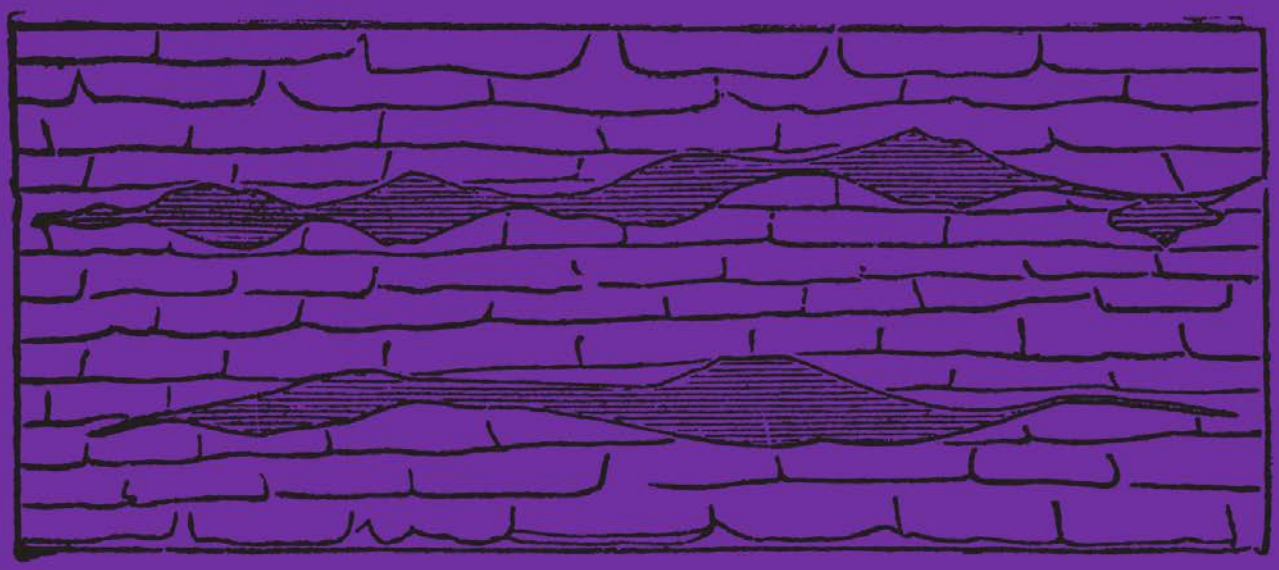
Oil and Gas Migration to Traps



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AUSTRALIAN EARTH SCIENCE EDUCATION

Oil and Gas Migration to Traps – Teacher Resource

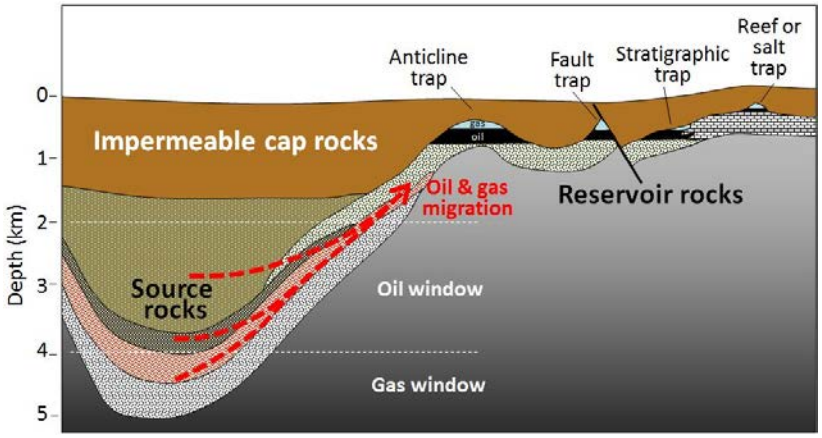
Powering Careers in Energy Link:

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

Background Information:

Typically, hydrocarbon accumulation depends on all 5 elements being in place to create a hydrocarbon deposit:

