1 Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. ESS3.A

Materials
For each lab group:
- A marble, small pieces of chalk (magnesium carbonate)*, pumice, granite, sandstone and shale
- 250mL beaker for each rock sample (6 total)
- Graduated cylinder
- Electronic balance
- Water

*Note: be sure to use **gymnast chalk**, magnesium carbonate, not chalkboard chalk for this activity.

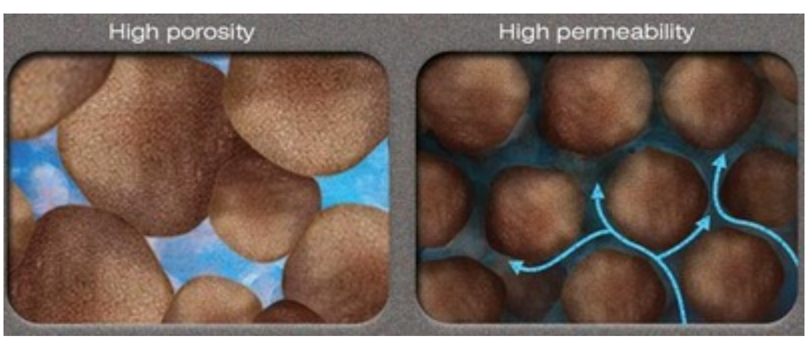
Introduction
Oil and gas are held underground in sedimentary rock formations and can be extracted through many different methods. Conventional drilling extracts "easy to reach" oil and gas, which flows to the surface through a vertical well. Unconventional drilling techniques, or drilling horizontal wells and the process of

hydraulic fracturing, are used to extract trapped oil and gas from geological formations. See the illustration below that compares drilling techniques to desserts.



Drilling into conventional sources is like sticking a straw in a jelly donut – the petroleum is trapped in a large single formation that just flows out under pressure. Drilling into unconventional sources like oil and gas shale is quite different, more like tiramisu – the petroleum is in many layers that have to be individually tapped using horizontal drilling and fracking methods to open up the rock. Saudi Arabia has a bunch of really big jelly donuts. The United States has lots of tiramisu, plus some pretty good jelly donuts as well. Source: Jim Scherrer

Sedimentary rocks have the ability to hold oil, natural gas, and water due to physical properties called porosity and permeability. Porosity refers to the tiny air spaces in the rock itself. Permeability is a measure of the ability a rock to allow water, oil, natural gas, or other fluids to pass through it. In other words porosity is the rock's ability to hold a fluid and permeability is the rock's allowance or resistance to flow of a fluid through it.



http://syntropolis.net/media/cache/de/f9/def995c3536dbd4528d05ebb9c6cd949.jpg

Experiment

Purpose

Demonstrate how different types of rock absorb water and how this relates to where we find oil and gas.

Problem

Which type of rock will hold the most water after being submerged in water for several days? How does this relate to the rock's porosity?

Hypothesis

Ask students to write an "If, then" statement relating back to problem.

Procedure

1. Weigh each sample and record the weight in the Raw Data Table provided.
2. Find the volume of your rock sample using water displacement method.
3. Record the volume of each sample in the Raw Data Table.
4. Dry off each sample after finding the volume.
5. Fill the 250mL beaker with 200mL of water.
6. Place each sample in beaker and leave it submerged in the water for 10 minutes.
7. After 10 minutes remove the rock sample, shake or dab off any excess water, and weigh and record the weight in the data table.
8. Place the sample back in beaker and repeat every 10 minutes for the remainder of the class period.
9. After the last measurement, cover each beaker with plastic wrap and leave them on counter.
10. Take weight measurements again after a 24-hour period and record.
11. Place the samples back on counter and repeat measurements daily for three days.

Analysis

Once students have completed their Raw Data Table, ask them to complete the Processed Data Table. Ask students to graph their results.

Conclusion Questions

1. Which rock had the highest porosity (% of water absorbed)?
2. Which type of rock has the potential to hold the most water, gas or oil? Explain.
3. In which type of rock would you expect to find an aquifer? Why?
4. If you were looking for a rock formation to hydraulically fracture for oil and gas, which formation would you choose and why? Choose between granite, sandstone, or shale.

