Geoscience Education

Gas: Energy and Change

Teacher Notes and Student Activities

Louise Mitchell

Record 1998/36

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

AGSO

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Gas: Energy and Change

Teacher Notes and Student Activities

Louise Mitchell

Record 1998/36

DEPARTMENT OF INDUSTRY, SCIENCE AND RESOURCES

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION
Executive Director : Dr Neil Williams

Record No. 1998/36
ISSN: 0 642 27373 1
ISBN: 1039-0073

Acknowledgements:

Thanks to Gary Lewis, Marita Bradshaw, Chris Boreham, Jane Blevin and Ian Hodgson from AGSO, and Allan Beasley from the Australian Gas Association, for scientific advice and editing. Thanks to Sue-Ellen Mackey, Gary Lewis and Jacques Sayers from AGSO, and RaeleneHearne and selected year 9's from MacKillop College, for their input and assistance with the activities. Thanks to Bev Allen and others in the AGSO library for assistance, and Jim Preston and Keven Asquith (BHP) for two diagrams.

Other Education Titles in this series include

Earthquakes (1995/20)	Student Activities
Volcanoes (1995/24)	Teacher Notes and Student Activities
Time and Life (1995/14)	Teacher Notes and Student Activities
Plate Tectonics (1995/8)	Teacher Notes and Student Activities
Silicate Chemistry (1995/19)	Teacher Notes and Student Activities
Australian Earthquakes (1995/25)	Slide Set
Australian Volcanoes	Slide Set
Volcanic Hazards	Slide Set

For information and sales call the AGSO Sales Centre on (02) 6249 9519.

Financial contributions from
- **The Australian Gas Association**
- **Epic Energy and**
- **Woodside Petroleum**

enabled the production of this resource.

Table of Contents

Curriculum Links

Gas: Energy and Change has been developed to provide an Earth Science component in the teaching of secondary level studies. Listed below are the curriculum links for the National Curriculum.

Science

Energy and Change
- Energy and us
- Transferring energy
- Energy sources and receivers

Earth and Beyond
- Earth, sky and people
- The changing Earth

Natural and Processed Materials
- Materials and their uses
- Structure and properties
- Reactions and change

Working Scientifically
- Conducting investigations
- Processing data
- Evaluating findings
- Using science

Studies of Society and the Environment

Resources
- Use of resources

Natural and Social Systems
- Natural systems

Time, Continuity and Change
- Time and change

Place and Space
- Features of places
- People and places

Investigation, Communication and Participation

Mathematics

Working Mathematically
- Using problem solving strategies

Space
- Using spatial ideas and techniques to interpret and draw

Number
- Written computation
- Calculators

Measurement
- Measuring

Gas: energy and change

This book looks at the role of natural gas in Australian society. It begins by looking at the nature of energy and energy changes. It then examines in detail the way that natural gas is formed, how it is found and taken from the ground and delivered to industry, your home or local service station. The chemistry of natural gas is explained, including the chemistry involved in the formation and subsequent use of natural gas. Finally, it looks at the environmental issues associated with the use of natural gas.

Natural gas is a fuel and, ever since civilisation began, humans have been using fuels for heating and cooking. The first fuel used was wood. During the industrial revolution in the eighteenth century, machines were built to convert the heat produced by the burning of fuels into a "force" that could be harnessed and made to do work. The steam engine was one of these. Since then, fossil fuels (coal, oil and gas) have provided the industrial nations with the energy to provide the standard of living to which we have become accustomed. Natural gas was a late starter amongst the fossil fuels, but today, because of its abundance, its relative greenhouse-friendly nature and new technologies, it is being more widely used.

Australia's current natural gas reserves are sufficient for at least 80 years. In addition, natural gas in the form of liquefied natural gas (LNG) has opened up new energy exports. Natural gas is expected to be Australia's fastest growing energy source until at least 2030.

Note on Terminology : In some places in this book petroleum is referred to rather than natural gas. This is because petroleum includes both oil and gas and it is more convenient when discussing the formation of oil and gas to talk about petroleum.

1. Energy and change—how does gas fit in?

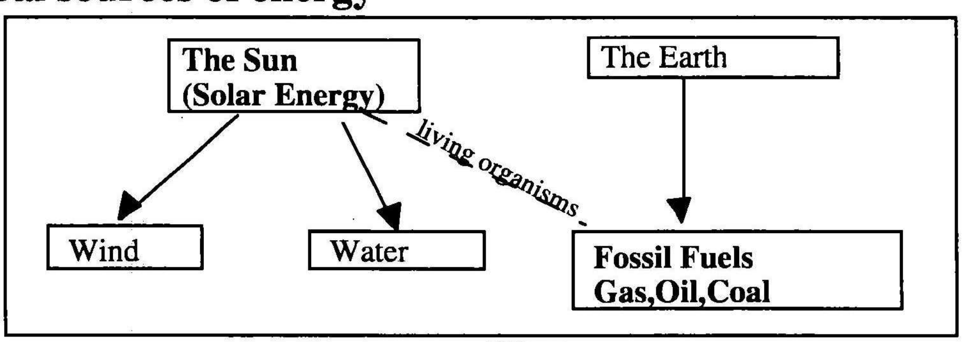
Energy

Energy is vital to our existence and our quality of life as a society and as individuals. Everyone knows what it feels like to be "out of energy"—they are not able to work as hard or do as much. The definition of energy—***the ability to do work***—applies not only to ourselves and the way we produce and use energy, but also to vehicles, appliances, tools, etc. In fact it applies to anything that uses some type of energy to do work. Natural gas, a fossil fuel, provides us with chemical potential energy. This energy is harnessed for work when the gas is burnt.

The energy stored chemically in fossil fuels originated from the sun. The energy from the sun has enabled living organisms to produce their own food from carbon dioxide and water ever since photosynthesis began. Given the right conditions, when organisms died, the carbon and hydrogen contained in their cells converted to hydrocarbons (oil and gas). These chemical transformations took place over millions of years under particular conditions in order to produce natural gas, oil and coal. The formation of the fossil fuels is a process in which energy conversions take place so that what once was solar energy is now energy stored in the Earth.

There are many different **types** of energy and each of these has a source which is ultimately natural, either the Earth or the sun. These natural sources of energy are described below followed by a classification of the different types of energy.

Natural sources of energy



1997LMsummary

Solar energy. The sun is the ultimate source of nearly all the energy used by modern society. Atomic energy, the tides and geothermal energy are examples of non-solar based energy.

The sun is our most important natural source of ***radiant*** energy. It provides us with both heat and light energy. This enables plants to grow which in turn gives energy to animals when they eat the plant material.

It may seem strange that we refer to wind and water as forms of solar energy, but they both derive their energy from the sun.

Wind. Wind is a result of the movement of air between high and low pressure areas of the atmosphere—differences produced in part by uneven heating of the atmosphere by the sun. Wind energy is harnessed through windmills, which are connected to grinding stones, electricity generators or water pumps. "Wind farms" have recently been set up, where hundreds of wind generators have been built in many countries.

Water. Water power is the result of water moving toward the sea from higher elevations where it has fallen as precipitation. The supply of moisture in the atmosphere is replenished on a continuous basis as the sun evaporates water on the Earth's surface. Twenty per cent of the solar energy reaching the surface of the planet is spent to drive the water or hydrologic cycle.

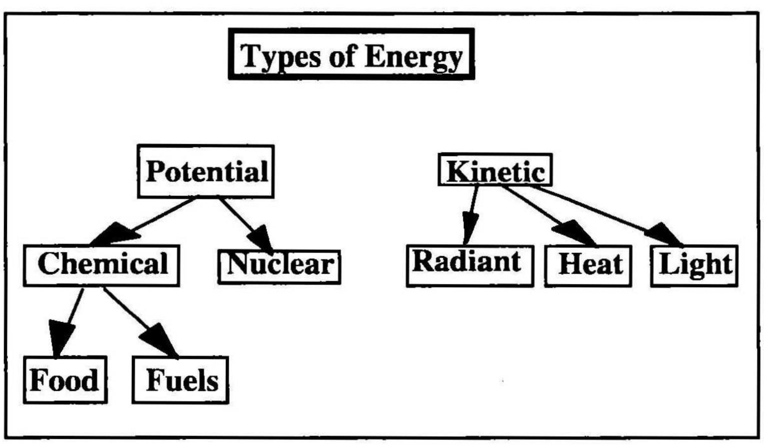
Water can be used as a source of energy by harnessing either its kinetic or potential energy. Running water can be used to turn large paddle wheels connected to grinding, milling and pumping machines. Water stored in high dams can be used to produce hydro-electricity.

Fossil fuels. Fossil fuels are our most important source of ***chemical*** energy. The definition of a fuel is any substance that can be burned to provide energy. Fossils are the ***remains*** of once living plants and animals. There are three main types of fossil fuels; coal, oil and gas. Coal is formed when the concentrated remains of dead plants are buried in the ground and over millions of years they undergo chemical transformations. Natural gas and crude oil can be formed from coal and also from an organic ooze found in rocks called source rocks. This organic ooze is made up of the preserved remains of marine phytoplankton, zooplankton and bacteria mixed with sediment. The coal and source rocks will yield oil and gas only if they "cooked" sufficiently in the ground. Although there are no visible physical fossil remains in crude oil and gas, the chemistry of the oil and gas can tell us whether it originated as plants, plankton, algae or bacteria.

By far the greatest proportion of oil and gas is formed from the remains of plants. Although the remains of animals can also be preserved in rocks (dinosaurs, shell fish, etc.) they only have a minor input to the organic matter in source rocks for fossil fuels.

Types of energy

As atomic theory (the idea that all matter is made up of atoms in certain combinations and structures) became widely accepted, so the many different forms of energy such as electrical, nuclear, radiant and chemical, have come to be considered as either potential or kinetic energy at the atomic and molecular level. Gas, oil and coal being sources of chemical energy can also be classified as sources of potential energy.

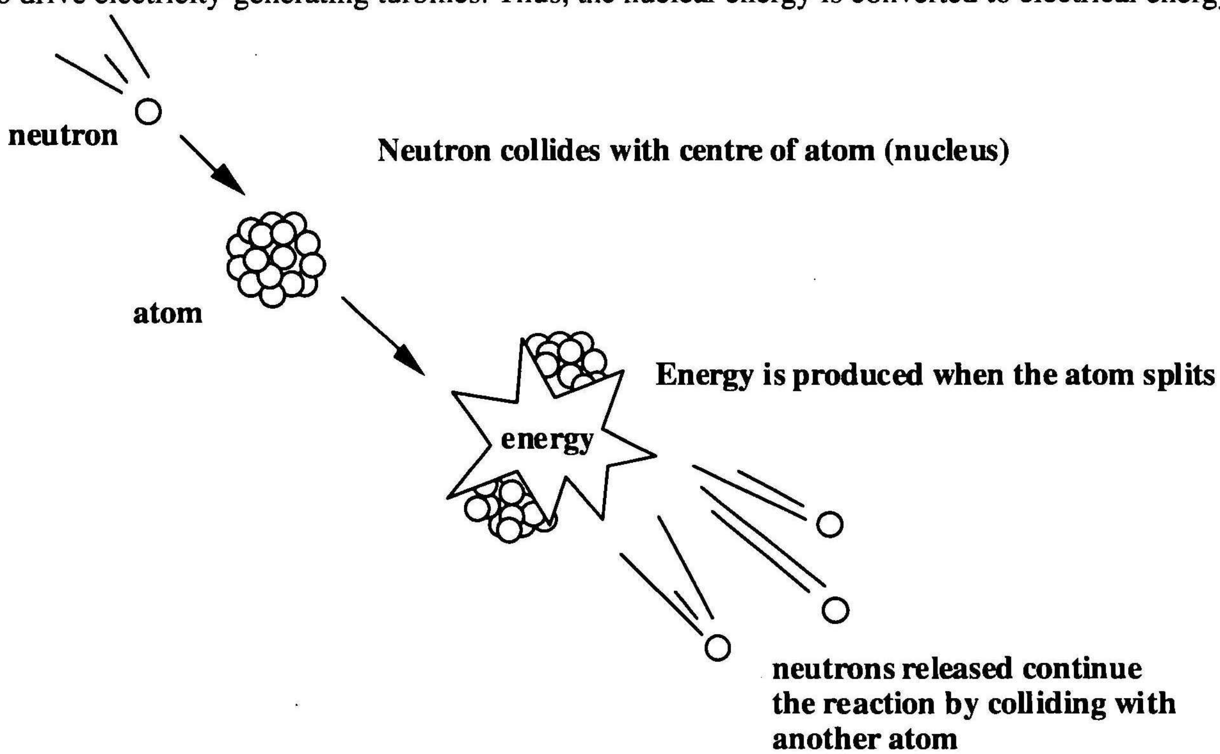


Potential energy. An object may store energy by virtue of its position. This energy is called potential energy because in the stored state it has the potential for doing work. There are a number of different types of potential energy including chemical and nuclear.

Chemical energy. Chemical energy in fuels is actually *energy of position* when considered at an atomic level. This energy is available when the positions of electric charges within and between molecules are altered. That is, when a chemical change takes place. Potential forms of chemical energy are found in fossil fuels, electric batteries, and the food we eat.

The beauty of chemical energy is that it is transportable and therefore we can take it to where we need to use it.

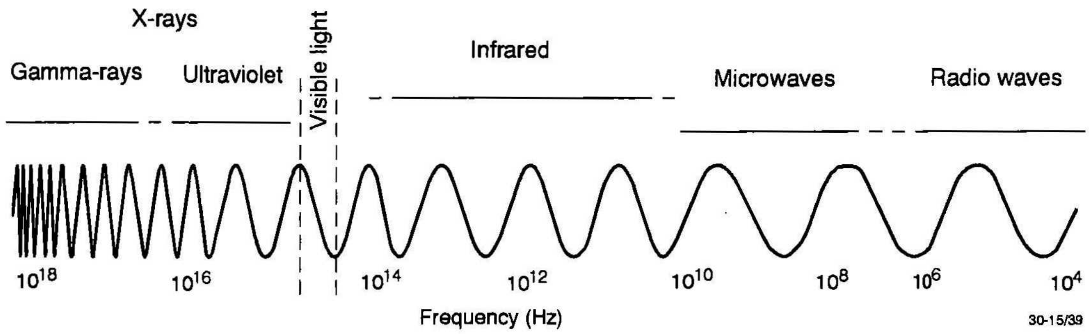
Nuclear Energy. Nuclear energy is the energy that is produced when a nuclear (inside the nucleus of an atom) reaction takes place. Nuclear reactions occur through either fission or fusion. Nuclear fission is a chain reaction in which the nuclei of heavy atoms split, forming smaller atoms of lighter elements. Each time a heavy atom splits it releases energy and particles which initiate the split of further atoms, thereby continuing the energy release. The energy released by the splitting atom is released as heat. The heat is used to convert water into steam, which is used to drive electricity-generating turbines. Thus, the nuclear energy is converted to electrical energy.



Nuclear fusion occurs in the sun. Atoms of hydrogen combine to form a heavier element (helium). The energy released is much greater than in fission. As yet, we have not developed the technology to commercially harness this form of nuclear reaction.

Kinetic energy. Kinetic energy is the energy of motion, at all scales, from a moving car to a vibrating particle. Kinetic energy underlies other seemingly different forms of energy such as heat, sound and light.

Radiant energy. Any energy that is transmitted by radiation is called radiant energy. Radiant energy travels through space and the air in the form of electro-magnetic rays. It includes radio waves, microwaves, infra-red radiation, visible light, ultra-violet radiation, X-rays and gamma rays. Heat and light energy are also forms of electro-magnetic radiation.



Heat energy. Heat flows from one material to another, as the energy is transferred. But once transferred the energy becomes internal—the vibration of atoms or molecules. We can save heat if we can contain it—insulation helps us to achieve this.

Light energy. Light energy can be considered as a combination of a stream of particles and wave motion.

Energy and change

Strictly speaking ***energy*** is not actually consumed. Rather, it is changed from one form to another. A fundamental feature of the universe is that energy is neither created nor destroyed (*law of conservation of energy).* It is usually transformed as it is transferred, but the energy of the universe is constant.

The process of energy transformation in the creation of fossil fuels takes place over hundreds of millions of years. It involves solar energy being converted to chemical energy in living organisms. This chemical energy is then transformed over geological time (periods often 10-100's millions of years) to the fossil fuels—coal, oil and gas. The resulting fossil fuels have potential energy in the chemical bonds.

When a fossil fuel is burnt, for example, the potential chemical energy is changed into heat energy, which can be converted to mechanical energy to run a car. When we use fossil fuels the sun of a million yesterdays is rekindled and that energy is used in seconds. In an electrical power plant this heat is harnessed and changed into mechanical energy, which is then converted to electrical energy for our use. Through this process, gas and the other fossil fuels are transformed into other products.

The statement above, "***energy*** is not actually consumed" contradicts what we would normally discuss as the consumption of fossil fuels. The combustion of fossil fuels actually degrades both the energy and the matter contained within, converting them both to less useful forms. For example, when we burn gas, heat is released, and the products of this process are carbon dioxide (CO_2) and water (H_2O). These are both essential compounds, but they are unusable as fuels—therefore, fossil fuels are commonly said to have been consumed.

2. The gas fuels

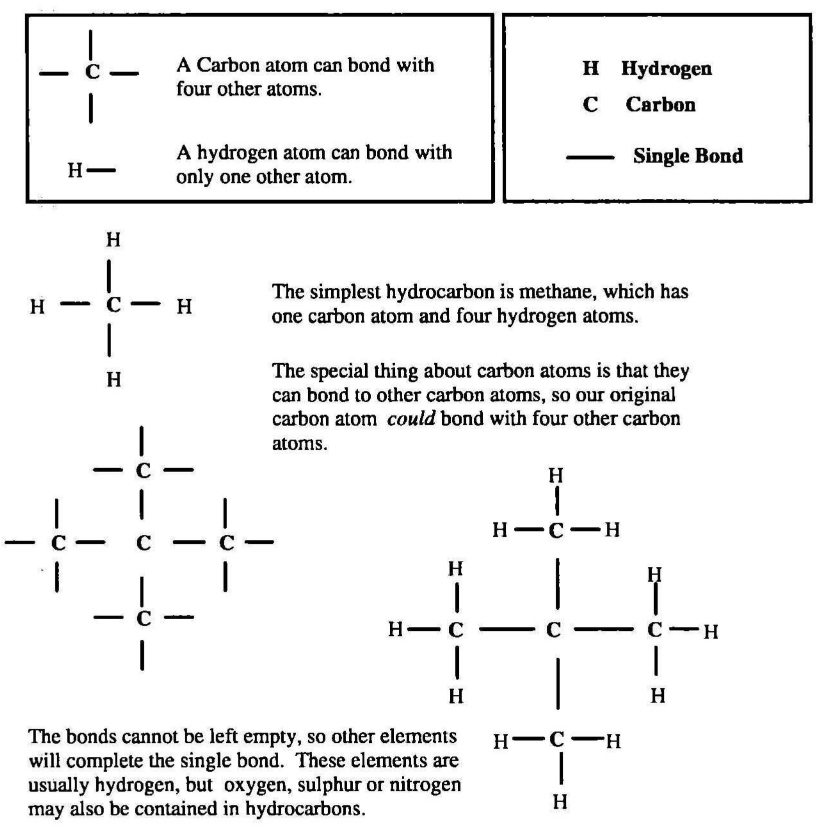
Most people have heard of natural gas and liquefied petroleum gas (LPG), but many don't know they are different. Both natural gas and LPG are made up of different types of hydrocarbons. Natural gas consists mainly of methane, which is the simplest hydrocarbon and LPG is made of propane and/or butane. LNG is liquefied natural gas—natural gas at high pressure and low temperature.