1. **Source rock** that contains enough organic materials rich in *kerogens* and placed under sufficient temperature and pressure conditions over an adequate time-period to create a *mature* hydrocarbon resource;
   - Heat and pressure convert organic matter into a substance called humin and then into kerogen. Time and temperature convert kerogen into petroleum.
   - In the mature source rock, the kerogen decomposes firstly to a thick *bitumen*. This continues to decompose to more mobile phases – oil and gas.
   - As the solid organic materials are converted to liquid and gaseous hydrocarbons, the volume required to hold these products increases, as does the pressure. This pressure due to volume expansion moves the hydrocarbons within and from the source rock, via pores and fractures.
2. **Migration** of oil and gas from the hydrocarbon source rock into the reservoir area, occurs through fractures and rocks that are porous and permeable (e.g. sandstone);
   - *Primary migration* – movement of oil and gas within the fine-grained mature source rock via pores and fractures.
   - *Secondary migration* – any movement in reservoir rocks outside of the source rock via pores and fractures, this is driven by the buoyancy of the hydrocarbons on water.
   - Generally, due to gravity forces, gas forms over the top of oil, which in turn forms over water.
3. **Reservoir rocks** have sufficient porosity and permeability to store and transmit gases and fluids;
4. **Traps** are any part of a reservoir rock sequence that hold commercial / economical quantities of hydrocarbons.
   - Traps are typically a series of reservoir rocks found in concave-downwards or pinchout shape that are sealed by a relatively impermeable layer;
5. **Seal** or **cap rock** is the low permeability rock above the trap that acts as a barrier to stop further migration upwards or laterally beyond the reservoir.
   - If no cap rock is present or the cap rock becomes fractured, then oil and gas in a reservoir has the potential to reach the Earth's surface and seep out.



Source: https://twitter.com/geoscitweeps/status/833313607081267201

Aim

To model and demonstrate *oil and gas migration* through porous lithologies (rock types) and/or fractures and how they collect in *traps*.

Materials

Per group

- Fine to medium grained sand (relatively clean)
- Glass jar with tight fitting lid (300mL to 500mL tall, narrow jar is preferable)
- Coconut oil or other oil that solidifies at ~20°C
- Food colouring (optional)
- Vegetable oil
- Plasticine (optional – solidified coconut oil can be used to create a seal layer and then heated insitu to use as oil)
- Ice cubes, blocks or bricks
- 2 bowls or beakers that will fit the jar at least up to ½ the height of the bottle and that can be used as a hot water bath and an ice bath.
- Tongs to hold jar if hot
- Access to a kettle

Safety Notes

Students may have food allergies. Please alert them to the foods they will be working with and ask them to not work with anything that may trigger an allergy for them.

Boiling water should be handled with care when pouring or placing jar into it. Tongs should be used to pick up jar if heated in hot water.

Method

Students should be given an overview of a basic hydrocarbon deposit using the **Background Information** provided above.

Students should collect all equipment and consider how to use this equipment to model and demonstrate oil and gas migration through porous and permeable rocks and how non-porous and impermeable rocks (seals) can create traps. Some examples have been pictured below to give an indication of various models and demonstrations that can be achieved.

Each time the bottle is inverted, heated, or cooled, different results can be observed. Students should create their design and experiment with their bottle model.

Students can record their methods and observations, including visually if possible (photograph on computer / electronic pad – refer to Example 3; or drawing on paper), on what they have modelled / demonstrated.

