GOING PLACES IN THOSE WIDE OPEN SPACES

a science activity on petroleum formation, porosity, and permeability

Grades 6-10

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This activity may be used (in conjunction with other activities) to achieve several of the Grades 5 and 8 Content Standards of the Nevada Draft Science Content Standards, which are based on the National Science Education Standards. A listing of those Nevada Draft Science Content Standards particularly addressed in this activity is on the last page of this exercise.

BACKGROUND

What is Petroleum and How is It Formed?

Petroleum (oil and gas) may be thought of as fossilized sun's energy. Through the process of photosynthesis, living organisms combine sunlight, carbon dioxide gas, and water to produce energy to live. When they die, if they are buried in such a way that they are not completely consumed by other organisms or inorganic attack by oxygen, then enough organic matter is left to be transformed into petroleum. One way for organic matter to be preserved is in a basin, such as a swamp or pond, where currents do not bring in much fresh oxygen. In this environment, the organic matter is scattered through the rock in low concentrations. If organic matter is buried under additional layers of sediment and heated slightly by the pressure of this overburden, the organic matter is converted into liquid and gaseous hydrocarbons which are lower in density than the enclosing rock. When squeezed by the weight of burial, they move through the pore spaces or fractures in rocks to the highest place they can reach, where they float on top of water in the pores of their host rocks. (Fill a clear cup with coarse gravel, add a half cup of oil and a half cup of colored water and observe and describe what happens).

Geological circumstances must be just right for the formation of an economic oil deposit:

- It must not be heated too high, or it will be converted to unusable minerals.
- It must migrate to and collect in a **porous** and **permeable reservoir** rock formation from which it can be pumped out.
- It must not be too deep to be discovered and used.
- It must accumulate in an **oil trap** beneath the earth's surface so that it does not reach the surface, be eroded, and evaporate or dissipate.

A trap is formed when the reservoir rock is deformed in such a way that it is gently tilted or folded and is sealed on top by an impermeable rock unit or an impermeable feature such as a fault. Sandstone, a coarse grained sedimentary rock, or a fractured rock unit may form a reservoir, and shale, a very fine-grained sedimentary rock, may form an impermeable seal. The relatively light petroleum floats on top of ground water which fills the pore spaces in the reservoir rock.

POROSITY AND PERMEABILITY

Porosity is the amount of open space or pore space between grains of a rock or sediment.
Permeability is how easily fluids can move through pores and cracks of a rock or sediment.

EXERCISE

Have students work in small groups, with a set of materials for each group.

Objective: To explore and measure the relative porosity and permeability of materials of different grain size and composition. To develop an understanding of the role of grain size and composition on porosity and permeability of earth materials with relationship to their ability to hold and transmit fluid natural resources such as petroleum or groundwater.

Materials: (use whichever of these or similar materials you can collect easily)
- pebbles (or marbles) (1-2 cm diameter, roughly uniform in size)
- coarse gravel (or glass beads, pea gravel), (<0.5 cm diameter, uniform in size)
- finer gravel, (or smaller glass beads)
- coarse sand
- clay, topsoil, or fine dirt
- coarse diatomite (or clean kitty litter)
- finely ground up diatomite
- metric measuring cup or graduated cylinder
- water
- large clear flexible plastic cups, at least 300 ml (16-ounce beer cups work well)
- large nail
- duct tape

Hypothesis:

Based on observation, which material do you think will be most porous (have the most pore space available to fill with fluid)? Least porous? Rank the materials (1,2,3...) as to expected porosity. Do the same for permeability (which will allow fluid to move through it fastest). You may use the worksheet provided, or make your own.

Procedure:

For identification, you may number the cups with permanent marker. Poke a hole in the bottom of each cup (from the outside) with the nail (the same size hole for each cup) and then cover the hole carefully with duct tape to make it watertight. Use one cup for each of the available materials: pebbles, coarse gravel, fine gravel, sand, clay, and diatomite. Fill each cup to the same level line with one of the materials.

Put water into measuring cup to an identified level and record the level (300 ml is a reasonable amount to start with). Pour water slowly and carefully into the pebble-filled cup until it is saturated just to the top surface of the pebbles. Record the amount of water remaining in the measuring cup and calculate the amount of water it took to saturate the material by subtracting the final water level from the initial water level. Estimate to the nearest 10 milliliters. Record this amount on the worksheet.

Repeat this procedure with each of the other materials and record the amount of water needed to saturate each cupful of material.

Holding another empty cup under the hole, remove the tape from the hole in bottom of cup and drain the water into the cup below. Time how long it takes each material to drain. After about 5 minutes, measure the amount of water drained from each cup and record on chart. Check again after 10 minutes to see if any more water drained out, and add this to the appropriate column on the worksheet. Compare the amount of water added to each cup to the amount of water retrieved from each cup of material. To calculate the percentage of water retrieved from each material, calculate:

$$\frac{\text{amount of water drained out}}{\text{amount of water poured in}} \times 100\%$$

Results and conclusions:

From the data recorded on your chart,

What is the relative porosity of each of the test substances (how much water can each accommodate in pore spaces)? Rank the materials by porosity.

From which was the most water retrieved after 5 minutes? 10 minutes? From which material was the least water retrieved? Which is the most permeable material? Rank the materials by permeability.

How did your findings compare with your original hypotheses? Brainstorm explanations for any differences.

Which material would make the best reservoir rock for a petroleum deposit? Why?

Which material would make the best seal for the top of an oil trap?
Why?