Hydrocarbons

Hydrocarbons are the simplest building blocks of organic compounds, which are defined as compounds in which carbon is a principal element of each molecule. This is why organic chemistry is often called carbon chemistry. Chemistry itself is often divided into two sections, organic chemistry (deals with most carbon compounds) and inorganic chemistry (anything not organic), but there are really no precise boundaries between organic chemistry and other areas of chemical science. Plastics, nylon, polyester, rubber, petrol, gas and all plant and living materials are organic compounds.

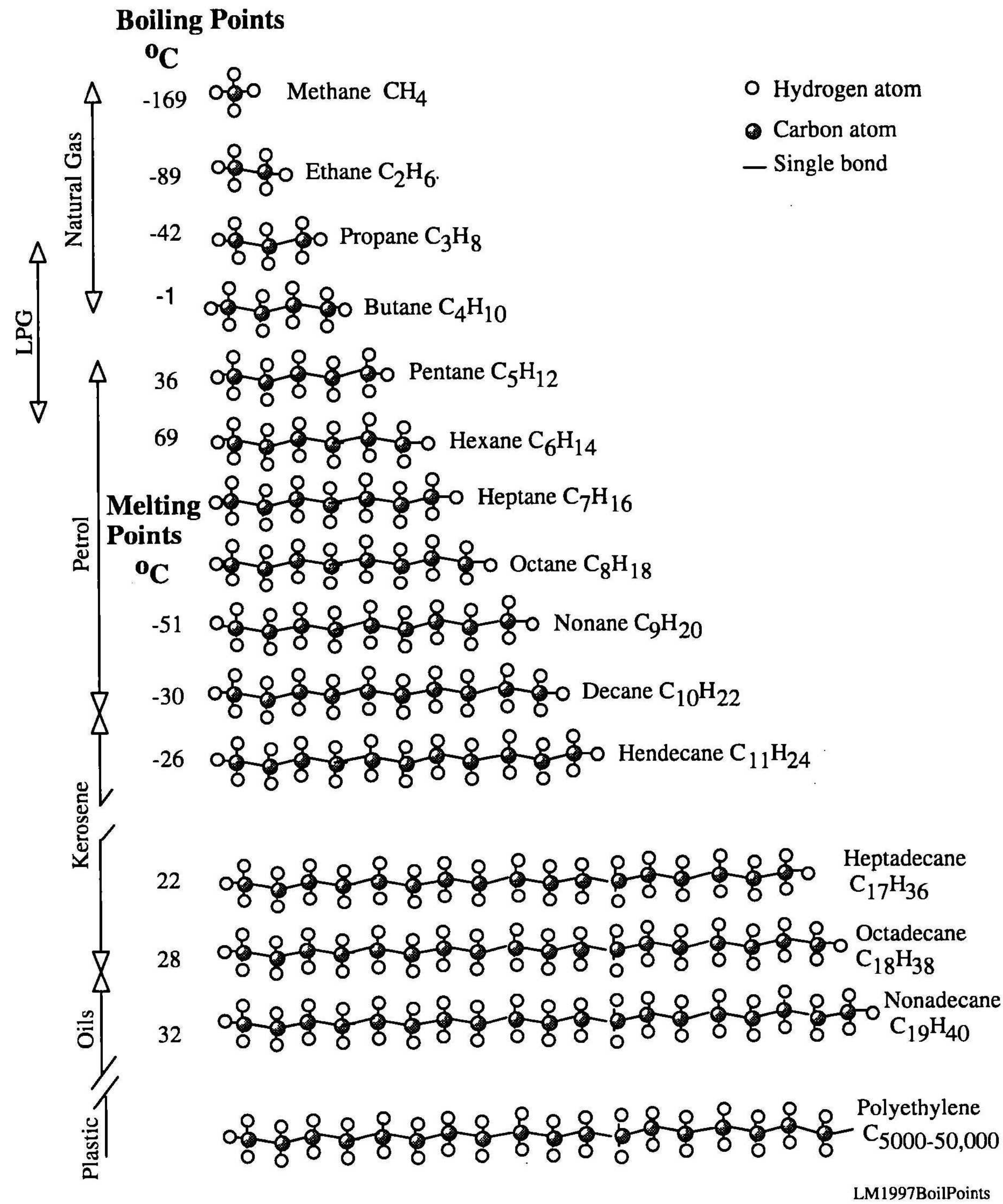
Hydrocarbons are substances which contain two elements, carbon and hydrogen. With such a limited range of composition, you might suppose that there would be little variety in the chemical properties of the hydrocarbons. However, this is not the case. The structure of hydrocarbons, which is a result of the way the carbon atoms bond with each other and with hydrogen, allows over a million different combinations. Many of these combinations also contain small quantities of sulphur, oxygen and nitrogen.

The Bonding Nature of Carbon



The key structural feature of hydrocarbons is the presence of stable bonds between carbon atoms. Carbon is the only element that is able to form stable, extended chains of atoms bonded through single, double or triple bonds. The chains that are formed through **single** bonding of more than one carbon are shown below. These are called the straight-chained hydrocarbons (alkanes) and they have a structural formula C_nH_{2n+2}.

The simplest member of the alkane family is methane. Methane is the main constituent of natural gas. In methane four hydrogen atoms share electrons with carbon, which shares its own electrons, one with each hydrogen atom. So each bond is made by the sharing of two electrons and there are four single bonds in total in the methane molecule.



Natural gas

Natural gas consists mostly of methane with varying amounts of ethane, propane, butane, nitrogen and carbon dioxide, depending on the material that it originated from. In 1994-95, for example, the composition of natural gas used in Melbourne was:

91.5%	Methane
5.0%	Ethane
0.6%	Propane
0.1%	Butane
0.9%	Nitrogen
1.9%	Carbon Dioxide

Some of the uses of natural gas include home heating, gas stoves, hot-water heaters and industrial applications.

At 1 atmosphere pressure, natural gas will become a liquid at -161.5°C. As a liquid, natural gas occupies only 1/600th of the volume of its gas state. This makes it economical to ship overseas as liquefied natural gas(LNG). Australia is a major exporter of LNG. On land it is usually more economical to move natural gas in pipelines.

Liquefied petroleum gas (LPG)

LPG consists of propane with minor amounts of butane. Propane and butane contain three and four carbon atoms, respectively. Propane is used for home heating and cooking in areas where natural gas is not available. Butane is used in disposable lighters and for some camping stoves and lanterns. LPG is also used as a fuel for vehicles in Australia.

Gas, liquid or solid?

Natural gas and LPG are gases at room temperature (around 25°C). The table below gives a comparison of the temperatures of the solid, liquid and gas states of water, salt and mercury with those of methane the main constituent of natural gas (all at 1 atmosphere pressure).

	Mercury, Hg	Methane, CH_4	Water, H_2O	Salt, NaCl
Melting Point	-37.87°C	-182°C	0°C	801°C
Boiling Point	356.58°C	-161.5°C	100°C	1413°C

MP -Melting Point - The temperature at which a solid changes to a liquid.
BP - Boiling Point - The temperature at which a liquid changes to a gas.

The gaseous forms of petroleum. Natural gas and LPG are the gaseous forms of petroleum. Petroleum is defined as material occurring naturally in the Earth composed predominantly of carbon and hydrogen compounds (hydrocarbons). Depending on temperature and pressure and the composition of the compound, petroleum can be found as a gas, liquid, and/or solid.

Petroleum is classified according to its density (mass / volume) and the complexity of the hydrocarbons. There are four main types of petroleum. Natural gas and LPG are classified as the dry gas portion of petroleum.

1. ***Dry gas***, a source of natural gas, consists mainly of methane (>98%). Liquefied petroleum gas (LPG) such as butane and propane are made from natural gas. LPG is kept in a liquid state under pressure for use in domestic and industrial applications.

2. ***Wet gas*** consists of methane, but with substantial amounts of heavier gas fractions and condensate composed of very light crude oil. Condensate can be obtained either by precipitation from the gas, naturally at surface temperature and pressure, or it can be separated from the gas stream by special equipment.

3. ***Light crude*** is a clear amber-coloured liquid. Light fractions, for example petrol and kerosene, are refined from light crude.

4. ***Heavy crude*** is a dark, denser liquid. Diesel fuel, fuel oil, lubricating oil and bitumen are refined from crude oil mixed with some lighter fractions. Many heavy crude oils are derived from light crude oils as a result of alteration in the reservoir through processes of water washing or biodegradation. Most crude oils contain sulphur. Minimisation of sulphur content in diesel fuel and fuel oil is important in the control of pollution. Most Australian oils are low in sulphur because of their origin from terrestrial (land-plant derived) source rocks.

How safe is natural gas?

Natural gas has a very good safety record. Being mostly methane, which is lighter than air—compare methane's atomic mass of only 16 amu with that of air, shown in the table below—it will rapidly rise and disperse if a leak occurs in, for example, a surface pipeline.Also, the use of natural gas in Australia is governed by rigorous safety standards.

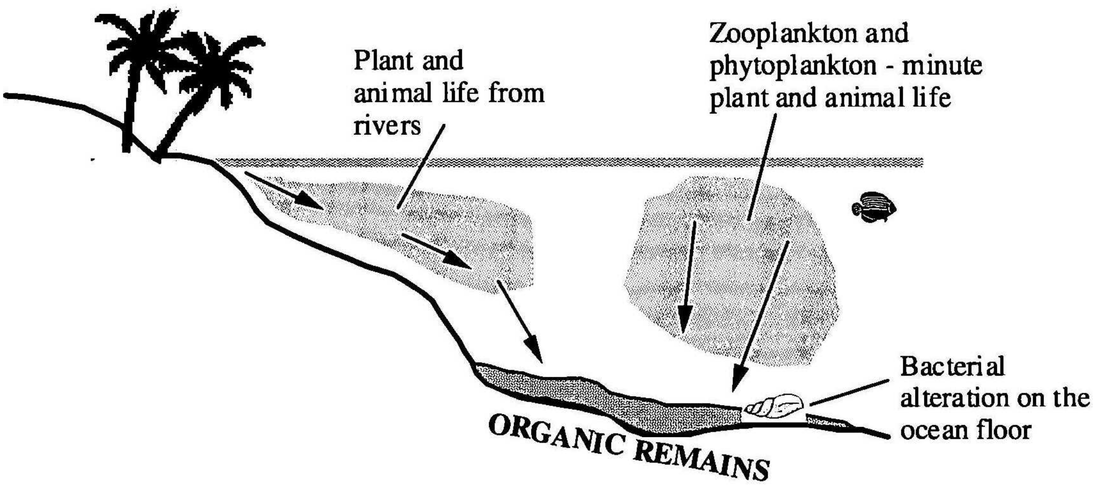
Composition of air

Component of air	*Percentage composition*	*Mass (amu)*
Nitrogen	78	28
Oxygen	21	32
Argon	0.93	40
Carbon Dioxide	0.03	44
Neon	0.002	20
Other : Helium, Methane, Krypton, Nitrous Oxide, Xenon, [a]	0.038	various weights

[a] Ozone, sulphur dioxide, nitrogen dioxide, ammonia, and carbon monoxide are present as trace gases in variable amounts.

3.The formation of natural gas—geological processes and chemistry

Fossil fuels are energy sources which are composed of organic matter—the remains of algae, bacteria and plants. These remains have been altered over time to form hydrocarbons.



Fossil fuels include petroleum (oil & gas) and coal. They are the end products of geological and chemical processes which began when organic material accumulated in muds and sediments at the bottom of lakes, swamps, oceans and other environments which allowed the dead organic matter to collect without being disturbed.

An understanding of the geological and chemical processes involved in the formation of petroleum is essential to the search for new deposits. Understanding the time-frame for the process in the context of the Earth's history can also help one appreciate the significance of these ancient resources.

Formation of gas and oil

The source of energy for all fossil fuels has come, ultimately, from the sun. In the case of oil and gas, microscopic marine algae (phytoplankton) living in the upper layers of the ocean absorb the sun's energy to convert carbon dioxide and water into simple hydrocarbon compounds, such as sugars. This process is called photosynthesis.

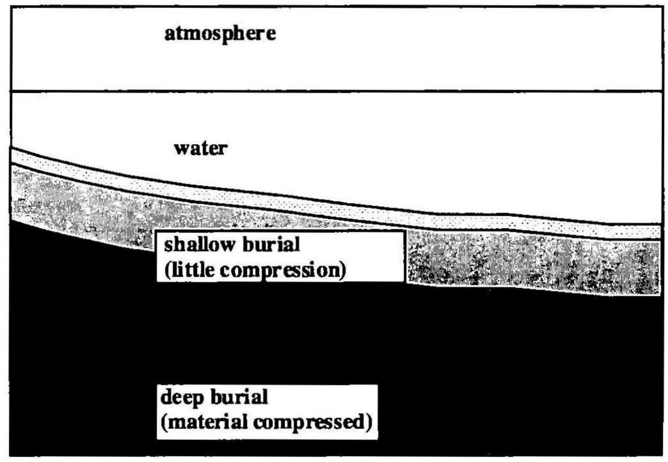
Photosynthesis

Photosynthesis is the major means for conversion of solar energy into forms that can be used by living organisms. The photosynthetic reaction that occurs in the leaves of plants is conversion of carbon dioxide and water to simple molecules (hydrocarbon compounds), for example:

$$\underset{\text{Carbon Dioxide}}{6\,CO_2} + \underset{\text{Water}}{6\,H_2O} \longrightarrow \underset{\text{Carbohydrate}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6\,O_2}$$

These simple hydrocarbons within the marine algae can later be converted within the food chain to more complex hydrocarbons. For example, when algae are eaten by fish the simple hydrocarbons are changed within the fish into more complex structures and combinations.

Geological processes



LM1997BuriedSedt

When algae and other microscopic creatures that live in seas and lakes die they accumulate in what geologists call a *sedimentary environment.* This is where mineral and rock particles that have eroded from higher land round about are deposited as sediment. (A desert is also a sedimentary environment, but in the context of oil and gas a sedimentary environment is always in water.) The deposits must accumulate either in deep water, low in oxygen and away from the churning action of waves, currents and burrowing organisms (bioturbation) or, if they are in shallower water, they need to be buried by other sediments quickly before the organic matter is eaten by other organisms or destroyed by oxidation.

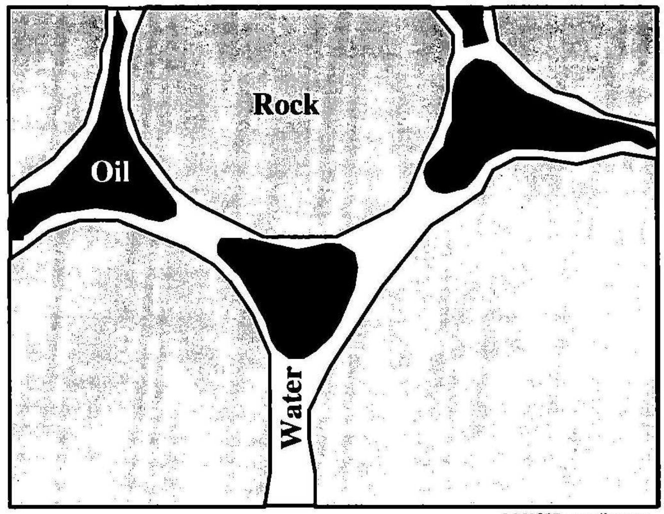
Environments that are similar to those in which gas and oil were formed exist today in many places around the world. One example in Australia is the Myall River in New South Wales, from Port Stephens to Forster. For many kilometres along the river you will see dreary tea-tree swamps, in which the water is black and the air dank with the smell of decaying vegetation. The sediment containing this organic material will be carried to the mouth of the river and deposited on the continental margin, where it may be buried and eventually become a source rock for a future petroleum deposit.

Source rocks. As the organic matter and mineral particles accumulate, the weight of the material being deposited on top compresses the layers deeper in the sequence. For example, a surface peat deposit 10 metres thick will eventually be converted to a coal seam only 1 to 2 metres thick at a burial depth of a few kilometres.

The compressed material is consolidated by this process and becomes rock—the petroleum source rock. The spaces between particles of this new sedimentary rock are called pores and the amount of space is known as the porosity of the rock. Porosity is related to permeability—the ability of the rock to allow fluid to flow through it. Sedimentary rocks can be broken into two types based on their porosity and permeability—rocks which prevent the flow of water or hydrocarbons (impervious) and those that allow it (porous). The impervious rocks are also called cap rocks, and the porous rocks are the reservoir rocks.

Reservoir rocks. After the organic matter has been deeply buried and changed into petroleum, it migrates, usually upwards, through porous rocks as a result of capillary forces and its buoyancy. The pore spaces are interconnected allowing the petroleum to move when it is under pressure. The porous rocks through which the petroleum migrates and from which it can be eventually extracted are called reservoir rocks. Sandstone formed from beach sand makes a great reservoir rock, as does porous limestone.

The diagram represents where oil might be contained in rock. Note that the oil sits above the water. If the rock contained gas and oil instead of oil and water, then the gas would sit above the oil; that is, the lighter material always lies above the heavier. Remember also that this is a two-dimensional representation of a three dimensional rock and, therefore, although the rock particles appear to be supported by the oil/water, they would actually be supported by other rock particles in the third dimension.



LM1997poreoilwater

Cap rocks. Impervious rocks (containing very little pore space) may sit above the reservoir rocks and act as a seal, preventing further migration of oil, gas or water. Examples of impervious rocks are dense shales or limestone, strongly cemented sandstone (pore spaces filled in), quartzite (metamorphosed sandstone) and evaporites—rocks made up of salts which crystallise when water bodies dry out. In all these rocks the pore spaces are too small to allow petroleum in. The most effective cap rocks are clay or shale, which are formed from mud and clay, which consist of very small particles.

Where would you look for natural gas?

If you were looking for natural gas or oil, the first thing you would look for is a sedimentary basin. A sedimentary basin is a large depression in the crust that is filled with sediments, which have been eroded from higher ground and carried by wind or water into the basin.

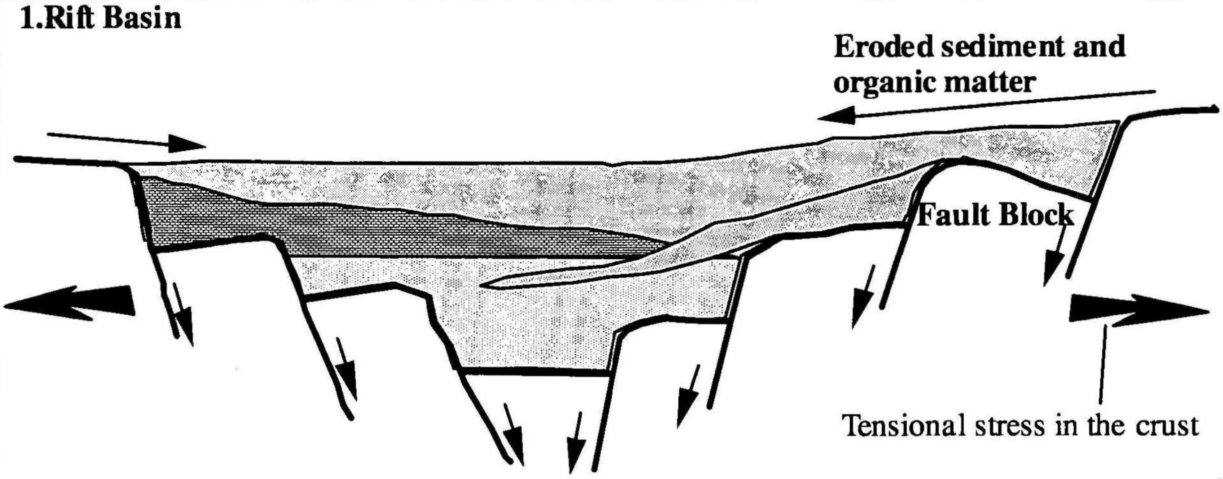
Sedimentary basins can be up to several kilometres thick (the thickness of the Earth's crust varies from 5 to 65 km). The rocks in sedimentary basins have commonly been gently folded and faulted.