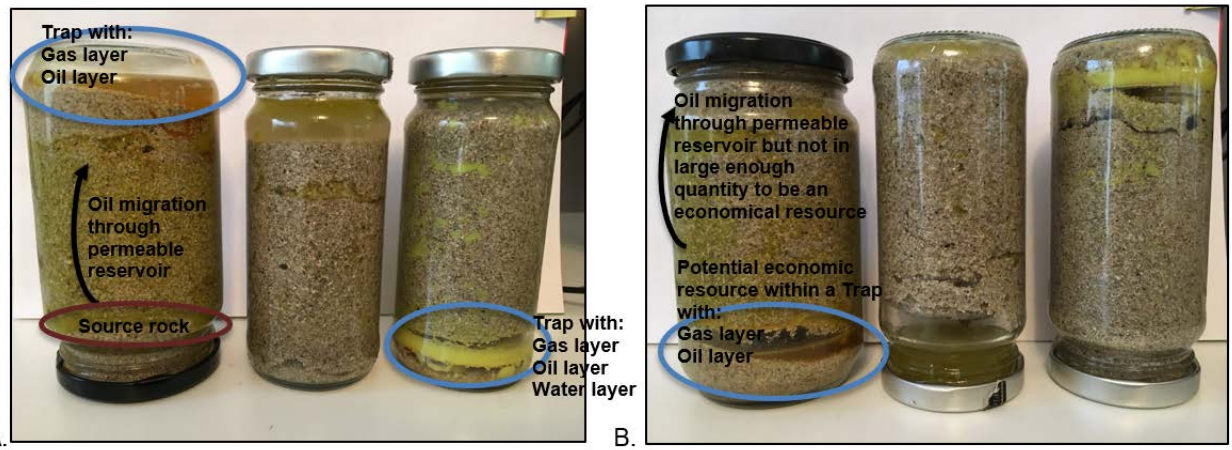
Example 1: Use of solidified coconut oil as the seal layer to create a trap (A). Then warmed (B) to form liquid oil (C).

Note: This can also demonstrate that solid organic materials decompose to bitumen then oil and gas under higher temperatures.

Example 2:

1. Add oil/s - solidified coconut first, which can be heated slightly then cooled to give flat layer in base (note that turmeric has been added to this coconut oil when liquid to give colour), then vegetable oil if also using (A);
2. Add water (B);
3. Sand is slowly added down side of jar and lightly packed – do not tightly pack – and leave a small space at top and screw top on tight.

4. Students can experiment with these jars by with placing oils and water at various levels; leaving larger space at the top; inverting jar; tapping jar very gently on desk to compact the sand; heat the oils; cool the oils; etc…



Example 3: Various trials with different oils and methods. Photographic visual representation of model with some labels (use of ICT in Science).

Student should be abe to explain how their model has demonstrated oil / gas migration and creation of traps / seals.

If they unable to demonstrate this, due to issue with their method, they should discuss what they could have done differently.

A **'Best Model / Demonstration' competition** could be undertaken to encourage greater thought and involvement in this activity. Students need to be able to explain the parts of their model / demonstration and how these relate to at least some of the parts of the 5 elements of a hydrocarbon deposit.

Results

Students should be able to model at least oil floating on water; then when sand is added, the oil/water migrates up through sand. Once inverted, students should be able to create a trap and demonstrate gas, oil and water separation in the trap.

Discussion

1. Did you notice more air space was created once the bottle was inverted at least once? Why?

   The sand had air space when added to the bottle, however once it took up the liquids (oil and water) and also the sand was compacted due to movement (inversion and tapping) the air was displaced. Refer to Example 2 above.

2. Were you able to observe any other features of a hydrocarbon deposit in your model / demonstration? List these features and/or label on your diagrams.

   Observations could include:

   - *fractures which liquids and gas use to move through (see Example 2-E, 2-F & 2-I);*
   - *two or more traps (see Example 2-L);*
   - *pinchouts (see Example 2-K & 2-L);*
   - *concave-downwards (see Example 2-I & 2-L);*
   - *oil-gas filled reservoir and oil-filled reservoir in one model (see Example 2-I & 2-L)*
   - *oil-water emulsion (see Example 2-J)*

