PRIMARY EARTH SCIENCE TEACHING

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FOSSIL FUELS 3

Natural Gas: Formation, Exploration and Production

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Introduction

Following on from our look at coal and oil in the previous two issues, we now take a close look at natural gas – the cleanest of the fossil fuels. As with coal and oil, gas contains energy trapped by living organisms millions of years ago and whose remains have been converted to a combustible fuel over that time. These burnable properties make it an extremely important energy resource, especially as it releases a great deal of energy but gives off far fewer harmful emissions than other fossil fuels. As there are some aspects of its formation that are the same as for oil, some repetition is necessary but will be kept to a minimum, so ideally this issue needs to be used in conjunction with issue 87. We will also look closer at the seismic surveys used during exploration. Another area of focus is the resource offered by shale gas and the usually controversial method of its retrieval known as fracking. Keywords are underlined to help guide more in depth research, form the basis of a glossary or as terms to use for internet searches.

What is natural gas?

Natural gas is a mixture of hydrocarbon gas with quite boring characteristics, as in its pure form it is colourless and odourless. It is found in certain sedimentary rock formations. A chemical is added to natural gas before it is distributed so people can smell it and detect any leaks.

How did gas form?

The initial formation of gas is the same as for oil: Microscopic organisms, especially planktonic sea-algae and bacteria, absorbed energy from the sun during their lives in the seas, lakes and swamps, which covered much of the Earth millions of years ago, and stored this energy as carbon. These organisms sank to the bottom after they died, were mixed with and covered by sediments and buried. These large quantities of dead organic material accumulated on the muddy beds at the bottom of sheltered seas, lakes or swamps, where bacteria soon used up available oxygen thus allowing organic accumulation to be preserved. These organic-rich muds were eventually buried even deeper by more sediments and became the source rocks for the formation of oil and gas. They were then ‘cooked’ slowly by pressure and heat, over millions of years, turning them into oil and/or gas. Burial to depths of about 3km produces mainly oil and some gas, the gas can collect above the oil or be held/dissolved within the oil. Burial about 4-5 km deep, where pressures and temperatures are much higher, results mainly in gas formation.

The heat and pressure deep inside the Earth’s crust causes the various constituents of the dead organisms, such as fat, wax and cellulose (cell walls or plant ‘skin’), to join together forming a dark substance called kerogen. As the source rock continues to heat up to the higher temperatures associated with the very deep burial, it releases short hydrocarbon chains which form light oil and eventually natural gas. This initial generation is followed by the gas moving away, or migrating, from the source rock.

Gas migrates upwards through permeable rock, such as sandstone, which has cracks and connecting pore spaces between the rock particles, allowing the flow of fluids and gases through them. This movement is very slow and it may take millions of years for the oil and/or gas to travel just a few kilometres. Like oil, gas becomes trapped in permeable reservoir rocks where these rocks are capped, covered, by impermeable rocks such as clays or extensive

layers of salt, which form a seal. Gas accumulates in large quantities in rocks in areas where there is a suitable cap rock which is the correct shape to provide an enclosed, upturned basin-shaped trap (figure 1). Gas is able to migrate and escape from these traps more easily than oil, but salt layer seals, common in the North Sea basin, are particularly good at containing the gas because the salt reseals any cracks which occur.

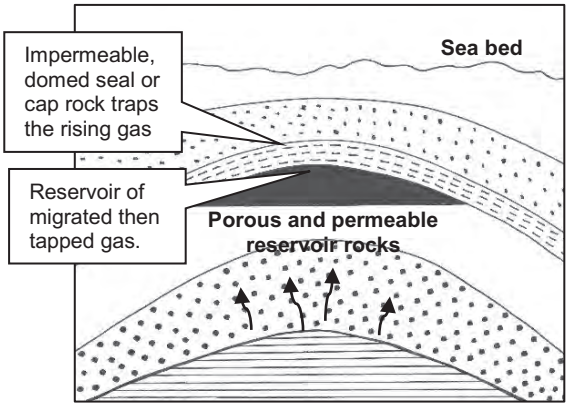

Figure 1 Migrating gas collects in the highest part of trap. Only gas if deep enough, or the gas may lie above or be associated with a layer of oil.