Sedimentary basin-forming processes. The theory of Plate Tectonics states that the Earth's crust consists of large and small rigid plates that slide over a semi-molten or plastic layer of the mantle. Sedimentary basins form because the Earth's crust is continually moving and being placed under stress because of forces deep within the Earth. While one area of crust is being compressed, another may be experiencing forces of extension. Stresses on the plates have caused warping. Compression results in upward warping, which forms mountains, which will then be subject to erosion and weathering. Extension in the crust results in downward warping, which forms basins, which then fill with sediments.

The cycling of the Earth's crust over millions of years has also changed the shape and size of ocean basins, as well as the location and shape of major mountain ranges and basins on land. Over time, the Earth's continents have clumped together and then been dragged apart. These changes, taking millions of years, have had a huge effect on the location of basins and rate of sedimentation. As a result of this, basins do not necessarily stay as basins for ever. Some former basins have been changed; for example, petroleum is currently being explored for in the highlands of Papua New Guinea in what was a basin during the Mesozoic age.

Types of sedimentary basins. Three different types of basin can result from extension of the Earth's crust:

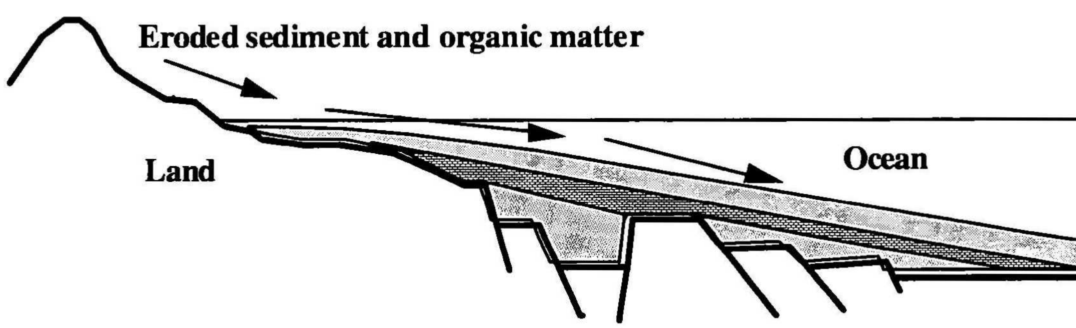
1.Rift Basin



In any of these basins, source material will accumulate in pockets of stagnant water which get trapped between fault blocks.

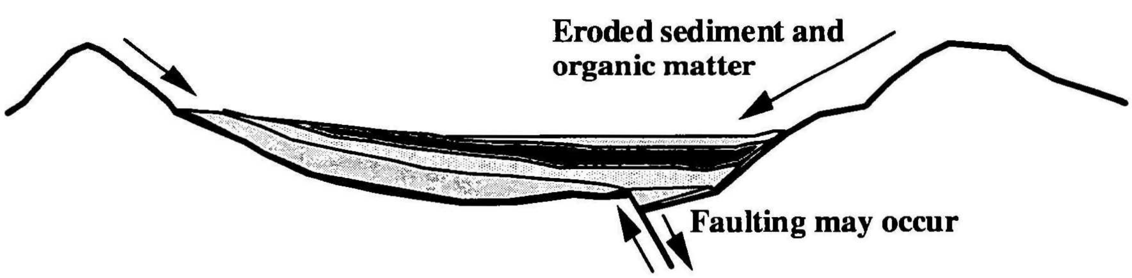
The sands that accumulate may become the reservoir rock.

2. Marginal Shelf Environment



Once a coastal shelf rift basin has ceased rifting, deposition of sediment begins. It is also called a "passive" margin because rifting is no longer occuring.

3.Intracratonic Basin



A shallow depression formed over a large area. The areas surrounding the depression may be uplifted slightly and these are the source of the sediment deposited into the basin.

M1998Intracratonicbasin

"Modified fron diagram on page 563, Perspectives of the Earth. I.F.Clark and B.J.Cook."

All of these types of basin occur in and around the Australian continent and have done so at different stages in Australia's geological history.
Rift basins occur where the crust is splitting apart. The Perth Basin is an example of this. It is part of a system of rift basins that extends down the west coast of Australia. This marks the line of separation of Australia from the Indian continent. Other rift basins are the Gippsland Basin and the Otway Basin. The Otway Basin formed as Australia and Antarctica separated along the southern margin of the continent.

At present we see a marginal shelf depositional environment in the Gulf of Carpentaria and Bass Strait. The sedimentary sequence at Barrow Island is also the result of deposition on a marginal shelf.

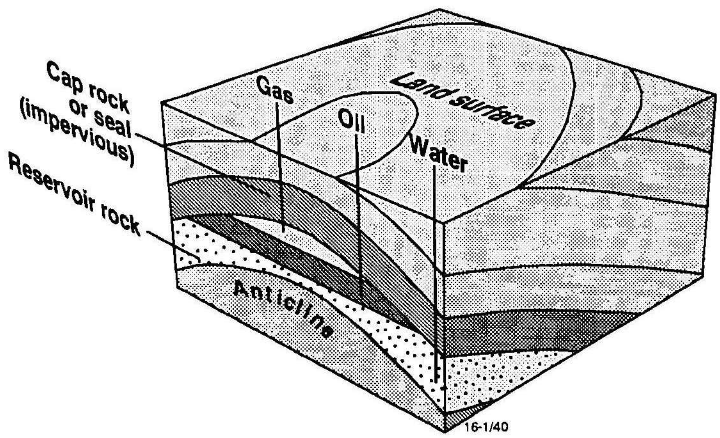
Two intracratonic basins are the Great Artesian Basin and the Murray-Darling Basin. The Great Artesian Basin is not shown on the diagram below, but it occupies one fifth of Australia, extending across parts of Qld, SA, NSW and NT. It includes part or all of the following sedimentary basins: Karumba, Bamaga, Georgina, Carpentaria, Galilee, Arckaringa, Eromanga, Gunnedah and Surat. It is called the Great Artesian Basin because its porous rocks contain water. Other intracratonic basins include the Canning, Amadeus, Cooper, Bowen and Surat Basins.

Basins of Australia : onshore and offshore

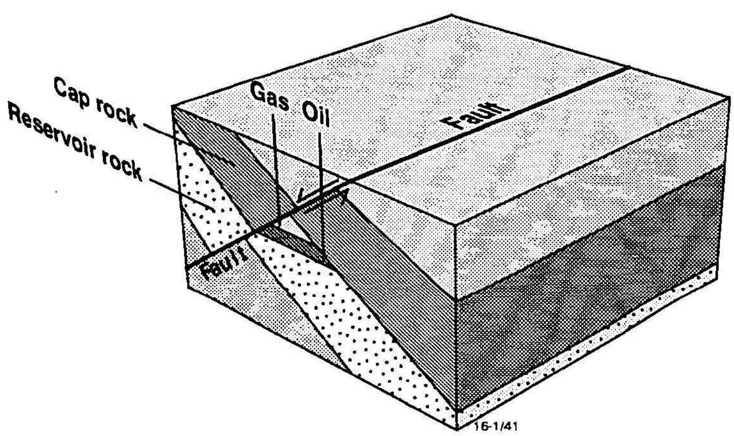
Geological traps

To allow oil and gas to accumulate in large amounts, the layers in which they sit need to be formed into structures called traps. A trap, as the name suggests, is a structure which prevents the petroleum from escaping to the surface. Traps fall into two main types; structural and stratigraphic. The major forms of structural traps are defined below—stratigraphic traps are too technical for discussion at this level.

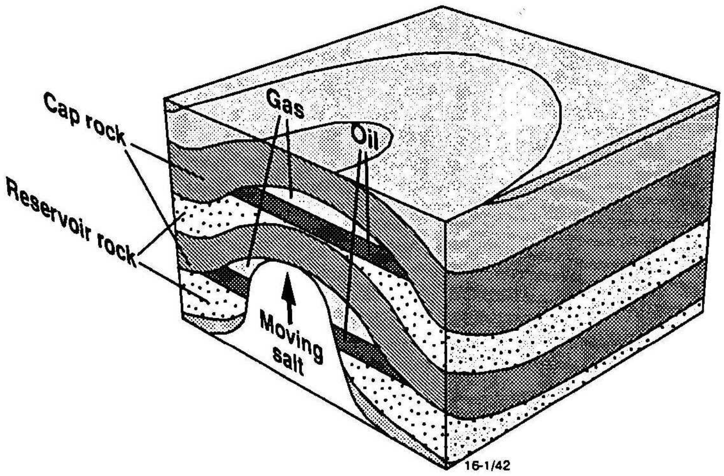
Anticlines. An anticline is simply a fold shaped like an arch or an elongated dome. Oil fields may extend for many kilometres along the crest of an anticline.



Faults. A fault trap forms where a cap rock has moved along a fault to seal off a reservoir rock preventing migration of the petroleum. The impermeable cap rock must lie above the potential reservoir rock. Sometimes small amounts of oil and gas can leak up the fault and reach the surface. Over a very long time this minute leakage could eventually empty the trap. It can also indicate the presence of oil beneath the surface, and the detection of oil "seeps" at sea is used by oil explorers to locate likely areas for detailed exploration



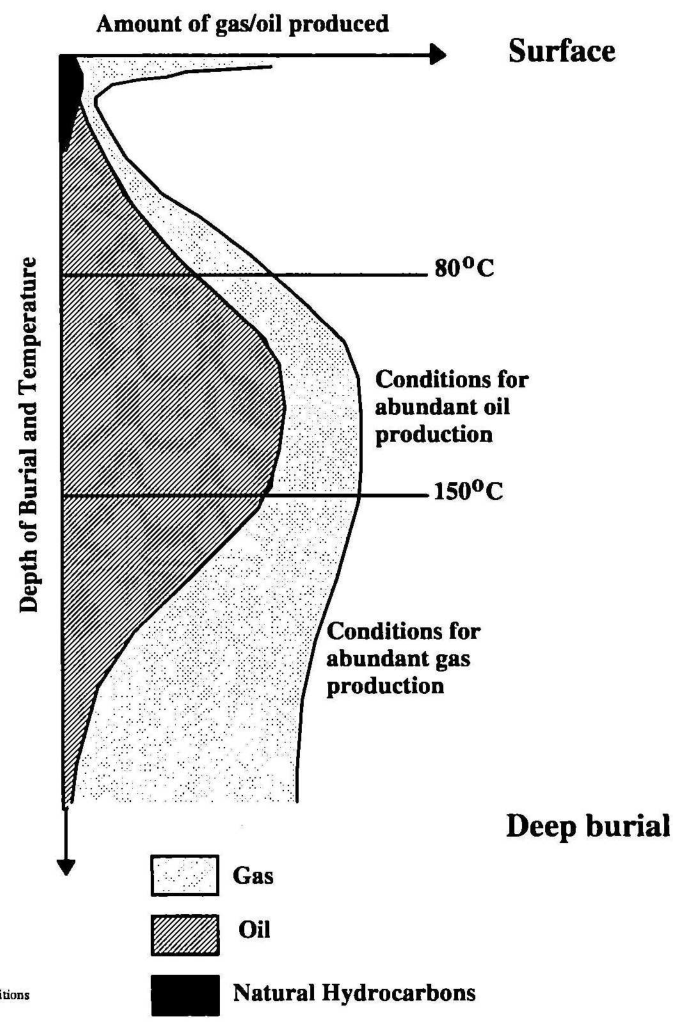
Salt domes. Salt domes are structures which formed by a moving mass of salt. Deeply buried beds of salt (called evaporites) were formed in the past by evaporation of sea water and subsequent burial. These are structures which can move upwards because of density differences. The rising domes bend the surrounding sediments upwards, producing reservoirs in porous beds cut off by the salt. Remember the salt is a cap rock (impervious) as is the clay/shale that the salt dome pushes.



Conditions for formation of gas and oil

80 to 150°C is the ideal temperature window for the formation of oil and gas, as shown in the diagram below. At higher temperatures, between 150 and 200°C, more gas than oil will be produced, and below 80°C, lesser amounts of petroleum will form. If the temperature exceeds 200°C, then the heavier petroleum products (oil) will be "cracked" to form lighter components, gas and coke.

In Australian basins, the ideal temperature is usually found at depths of 1000 to 5000 metres below the surface. In the Gippsland Basin, oil and gas have been formed at between 3500 and 5000 metres.

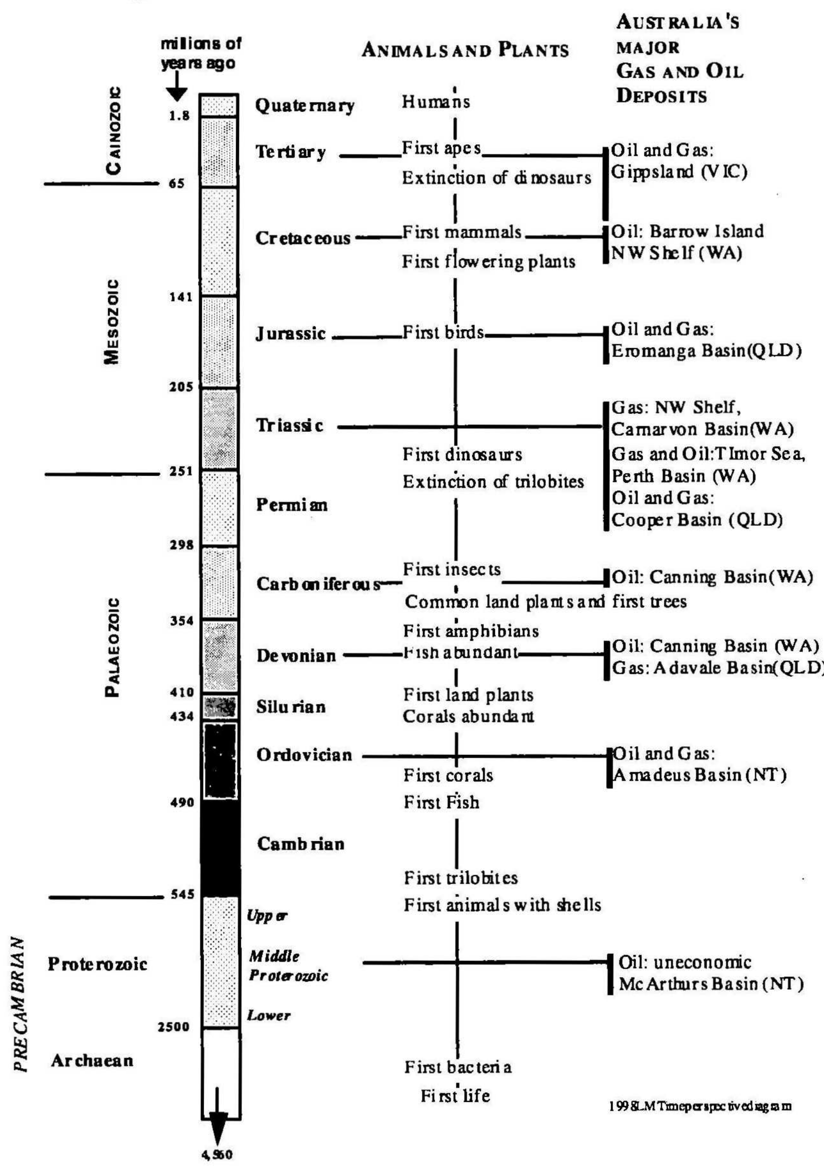


Gas and oil & geological time

The sequence of events that leads to the formation of oil and gas can take hundreds of millions of years. In geological time this is not that long, considering the age of the Earth has been dated at about 4560 million years.

Most of the oil and gas that has already been extracted from the ground, as well as what we know is still in the ground (reserves), was formed less than 500 million years ago. This is approximately one tenth of the age of the Earth. More than 80% of the world's known oil is found in rocks that formed in the last 6% of geological time. The world's oldest oil has been found in rocks 3000 million years old.

Geological Time Line



The oil and gas reserves in the Gippsland Basin, Bass Strait, have taken around 100 million years to form through this sequence. The source rocks for the oil formed in coastal swamps between 100 million and 70 million years ago. The reservoir rocks are beach sands which formed between 90 million and 30 million years ago. The cap (seal) rocks are deep water marls (fine mudstones) that formed between 40 million and 20 million years ago.

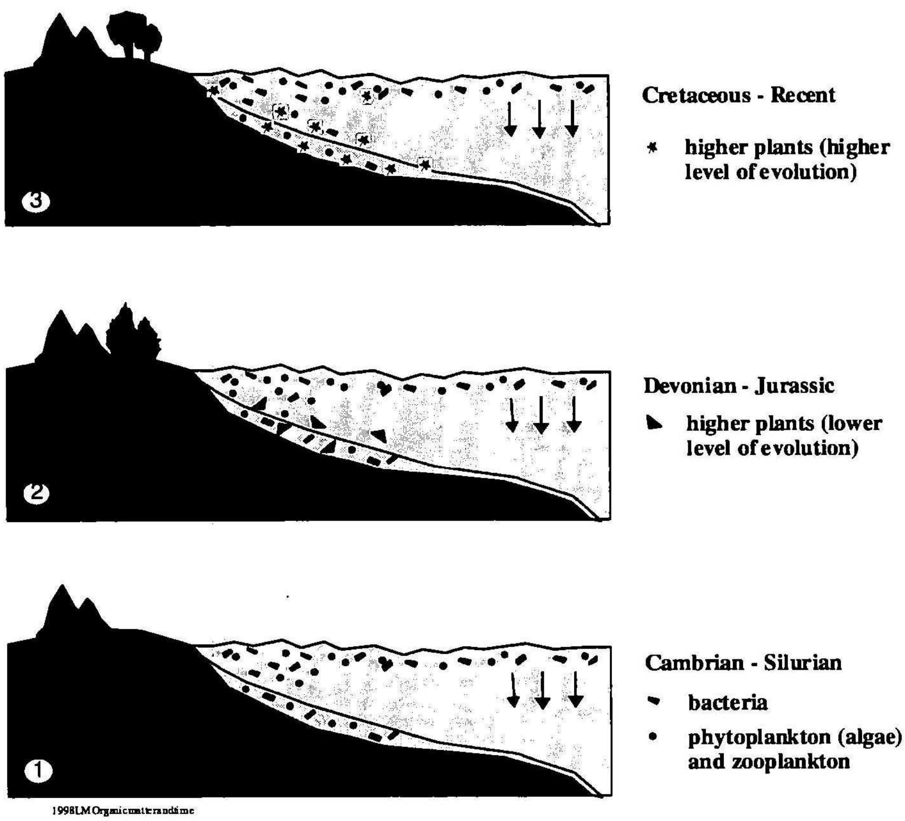
There is a rough correlation between geological age and the likelihood of gas and oil being preserved. The older the rock is, the greater the chance it will have been eroded, deformed or involved in metamorphism. These processes destroy gas and oil or allow it to escape to the surface. Younger rocks, therefore, are more likely to contain oil and gas.

The composition of petroleum

Petroleum may vary in composition, depending on where it is found. The variation will have been caused by any of these factors:

1. The composition of the original organic matter;
2. The heat of formation, which usually is directly related to the depth of burial;
3. The alteration that occurred after accumulation of the oil or gas.

It is also interesting to note that the composition of petroleum differs according to the age of the source material. Cambrian to Silurian deposits, which contained only bacterial and algal organic remains are different in composition to Cretaceous deposits of petroleum, which contain the remains of plants, which did not exist during the earlier period.