5. Explain the importance of the cement casing used during fracking and relate this to porosity.

Conclusion
Ask students to revisit their hypothesis, discuss their results, address the strengths and weaknesses of the experiment, and list two suggestions for further experiments or research.

Teacher Notes
Do not use chalkboard chalk for this experiment, it dissolves too quickly. Magnesium carbonate is gym chalk and can be purchased at sports supply stores (or if you have a gymnastics team, maybe you can borrow some from them). A 1lb box will be adequate for several experiments.

Pieces of sample rock need to be small enough to fit into a large (500mL) graduated cylinder. You may need a hammer to break samples into small enough pieces or use samples from a rock sample kit.

You can use other types of rock samples such as scoria or basalt. Just be sure to use a piece of shale and sandstone to represent the actual rock formations associated with oil and gas drilling.

Extension
Repeat this experiment with oil, remembering that oil is less dense than water and so will occupy more space than the water.

Raw Data Table

Rock sample masses (grams) before and after being placed in water for up to 72 hrs (3 days).

Rock Type	**Initial Volume (mL)**	**Initial Mass**	**Mass measurement after…**							**Overall Change in Mass**
			10 min.	**20 min.**	**30 min.**	**40 min.**	**24 hours**	**48 hours**	**72 hours**	
Marble										
Chalk										
Pumic										
Sandstone										
Shale										
Granite										

Note: Water's density is = 1g/mL therefore, water has a unique relationship between its mass and volume: 1 gram = 1cc = 1mL .

Processed Data Table

Volume (mL) of water absorbed by rock samples over a 3 day period

Rock Type	Total Volume of Water Absorbed	Volume of Rock	Percent of Water Absorbed
Marble			
Chalk			
Pumic			
Sandstone			
Shale			
Granite			

Calculations: To find the percentage of water absorbed by each sample we need to know the overall change in mass of the rock sample. This change in mass relates to the amount of water or volume of water absorbed by the rock.

Use the following formula:

$$\frac{\text{Volume of water absorbed (mL)= overall change in mass}}{\text{Volume of rock sample (mL)}} = \text{\% of water absorbed}$$

Example: Water absorbed was 3mL and volume of sample was 25mL

$$\frac{3\text{ mL}}{25\text{mL}} = 0.12 \times 100 = 12\%$$

Make a Fracking Model

Introduction
Students will design a model to demonstrate how hydraulic fracturing aids in extracting oil and gas from shale deposits thousands of feet beneath the Earth's surface.

Credits
Activity developed by UCAR AirWaterGas Teachers-in-Residence Shelly Grandell, Tori Hellman, and Rebecca Bradford.

This activity is modified from the NEED Project Fracturing With Gelatin Activity, found in the Wonders of Oil and Gas Unit.

Grade level
6-12

Time Required
Class Time: 1 block period ~100 minutes or two 50-minute class periods

Learning Goal: *Students will understand that horizontal drilling allows for more surface area of host rocks to be fracked after designing a model that demonstrates hydraulic fracturing methods.*

Lesson Format: Hands-on activity

Next Generation Science Standards
MS ESS3.A Natural Resources*: Humans depend on Earth's land, ocean, atmosphere and biosphere for different resources, many of which are limited or not renewable. Resources are distributed unevenly around the planet as a result of past geologic processes.*
HS-ESS3-1 *Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. ESS3.A*
HS-ESS3-2 *Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. ESS3.A, ETS1.B*
HS-ESS3-4 *Evaluate or refine a technological solution that reduces impacts of human activities on natural systems ETS1.B, ESS3.C*

Materials for 10 groups
- 40 packets of gelatin (Knox Gelatin works well.)
- Ten 20 oz, clear, plastic bottles, rinsed
- One box of Plaster of Paris
- Ten cups
- Ten spoons
- Water
- Ten binder clips (or paper clips)
- Ten veterinary catheter tubes (size 10-14 French)
- Ten Leur lock syringes (that are the same size as the catheter tubes)
- Ten large straws that catheter tube will thread through

Preparation

1.) *Collect empty plastic water/soda bottles well before lab (have students bring in bottles at least a few days before the lab).*
2.) *Make the gelatin at least one day before (use 1:4 ratio for more stable gelatin), and pour into the plastic bottles. Cool the gelatin in a refrigerator overnight.*
3.) *In class, before students begin, mix plaster. Make the plaster right before you plan on using it, as plaster hardens quickly. Distribute it to students in the cups.*

Introduction

Show students a picture of a stratigraphic column that contains a deep, tight, oil and gas bearing shale. Ask students to come up with ideas as to how they might access this deposit. Tell them that they may only make a 10-12 inch hole on the ground surface to reach the deposit.