Gas Exploration and Production

Methods of finding gas fields are like oil exploration with both often being found together. See issue 87 for more detailed information about drilling and recovery.

When gas first reaches the surface it is not pure enough to be piped straight to the shore. It needs cleaning to remove any oil, water or other gases and this is usually done close to the well. The removed contaminants are not wasted but used for other purposes. The processing of natural gas is not as complicated as it is for oil but it is still necessary.

When a possible gas field has been located, as with oil, exploratory wells are drilled to test out the survey results before full-sized rigs are set up for long-term recovery and production to take place. As with oil, the difference in pressure between that at the surface and the pressure at the depth of the gas reservoir is the force that drives the gas to the surface – reservoir drive.

Seismic Surveys Explained

Seismic surveys help gas and oil companies to locate possible new oil and gas fields. Such surveys need very detailed knowledge of geology and the best places to look; a lot of very expensive, sensitive equipment and people (geophysicists) who can understand the signals and results. Seismology is the science that investigates movements within the Earth, such as during earthquakes, but it can also detect very small vibrations. The Earth is made up of many different layers, all with unique properties which determine how fast vibrations (or seismic waves) can travel through them.

In order for the geophysicists to 'see' the layers of rock deep down in the Earth, they set off some artificial shock (seismic) waves. In the past this was done by setting off small explosions, but recently non-explosive impacts from special vehicles are used onshore (on land) and offshore (at sea) large ships tow huge air guns to generate the vibrations by blasting compressed air at the sea-bed (Figure 2). Both methods produce seismic waves which travel through the Earth's crust. After travelling through the various layers of rock these seismic waves, or vibrations, are reflected (bounced) back to the recording equipment (geophones on land; hydrophones at sea) listening at the surface, then transferred to the seismometer to be measured and interpreted. The amount of time it takes for the seismic wave to be reflected back, allows the scientist to know the types of rock it went through, the shapes they form and whether oil and/or gas are likely to be present. It is like bouncing a ball on the playground then bouncing it on sand; the ball bounces differently on each surface and the difference can be detected. The geophysicists can make maps of the underground structure down many kilometres. Recent advances in technology have also allowed them to produce 3D images of underground rock formations.

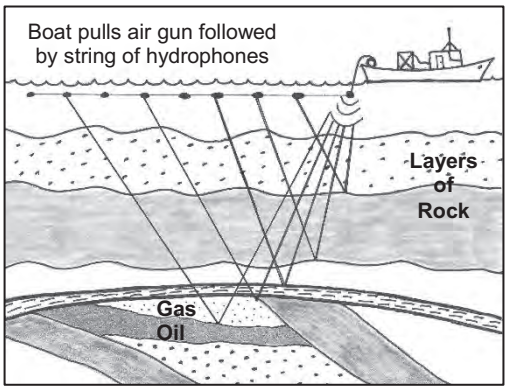

Figure 2 Seismic survey conducted from a ship. The shock waves from the air gun penetrate the layers of rock beneath the sea bed and are reflected back to the hydrophones.

Shale Gas

Unfortunately the gas and oil reserves are beginning to run out so new areas are being explored. Shale gas is found in fine-grained sediments which contain a lot of organic material, the remains of dead organisms as explained on page 1 and in issue 87. These fine-grained sediments (with grains smaller than sand), known as gas shales are source rocks that have not released all their hydrocarbons (oil and gas). Although these shales are quite porous they are not very permeable (fluids, gas or oil cannot move through these rocks easily) so the gas or oil is trapped within. For rocks to be permeable (fluids can flow through) cracks need to be present or pore spaces (spaces between individual grains) need to be connected to each other.

Fracking – a controversial method of gas extraction

To extract the gas and oil from the shale it is more difficult than from the reservoirs. The method used is hydraulic fracturing, more commonly known as fracking.

To obtain the oil and gas from the shale, a hole is still drilled down to the shale beds then horizontally along the rock beds (layers). As the drill passes through the shale beds it opens some of the pores allowing the gas and oil to escape. The particles then migrate along the drilled area back to the main vertical drill point and then to the surface. This is a very slow process so to make the system more efficient a liquid, mainly water and sand with some chemicals, is pumped into the drill hole at high pressure which creates small fractures in the shale beds. The pressure is then reduced leaving small particles of sand between the shale beds. These particles open the pore spaces, connecting them together, making the shales more permeable and thereby releasing the gas and oil. The method can be used a number of times at each well but more pressure is needed as the production of oil and gas declines.