Supplied by Jim Preston BHP Petroleum

Methane is also produced by "methanogenic bacteria". In fact, 35% of the world's reserves of methane occur in the giant gas fields of West Siberia. The methane is attributed to biogenic bacteria, which function at shallow depths (less than 1000 metres)-they use carbon dioxide and simple organic acids as a food source and methane comes out!

Sequence of events—formation of gas and oil

Natural gas and oil will only be formed and trapped if a set of necessary conditions is met. These conditions must *all* be met; however, they do not have to occur precisely in this order.

Time

Organic matter (contained in living organisms and made up of complex hydrocarbons) must be in sufficient supply in the environment. Environments that will contain a lot of life and, therefore, a lot of organic matter are coastal waters, areas behind reefs, the continental shelf and slope, lakes and delta environments.

Organic matter must be buried in the sediment before being eaten by scavengers or being destroyed by oxidation (combining with oxygen). Normally when a plant or animal dies it undergoes a process of decay which occurs because of bacterial activity. The bacteria that live in an oxygen-rich environment (aerobic bacteria) work much faster than bacteria that live in oxygen -poor environments (anaerobic bacteria). Therefore, the absence of oxygen increases the chance of organic matter being buried before it decays. Environments such as swamps and lagoons are low oxygen environments. When walking through swamps and lagoons you might detect an unpleasant smell, for example, rotten egg gas, indicating you are in a low oxygen environment.

The sediments (sand, mud, etc.) containing the layers of organic matter are deeply buried, compressed and turned into rock, (source rocks).

The organic matter is transformed at depth (where temperatures are higher), by slow chemical reactions, to oil and gas.

Oil and gas formed in the source rocks migrate into very porous rocks (reservoir rocks) where they are stored .

Traps and seals develop so that the oil/gas does not escape. Traps may develop by folding or faulting of the sequence of rocks and seals are formed by layers of impervious rocks.

The deeper rocks are buried, the higher the temperature, but it must not be too high $(>200^{o}C)$. If the heat is enough to turn rocks into slate or higher grade metamorphic rocks, then instead of gas and oil, graphite (used in lead pencils) will be formed!

Folding and faulting of the rocks must not be too severe or traps may become breached and leak.

The beds must remain buried. If they are exposed to erosion, the gas or oil may be lost.

The pore spaces of the storage rocks must remain open so that the gas or oil can be pumped out of the formation. Swelling clays or mineral cements deposited by groundwaters can fill the pores of resorvoir rocks and stop the recovery of all the gas or oil.

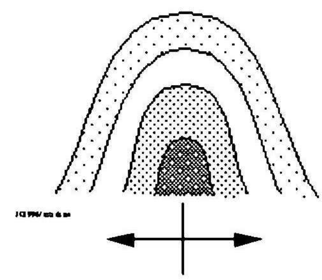
100 million years

LM 1998Sequence

4. Exploration methods & estimating reserves

People first became aware of petroleum through natural "seeps" or spots in the Earth's surface where shallow deposits of gas and crude oil were escaping from the Earth. So when prospectors began to seek greater volumes of petroleum the easiest way to find it was to look for evidence of seeps on the surface of the Earth. This led to the discovery of many of the world's great oil fields in the USA, the Middle East and Venezuela.

As early as 1842 it was learned that petroleum seeps quite often occurred on anticlinal folds. Then, at the turn of the century, having realised that the basic tool in any search for petroleum is a knowledge of the Earth itself, companies began employing geologists and geophysicists to help them in their search for oil.



Anticlinal fold

There are a number of steps that take place when a company is exploring for petroleum:
1. Basin analysis;
2. Acquisition of an area to explore;
3. Acquisition of geophysical data;
4. Defining leads and prospects;
5. Drilling an exploration well.

Basin analysis

The search for gas and oil begins with geologists using their knowledge of the Earth to locate prospective areas. These are areas that are likely to contain source and reservoir rocks.

As we have already seen, a favourable system must contain the following:

Source rocks
A migratory pathway
Reservoir rocks
Traps and Seals

The number of conditions that have to be met make you wonder how it is that we keep finding new fields! Once nature has met it's challenge and produced the gas and oil—we are faced with the challenge of following the clues to find it.

Geophysical methods. At this stage of exploration, geophysical methods are used to determine the large scale structures in an area. Geophysics, as the name suggests, is the study of the physical properties of the Earth. Measurements are taken from a single small plane or from the ground. The main geophysical surveys used to find trap structures or buried reefs of sand bars where oil and gas might accumulate are *magnetic* and *gravity.*

Magnetics. The magnetic signature of metamorphic and igneous rocks is greater than that of sedimentary rocks. The results will indicate the thickness of a sedimentary sequence and broad trends in a structure. Using this method it is possible to map the extent of a basin.

Gravity. Small variations in the Earth's gravity field, a result of variations in density of sedimentary rocks and crustal rocks, can be mapped. This method will give indications of structures, but it is not sufficient to locate a drill site.

During a survey, data for an entire area are collected by flying along survey lines. The aircraft flies at a set height about 80-100 metres above the ground along survey lines around 200-400 metres apart. The data are then processed to remove non-geological background information for the specific data type.

The role of geological surveys in finding petroleum resources. Before exploring a particular area, an exploration company needs regional geological and geophysical information so that they can target areas which they consider to have highest prospectivity. In Australia, each state and the Northern Territory have their own geological surveys. These surveys work together with AGSO (the Australian Geological Survey Organisation) on a number of programs such as the National Geoscience Mapping Accord (NGMA) to provide regional geoscientific data for the exploration industries across the Australian continent.

The cost of undertaking these regional surveys, many of which will not prove to be prospective, is high. By having a geological survey, governments provide exploration and mining companies with data designed to encourage the company to undertake further exploration. As well as producing regional maps, the surveys also carry out research aimed at better understanding the processes that determine the formation and distribution of oil and gas. At a smaller scale, geochemists' research includes fingerprinting the gas and using isotopes, so that we can tell where it has come from.

Australian Geological Survey Organisation (AGSO)

The Australian Geological Survey Organisation was established in 1946 as the Bureau of Mineral Resources to provide a national geological survey focus during the post-war development period. Since this time, the Organisation has been instrumental in the discovery of numerous mineral and petroleum deposits and continues to provide survey data and geological advice to government, industry and research institutions.

AGSO's Petroleum and Marine Division is involved in two main programs aimed at encouraging and assisting Australia's petroleum industry.

Australian Ocean Territory Mapping Program

This program will provide geoscientific information, maps and data to:

- maximise and sustain Australia's legal continental shelf claim;
- encourage petroleum resource exploration on Australia's continental margin;
- help make exploration activity more cost effective;
- support Government decision-making on offshore exploration and development and facilitate marine zone management.

National Geoscience Mapping Accord

In cooperation with State and Territory geological surveys and agencies, provide geoscience information, maps and date to:

- encourage petroleum resource exploration in Australia.
- help make petroleum exploration more cost effective.
- assist responsible resource management.

Acquisition of areas for exploration

To explore in a particular area you must have an exploration permit or lease from the government or land owners of the land or ocean territory. This permit is legal, written permission for a company to explore and it sets out in detail the rights and responsibilities of both the company and the owner of the area.

Acquisition of seismic data

An explosion, at the surface of the ground or water generates shock waves. Some of these waves will be reflected when they cross a boundary in which the velocity of the wave changes. For example the boundary between water and rock, or the boundary between sandstone and shale rock types. The reflected shock waves are received at the surface by devices called geophones. By measuring the time it takes for these waves to travel (transit times) and then processing the data, the subsurface structure can be worked out. In the past it could only be worked out in 2 dimensions, but new technologies in data processing and representation can now give us a 3-dimensional seismic image. The acquisition of seismic data can be summarised as follows:

1. Generate a short, sharp shock wave
2. Record its return to the surface
3. Generate a picture
4. Make a map

There are some limits to what seismic techniques can deliver—otherwise the risk involved in exploration would not be as high as it is:
1. The signal received gets worse the deeper we attempt to go.
2. Some materials, such as salt, do not allow seismic waves to penetrate through.
3. Other materials, such as carbonates, attenuate or weaken the signal returned to the listening device.
4. Although we only want the signal that is a result of the shock wave reflecting off a layer and being received by the listening device, there are many more signals received from a single layer due to reflection between layers.

The processing of the data to improve the picture is, therefore, an incredibly complex process. Although complex, it must be as precise as possible in order to give the most correct picture, which is then interpreted to make a map of the geology below the surface.

In Australia, seismic acquisition costs are approximately as follows for:
Onshore $3000 to $4000 per kilometre
Offshore $1000 per kilometre

Then there is the cost of hiring the processing vessel, ~$10 000/day + maintenance + fuel.

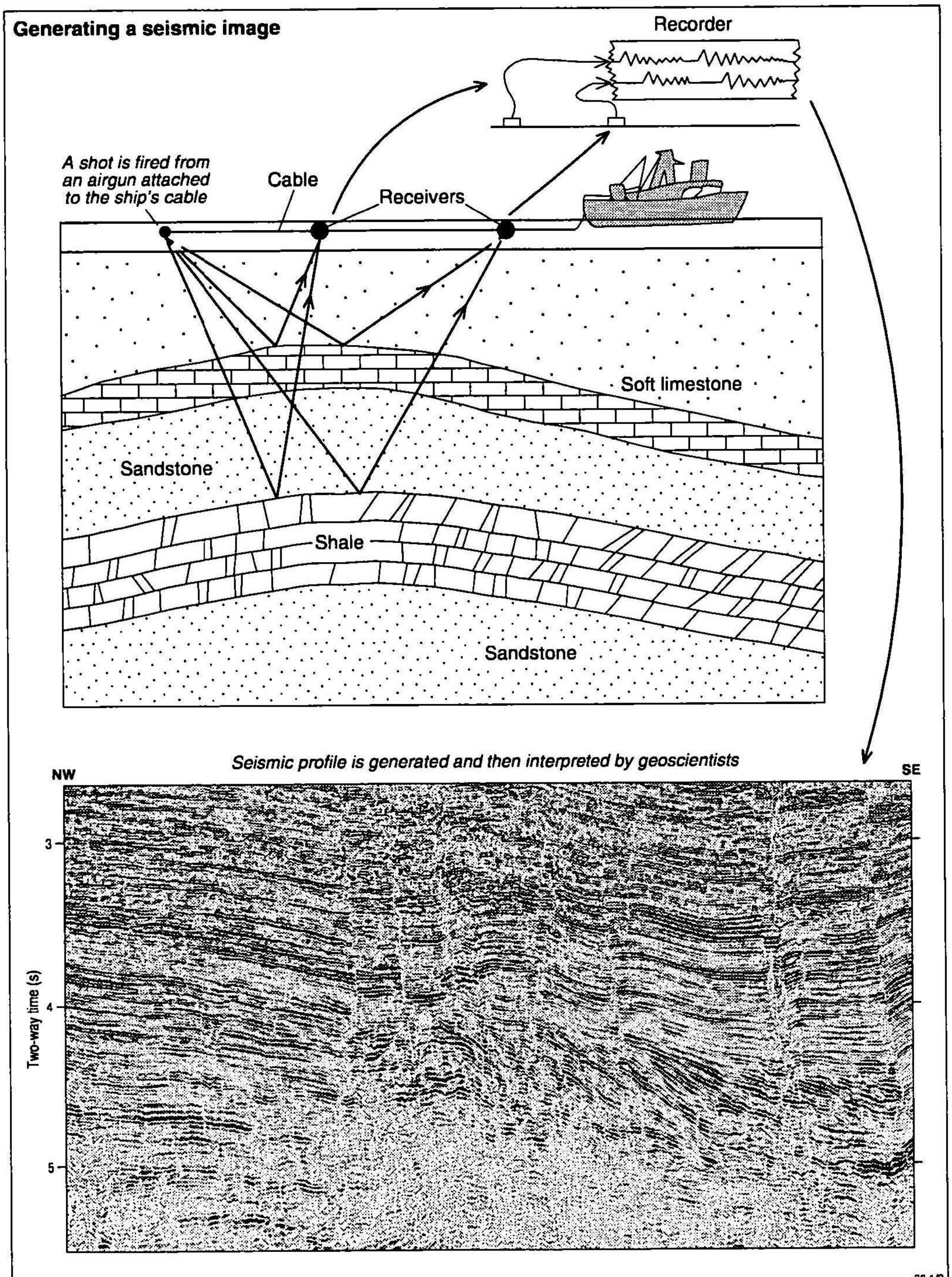
Other methods that can be used to detect prospective areas include:
- ***Airborne laser fluorescence***— Most of the world's known hydrocarbon-producing basins leak. Oil seeps indicate that either a petroleum system currently exists in an area or has existed there in the past. Special equipment called a laser fluorosensor can detect small, thin films of oil. The fluorosensor emits a laser beam. This is absorbed by the oil, which 'fluoresces' and emits light of a longer wavelength which is detected by the laser fluorosensor.

- ***Surface geochemistry***—A submerged seawater sampling device is towed close to the sea floor, from where it continuously pumps seawater up into a geochemical laboratory on the ship which is towing it. There, hydrocarbons are extracted and measured using a method called gas chromatography.

Defining leads and prospects

The map of the geology below the surface will indicate particular structures that could contain oil or gas—traps. The geologist will define the potential traps and the most likely places in which petroleum will be found, in order for the next stage to begin.

Generating a seismic image



Drilling an exploration well

The only way to find out for certain whether a trap structure actually contains oil or gas is to drill into it. The cost of drilling is so high that the decision to drill is made after careful consideration of all available geological and geophysical data together with economic aspects of whether a structure may contain sufficient petroleum to be commercially viable.

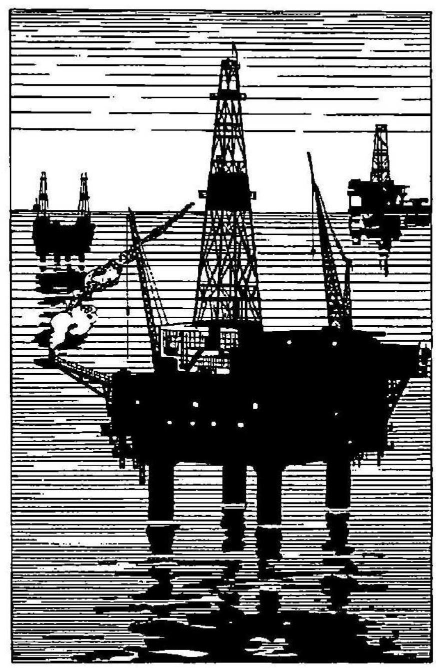
Drilling is done with a rotary drilling rig. The bit cuts through the rock. Rock chips and cores are recovered at the surface of the hole for examination. If the presence of petroleum is detected there are a number of tests that can be run that will indicate the fluids present, the pressures and flow rates. In any case, special measurements are taken at the deepest point in the hole and at one or two intermediate depths, by lowering a sensitive instrument that can record properties of the reservoir and rock types.

If a discovery is made, longer term testing and evaluation are carried out and assessed from technical and economic viewpoints.

Costs involved in drilling vary with location, but are typically :

Onshore	\$750 000 to \$1 million per hole
Offshore	\$2 million to \$10 million per hole

Case study—Bass Strait. During exploration of the Bass Strait, offshore from Victoria, BHP began with an airborne magnetometer survey along lines 3 km apart across the whole Bass Strait area. This established the broad limits of the sedimentary basin. A marine survey was then planned which covered the areas of the basin where the sediments were at their thickest. From the seismic records obtained, maps were drawn and features were interpreted. Some of the favourable features of the basin were:



- the existence of a thick sequence of sediments of a prospective age
- the high probability of good reservoir and source rocks
- the existence of suitable structures for trapping oil offshore
- evidence of oil and gas in onshore wells in the same basin
- the large size of the basin and its position relatively close to population centres

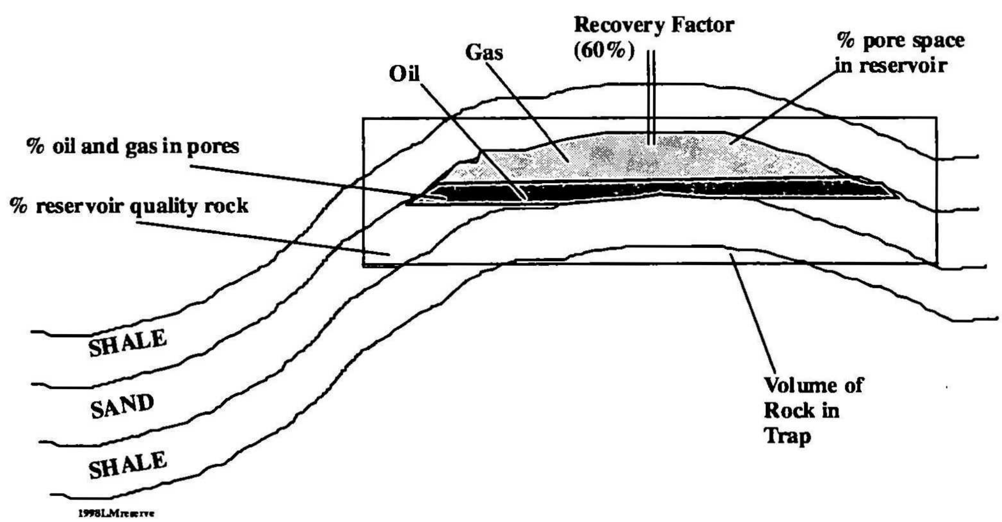
Bass Strait has produced significant amounts of gas and oil for Australia.

Estimating reserves—how much is down there?

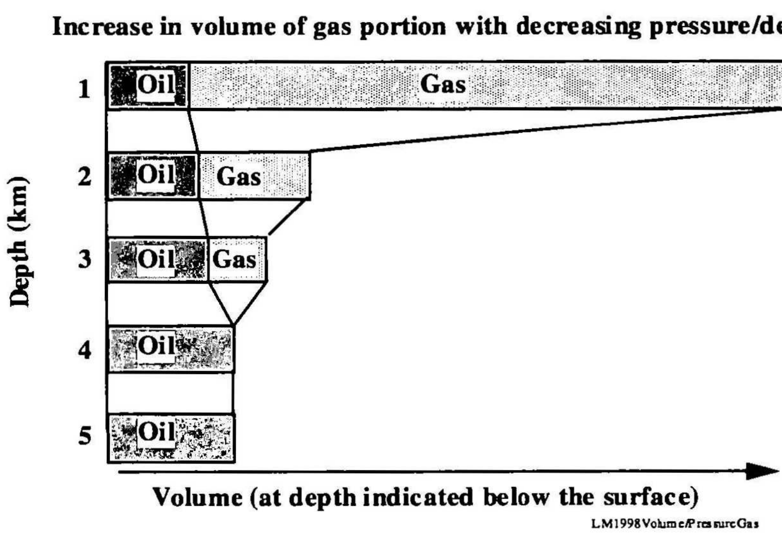
Before a company starts producing from their well, they need to determine whether it is economic to do so. In order to work out the viability, the reserves of gas and oil have to be estimated.

In order to calculate the amount of petroleum in a given field a number of factors must be considered. These include:

- the volume of rock in the trap,
- the percentage of reservoir quality rock,
- the percentage of pore space in the reservoir,
- the percentage of oil or gas in the pores,
- the recovery factor (usually 35-40% is left in the ground),
- and the change in volume of oil and gas as they ascend to the surface from depth.



