Natural Gas Geology

Objective
The student will understand how permeable and impermeable rock layers and porosity influence the accumulation of natural gas.

Curriculum Focus
Science
Art

Materials
- Three sponges
- Clay
- Food coloring
- Water

Key Vocabulary
Hydrocarbons
Impermeable
Kerogen
Migration
Permeability
Porosity
Reservoir rock
Source rock

Next Generation Science Correlations
4-ESS1 - 1
4-ESS1.A
4-ETS1 - 1
4-ETS1.A
5-PS1 - 1
5-PS1.A
5-ETS1 - 1
5-ETS1.A
MS-LS4 - 1
MS-LS4.A
MS-ESS1 - 4
MS-ESS1.C
MS-ESS3 - 1
MS-ESS3.A
MS-ETS1 - 4
MS-ETS1.B

Introduction

Oil and natural gas are thought to have originated from organic matter - ancient plankton, algae and land plants. Due to its abundance, plankton was the most important source of organic matter for oil and natural gas formation. As the plankton died and settled to the bottom of ancient lakes and oceans, it underwent bacterial decomposition.

The early stage of oil and natural gas maturation involves the formation of kerogen. Kerogen is a solid organic material derived from the decomposition of plankton, algae and land plants; which when heated releases hydrocarbons. At depths of 7,600 feet or more, crustal heat flow and pressure from overlying sediments provide sufficient heat to break down (crack) the kerogen. Kerogen begins to break down at a temperature of 76 C (170 F). The pressure from the overlying sediments also transforms the underlying sediments and clays into sedimentary shales.

Over geologic time, and due to pressure of overlying sediments and crustal heat flow, the temperature increases with depth. The increased temperature transforms long-chain liquid hydrocarbons (oil) into short-chain gaseous hydrocarbons (natural gas). Therefore, petroleum reservoirs below 20,000 feet commonly produce only natural gas.

Rock in which organic matter has been transformed into oil or natural gas is called source rock. The rock in which the oil or natural gas accumulates is called reservoir rock. Shales (which are rich in organic matter) deposited in an anaerobic marine environment are the best source rocks, whereas, sandstone, limestone and dolomite are common reservoir rock.

Porosity and permeability are important characteristics of rocks; for it is in the pores of rocks that the oil and natural gas accumulates, and the permeability, which allows the oil and natural gas to migrate. Porosity is the ratio of the volume of pores to the total volume of the rock. Permeability is the measure of how easily fluids (oil and/or natural gas) can pass through rock. The key to permeability is the degree to which the pores in rock are connected to form channels, which allows the oil and/or natural gas to flow through the rock.

The migration of oil or natural gas through porous, permeable rock layers is a result of the pressure or weight from overlying sediments. The pressure or weight compresses the rock, closing the pores and "squeezing" the oil or natural gas out. Some rocks are able to maintain their porosity and permeability under compression better than others. For example, sandstones maintain their porosity and permeability better than shales, and thus are an excellent reservoir rock.

Since oil and natural gas can be formed from aquatic organisms, they are commonly found in association with water. Because of buoyancy, oil and natural gas migrate up through water and accumulate at the top of water reservoirs.

For oil and natural gas to accumulate, a geologic trap must exist. A geologic trap consists of an impermeable rock layer (called a cap rock) and a geological structure that prevents migration. There are two basic types of geologic traps, structural and stratigraphic. Structural traps are the result of displacement in the rock strata. Stratigraphic traps are due to the deposition of sediments that form the rock strata.

Procedure

1. Place several drops of colored water on a sponge. The colored water represents natural gas and the sponge the reservoir rock.
    a. How is natural gas contained in reservoir rock? (Natural gas accumulates into the small open spaces of the sponge material.)
    b. How is porosity important to natural gas accumulation? (Pore space or porosity allows natural gas to fill in "empty" space in the sponge material.)
2. Push down on the sponge.
    a. Where does the colored water or natural gas migrate? (The colored water migrates upward to the open spaces in the sponge material.)
    b. What does pushing down on the sponge create? What happens to the pores in the sponge? (Pushing down on the sponge creates a similar effect of the weight of the overlying rock layers that create heat and pressure to change the organic material into natural gas. The pore space gets smaller with pressure.)
    c. How might this relate to the migration of natural gas from source rock and within reservoir rock? (The pressure forces natural gas to move or migrate into other nearby pores in the rock.)
3. Add more colored water to the first sponge. Place a second sponge on top of the first sponge. The second sponge represents a permeable rock layer. Again push down on the sponges.
    a. Where does the colored water migrate? Does any colored water migrate to the second sponge? (Colored water migrates upward to the pore space in the other sponge as well if there is enough colored water.)
    b. How might permeable rock layers, such as sandstone and limestone, affect the accumulation of natural gas? (The more pore space there is in a rock layer, the more natural gas will accumulate.)
4. Place a layer of clay on top of the first sponge and a new, dry sponge on top of the clay. The clay represents an impermeable rock layer or cap rock. Again press down on the sponge-clay-sponge apparatus.
    a. What effect does the impermeable layer have on the migration of colored water? (No colored water migrates to the sponge above the clay layer.)
    b. Why is the impermeable layer called a cap rock? (The impermeable layer acts like cap… trapping the natural gas.)
    c. Explain how impermeable rock layers, permeable rock layers, cap rocks, porosity and source rock influence the accumulation of natural gas. (Source rock must have significant amount of organic material that can be altered into a source of natural gas. Permeable rock layers with good porosity allow natural gas to accumulate. Impermeable rock layers or cap rocks stop the migration of natural gas through the next rock layer.)

To Know and Do More

Draw a diagram of the colored water, sponges and clay layer as layers of rock and natural gas deposits - labeling: natural gas, permeable rock layers and impermeable layer (cap rock). Compare your diagram with other students' diagrams.

Research present day natural gas deposits found in North America. Which state or providences have the largest deposits? Does the state where you live have natural gas deposits? Describe the rock type (sandstone, limestone, etc.) of the reservoir rock.