Session 3: Petroleum Geology; Review for Test #1

Prepare to Teach

Session Overview

Session 3 provides an understanding of the basic geological concepts that pertain to the formation of hydrocarbons within the earth's crust, then goes on to describe how hydrocarbons originate, migrate and accumulate in reservoirs. The students then learn about the physical dynamics of the reservoir and conclude with a discussion of the economics associated with removing hydrocarbon fluids from a reservoir.

Class Preparation Checklist

- ☐ Review the homework assignments issued during the last sessions.
- ☐ Download and print copies of the directions for the porosity experiment (Topic 6) from the following website URL: http://www.slb.com/seed/en/lab/porosity/index.htm.
- ☐ Collect the following materials for the porosity experiment:
  - Gravel, sand and silt
  - 3 beakers, 500 milliliters each
  - 100 milliliter graduated cylinder
  - A large pitcher of water
- ☐ Download and print copies of the directions for the absorbency experiment (Topic 13) from the following website URL: http://www.slb.com/seed/en/lab/absorb/index.htm.
- ☐ Purchase the CD "Natural Gas Energy in Science" from the National Energy Foundation at http://www.net1/org. Make copies of the Hydrocarbon Geology activity.
- ☐ Create questions for the test review.
- ☐ Arrange for flipchart easel, flipchart paper, and markers OR whiteboard and markers.
- ☐ Arrange for overhead projector and overheads, if used.
- ☐ Bring texts or other materials to be used in this course.

Learning Objectives

1. Discuss the basic concepts of geology related to oil and gas exploration and production.
2. Describe the origin, migration and accumulation of oil and gas.
3. Discuss the principles of fluid flow in porous media.
4. Characterize the composition of reservoirs and composition of reservoir fluids.
5. Discuss the pressure variables associated with reservoirs.
6. Discuss basic reservoir economics.

Agenda

Activity	Estimated Time
1. Agenda	5
2. Homework Review	15
3. Learning Objectives	5
4. Basic Geology	25
BREAK	10
5. Petroleum Origin and Migration	15
6. Porosity Experiment	15
7. Petroleum Accumulation	10
8. Reservoir Fluids and Pressure	10
BREAK	10
9. Reservoir Economics	10
10. Review Activity	15
11. Review for Test #1	25
12. Summary and Wrap-Up	10
BREAK	10
13. Additional or Lab Activities	50

Begin Lesson

1. Agenda

Time: 5 minutes

- Distribute the handouts to students (see Class Preparation Checklist).

DISPLAY
SLIDE #1

Slide 2: Agenda

- Review the agenda for today's class.

2. Homework Review

Time: 15 minutes

- Go over the homework assigned last session.
- Collect any assignments that you choose to review and count for a grade.

3. Learning Objectives

Time: 5 minutes

DISPLAY
SLIDE #2

Slide 2: Learning Objectives

- Discuss the ***Learning Objectives*** for this session.

  NOTE: The time spent on objectives should be more than just reading them to the class. If possible, refer to these objectives often during the remainder of the session.

- Explain that knowledge mastery as it relates to the course/session objectives ensures student success on graded items.

4. Basic Geology

Time: 25 minutes

In order to understand how fossil fuels (oil and gas) are formed, we must first understand some simple geology concepts. Once we understand these concepts, we can then explore the processes that contributed to the formation of petroleum reservoirs.

DISPLAY
SLIDE #3

Slide 3: Earth's Layers

- The large–scale structure of the Earth has several layers including:
  - Inner core (solid)
  - Outer core (liquid)
  - Mantle (solid)
  - Crust included in Lithospheric plates
  - Oceanic crust and continental crust

DISPLAY
SLIDE #4

Slide 4: Earth's Crust – Permian Era (286 – 245 Million Years Ago)

- In the Permian Era – one *super continent* called Pangea

  NOTE: Introduce the concept that plates can move.

DISPLAY
SLIDE #5

Slide 5: Earth's Crust – Triassic Era (245 – 208 Million Years Ago)

- Pangea separated over millennia. Notice the changes with each subsequent era.

