Exploration Drilling

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Exploration Drilling – Teacher Resource

Powering Careers in Energy Link:

Unit 2: Demonstrate an understanding of the importance of science in LNG operations.

Background Information:

Once a hydrocarbon prospect has been identified, geoscientists decide on an exploration well location. Prior to drilling, location surveys, environmental assessments and government permissions need to be sought. Contractors are then engaged to carry out the drill process. A drill rig is selected, based on whether the drill site is onshore or offshore. If offshore, a drill rig needs to be able to operate in the required water depth. In shallow water depths (up to 150m) jack-up rigs can be used. In deeper water either semi-submersible, or more rarely, drill ships need to be used (Figures 1 and 2).

Figure 1: From left to right; Onshore rig (foxoildrilling.com), jack-up (offshore.fleet.com), semi-submersible (km.konsberg.com) and drill ship (ships.lv)

Figure 2: Water depth drilling rigs and ships can operate in (rigbook.blogspot.com)

The aim of an exploration well is to find (prove) hydrocarbons. If the well is successful, further appraisal wells are drilled to determine the potential volume of hydrocarbons. This will determine if the field is economic for development.

A drill rig and crew are contracted to drill an exploration well, overseen by the exploration company. The well is cased at pre-assigned depths for borehole stability. During drilling, wireline logs are gathered. These measure the physical properties of rocks. In exploration/appraisal wells a core sample of the reservoir is often taken for analysis and as a calibration for wireline logs. In a successful hydrocarbon well, fluid samples and well tests are done to establish fluid type and flow properties. Many tests and analyses are run on both core and fluid samples in laboratories to determine properties; including fluid type and viscosity, core porosity/permeability testing, rock strength, petrography (reservoir rock composition). The resultant product is a composite well log and completion report comprising all the data analyses. This aids in reservoir description and fluid description and is invaluable in planning future appraisal wells and/or as input to a 3D field model for field development planning.

Aim

To understand the process of exploration drilling and the data that can be collected from this.

Materials

Per group of students:

- Containers = rectangular Pyrex container or laboratory tray (or if supplies are limited = plastic cups or glass beakers)
- 3 containers of sand of different colours, one of clay (split into bags for groups)
- Gloves
- Spoons
- Water in a spray bottle
- Clear plastic straws
- Ruler

Safety Notes

Do not throw sand around.
Mop up spills immediately.
Be careful if working with glass beakers.
Wear safety glasses.
Use gloves to handle sands and clays.

Method

Find out what your students know about drilling. Show them any drill bits, core samples or well logs you may have.
Run through the drill sequence in preparation for the student activity.

Split the students into groups of 3. Outline on the board the stratigraphic sequence the three layers of sand and one layer of mud need to be 'deposited' into the containers in. The oldest will be at the bottom and the youngest on the top, as shown below;

	Reservoir C	**youngest**
	Inter-reservoir shale	
	Reservoir B	
	Reservoir A	**oldest**

Reservoir stratigraphic sequence (rock layers)

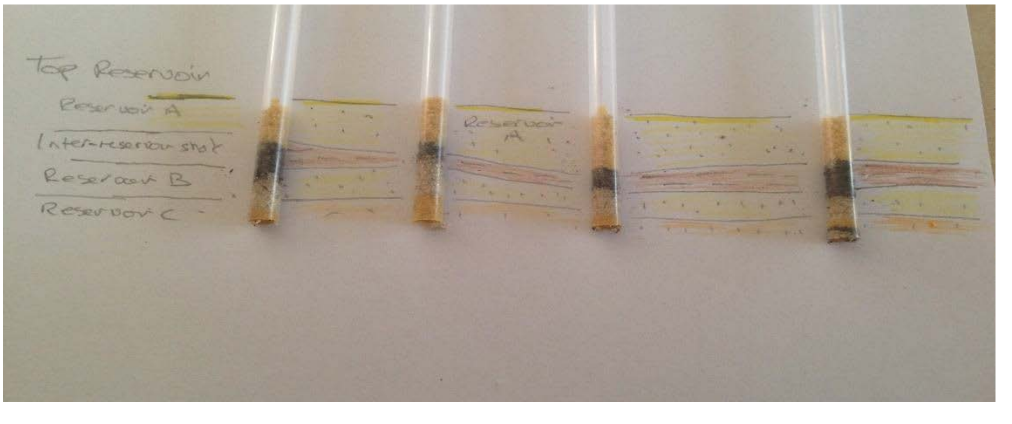
Layers can vary in thickness, but on average they will be 1 to 2cm thick. As students put down layers they should spray each lightly to allow cohesion between the grains. They must not be soaked.