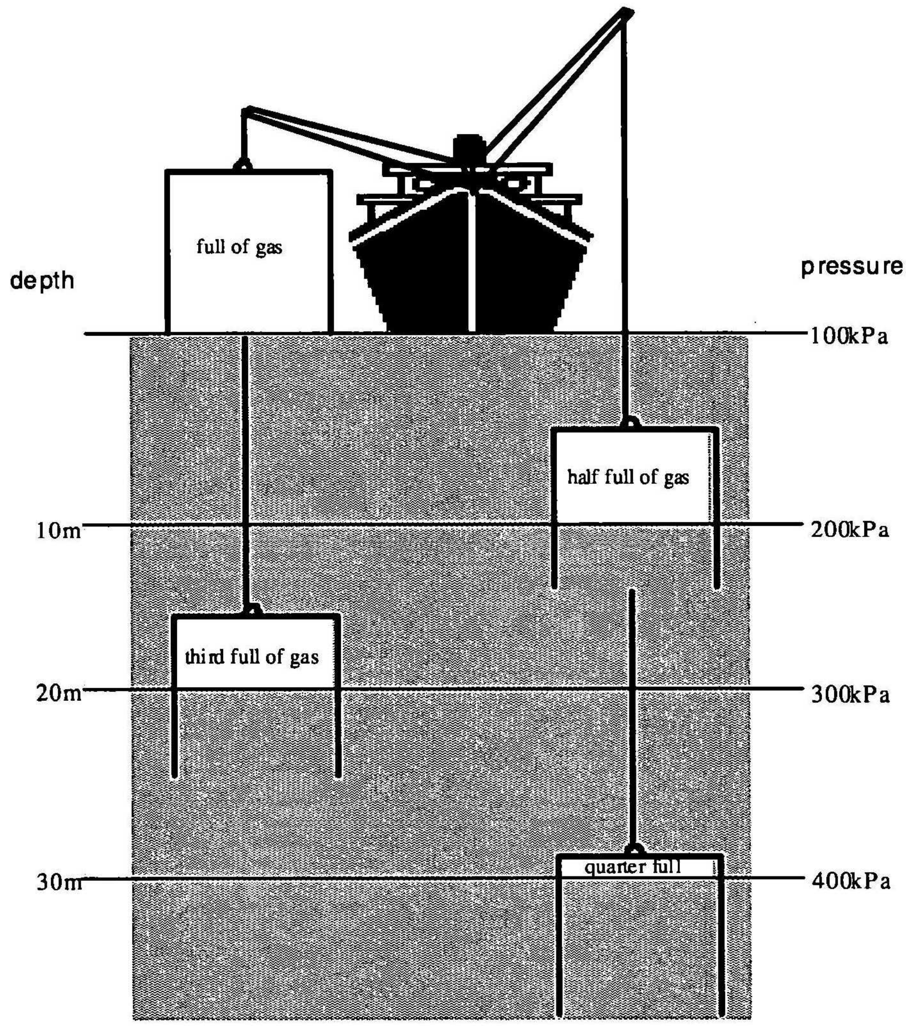
Oil shrinks—gas expands. There is a direct relationship between the volume of a gas and the pressure under which it exists. When extracting petroleum and calculating reserves, this principle must be considered. The volume that the gas takes up at 3 km depth will be less than the volume it takes up at shallower depths. This is due to the decrease in the pressure on the gas.



Supplied by Jim Preston BHP Petroleum

You will notice in the graph above that the oil that is present at 4 & 5 km depth suddenly becomes gas and oil at shallower depths. Just like sugar will dissolve in water and even more sugar will dissolve in a hot cup of tea; natural gas will dissolve in the liquid oil and more will dissolve as the pressure increases. This is why we see a large amount of gas at a depth of 1 km when there was pure oil at 5 km depth.

A different scenario, displaying the direct relationship between volume and pressure, is shown in the diagram. As a large bell is lowered in the ocean, the volume of air decreases because of the pressure increase with depth.



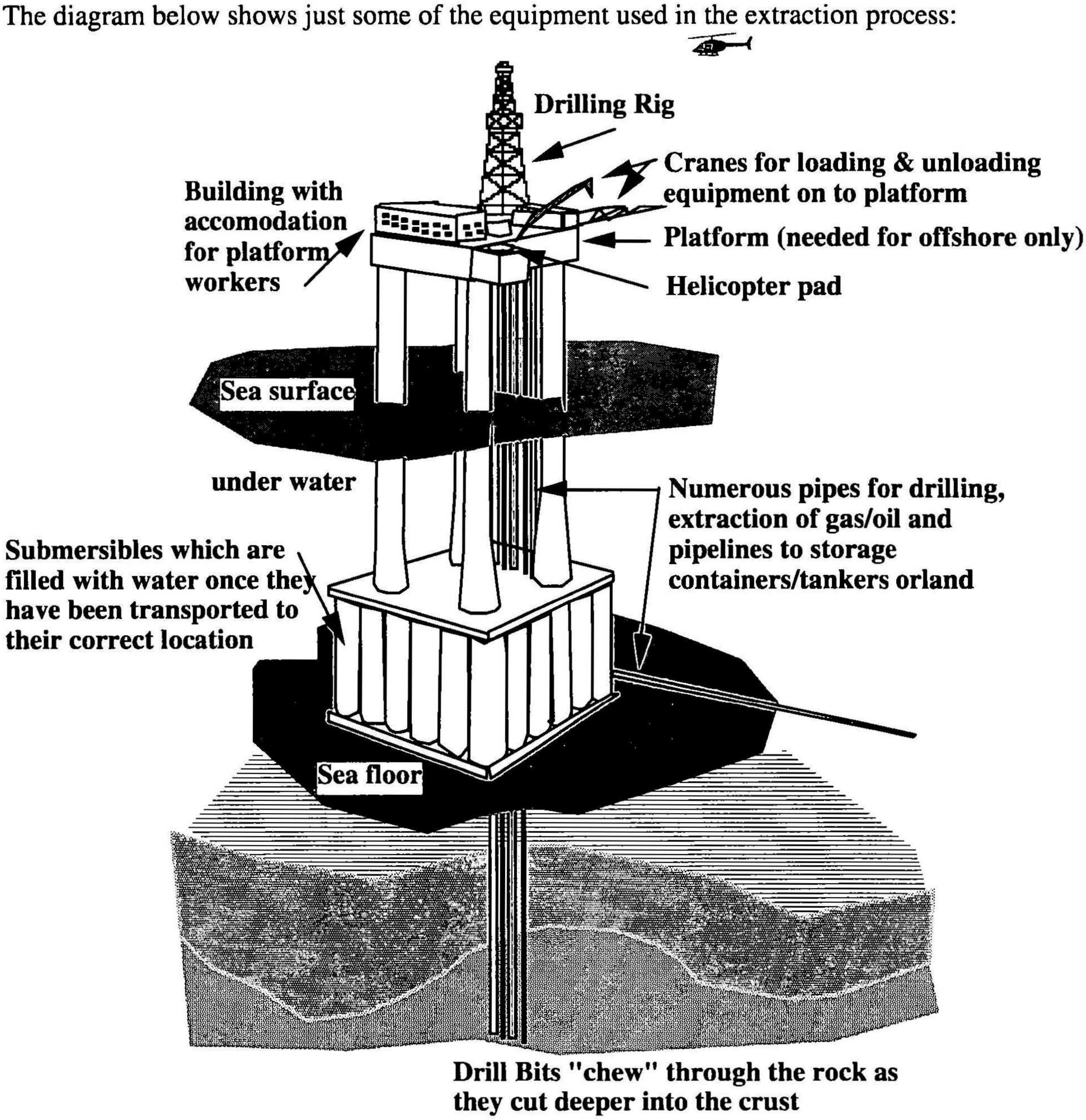
5. Extraction of natural gas

The extraction of large quantities of natural gas can only occur with appropriate, purpose-built equipment and the "cooperation" of the rock hosting the resources.

Equipment

Extracting the reserves of gas that exist under the ground is a complex technological feat. The machinery and equipment used at this stage is expensive. Exploration companies lease or purchase the necessary equipment.

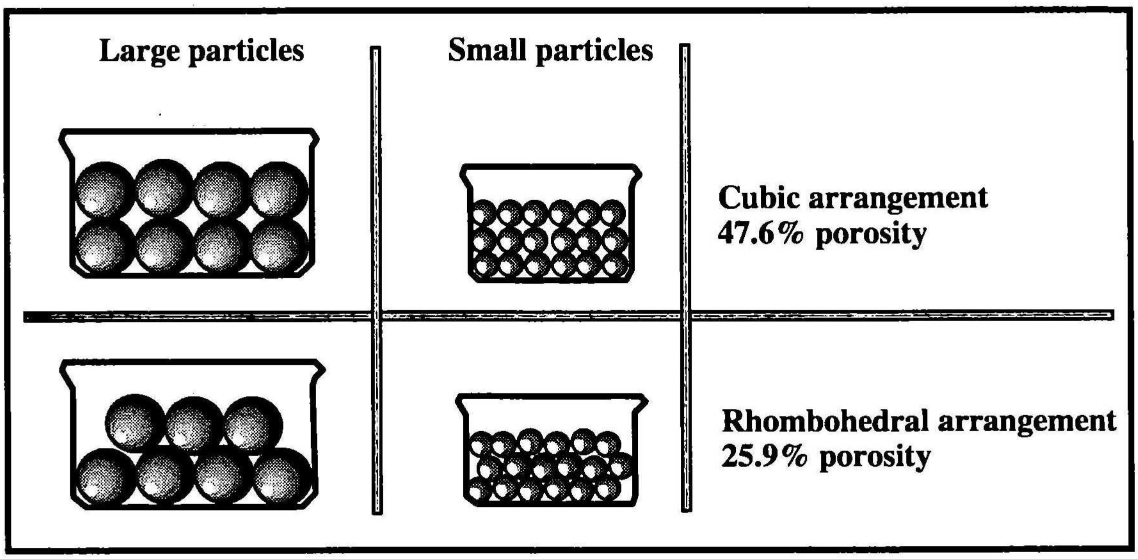
The diagram below shows just some of the equipment used in the extraction process:



A "well-behaved" rock

Even if natural gas is present in the rock and the equipment necessary for extraction is available, companies will only be able to extract natural gas if it is able to flow through the reservoir rock. The ability of oil and gas to flow through the reservoir rock into the well for extraction is determined by two factors, *porosity* and *permeability*.

Porosity. Porosity is the capacity of the rock to *hold* a fluid. The porosity of a rock is expressed as the percentage volume of non-solid (or fluid) portion of the reservoir divided by the total volume of the reservoir. The diagram below illustrates the concept of porosity.



In the diagram the particles in each container are all the same size. In reservoirs the particles of sediment that make up the rock are never all the same size and the actual porosity in rocks may range from 3% to 40%(rare) with the most common value being 20%.

Porosity tends to decrease in deeper, older layers. This decrease is caused by the weight of overlying layers and by particles becoming cemented together. In other cases porosity can be created and this is known as secondary porosity. It may be the result of fracturing, or the result of groundwater dissolving limestone. Secondary porosity enables fluids to flow through the reservoir more easily because pores or openings are much larger.

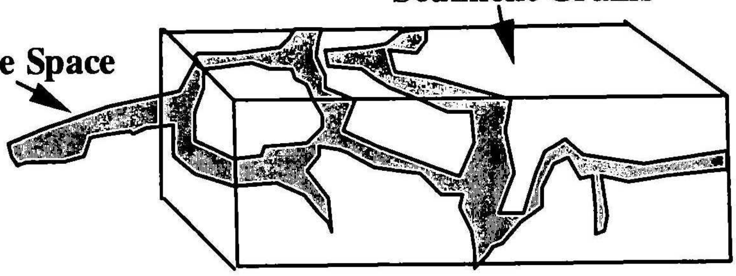
Permeability. The permeability of a reservoir describes the ability of a fluid to *flow* through the formation. If permeability is so low that the gas will not flow from the reservoir to the well the cost of extraction will be prohibitive. This occurred in the Mesa Verde gas field in Wyoming, USA. Millions of dollars were spent on the rich natural gas deposit, but the sands were too tightly packed to let the gas flow through.

The permeability is determined by several factors:

- viscosity of the fluid,
- size and shape of the formation,
- pressure on the fluid.

The unit of permeability is a *darcy*.[1] In most reservoirs, the average permeability is less than one darcy, so the usual figures are in thousandths of a darcy, millidarcies (md). The permeability of some rocks is listed below:

Fine-grained sandstone	5 md
Coarse sandstone (all grains the same size)	475 md
Coarse sandstone with fine grains	10 md



Permeability depends on the inter-connectedness of the pore spaces

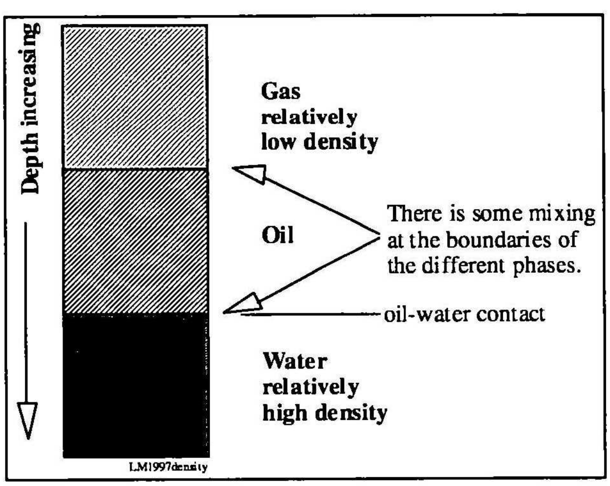
Like porosity, permeability decreases as depth of burial increases. The weight of the overlaying layers acts to compact the grains closer together. Another effect of depth is that cementation occurs. This is where ground water may precipitate the dissolved minerals it is carrying, reducing the amount of free space and the flow paths that the oil and gas would previously have had.

A reservoir that may produce great quantities at one depth, may be of no economic value at a greater depth if the petroleum cannot flow through the rock to the well.

The driving force. In addition to the characteristics of the rocks, a driving force must be present in the reservoir in order for flow to occur. In order to understand the force behind the flow we need to first understand the concepts of *pressure* and *gas saturation* in oil.

Pressure. The pressure of any gas is caused by the bombardment of the walls by the particles. The particles colliding with the wall exert a force on the wall which can be detected as the pressure of the gas.

Gas saturation. The gas, oil and water in a reservoir normally tend to separate. The gas is on top of the oil which is on top of the water due to their respective densities. At depth, however, gas may be dissolved in oil without maintaining separate layers.



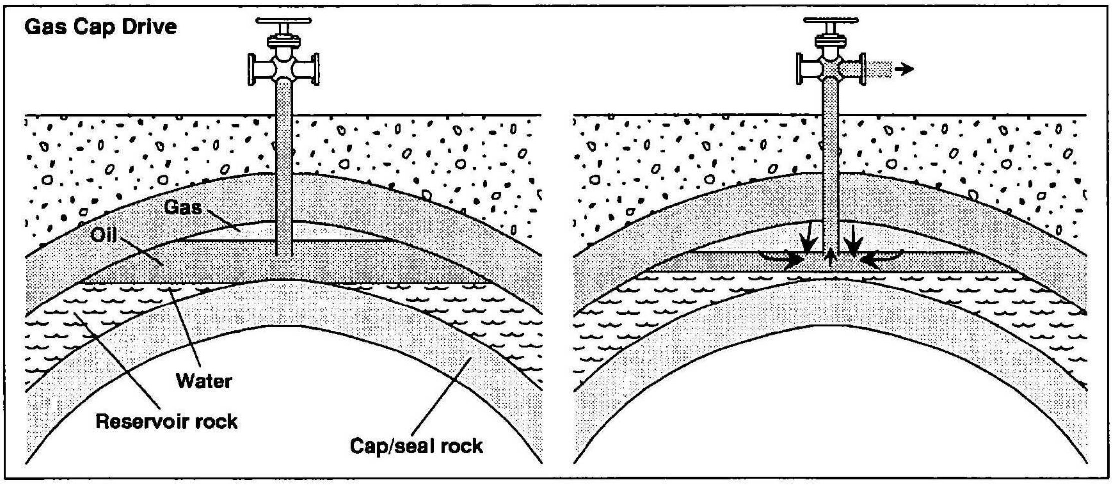
This is because of the effect of pressure on solubility. The amount of gas that will dissolve in oil increases as

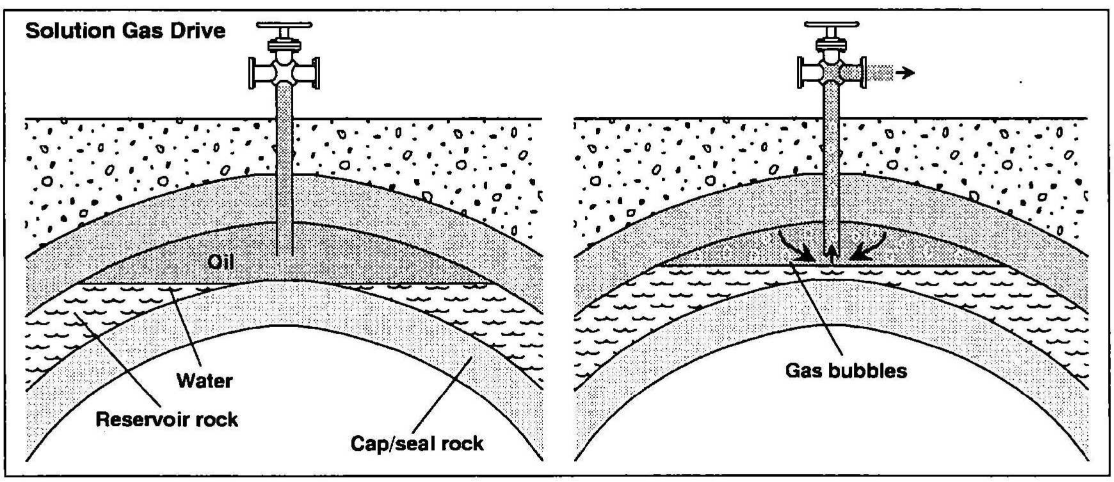
[1] One darcy is equivalent to the flow of 1 cubic centimetre per second of fluid with a viscosity of 1 centipoise (unit of thickness).

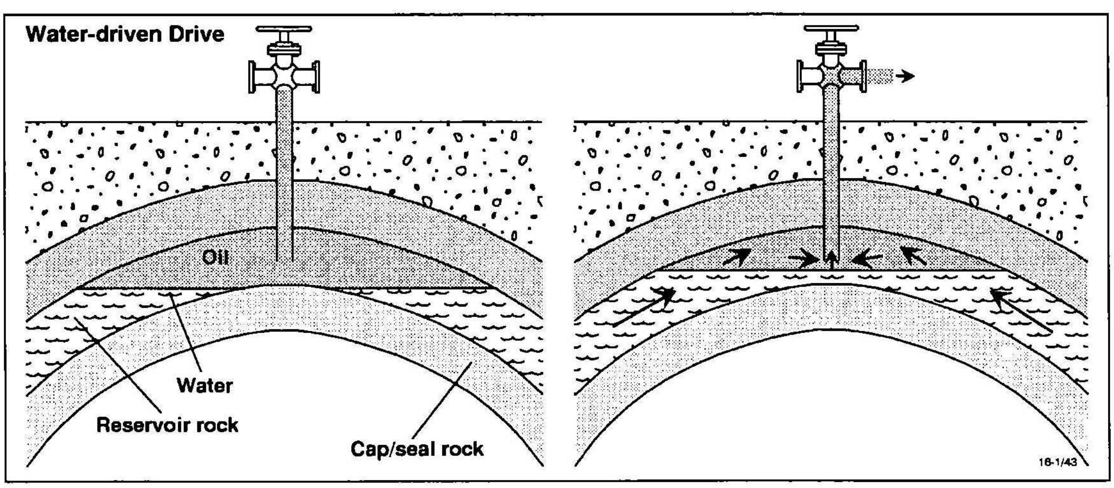
the pressure or depth increases. The amount of gas that will dissolve depends on the composition of the oil. When the oil can dissolve no more gas it is said to be saturated.