DISPLAY
SLIDE #6

Slide 6: Earth's Crust – Jurassic Era (208 – 144 Million Years Ago)

DISPLAY
SLIDE #7

Slide 7: Earth's Crust – Cretaceous Era (144 – 65 Million Years Ago)

DISPLAY
SLIDE #8

Slide 8: Earth's Crust – Today

DISPLAY
SLIDES #9 - 11

Slide 9 - Plate Tectonics;
Slide 10 – Continental Drift Theory;
Slide 11 – Convection Theory

- Definition: the theory that explains the processes that cause the earth's crust to move and change shape
- 1910: Continental drift (Alfred Wegener)
- 1920: Convection theory (Arthur Holmes)
- 1960: Sea Floor Spreading (Harry Hess and R Deitz)
- 1968: Subduction Zones
- This theory is now referred to as plate tectonics

DISPLAY

SLIDE #12

Slide 12: Sea Floor Spreading

- Divergence; ocean crust forms at mid-ocean ridges
- Is forced aside by new crust over time
- Ridges are symmetrical

DISPLAY

SLIDE #13

Slide 13: Plate Boundaries

- *Convergence*: The movement of tectonic plates toward each other. The resulting collision may create subduction.
- *Subduction*: A process by which the edge of one continental plate is drawn under a neighboring plate.
- *Continental Rifting*: A large area of the surface where plates of the earth's continental crust are moving away from each other, forming an extensive system of fractures and faults.

DISPLAY

SLIDES #14 - 19

Slide 14: Warp
Slide 15: Folds
Slide 16: Domes
Slide 17: Basin
Slide 18: Faults
Slide 19: Geologic Structures

Three basic structures result when rocks change shape due to tectonic movement:

- *Warps*: Where areas of formerly horizontal crust have become slightly tilted as a result of the rise or fall of broad areas of the crust without fracturing.
- *Folds*: Rocks that have buckled into wavelike structures.
  a) *Domes*: Geologic fold that plunges on all sides like an inverted bowl.
  b) *Basins*: Geologic fold that dips downward toward a common center.
- *Faults*: Areas where rocks, anticlines and synclines, break and fracture as two sections of the crust move in relation to each other. Common surface features produced by faulting include:
  a) *Graben*: Elongated blocks of crust between two faults that have sunk in relation to the surrounding crust.
  b) *Horst*: Elongated blocks of crust between two faults that have risen in relation to the surrounding crust.

DISPLAY

SLIDE #20

Slide 20: Types of Rocks

Three types of rocks found in earth's crust based on how they were formed:

- *Sedimentary*: Rocks formed by surface processes of the deposition of sediment. Examples are limestone, sandstone and clay.
- *Igneous*: Rocks formed by the cooling and solidification of molten earth material. An example is granite.
- *Metamorphic*: Original rocks (either sedimentary, igneous or other metamorphic rocks) are altered in composition, texture, or internal structure by extreme heat, pressure, and the introduction of new chemical substances. An example would be limestone that has metamorphosed into marble.

Break 10 minutes

5. Petroleum Origin and Migration

Time: 15 minutes

Now that you understand some simple geologic concepts, we will examine how these concepts relate to the origin, migration and accumulation of oil and gas. First, we will discuss the two different theories that seek to explain how oil and gas reservoirs are formed, the organic theory and the inorganic theory.

DISPLAY

SLIDE #21

Slide 21: The Organic Theory

- Oil and gas formed from remains of plants and animals
- Organisms that lived in rivers and seas subsequently died and became trapped in seafloor
- Were unable to decay normally because of a lack of oxygen or had a quick burial
- Sediment deposited over organic matter trapped it in the seafloor
- Increasing pressure from continued sedimentary deposits, high heat, chemical reactions and other forces transformed organic matter into oil and gas

The Inorganic Theory

- Material left over from the formation of the solar system or was formed into petroleum later within the depths of the earth.
- Most exploration today is based on the **Organic Theory**.

DISPLAY

SLIDE #22

Slide 22: Porosity

- Petroleum reservoirs are **not** giant pools of fluid **nor** are they large caves filled with oil and gas.
- Petroleum reservoirs **are** rock formations that hold oil and gas like a sponge holds water.
- Rocks that can hold oil and gas contain small openings, called pores.
- These rocks are referred to as porous; and porosity can be measured.

- The more porous the rock, the more petroleum it can hold.
- These rocks must also be permeable (pores are connected) if they are to be useful.
- A porous formation is not always permeable, but very porous formations are usually very permeable.