Students may take a picture of their reservoir sequence, as shown below;

Students then use a plastic straw to take samples or ‘core’ from their ‘reservoir’ sequence. They should look like below;

Results

Students fill out their worksheet and draw a picture of the reservoir sequence and core. They describe their core. If working in larger containers they should take core from three other locations too. If working in smaller containers they could compare their core with the core from three other groups. They align their cores based on the top reservoir and compare thicknesses of each sequence for each of the cored wells. They can then fill in a section and correlate between the wells, showing a thickening and thinning of the reservoir (as below).



In a real exploration well, the core would be calibrated to the wireline logs and the correlation would use the wireline logs. The cored section may not acquire a full reservoir thickness.

Due to improvements in logging technology, wells are often logged whilst being drilled. This uses an LWD (Logging while Drilling) tool, which is attached behind the bit. This data can then be relayed to the office for geologists and petrophysicists to review whilst drilling, in order to make decisions. Some logs still need to be run after the well has reached Total Depth (TD). LWD logs can be downloaded on completion of the well (TD - total depth) for more accurate measurements. This is referred to as MWD (Measured while Drilling) logs.

Discussion

1. What is a core sample?

A core sample is a cylinder of rock or sediment drilled from out of the subsurface

2. Who uses core samples?

Geologists, petrophysicists, engineers and drillers use core samples. Geologist use them to establish reservoir type (e.g is this a delta sandstone, fluvial (river) sandstone or shoreface (beach sandstone) and quality (what is the porosity and permeability). Samples are taken to look at porosity and permeability and cements in ***thin section*** *by petrographers. Thin sections are very thin slices of rock that are cut polished and viewed under a microscope. Reservoir engineers use this information too to ascertain flow regimes in rocks. Drillers use core for rock strength measurements.*

3. What are cores used to calibrate?

Cores are used to calibrate wireline logs, in relation to reservoir type (environment of deposition) and quality (porosity/permeability). Porosity and permeability measurements from rocks are used to calibrate wireline log measurements.

4. What information does the core correlation give you?

The core correlation tells you about the differing thickness of the reservoir sands at each well location, so a map of individual reservoir sequences can be drawn. They also identify if there are any missing reservoir sections or shale sections.

5. How could this information help you in exploring for oil and gas?

Geologists use these to help map out the reservoir distribution and quality to identify potential hydrocarbon traps.

Evaluation

1. How is your core sample the same as a real core sample?

It takes a 'slice' of rock through the reservoir. It is a cylinder.

2. How is it different?

Our rock is unconsolidated (i.e. not cemented). It is sand, not sandstone.

3. What would be a better horizon to hang your correlation on? Explain why.

It would be better to hang it on a horizon where you can identify the top in each cored well. The top of the shale horizon would be good for this, because then you could have a good visual of the thickness of the reservoir sections.

4. Did you have any difficulties extracting the core? Did you recover it all?

Some students may have lost some core. It may have been too loose (unconsolidated) and fallen out of the bottom of the straw (the core barrel). In the real world the percentage of core recovered is always documented, i.e. the amount of core recovered (in metres) to the amount of section drilled (in metres).

6. Would you make any improvements to the method of this investigation? If so, what? *Any reasonable suggestion goes here. Drill more wells, have thicker sections, make sure sands are damp enough to recover, have a map of well locations to map out thickness of reservoirs etc. and produce reservoir isochore maps (maps of thickness).*

Extension:

- Students could set up an area of varying sediment thickness and have others ‘explore’ it by drilling.
- Students make a map of their well location and construct reservoir thickness maps for each reservoir unit.
- They analyse and interpret their maps.