Depending on the pressure, you may have any one or a combination of the following scenarios:

- gas present within an oil layer (under-saturated in gas);
- gas and oil layers present because the oil is saturated with gas and excess gas is present;
- only oil present;
- only gas present.



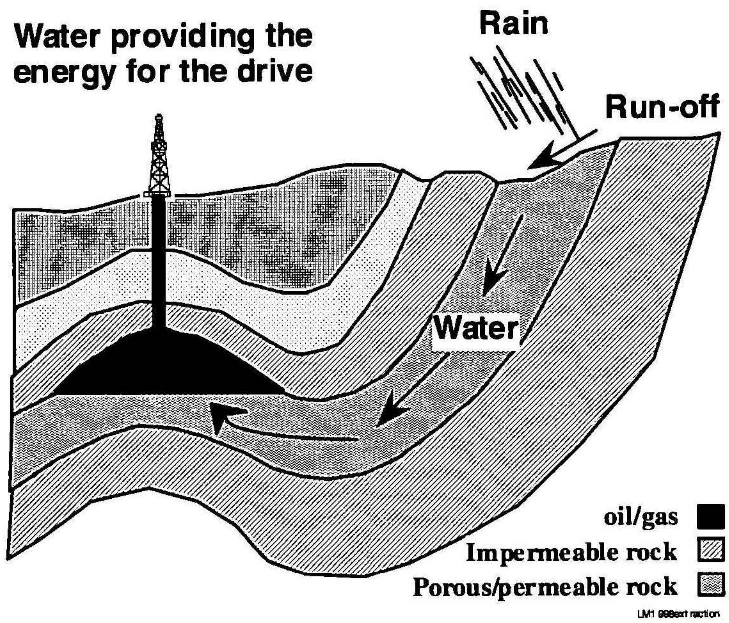




If gas is present, and no gas production wells are drilled into the gas, but wells are drilled into the oil, the gas will expand as the oil is tapped and it will push down on the oil, driving the oil to the surface. This is called a gas-cap drive.

If the pressure in the reservoir is so great that all of the gas is dissolved in the oil and no gas bubbles can form, when a well is drilled and the pressure is relieved, the gas will come out of solution and begin to form bubbles. As these expand their pressure will force the oil into the well and up to the surface. This is called a solution gas drive.

In a third type of reservoir, water provides the energy for the drive. The water is pushing up against the petroleum. As the petroleum is withdrawn, the water fills the spaces in the rock.



The water flowing through permeable rocks increases the pressure on the oil. Once the oil is drilled it provides a natural driving force for the oil to rise to the surface.

6. Australia's natural gas potential

Natural gas in Australia

Sedimentary basins suitable for gas and oil accumulation occur over a large part of continental Australia and along its continental shelf. The major ***gas*** (and associated oil) fields occur in the Carnarvon, Browse, Bonaparte, Cooper, Gippsland and Perth Basins. The locations of the sedimentary basins hosting the major gas deposits in Australia are shown in chapter 8. Large ***oil*** fields have been found in the Gippsland, Carnarvon, Browse and Bonaparte Basins. Other smaller oil fields exist in the Amadeus, Otway, Perth, Canning, Cooper-Eromanga, Browse, Bowen, Surat and Carnarvon basins.

The key natural gas production areas in Australian states are:

- Victoria—The Gippsland Basin supplies over 98% of Victoria's natural gas. The rest comes from gas reserves at Port Campbell in Western Victoria (supplying to Portland and Warrnambool) from the Otway Basin.
- Western Australia—The Carnarvon (North West Shelf) and Perth Basins provide most of Western Australia's gas supply. The gas fields that are located in the Carnarvon Basin are the Goodwyn, North Rankin, Tubridgi, Harriet and Griffin fields.
- South Australia—The Cooper/Eromanga Basins and the Otway Basin are the main production basins for South Australia.
- Queensland—There are 4 main gas production areas in Queensland, located in the Bowen/Surat and Cooper/Eromanga Basins. These areas are called Roma, Silver Springs, Kincora and the Denison Trough. Queensland also has large reserves of coal seam methane. Supplies of this are expected to last at least several hundred years at current rates of gas consumption.
- Northern Territory—The Amadeus Basin in central Australia contains the Mereenie and Palm Valley gas fields, the first to be discovered in the Northern Territory in the 1960's. Off-shore in the Bonaparte Basin lies the Bayu/Undan gas and condensate fields. The Petrel and Tern gas fields, also in the Bonaparte Basin, could also supply gas to the NT.
- Tasmania— Tasmania has potential reserves of natural gas at the Yolla field in Bass Strait.
- New South Wales—Although it has no large gas fields, it may not always be entirely dependant on natural gas supplies from interstate. There are substantial reserves of coal seam methane in NSW, mainly in the Sydney and Gunnedah Basins.

Australia's natural gas resources and reserves.

Australia is relatively unexplored for natural gas. Natural gas has previously been viewed as second prize in the search for oil. However, it is proving to be Australia's fastest growing energy resource.

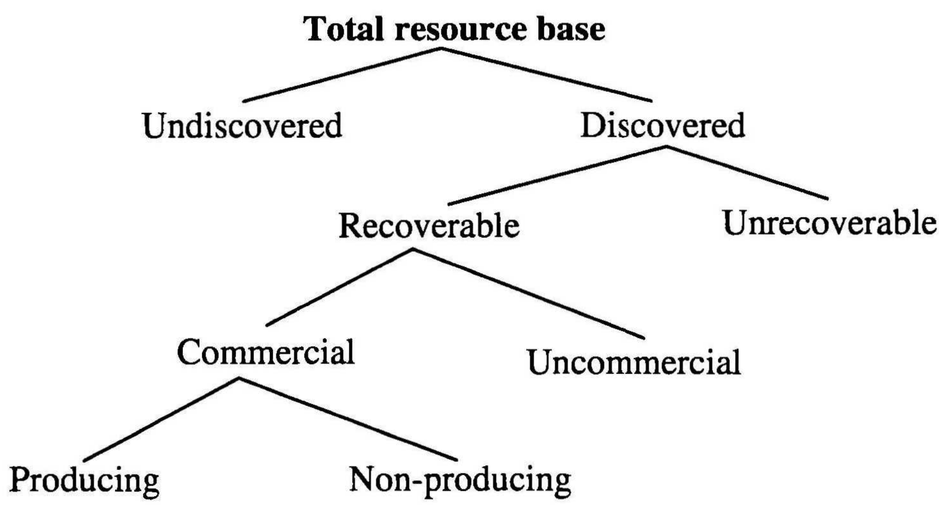
The search for gas has, up until recently, concentrated on the sedimentary basins on the continent and ***shallow*** continental shelf. However, it will take many discoveries to supply Australia's demand in the future, so exploration companies are now looking in deeper offshore areas in the hope of finding more and larger fields. This has been made possible by the development of deepwater drilling and recovery methods. Current technologies allow drilling in ***water depths*** approaching 2000 metres. Further discoveries are also being made in basins considered well explored because of the advent of new exploration technologies.

Very large gas fields have been discovered on the North West Shelf at water depths of over 100 metres. Exploration in deeper water (800 to 2000 metres) on the Exmouth Plateau has discovered large reserves of gas, but very high development and operational costs involved in recovery from water depths of 1000 metres, 200 km offshore make the resource uneconomic to develop at the present. It is estimated that the basins of the North West Shelf contain most of Australia's undiscovered gas reserves and about half of Australia's remaining undiscovered reserves of oil.

The level of reserves is affected by a number of different factors, such as exploration successes and production technology. It is not possible to predict the ultimate level of Australia's gas reserves, but experience here and overseas suggests that there will be significant additions in the future.

There are a number of different categories of gas reserves:

Categories of Gas Reserves



In calculations of Australia's reserves, undiscovered resources are included. This is done using an average level of reserves that have been discovered in the past. The reserve estimates are all highly conservative and include only basins that are currently producing.

Australia's Natural Gas Reserves (1998)
Source: Oil and Gas Resources of Australia.

Basin	**Billion cubic metres**	**Trillion cubic feet**
Adavale & Amadeus Basins	0.54	0.02
Bonaparte Basin	10.48	0.37
Bowen Basin	2.74	0.1
Carnarvon Basin	530.16	18.72
Cooper/Eromanga Basins	77.92	2.75
Gippsland Basin	133.70	4.72
Otway Basin	0.75	0.03
Perth Basin	4.33	0.15
Surat Basin	0.71	0.03
Total	**761.32**	**26.89**

Coal seam methane reserves and resources

Gas is also found on the continent, where it is trapped in coal seams. Being natural gas, it is composed primarily of methane, thus the name coal seam methane. It is a potentially valuable gas resource and Australia is estimated to have the fourth largest reserves in the world (behind Russia, Canada and China). At present, coal seam methane is being supplied from the Bowen Basin in Queensland to residential, commercial and industrial customers in Brisbane, Toowoomba and on Queensland's south coast. Other potential coal seam methane resources have not been brought to production because they cannot currently compete with other more economic energy sources. It is, however, a potentially valuable gas resource in Australia.

The major coal basins in Australia which have the potential for coal seam methane production are located in New South Wales and Queensland and include the Galilee, Bowen, Surat, Clarence-Moreton, Gunnedah, Sydney and Gloucester Basins. Some coal deposits in Western Australia may also contain gas resources. But we do not yet know for sure whether these coal basins will be able to produce coal seam methane.

Issues. There are a considerable number of questions which will need to be addressed before coal seam methane becomes a commonly used fuel. One of these questions that is particularly relevant to the Sydney Basin is the issue of competing land uses. It has been suggested that the coal seam methane resources of the Sydney Basin could meet Sydney's gas needs for between 60 to 180 years (Warren Centre, 1994). However, some parts of the discovered resources may not be able to be accessed due to the presence of office buildings, road and suburban developments and national parks. Other barriers to coal seam gas production include cost of production and environmental issues. A potential environmental problem is the disposal of groundwater from coal seam wells. Groundwater is extracted along with gas from coal seams and it is costly to reinject it into deep aquifers. The cost of treatment of groundwater to make it of useable quality has to be factored in when determining the cost of production.

The future

Australia's reserves of ***fossil fuels*** will keep us going well into the next century. The lifetime of total world ***gas*** reserves is currently estimated at 66 years; ***crude oil's*** estimate is 42 years. Other figures estimate that the amount of recoverable gas, oil and coal, is sufficient to last another 170 years at current consumption rates. How long our reserves will last is obviously debatable, but we do know that there is a limited amount of these resources. What is also known is that we have continued to discover more reserves, beyond what was predicted even 20 years ago. It is certain that we will continue to make more discoveries and as new technologies become available known deposits that we have been unable to extract will become accessible and, eventually, economic. In the meantime considerable effort is being directed towards the development of renewable energy sources like solar and wind power. This provides the opportunity to reduce our reliance on fossil fuels over a period of time.

Gas hydrates—eastern Lord Howe Rise

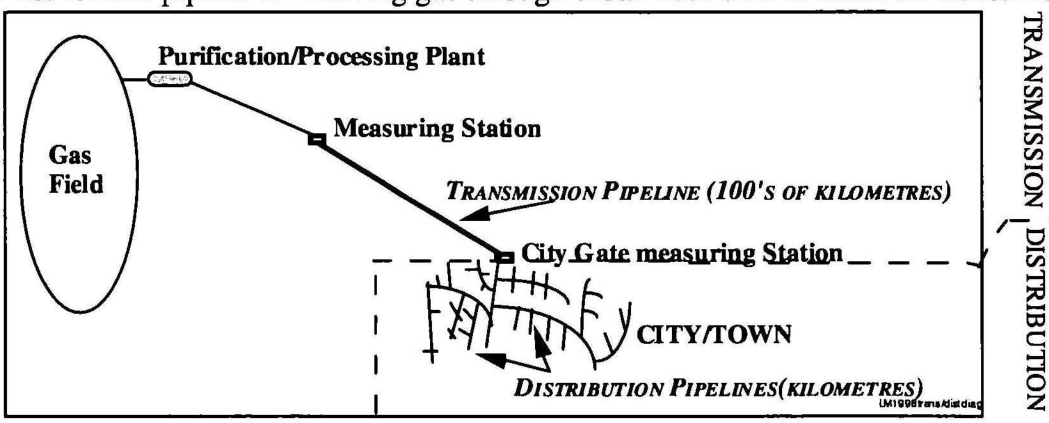
Gas hydrates may be an enormous source of natural gas in the future. Gas hydrates are ice-like crystalline solids formed from mixtures of water and gas. 1 cubic metre of hydrate can yield 164 cubic metres of methane, which is 2 to 5 times greater than the methane produced from conventional gas reservoirs at similar pressures. Gas hydrates have been known to chemists since 1810 and first became of interest to the petroleum industry in the 1930's when it was realized that hydrates can block pipelines. Some estimates suggest that the total amount of gas hydrates worldwide contains twice the amount of carbon in all known oil, coal and natural gas reserves together.

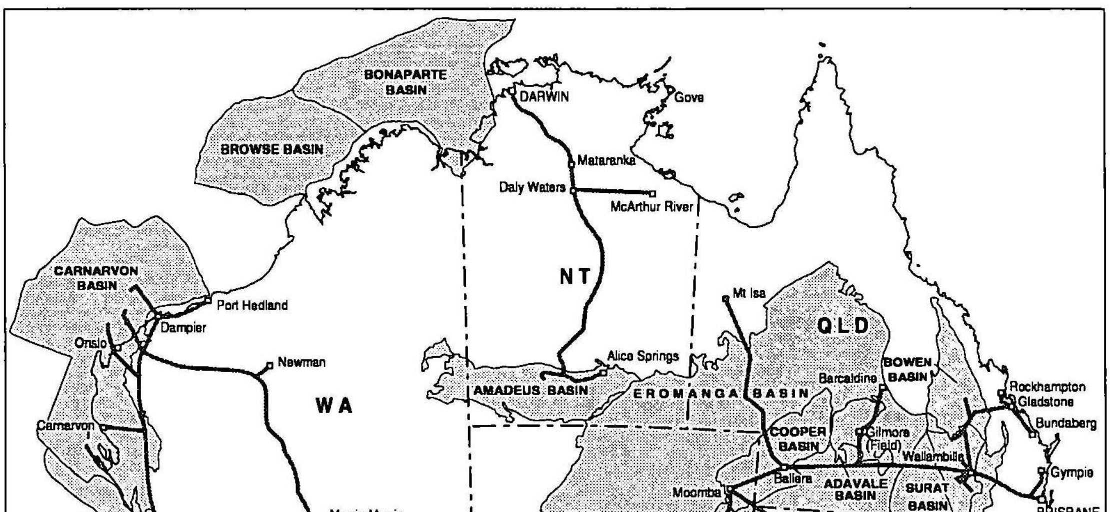
The Australian Geological Survey Organisation's R.V. Rig Seismic collected data resulting in strong indications of this gas hydrate deposit on the Lord Howe Rise. The deposit is of particular interest because of its immense size, its open location and its shared national ownership. (Exon, N.F. et al, 1998). *The technologies enabling extraction of this resource have not yet been developed. It is estimated that it will be at least 70 years before we will be able to successfully extract gas hydrates.*

7. From the well to the user

Once it has reached the surface, natural gas is transported by pipelines from the well to the processing plant. Before the gas is transported from the gas field it is purified to remove unwanted chemicals such as carbon dioxide and water. Where the gas is to be transported overseas it is changed to liquified natural gas. On land, the transportation of natural gas from the purification plant to the consumer occurs through pipelines. The two types of pipelines involved are:

- Transmission pipelines—hauling large volumes of gas over large distances from the processing plant to the city gate.
- Distribution pipelines—moving gas through urban networks to reach the consumer.





Australia's transmission pipelines

Transmission pipelines

Natural gas pipelines did not appear in Australia until the late 1960's. The pipelines that exist in Australia covered 15,600 km in 1998. Apart from Tasmania, which does not have any recognised available natural gas, and NSW and the ACT, which source their natural gas from interstate, all other states source their gas mainly from within their own borders or from reserves in deposits located on the continental shelf (offshore).

Materials, installation and maintenance. Natural gas transmission pipelines are constructed from high tensile strength steel, which has the desirable properties for gas transportation under high pressures. Being steel, however, it is subject to the effects of corrosion or rusting. Pipelines that are installed are generally protected from corrosion by coatings and cathodic protection (see box below).

The installation of transmission pipelines generally follows these steps:

1. Fencing—where temporary gates are constructed in fences in rural areas.
2. Clearing and Grading—where needed so that access is made possible.
3. Trenching—excavation of the trench for the pipe.
4. Pipe stringing—distribution of the pipes along side the trench for welding.
5. Pipe bending—to accommodate sharp changes in direction, vertically or horizontally.
6. Welding—individual pipe lengths are welded together to form a string.
7. Joint coating —cleaning and priming of pipe surfaces and application of a joint coating material
8. Lowering in—to the trench.
9. Backfilling—carried out shortly after placement of padding.
10. Clean-up and restoration—compacting the backfill and restoring original ground contours. Topsoil is spread from the stockpile created at step 2 and reseeding and fertilising is carried out to enable regrowth of vegetation. Warning signs and aerial markers are erected and fences restored.
11. Hydrostatic testing—the pipe is filled with water and pressure tested and any leaks repaired.
12. Commissioning—gradually bringing the pipeline up to operating pressure.

What is cathodic protection?

*When any metal is buried underground it is surrounded by soil/earth materials (containing salts) and exposed also to ground waters containing oxygen. In order to corrode (chemically break down) a metal the necessary ingredients are salt, water and oxygen—so shallow burial is the perfect environment to create rust. However, certain metals will corrode in preference to other metals. The list of metals arranged in order of most easy to corrode to most difficult is called the **Activity series of metals.***

Easiest to corrode ◁———————————▷ **Hardest to corrode**

Aluminium	Zinc	Chromium	Iron	Nickel	Tin	Lead	Copper

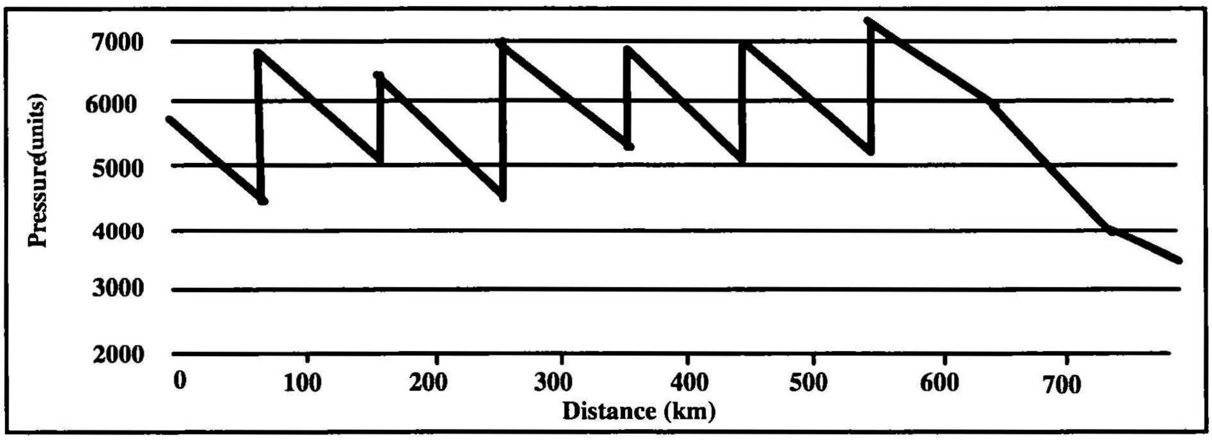
Steel is made up primarily of iron. When pipes have been placed in the ground, a metal that is more likely to corrode than iron is placed in contact with the pipe to prevent the pipe itself corroding. The metal being used for cathodic protection has to be monitored and replaced when it is no longer doing its job. In some pipelines, e.g. water pipelines, the iron is coated with a thin layer of zinc. Because the zinc is more easily corroded than iron it will protect the iron until all of the zinc has been corroded.