TIP

Well fluids exist within rock pores and can only flow to the degree permitted by the permeability of the rock. Therefore, if an operator opens a choke, the immediate effect that can be expected is a drop in the downhole pressure.

6. Porosity Experiment

Time: 15 minutes

- Distribute procedures for this experiment.

  NOTE: These procedures should have been printed from the online source as recommended in the preparation checklist.
- Set up the materials.
- Discuss the procedure.
- Conduct the experiment.
- Discuss the results.

7. Petroleum Accumulation

Time: 10 minutes

DISPLAY

SLIDE #23

Slide 23: Seeps

Seeps

- Initially, petroleum is dispersed and does not form in large concentrations. Over time, petroleum migrates through porous rock and accumulates in pools.
- Tectonic forces can press the oil out of impermeable shale into more permeable formations.

- Oil and gas moves toward a surface unless trapped by subsurface geological formations. Locations where oil and gas find the surface are called **seeps**.

Traps

- Geological rock formations that contain hydrocarbons, both oil and gas, and prevent the hydrocarbons from rising to the surface are known as **traps**. Two basic types of traps:
  a) Structural Traps
  b) Stratigraphic Traps
- **Structural traps** occur when the reservoir formation deforms and are generally formed by the folding or faulting of the reservoir rock. Three common types of structural traps are fault, anticline and dome plug traps.

DISPLAY

SLIDE #24

Slide 24: Structural Traps – Fault Type

- **Fault traps** are formed when layers move along a fault line causing the permeable layer containing hydrocarbons to be trapped under an impermeable layer.

DISPLAY

SLIDE #25

Slide 25: Structural Traps – Anticline Type

- **Anticline traps** are formed when strata folds into the shape of an arch (long and narrow).
- **Dome plug traps** are formed when strata folds into the shape of a dome (circular); dome plugs are usually made of nonporous salt.
- Cap rock layers seal the anticlines and dome plugs, preventing hydrocarbons from seeping to the surface

DISPLAY

SLIDE #26

Slide 26: Stratigraphic Traps

- **Stratigraphic traps** result when either a nonporous formation is sealed off or when the reservoir rock incurs a change of porosity or permeability. Two common types of stratigraphic traps are the unconformity and lenticular traps.
- **Unconformity traps** are created when a porous rock layer erodes and is replaced with a nonporous rock layer, which traps the oil.
- **Lenticular traps** are created when the permeability within the rock layer is altered.

8. Reservoir Fluids and Pressure

Time: 10 minutes

DISPLAY

SLIDE #27

Slide 27: Reservoir Fluids

- Reservoir fluid consists of oil, gas and salt water. These fluids can be mixed or layered. When layered the water is on the bottom, oil on top of water and gas on top of oil.
- **Salt water** (referred to as connate water) remains from sedimentary beds, which were saturated with salt water.
- **Free water** is accumulated along with the petroleum throughout reservoir development
- **Oil** pushes water to bottom of reservoir.
- **Natural gas** provides pressure, which pushes oil out of the reservoir when a well is drilled.
- **Solution gas** will stay in solution within the oil given high pressure and low temperature conditions and lowers the viscosity of the oil making it flow more easily.
- **Free gas** forms a gas cap on top of the water layer.
- **Oil-water contact line** is where the oil and water layers meet; it is important for the petroleum engineer to know where this line is because the producer does not want to pump up water with oil.

DISPLAY

SLIDE #28

Slide 28: Reservoir Pressure

- Reservoir fluids are under pressure. Reservoirs experience normal and abnormal pressure.
- **Normal pressure** in a reservoir (***with*** a connection of some sort to the surface) is exerted by the fluids themselves just as the water in the ocean exerts higher and higher pressures the deeper one goes.
- **Abnormal pressure** (***without*** a connection of some sort to the surface) in a reservoir is created by the weight and pressure of the overlaying rock.