Here is an example from the Oklahoma area: (students would need to access the red and green beds)

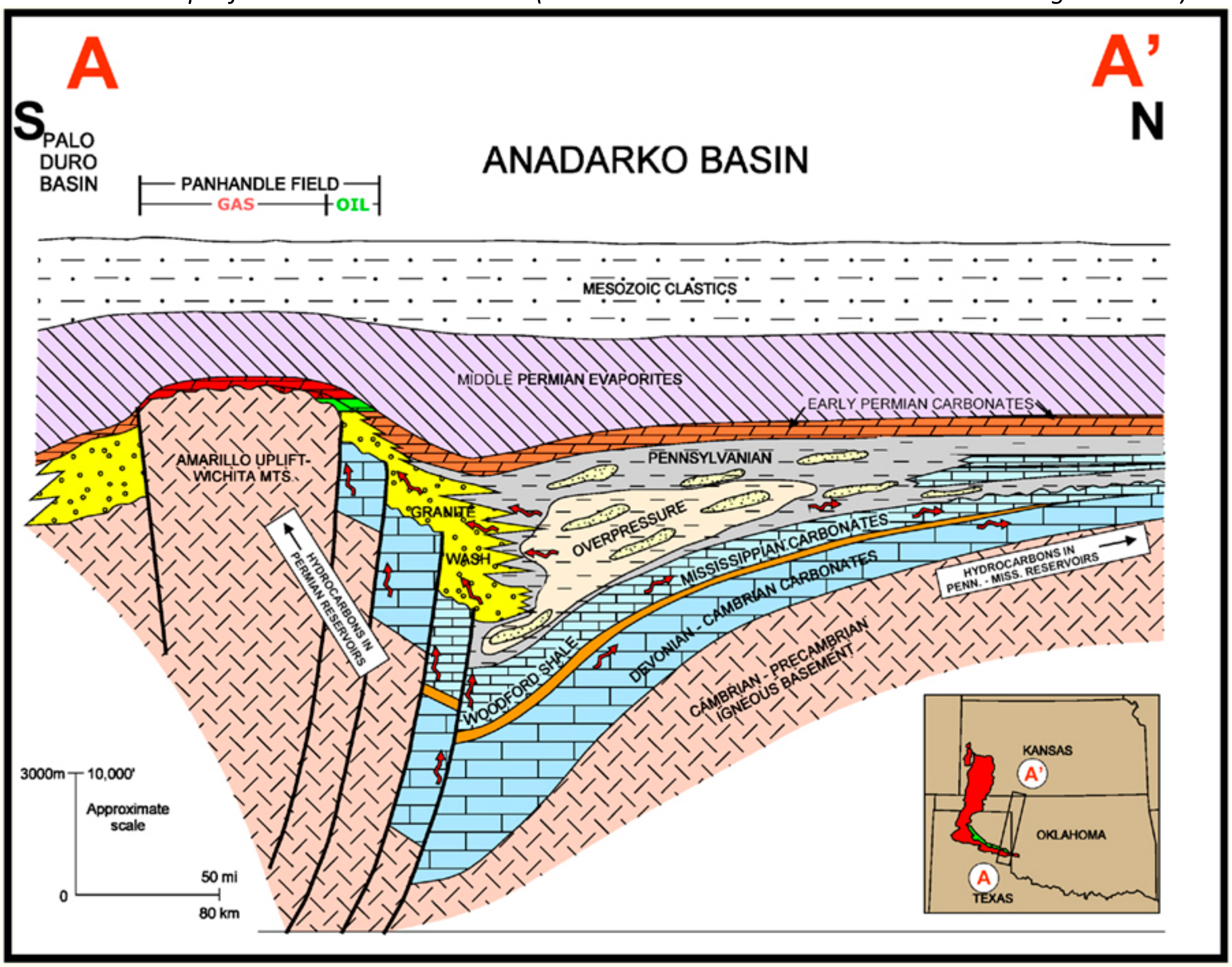


Image from: Fierstien, John. The Anadarko Basin Makes Oklahoma Oil & Gas More Than OK. Drillinginfo, 9 Dec. 2014. Web. 13 Nov. 2015. <http://info.drillinginfo.com/>