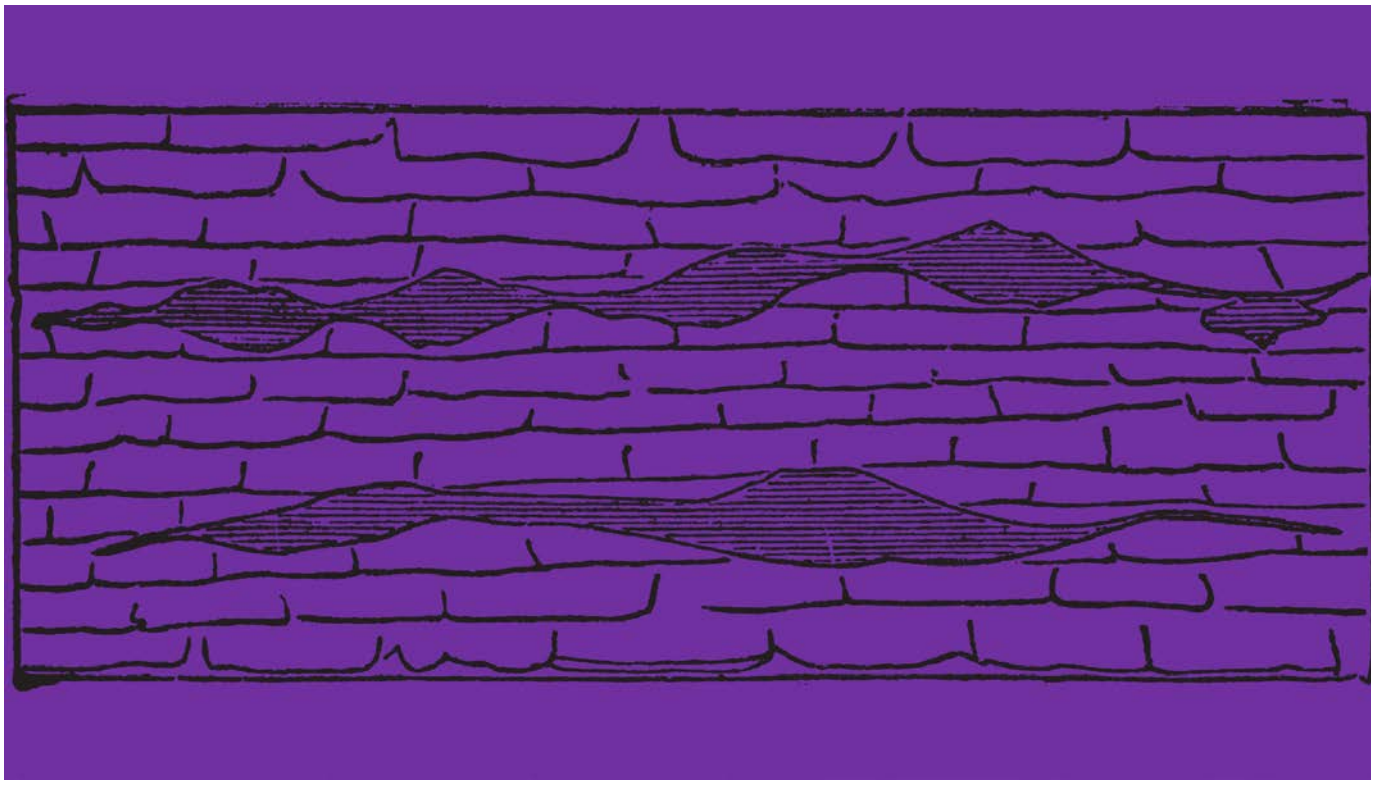
Evaluation

Which of the 5 elements of a hydrocarbon deposit were you able to model and demonstrate?

1. ***Source rocks*** *– solidified oil*
2. ***Migration*** *through the* ***Reservoir rocks*** *(sand) to achieve gas on top of oil on top of water*
3. ***Traps*** *created as sand is compacted and bottle inverted. Migration of oil and gas to these traps. Separation of gas on oil on water.*
4. ***Seals*** *created by compacted sand and/or solidified oil.*

Extension:

Depending on the quantity of materials available, students could experiment with several bottles and combinations of oils, air space, water, techniques, etc (Example 3).



Worksheet: Oil and Gas Migration to Traps

Aim

To model and demonstrate *oil and gas migration* through porous lithologies (rock types) and/or fractures and how they collect in *traps*.