Break 10 minutes

9. Reservoir Economics

Time: 10 minutes

Review the following information with your students:

- When we hear the term oil and gas reservoir, we think of all of the activities that are associated with finding, drilling and producing oil and gas. However, the reservoir is far more than a physical container thousands of feet underground where oil and gas deposits are found in rock formations.
- The reservoir is actually a financial container, similar to a bank, where millions of dollars worth of potential are stored. The company owning the rights to the resources must conduct complex scientific and financial calculations and modeling to ensure that the reservoir has sufficient volumes of oil and gas to bear the cost of exploration, drilling and producing to make it a profitable venture for the investors.
- It is a high-risk venture, because a huge capital outlay is required to drill, complete, and equip the well to produce and bring the products to market. It is not until that process is complete that the energy company will know if the well will be a success or not. And, it may be years until the full economic potential of payout and profit is achieved.
- The reservoir is the bank in which the financial potential is stored, and it is up to the men and woman of the energy industry to utilize knowledge, skill and the latest technology to bring the energy to the marketplace for the use of people around the world and to allow a reasonable return on investment for the energy companies.

10.Review Activity

Time: 15 minutes

DISPLAY
SLIDE #29

Slide 29: Question 1 - Major geological layers include the following except:

a. mantle
b. crust
c. pangea
d. inner core

DISPLAY
SLIDE #30

Slide 30: Answer – Pangea

DISPLAY
SLIDE #31

Slide 31: Question 2 - The theory that explains continental drift is called:

a. shelf mnemonics
b. seam kinetics
c. plate tectonics
d. mass diuretics

DISPLAY
SLIDE #32

Slide 32: Answer - Plate Tectonics

DISPLAY
SLIDE #33

Slide 33: Question 3 - The process by which one plate is thrust beneath another is called:

a. subduction
b. sublimation
c. contraction
d. injection

DISPLAY
SLIDE #34

Slide 34: Answer - Subduction

DISPLAY
SLIDE #35

Slide 35: Question 4 - Common fault types include the following except:

a. reverse dip slip
b. lateral
c. overthrust
d. ventricle

DISPLAY
SLIDE #36

Slide 36: Answer - Ventricle

DISPLAY
SLIDE #37

Slide 37: Question 5 - Major rock types include the following except:

a. sedimentary
b. philanthropic
c. metamorphic
d. igneous

DISPLAY
SLIDE #38

Slide 38: Answer - Philanthropic

DISPLAY
SLIDE #39

Slide 39: Question 6 - Theories explaining the origin of petroleum are:

a. graphic and mechanical
b. organic and inorganic
c. chemical and biological
d. macro and micro

DISPLAY
SLIDE #40

Slide 40: Answer - Organic and inorganic

DISPLAY
SLIDE #41

Slide 41: Question 7 - Locations where oil and gas find the surface are called:

a. wells
b. fissure
c. leaks
d. seeps

DISPLAY
SLIDE #42

Slide 42: Answer - Seeps

DISPLAY
SLIDE #43

Slide 43: Question 8 - Geological formations that prevent oil and gas seepage are called:

a. sinks
b. warps
c. caps
d. traps

DISPLAY
SLIDE #44

Slide 44: Answer - Traps

DISPLAY

SLIDE #45

Slide 45: Question 9 - The characteristic that allows rock to hold fluid and gas is known as:

a. virtuosity
b. capacity
c. porosity
d. elasticity

DISPLAY

SLIDE #46

Slide 46: Answer - Porosity

DISPLAY

SLIDE #47

Slide 47: Question 10 - Reservoir fluids consist of oil, gas and water.

a. True
b. False

DISPLAY

SLIDE #48

Slide 48: Answer - True

11. Review for Test #1

Time 25 minutes

- Use your prepared questions to review students for the test to be given during the next session.
- Have students refer to their notes. Answer any questions they may have over the topics to be covered on the test.

12. Summary and Wrap-Up

Time: 10 minutes

- Use learning objectives to summarize material presented during this session.
- Encourage students to ask questions on concepts not understood.
- Review the homework assignments that must be completed before the next class period, to include:
  - Read appropriate text pages on exploration, the topic to be covered during the next session.
  - Study for the first test.

Break 10 minutes

13. Additional or Lab Activities

Time: 50 minutes

If your campus offers this course as a four credit hour course, assign one of the following activities (or create one of your own) to supplement the lecture:

- Activity #1: The Absorbency of Rock Experiment
  - Distribute procedures and worksheet for this experiment (printed from the online source as recommended in the Class Preparation Checklist). Instruct students to conduct this experiment and document their results on the worksheet provided.
- Activity #2: Hydrocarbon Geology
  - Instruct students to read the short article and answer the study questions.