Students will have a variety of answers. Lead the discussion into surface area by asking: How can we access the oil and gas bearing formation beyond the area reached with a vertical well? In oil and gas terminology, traditional drilling technology using vertical wells is called conventional oil and gas extraction.

Directions

- Pass out materials to groups.
- Instruct students to assemble the catheter apparatus

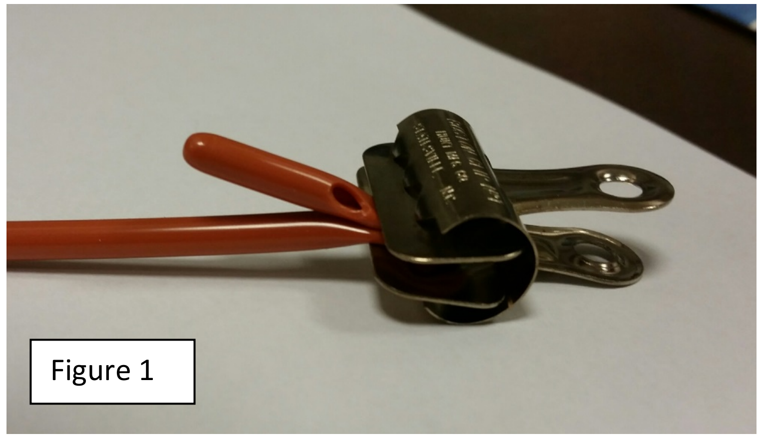


Figure 1

Catheter Assembly:

- Attach open end of catheter tubing to a syringe
- Use paper clip or binder clip to pinch bottom of tube ABOVE holes, this will prevent fluid from leaking before injection (see Figure 1).

Procedure:

1. Take bottle with gelatin and lay on side. Tell students that the gelatin in the bottle represents a horizontal layer of rock that contains fossil fuels.
2. Insert the straw to bore a hole about two thirds of the way through the gelatin. DO NOT GO ALL THE WAY TO BOTTOMOF THE BOTTLE! (see Figure 2) Tell students that this is analogous to horizontal drilling in which a well is drilled from the surface down and then the drill bit is turned to drill through the rock layer.

Figure 2

3. Place thumb over end of straw, pull out slowly, and making sure to extract the gelatin core completely. This is the most difficult step. If there is not enough suction the gelatin core may not come out of the bottle completely, and the experiment won't work if the bore hole is blocked. Tip: You can apply suction with your mouth on the straw to extract the core as well.
4. After clearing the straw, reuse the straw from step 3, and place it into the bore hole, (you will need to hold onto the straw during injection of fluid (see Figure 2)). This straw will serve as the well casing.
5. Using the fracking catheter assembly already constructed, fill the syringe full with the plaster mixture (ie. fracking fluid) while it is attached to the catheter tube, allowing the mixture to fill the tubing until both the syringe and tube are full. Tell students that the plaster is a good representation of fracking fluid because it is granular and the grains represent the sand (proppant) in real fracking fluid.