References:

Figure 1: Onshore oil drilling rig. Retrieved from http://www.foxoildrilling.com/rig-types.html
Figure 1: Jack-up rig. Retrieved from http://offshore-fleet.com/data/jackup-rig.htm
Figure 1: Semi-submersible rig. Retrieved from https://www.km.kongsberg.com/ks/web/nokbg0238.nsf/AllWeb/78235B77DFF30907C12575BC002A9394?OpenDocument
Figure 1: Drill ship. Retrieved from http://www.ships.lv/en/vessels/9609407-west_vela.html

Figure 2: Water depth drilling potential of each rig type, jack-up, semi-submersible and drill ship. Retrieved from http://rigbook.blogspot.com.au/search/label/RIGBOOKS

Figure 3 (student worksheet). Sandstone core samples. Retrieved from https://www.dea-group.com/en/technology/exploration/core-analysis

Worksheet: Exploration Drilling

Once a hydrocarbon prospect has been identified, geoscientists drill an exploration well. Different drill rigs are used based on whether the prospect is onshore or offshore. If offshore a drill rig, or more rarely, drill ship is selected, based on the water depth. In shallow water depths (up to 150m) jack-up rigs can be used. In deeper water semi-submersibles or drill ships are used (Figure 1 and 2).

Figure 1: From left to right; Onshore rig, jack-up, semi-submersible and drill ship.

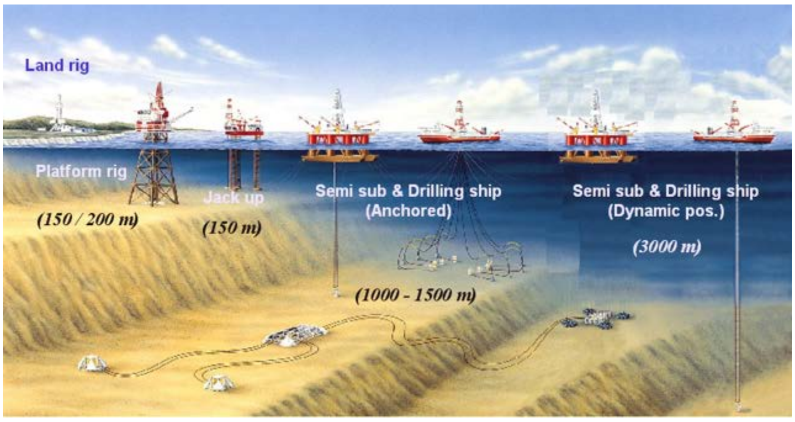


Figure 2: Water depth drilling rigs and ships can operate in.

The aim of an exploration well is to find (prove) hydrocarbons. If the well is successful, further appraisal wells are drilled to determine the potential volume of hydrocarbons and whether the field is economic.

Various data and samples are taken in an exploration well, including cuttings, wireline logs, core and fluid samples of hydrocarbons (if successful) and formation water. This activity looks at coring in exploration wells. A core is a sample of rock taken from the borehole, generally of the reservoir (Figure 3). This supplies very valuable data for the geologists, petrophysicists and geophysicists.

Figure 3: Reservoir core sample, sandstone. (from dea-group.cpm)

Aim
To understand the process of exploration drilling and the data that can be collected from this.

Materials
- Container (laboratory tray, beaker or other)
- Sand of three different colours, one of clay
- Spoons
- Water in a spray bottle
- Clear plastic straws
- Ruler

Safety Notes
Do not throw sand around.
Mop up spills immediately.
Be careful if working with glass beakers.
Wear safety glasses.
Use gloves to handle sands and clays.

Method:
1. Collect all listed materials.

2. Fill your container with 1 to 2 cm of each of the sands and shale as shown in the stratigraphic sequence on the next page (make sure you vary the thickness of each across the container). After you place each layer mist it with water to make it cohesive. Do not soak them!

	Reservoir C	**youngest**
	Inter-reservoir shale	
	Reservoir B	
	Reservoir A	**oldest**

Reservoir stratigraphic sequence (rock layers)

3. Use a plastic straw to take a sample of 'core' from your 'reservoir' sequence. Describe and draw what you see in the 'core' in your results.

4. Measure the thickness of each sequence and document beside the core, with a description.

5. Drill three more cores, if using a large container. If you are using a small container (like a beaker) swap your core with students from three other groups. Be very careful not to lose any core.

6. Draw a 'correlation' between all four cores in your results. Make it horizontal based on the top reservoir ('hang' on the top reservoir).

Results

Core drawing and description

Correlation between the four cores

Discussion

1. What is a core sample?

2. Who uses core samples?

3. What are cores used to calibrate?

4. What information does the core correlation give you?

5. How could this information help you in exploring for oil and gas?

Evaluation

How is your core sample the same as a real core sample?

How is it different?

What would be a better horizon to hang your correlation on? Explain why.

Did you have any difficulties extracting the core? Did you recover it all?

Would you make any improvements to the method of this investigation? If so, what?