The condition of the pipeline is monitored throughout its lifetime. Instrumentation is installed with the pipelines so that measurements can be taken (temperature, pressure, flow rates), operations can be controlled (opening and closing valves, starting and stopping compressors) and cathodic protection systems can be monitored. The information recorded at the pipeline is transmitted to an operator using satellite or microwave data transmission systems.

How is gas made to move through the pipelines? In order to move gas through a pipeline, the inlet pressure has to be greater than the outlet pressure. The gas will move from higher to lower pressures. But as the gas travels along the length of a pipeline, its pressure gradually declines, mainly due to friction with the pipe wall. Many pipelines, particularly those of larger diameter have an internal lining, typically epoxy paint, which serves to reduce the roughness of the internal pipe wall surface and hence to reduce the pressure drop due to friction.

To increase the pressure in a pipeline—in order to increase the amount of gas flowing—compressors are used to boost the pressure. Maximum efficiency is achieved by operating pipelines at their maximum allowable operating pressure.

ACTIVITY IDEA



Here is a graph of the effect of compressor stations on the pressure of the gas flowing through the Moomba to Adelaide Pipeline.

Question. Where are the compressor stations located?
Answer. At approximately 70km, 180km, 270km..... from Moomba.

Gas in the transmission pipeline. The amount of blood you have in your body includes all of the blood flowing to and from your heart through veins and arteries. In the same way, the amount of natural gas available includes the gas that is actually in the transmission pipeline. Given that these pipelines traverse enormous distances and contain gas at high pressures, the pipelines are considered as a type of storage vessel. The amount of gas stored in a pipeline is referred to technically as "linepack". The longer the pipeline and the greater the diameter and pressure, the greater the linepack.

During periods of very high demand for gas (e.g. evenings in winter in cold climates), the quantity of gas being drawn from a pipeline may exceed the quantity being received into the pipeline from the purification plant. The balance can be made up from linepack. Similarly if breakdowns occur some linepack may be available to maintain gas deliveries until repairs can be made.

The $ cost of transmission pipelines. The economics of pipelines are largely determined by the trade-off between pipeline construction costs and compression costs. A given flow can be transported either by a larger diameter pipe (which will involve higher construction costs but lower compression costs) or a smaller diameter pipe (which will involve reduced construction costs but additional costs for the purchase, installation and operation of compressors).The value of the existing transmission pipelines in Australia is billions of dollars. New Australian pipeline proposals, totalling 11 000 km, require an investment estimated at $6 billion.

Benefits and impact of transmission pipelines. The impact on society and the environment of the transmission pipelines occurs during the construction phase. It typically takes little more than a month from clearing and grading to the commencement of restoration. Before this can actually occur in some cases the corridor of land may need to be acquired by the pipeline owner. Local indigenous groups and landholders are consulted to ensure the protection of native title, culture and heritage along the length of the pipeline. A vital aspect of planning the pipeline route is the impact of its construction on the environment and the native flora and fauna.

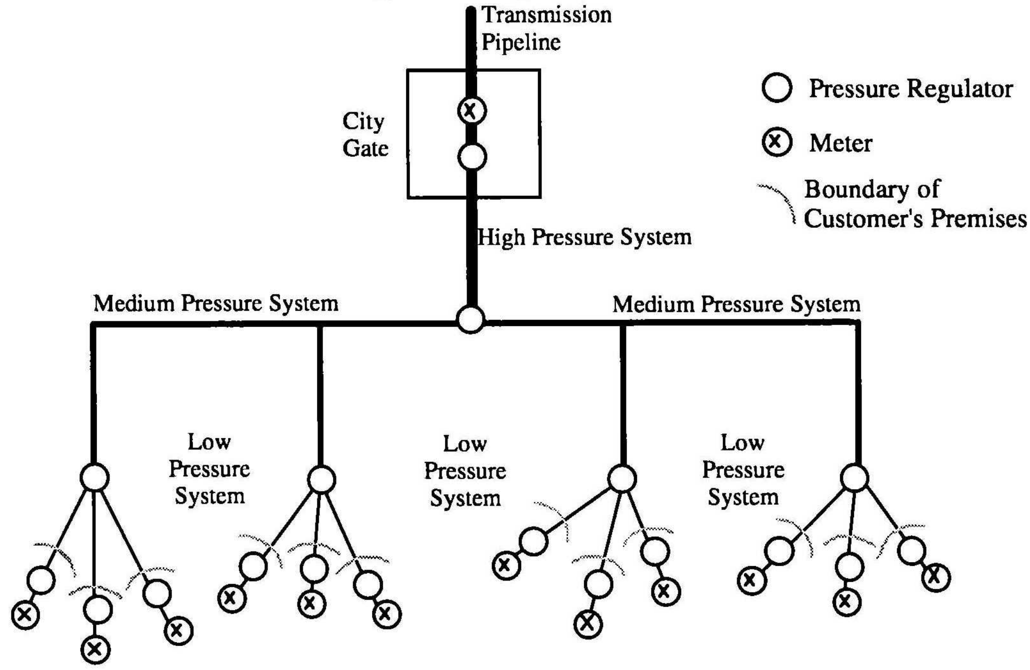
For the Mt Isa pipeline in Queensland, the final route was much further to the east of the initial route. This was in order to avoid areas inhabited by the bilby—one of Australia's rare endangered species. Construction was not carried out at night-time to accommodate the nocturnal nature of the bilbies. Avoiding the bilby habitats meant the pipeline zig-zagged for about 50 km, though this is not regarded as unusual.

Once they have been installed, pipelines carrying enormous quantities of natural gas to city gates are unobtrusive. In fact most people don't know the transmission pipelines are there!

Distribution networks

At city-gate stations the pressure is usually reduced before gas enters local distribution networks. From here the natural gas distribution industry takes over, distributing the gas to homes, offices, factories and service stations.

Schematic diagram of a gas distribution network



Natural gas distribution represents an important facet of Australia's energy delivery system. Gas networks are located beneath the ground, providing the means of safe, reliable and unobtrusive delivery of natural gas to existing and future end users. The main elements of a distribution network are:

- the gate stations where custody transfer of gas occurs;
- the distribution mains which carry gas from gate stations to end users;
- pressure regulating stations which control the pressure of gas entering sections of the network and also at the premises of end users, usually immediately before the gas meter;
- services which convey gas from mains in the street to the premises of end consumers; and
- meters which measure the quantity of gas entering a system and the quantity used by end users.

Gate stations. Gate Stations measure the quantity of natural gas energy entering and leaving a transmission system for the purposes of customer billing and gas balancing. By law, a small quantity of odorant must be added to gas entering distribution systems for safety reasons. The substances used are compounds containing sulphur, usually mercaptans, which possess a characteristic odor.

Large industrial customers are frequently supplied directly from transmission pipelines or from the high pressure steel mains of distribution networks.

Distribution network pipelines. Until the late 1960s distribution networks were primarily built using cast iron pipes and unprotected and protected steel pipes. Nowadays steel pipe is coated and cathodically protected to prevent corrosion. Since the mid 1970s most mains laid have been either plastic (PE, PVC or nylon) or coated and cathodically protected steel. In addition to new sections of networks, plastic pipes are commonly used in mains replacement. Advantages of plastic pipes are that they:

- are inexpensive and light weight;
- exhibit high corrosion resistance;
- are easy to lay and join;
- can operate at higher pressure than cast iron pipes, thus permitting smaller diameter pipes;
- have lower maintenance costs.

Metering—the end of the line. Metering is necessary for billing purposes where custody transfer occurs such as when gas enters distribution networks and leaves them at the premises of end users. Developments are continuing around the world in the technology of meters themselves and of meter reading.

Typically, domestic and commercial meters are read manually. This process becomes costly when there are multiple meters or they are located in positions which are difficult to access. Some hard to read meters also may create a physical danger for the meter reader. As industrial customers require more detailed information which is supplied through flow computers, their meters are frequently read remotely via telemetery to a central data collection point.

Major advances are being made in automated meter reading. The range of technology embraces radio frequencies, fibre optics and smart cards.

How a gas meter works. What you see when you look at a gas meter is a box with two holes in it. One hole is the inlet pipe, the other is the outlet pipe. Inside the box you have a measuring device. The measuring device contains two "lungs" called bellows which fill up alternately. As one fills up two things happen, firstly the other bellow is forced to empty through the outlet pipe because of space limitations. Secondly, the expanding bellow turns a mechanical cog which registers how much has been transferred on the meter. The meter measures the volume of gas that is transferred and this is about 1 litre for each bellow. The units that a gas meter records in are cubic metres.

Liquefied natural gas (LNG)

Transportation of gas through pipelines is economic on land. To transport natural gas out of Australia it is converted to Liquefied Natural Gas (LNG). LNG is produced when natural gas is chilled to a temperature of minus 161.5 ºC , the temperature at which it liquefies. As a liquid, the product condenses to 1/600th of its normal gaseous volume and can be easily transported by ship.

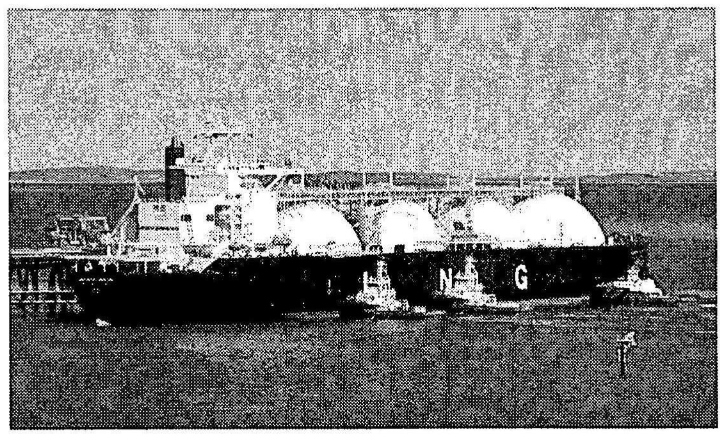
At its destination, the LNG is re-gasified for reticulation to homes and industries or for use as a fuel in power generation.

The clean burning qualities of LNG have made it an increasingly popular fuel, particularly for power generation, in countries wanting to reduce their Greenhouse emissions.

Since 1990, world trade in LNG has been growing at an average annual rate of around 6.8% including a 12.4% rise between 1995 and 1996. In 1997, total world trade was estimated at around 82 million tonnes.

Japan and South Korea are the two largest importers of LNG, accounting for 58% and 14% respectively. Combined with Taiwan's import quantity, Asia dominates world trade with over 75% of all imports. Asian and Australian exporters account for over 66% of all exports.

Australia exports LNG to a number of countries and transportation takes place in one of eight specialised tankers delivering Australian LNG overseas. Each of these tankers hold 125,000 cubic metres of LNG. That's equivalent to about 70 Olympic sized swimming pools.



Australia entered the world LNG trade with the first shipment from the North West Shelf to Japan in 1989.
Development of the massive North West Shelf Gas Project was a triumph for Australian engineering and construction. The project is based on substantial offshore gas reserves discovered in the Dampier Sub-Basin on the North West continental shelf in the early 1970s. Commencing in 1985 and extending over the next four years, the first two of an eventual three LNG processing trains, four LNG storage tanks and a loadout jetty were built. Following commencement of LNG exports to Japan in 1989, construction of the third LNG processing train was completed in 1992 and the Project's second offshore platform, Goodwyn A, commenced production in early 1995.

A fleet of eight LNG ships, specially designed to run on boil-off gas from their cargoes, was built to service the Australia-Japan LNG trade. Under 20 year contracts with the eight customers, LNG deliveries from the North West Shelf to Japan reached 7.5 million tonnes a year in 1997. Other "spot" sales of LNG have been made to Spain, South Korea, Turkey and the USA. Australian LNG is now set to play an even bigger role in the international gas industry. The North West Shelf venture partners are planning a major of the North West Shelf Project.

Australia is blessed with abundant gas reserves, particularly off its north and west coasts. There are also significant potential markets for this gas among the conveniently-located developed and developing economies of the Western Pacific Rim. In addition to the major expansion planned for the North West Shelf Project, a number of potential new Australian LNG projects are currently under consideration. These include development of the large Gorgon gas fields, located off the north west coast of Western Australia, and the Northern Australia Gas Venture which is investigating the feasibility of a large-scale domestic gas and LNG export project to be based near Darwin, in the Northern Territory.

Other Australian gas resources with potential for future LNG development include the Brecknock gas field in the Browse Basin off Western Australia, the Bayu/Undan deposits in the Timor Sea and, on a smaller scale, the Macedon gas resource off Western Australia.

8. How natural gas is used

Early prospectors were unaware of the uses of gas. When they found it along with oil it was normally burnt off. However, natural gas was used as far back as 2000 years ago, when the Chinese piped gas through bamboo tubes into their homes to generate light.

Prior to 1970, most of the gas used for Australian homes and industry was produced from coal or oil at the gas works near the city or town using the gas. As gas pipelines have been installed around the country, gasworks have closed down and natural gas has been piped from the gas fields. The use of gas in industries and homes increased in the 1970's and 1980's as oil prices climbed and gas prices remained relatively stable.

Uses of natural gas

Natural gas is used mainly in

- industry (57%)
- power generation (21%)
- households (16%)
- commercial sector (6%)
- transport (<1%)

Households. The major uses of energy in households are water heating, heating, cooking, which can be sourced from either gas or electricity and, refrigeration and lighting, which are almost entirely electric products.

Gas is the second most used energy source for households, electricity being the largest. The main applications of gas in households are cooking, heating and water heating. Other applications include barbecues (both natural gas and LPG) and pool heating. There is also significant research and development work occurring both in Australia and overseas, covering applications such as gas clothes drying, gas cooling and combined applications including gas/electricity and gas/solar products.

Hot water. There are two main types of gas hot water heaters: gas continuous flow units and gas hot water storage units. Gas continuous flow systems heat water as it is required and are compact as they do not require a storage area. The other main type of water heater is a gas storage hot water unit which stores heated water in a fully insulated tank that can either be internally or externally located. Centralised gas hot water units are also used in many medium density residential developments. Gas boosted/solar hot water units are also available to households.

Cooking. In recent times there have been improvements to the design and performance of gas cooking appliances including the introduction of gas wok burner hotplates and cookers, temperature controls and improvements in design and styling. At an international level there have been developments in gas cooking applications toward lower NO_2 hotplates in order to address the issue of indoor air quality. Electric glass/ceramic hotplates have been rapidly increasing in the market due to their ease of cleaning and aesthetic design. Similar gas hotplates have been designed with gas burners underneath a glass/ceramic panel. Development of a combination gas and microwave oven is also being pursued in Japan and is attracting considerable interest worldwide. Combination gas and microwave ovens enable exclusive gas cooking, exclusive microwave cooking and combination gas and microwave cooking. The combination cooking can heat foods from the inside with the microwave and from the outside with gas at the same time and reduce cooking time and save space.

Heating of space.

The main types of natural gas residential heating are:

- ***Central heating.*** Central heating begins with a single furnace (in the roof, under floor boards or outside the home) which heats air. The warm air is then circulated throughout each room of the home via small air vents. Evaporative cooling options are often added to these systems.

- ***Flued heating.*** Flued heaters are vented to the outside air, and as such the by-products of combustion are channelled to the outside air. Flued heating can be either radiant heating (e.g. gas log fire or gas pot) or convection heating where warm air is circulated via a fan.

- ***Portable heating.*** Natural gas portable heaters range from small to large. They are flueless and can be disconnected and stored out of sight in the summer.

- ***Hydronic heating.*** Hydronic heating systems use hot water as the radiant heat conductor. A natural gas storage or continuous flow unit provides hot water which is connected to a hydronic heating system that can have radiator panels, convector panels or skirting panels. This system is ideal for medium density and high rise developments and is used in schools and hospitals.

Recreational uses. Liquid Petroleum Gas been a major source for barbecues for a long time. Piped natural gas is now also being used for fixed barbeques in the home. Other recreational gas applications include swimming pool heating, spa heating, outdoor gas lights and outdoor patio heating.

Gas cooling. Gas cooling in Australian households is not common at present, but it is under development internationally. In Japan they have trialed natural gas cooling appliances which were to be introduced into the residential marketplace in 1998.

Clothes drying. The gas clothes dryer is an alternative to electric clothes dryers and already 20% of households in the USA are using the gas alternative.

Commercial sector. The commercial sector of the economy includes shops, restaurants, offices, hospitals, schools and universities. In this sector natural gas is used principally cooking, hot water, steam raising and space heating. More recently it has been used for electricity generation combined with heating (cogeneration).

Industry. The industrial sector is made up of the manufacturing, mining and minerals processing sectors.

The Australian and New Zealand Standard Industrial Classification System
Divisions relating to the industrial sector

Manufacturing	*Mining*
Food, Beverage and Tobacco Manufacturing	Coal Mining
Textile, Clothing, Footwear and Leather Manufacturing	Metal Ore Mining
Wood and Paper Product Manufacturing	Other Mining
Printing, Publishing and Recorded Media	Services to Mining
Petroleum, Coal, Chemical and Associated Product Manufacturing	
Non-Metallic, Mineral Product Manufacturing	
Metal Product Manufacturing	
Machinery and Equipment Manufacturing	
Other Manufacturing	

The main way gas is used in industry is in process heating, that is, heating a material that is undergoing a manufacturing process. Process heating applications include glass melting; heating and melting of metals; drying of minerals; foodstuffs and chemicals; liquid heating and incineration of wastes. Natural gas is used most by the metal products division—predominantly for use in alumina kilns and ore smelting; the chemical industry division—where natural gas and ethane are used as a feedstock for fertiliser, explosives, acid and plastics; the glass, brick and cement industries, where natural gas is predominantly used in kilns; and in the food, chemical, and paper industries, where it is used for steam production. Another important use of natural gas in the industrial sector is as a feedstock for the production of ammonia-based fertilisers, methanol and hydrogen.

Making fertiliser from natural gas!

One of the lesser known uses of petroleum is the production of ammonia, NH_3. Chemically, ammonia is a compound of nitrogen and hydrogen. Nitrogen is one of the main constituents of the atmosphere, while hydrogen is taken from hydrocarbons. Ammonia is the world's second largest synthetic chemical product (the largest is sulphuric acid, H_2SO_4). Something like 1.6% of the global consumption of fossil fuels goes into the manufacture of ammonia. Ammonia is used to produce high-nutrient fertilisers such as urea. Ammonia also provides a base material for making explosives and a range of other manufactured products. The most popular way to produce ammonia is from natural gas.

Natural gas is the preferred source for the production of ammonia for 3 reasons :
1. It is the most hydrogen rich of all the possible sources. Natural Gas is made up mainly of methane, CH_4, in which for every one carbon atom there are four hydrogen atoms. Other sources include naphtha, LPG, fuel oil, coal and coke.
2. It is more expensive to convert 'heavier' sources such as naphtha, LPG and fuel oil because they are more complex.
3. Natural gas is the most readily available, easily deliverable and therefore the most favourable priced source.

Gas is also used in the industrial sector for space heating and cooling.

Transport/vehicles. Natural gas can be compressed and, therefore, it can be used very efficiently in place of petrol to power cars and trucks.. The use of natural gas in transportation is only in its infancy and it is expected to increase as new technologies and environmental considerations come in to play in the future.

Power generation. Natural gas is used for power generation in

- power station turbines,
- cogeneration plants.

Cogeneration is the combined production of heat energy(steam) and electricity from the same fuel source. The steam can be used to drive a turbine to produce more electricity instead of being wasted. Cogeneration is not new technology. It has been used for nearly 100 years in a variety of applications.