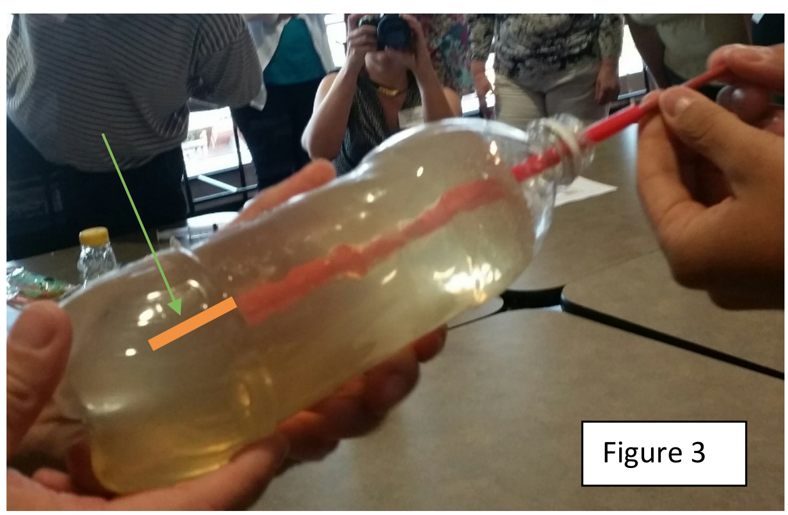


Figure 3

6. Carefully put the plunger back into the syringe, without pushing the fracking fluid out.
7. Remove the binder clip and insert the catheter tubing into the straw, or well casing, until the tube extends past the borehole straw approximately 3 cm. into the gelatin (see Figure 3).
8. Using very firm, steady pressure, push the plunger to inject the plaster into the gelatin.
9. Observe the fracturing pattern of the gelatin.
10. Pull the tubing out of the gelatin carefully, trying not to disturb the fractures.
11. If desired, you can allow the gelatin and plaster to sit until the plaster hardens, and you can then extract the plaster cast of fracture pattern to make further observations by cutting the plastic bottle away and discarding the gelatin.

Assessment
Students should sketch and label their model and demonstrate an understanding of the relationship between the model and what a real hydraulic fracturing process would look like.

Assessment Questions students could be asked:

1. Why did you have to apply pressure to fracking fluid to create fracture patterns?
2. How does this model represent hydraulic fracturing?
3. How does this model NOT represent hydraulic fracturing?
4. What improvements could be made to the model to make it more accurate and realistic?
5. How does the plaster simulate fracking fluid?
6. How does the plaster NOT simulate fracking fluid?
7. What does the casing straw represent? What kind of materials would you need to construct casing in the real world? Why?
8. Do you think if you changed the density of the fluid, would the fracture patterns be the same? Why?
9. What is the purpose of the proppant (grains) in the fluid?
10. Why do we hydraulically fracture wells?

Background information:
Access to oil and gas deposits in the U.S have become increasingly accessible through the advent of hydraulic fracturing. Hydraulic fracturing, known as fracking, is the process in which and oil and gas bearing host rock, such as shale, is injected with fracking fluid at high pressures to stimulate flow of hydrocarbons out of the well.

Fracking fluid is a mixture of water with sand and chemicals to aid in flow down the well. Wells used for hydraulic fracturingl can be vertically or horizontally drilled. Horizontal wells begin with an initial wellbore (the vertical component) then the hole is gradually turned about 90 degrees to be oriented horizontally within the oil and gas bearing formation. Horizontal wells can spread out for miles. Some single vertical wells can have multiple "fingers" spreading out in different directions inside the oil and gas bearing formation.

For a more detailed description of the fracking process, visit these sites:
http://www.fracfocus.org/hydraulic-fracturing-process
http://www.usgs.gov/hydraulic_fracturing/
http://www2.epa.gov/hydraulicfracturing

Extensions
Try using different fluids than Plaster of Paris, or vary the density of the Plaster of Paris. Discuss how different mixtures of fracking fluid are used for different wells and types of rock.

Use activity as an inquiry project. Provide the students with all of the materials and have them develop a design to model hydraulic fracturing that minimizes risk to groundwater and surface spills. Have the students defend why their model best represents hydraulic fracturing.

Alternate Procedure & Materials:
If you are unable to find catheter tubing, you can use two straws with different diameters, with one that fits inside the other. Follow the procedure below:

Straw Assembly:

- About 10 millimeters from one end of small straw, use a push pin to poke about ten holes 5 millimeters apart, with five holes on each side in a straight line.
- Use a small piece of duct tape to seal the perforated end of the small straw.
- Use duct tape to attach a syringe to the non-perforated end of the small straw and insure that no leaks are possible.
- Cut one large straw for the borehole/casing in half and set aside.
- Follow the above procedure starting on step 3.