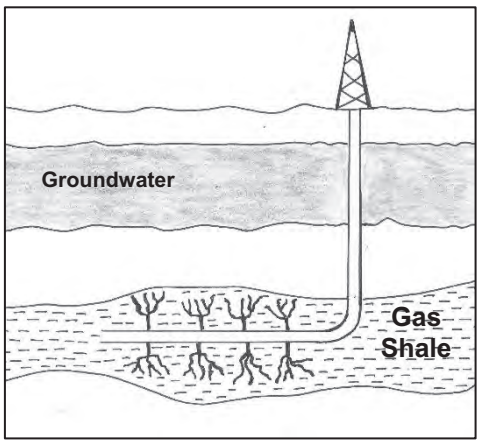

Figure 3 Simple diagram of a fracking site showing the direction of drilling and small fractures in the shale releasing the gas and allowing it to be pumped back to the surface.

A Little Background History

Fracking has been used in the oil industry since 1860. Then it was a low pressure system to increase oil production at standard oil wells. The high pressure fracking was first used in America in 1947 to extend the area of the oil reserves. The first operational well was sunk in 1949, also in America. There are now many wells in the USA using the fracking technique. In the UK some experimental fracking has taken place and a number of companies are now requesting permission to sink oil wells in the North of England where tests have revealed the location of oil shale deposits. As the UK government has set regulations for fracking within the UK they will have to decide on the need for more gas and oil against the possible damage which may be caused to the environment.

In the UK, fracking has been surrounded by controversy and scepticism, most likely due to the public's lack of knowledge and understanding as well there being some reluctance on the part of the exploration companies in explaining exactly what they are going to do, the chemicals they pump into the shales, the possible effects from this forced cracking of the rock and the potential for environmental damage. People are worried about whether the liquid injected into the wells could contaminate the ground water in the area, which would then affect the drinking water supply. This concern is probably a valid one because once the liquid is pumped into the well there is little control over its movement within the rocks. To reduce these problems the industry takes some precautions, such as mixing the liquid on the surface before injecting into the well and cementing the steel pipes into the well to depths below the ground water. This prevents the leaking of the liquids into the ground water as it is pumped in. As the well is deepened the

pipes are extended. Most of the fracturing liquid is returned through the well and is then recycled in the future fracking operation at the site. Another concern is about the possibility of fracking causing earthquakes or tremors.

All ground water in the areas of a well is examined for contamination. Most of these actions are in place in the USA where a lot of the fracking takes place. Many of the surface problems are from the initial setting up of the drills to form the wells and the construction of the pipelines. This part of the operation is short lived. Once the well has been sunk the surface area covered is about the size of one house. The road transport then is very small as the gas is transported through pipelines.

Whole Class Activity

This is a very good cross-curricular activity using IT, literacy, numeracy, drama and art, all of which could be done as part of a class project.

Divide the class into two main groups. Working in pairs or threes within each group, ask pupils to research aspects of fracking as portrayed in the media. One half of the class should focus on positive points, such as the advantages of boosting the gas supply and not having to rely so much on imports; the other group should focus on negative reactions to fracking, such as environmental concerns, risks to ground water, earthquakes potential etc.

Individual pairs or groups should then choose a specific location where fracking has taken place, or has been named as a possible exploration site, and find out what the reaction has been in that area. Examples include the north west of England and the possible associated problems in the Blackpool area.

Set a day for the presentation of each group's finding to be given to the rest of the class. Once all the information has been presented to the pupils it would be a good idea to set up a class debate where the arguments for and against fracking could be presented and discussed. This could be done quite formerly with pupils engaging in some role play, for example as reporters, newscasters or being part of an action group.

Extension Activity:

Similar research and debates could also be carried out for coal mining, especially open-cast; on-shore oil production or even the need for greener energy as an alternative.

Useful Websites:

British Geological Survey: http://www.bgs.ac.uk/research/energy/shaleGas/basics.html

National Geographic: http://education.nationalgeographic.co.uk/education/media/how-hydraulic-fracturing-works

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