Materials

Per group

- Fine to medium grained sand
- Glass jar with tight fitting lid
- Coconut oil or other solidified oil
- Food colouring (optional)
- Vegetable oil
- Plasticine (optional)
- Ice cubes, blocks or bricks
- 2 bowls or beakers that will fit the jar at least up to ½ the height of the bottle and that can be used as a hot water bath and an ice bath.
- Tongs to hold jar if hot
- Access to a kettle

Safety Notes

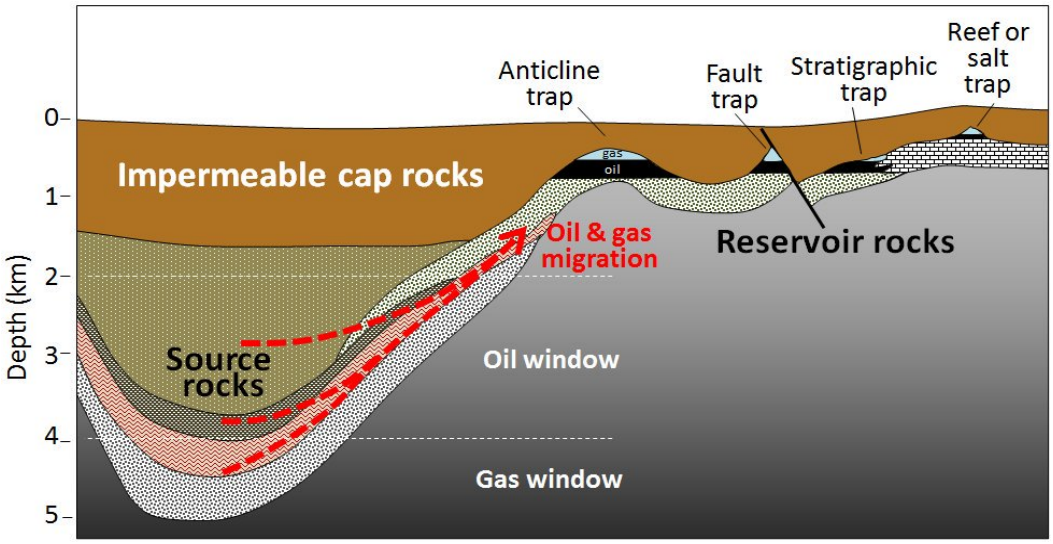
If you have any food allergies, please take the time to learn the ingredients of the foods being used today. Don't work with any that may trigger a reaction or that you have any doubts about.

Boiling water should be handled with care when pouring or placing jar into it. Tongs should be used to pick up jar if heated in hot water.

Method

1. Collect the listed materials.
2. Using the diagram below, discuss in your group how you would use the equipment provided to model and demonstrate some or all of the 5 elements of a hydrocarbon deposit.

1. **Source rocks**
2. **Migration**
3. **Reservoir rocks**
4. **Trap/s**
5. **Seal or cap rocks**



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3. Add your chosen materials to your bottle; carefully considering the order of addition.
   a. Ensure you add some water to the bottle
   b. Think about the properties of the different oils provided, and how a hot water bath or cold water bath might affect these.
   c. Leave a small air gap in the top of the bottle (~1cm).
   d. Lid must be screwed on tight once all materials for model have been added.
   e. You can invert the bottle slowly and/or quickly for different results and observe the change, not just the end product.
   f. By VERY careful tapping the bottle on the desk (use book or other padding to ensure bottle does not smash) or shaking vertically up and down.
4. Note down your observations in the provided results table.

Results

Sketch or photograph some of the elements you've found and label them.

Discussion

1. Did you notice more air space was created once the bottle was inverted at least once? If yes, why do you think this happened?

2. Did you observe any other features of a hydrocarbon deposit in your model / demonstration? List these features and/or label them on your diagrams.

Evaluation

Which of the 5 elements of a hydrocarbon deposit were you able to model and demonstrate? Draw and label diagram that combines each of these.