Applications of cogeneration are found in building complexes such as hospitals and in a range of industrial plants such as oil refineries.

Natural gas is the preferred fuel for cogeneration systems because of its availability, competitive price, ease of handling and its environmental advantages. A number of waste sources can also be used for fuel, for example, agricultural wastes, landfill gas from garbage dumps (biogas), waste heat from industrial processes and coal and oil products and LPG are used in some cogeneration plants.

Biogas

Gas may also be produced as a by-product from garbage tips—biogas. Biogas is also known as 'swamp gas' or 'marsh gas' and it can be burnt like natural gas to provide heat for homes, commerce and industry. It is produced when animal waste or other organic material rots in the absence of oxygen. This can happen where rubbish has been buried underground. It also happens in the digestive systems of humans and animals when bacteria break down food.

This natural process can be copied to provide us with an energy source. The most common material used to produce biogas is manure produced by livestock. After a 'digestion' process takes place the biogas produced is collected and stored in a tank for later use. Naturally occurring biogas is sometimes found where organic matter decomposes underground, particularly in garbage tips. The biogas can be trapped in large pockets in tip material. It is collected by inserting pipes into the pockets (not unlike petroleum extraction). In Victoria, this method is being used to generate electricity for homes and factory use. The biogas is mainly methane (a greenhouse gas). By using this gas we reduce the more active greenhouse gas—methane—and convert it to carbon dioxide—which has a lesser greenhouse impact.

Estimates predict cogeneration will be able to save up to 30% of the fuel that would be required to produce the same amount of energy separately. This will also result in a similar reduction in the amount of CO_2 (greenhouse gas) emitted.

Natural gas is a fuel

The reason natural gas is such a useful fuel is due to its transportability, cost, efficiency and cleanliness.

All fuels have measurable fuel values. The table below compares the fuel value of natural gas with the fuel values of some other common fuels, including food.

Fuel values of some common fuels

Approximate composition	*Fuel value kj.g^{-1}*
Apples	2
White bread	10
Rump steak (grilled)	12
Roasted peanuts	24
Butter	30
Wood	18
Black coal	30
Brown coal	11
Charcoal	34
Petrol	48
Natural gas	50
Ethanol	30
Methanol	23

The units used for fuel value are kilojoules per gram. The fuel value gives the number of kilojoules produced per gram of substance consumed. The SI unit of energy is the joule (J). One thousand joules is equal to one kilojoule. To appreciate the size of a joule, a 100 Watt light bulb produces 100 J of energy each second that it is on.

It is clear from the data in the table above, that natural gas and petrol give the most energy per gram of substance burnt. This is one reason why they are the most commonly used fuels.

What happens when we burn natural gas? We all know that in order to burn something, or have a flame, air is required. More particularly, the oxygen portion of air is essential to support combustion. So when natural gas is burnt, it reacts with oxygen in the air. The products are carbon dioxide and water. This can be represented by a chemical equation as follows:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

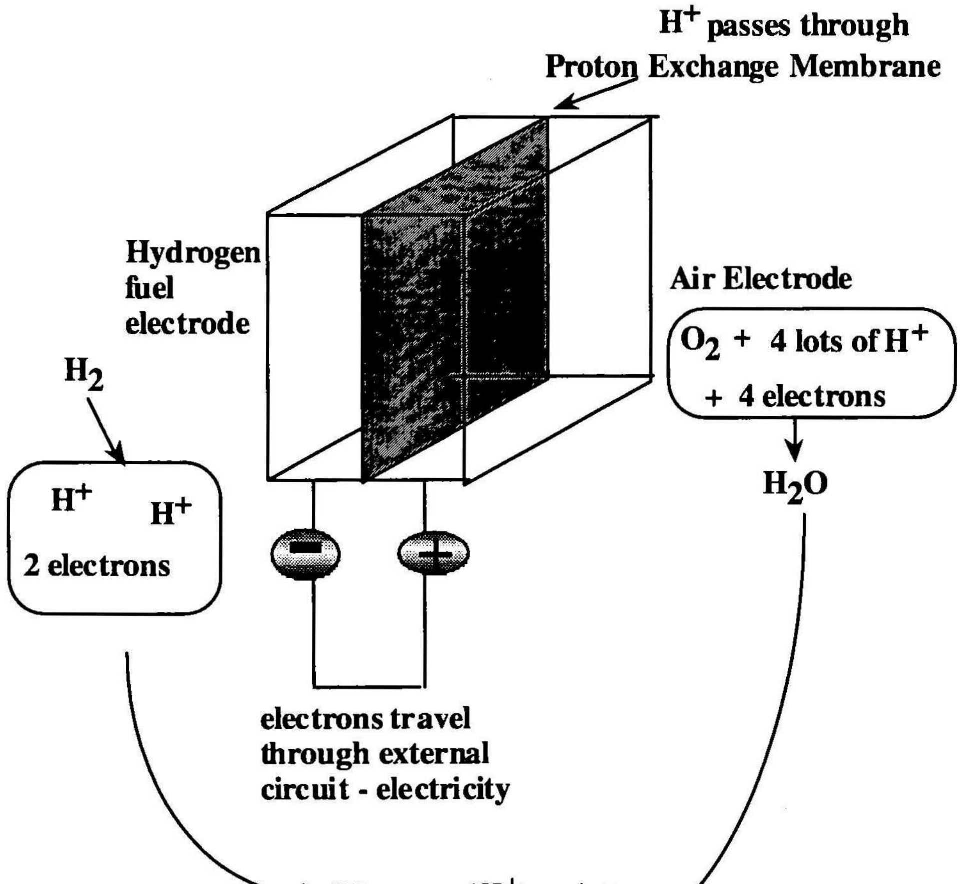
Natural Gas(Methane) + Oxygen → Carbon Dioxide + Water

The process changes methane, a more active greenhouse gas, into carbon dioxide, which is relatively less active as a greenhouse gas.

Future technology using natural gas—fuel cells. In a fuel cell, a chemical reaction corresponding to combustion takes place, but no burning actually occurs. The chemical energy is converted into electricity. Natural gas is used to supply hydrogen which is one of the two fuels needed for a fuel cell. Methanol, gasoline or pure hydrogen can also be the source of hydrogen. Hydrogen fuel and oxygen from the air are combined electrochemically in the fuel cell. Electricity is produced along with the by-products heat and pure water vapour.

How it works. Two electrodes (an electrode is like the positive/negative terminal of a normal battery), each coated with a platinum metal (a catalyst) are bonded to an electrolyte called a proton exchange membrane (PEM). Hydrogen fuel passes over the fuel electrode and separates into electrons and protons. The protons migrate through the PEM to the air electrode where oxygen from the air, O_2, combines with the protons, H^+, and the electrons from the external circuit to form water, H_2O. The electrons are conducted through the external circuit and create useable electric current.

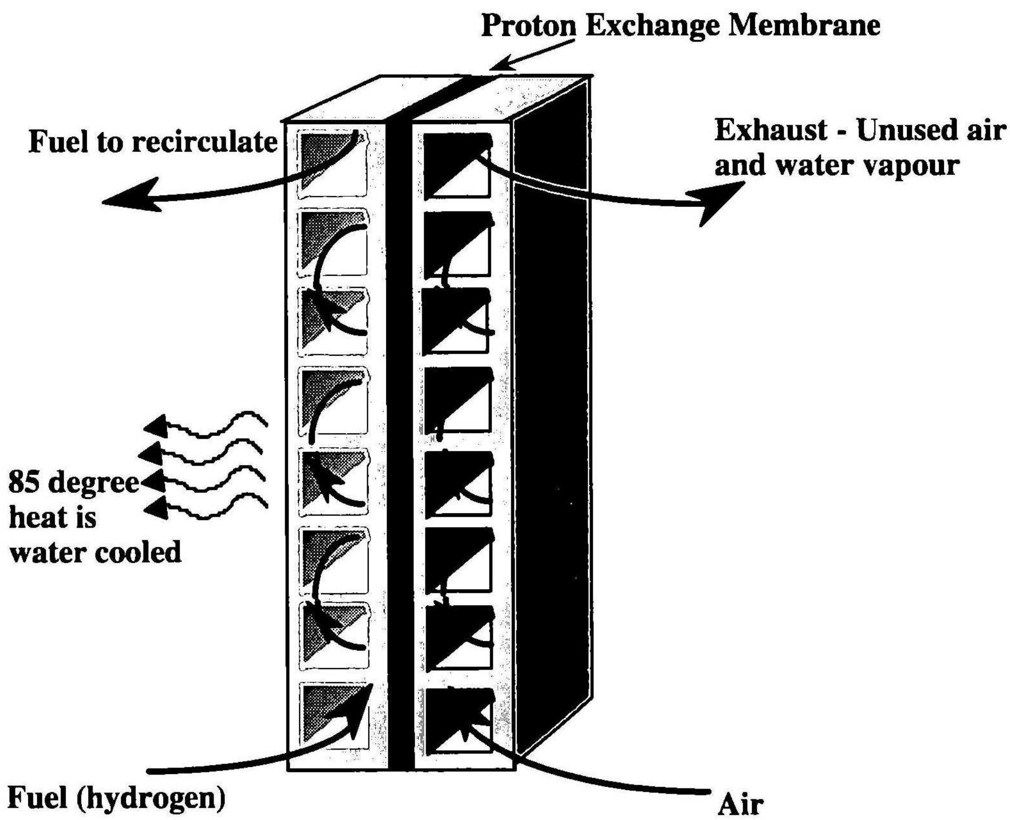
When a series of cells are stacked together, this increases the voltage. The more cells—the more power.



$$2H_2 \longrightarrow 4H^+ + 4e^-$$

$$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$$

Overall: $2H_2 + O_2 \longrightarrow 2H_2O$ + electric energy



How do fuel cells differ from internal combustion engines and batteries?

Internal combustion engines (ICEs) operate by burning fuel to create heat. This heat is then converted into mechanical energy and then kinetic energy, or by turning a generator into electrical energy. The efficiency of this conversion process is affected adversely by losses of heat and friction. Fuel cells are up to two to three times more efficient than ICEs because they convert the fuel directly to electricity. Unlike ICEs they do not burn fuel and therefore do not produce air pollutants and emissions resulting from combustion.. Like an ICE fuel cells use fuel from a tank that can be quickly refuelled and they operate continuously as long as fuel is supplied.

Batteries are used to store energy. Battery electrodes store the fuel that will produce the electricity via chemical reactions. As the battery is used the fuel in the electrodes will eventually be consumed and the battery will go flat. In order to recharge the battery, electricity needs to be passed into the battery to reconstitute the electrodes. Both batteries and fuel cells are electrochemical (non-combustion) sources of electricity, they have high efficiency, quiet operation and none of the emissions from combustion. However, batteries do need to be recharged and rely ultimately on central power plants to create the electricity to recharge them.

Fuel cells operate continuously as long as fuel is supplied (natural gas, methanol, gasoline or hydrogen). Their power density is sufficient to power an automobile, they can be refuelled just like an ICE and because they have no moving parts they have good reliability and long operating lives. In the future it is likely we will see fuel cells being used more and more for a variety of applications.

Applications of fuel cells

Transportation. Fuel cells are used in space shuttles. On the ground fuel cell engines are already comparable to conventional engines in terms of size, weight, operating life, acceleration and speed, range and refuelling time. This together with much higher efficiency than internal combustion engines (ICE's) and without the significant polluting emissions that come from ICE's place fuel cells in a promising position for the future. The present challenge for companies involved in development is to reduce the costs and establish volume manufacturing processes.

Stationary applications. Fuel cell power plants are under development. The advantages of these include negligible emissions, low noise and vibration and simple installation requirements. In August 1997 a 250kW fuel cell power plant fuelled by natural gas successfully generated electricity. It will undergo further vigorous testing before commercial introduction after the year 2000.

Other applications include portable power, with fuel cells being developed for remote, recreational and emergency power applications.

The widespread use of fossil fuels is a very recent phenomenon in the history of human existence, covering only the last 200 years. This represents only 0.2% of the 100,000 years that our modern humans have been around. If these 100,000 years were represented by a day, then we have been using fossil fuels for less than 3 minutes. This is rather amazing considering the integral part that the use of these fuels plays in many of our lives.

9. Environmental issues

There is a growing awareness in our communities of the impact of human activity on the environment. One of the key challenges facing us all is the fact that we want to maintain our standard of living and at the same time reduce the negative impact that we are having on the environment. Finding the balance between these two goals is the aim of most companies and government organisations, and the phrase "sustainable development" describes this ethos.

"Sustainable development's basic aim is to meet the needs of the present without compromising the ability of future generations to meet their own needs" (State of the Environment, Australia, 1996). Following much consultation with the community, the Australian Government adopted a National Strategy for Ecologically Sustainable Development (ESD) in 1992. ESD's strategy should improve the total quality of life both now and in the future, in a way that maintains the ecological processes on which life depends.

The Earth's atmosphere is a vital component contributing to these ecological processes. It is the atmosphere that is most directly affected by the production of energy from fuels. Natural gas has an important role in sustainable development, so that while we tackle the long-term task of developing other renewable energy sources, we can maintain our quality of life with a reduced impact on the environment.

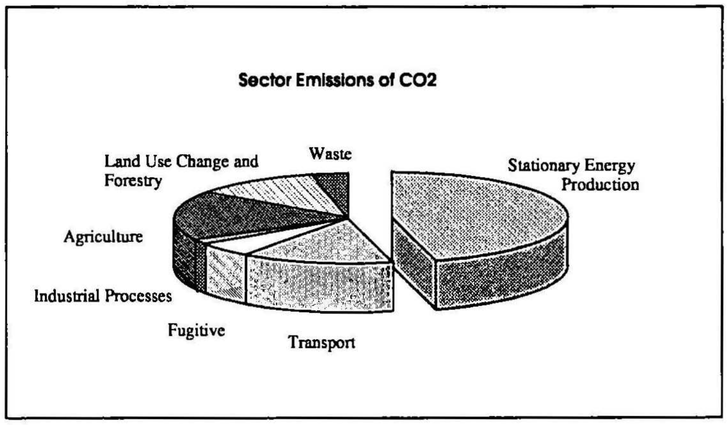
Global climate change

The Earth's atmosphere and climate has varied widely in the 4 560 million years that our planet has existed. (The "*climate change* " title in this series provides further information on this topic.) There have been many natural causes of the variations in climate around the Earth, including the composition of the atmosphere. Over the past 150 years it appears that human activity has increased the amounts of greenhouse gases entering the atmosphere. Many scientists consider that an increase in the concentrations of greenhouse gases may have the potential to induce significant climate change, which may include actual temperature change and sea level change. This is the "global warming" theory.

Greenhouse gases. The greenhouse gases include carbon dioxide, methane, tropospheric ozone, nitrous oxide, water vapour and chloro-fluoro-carbons (CFCs). Without these naturally occurring greenhouse gases and the greenhouse effect, we would be living in a world whose average temperature was -18°C instead of the 16°C we are used to . The increase in concentrations of greenhouse gases is predicted to lead to an **enhanced greenhouse effect.** (Schwartz, A.T., et al, 1994).

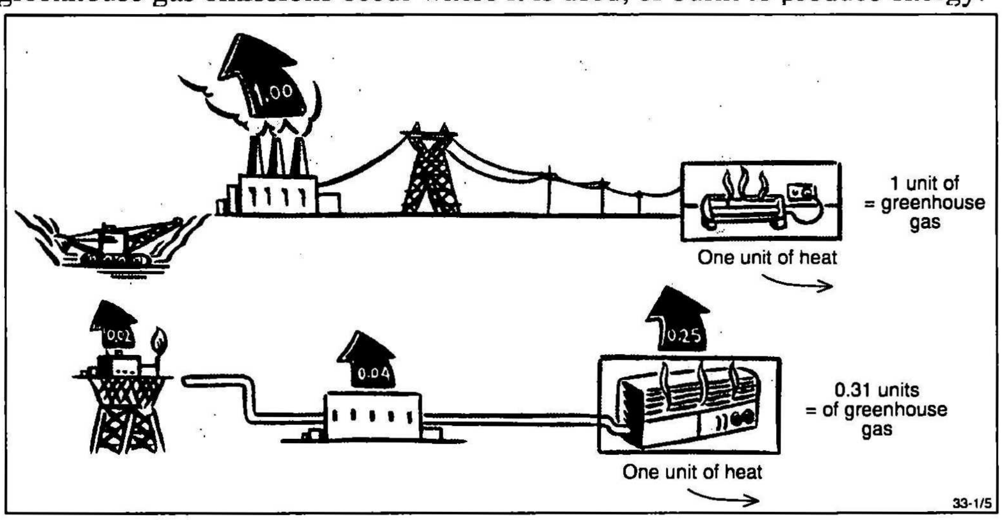
The main contributor to greenhouse gas emissions in 1995 in Australia was the energy sector (stationary energy production). Stationary sources of energy production include electricity generation, petroleum refining and fuel use in the industrial, commercial and residential sectors.

Contribution to total CO_2-equivalent emissions by sector 1995. Total emissions were calculated by converting all greenhouse gas emissions to the equivalent of carbon dioxide emissions. Source: Environment Australia WWW site.



Production of greenhouse gases. (The information in this section is sourced with permission from Global Warming cool it!, Environment Australia, 1997, unless indicated otherwise).

Fossil fuels (coal, oil, gas) are often lumped together and considered to play a large role in the production of greenhouse gases. When assessing the impact of any of the fossil fuels, on the production of greenhouse gases, calculations must be made over the full cycle; from extraction, to processing, distribution and utilisation. The diagram below shows that for electricity, most losses, and greenhouse gas emissions, occur at the power station. For natural gas, most greenhouse gas emissions occur where it is used, or burnt to produce energy.



The following discussion concentrates on the comparative effects of the utilisation of natural gas.

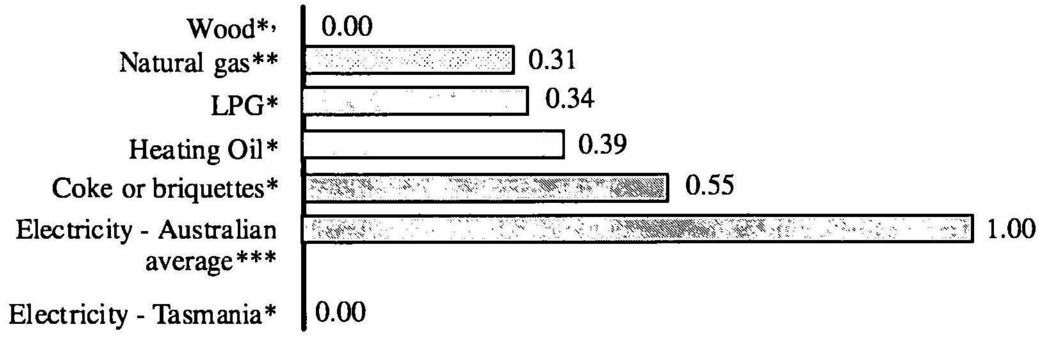
Greenhouse gases are generated when wood or any fossil fuel is burnt. The amount of greenhouse gas generated depends on:

- the amount of carbon in the fuel's chemical structure, and
- the size of the energy losses in mining, converting and using a fuel.

Natural gas is the cleanest burning of all the fossil fuels. The main chemical component of natural gas is methane—the simplest hydrocarbon. Natural gas has a low sulphur content and when burned it emits very few particles (The Australian Gas Association).

Differences in chemical structure and carbon content mean that burning natural gas generates two thirds as much greenhouse gas as producing the same amount of energy from coal. Oil is mid-way between gas and coal. (This assumes all fuels are burnt at the same efficiency).

Amounts of greenhouse gas from different energy sources
Kilograms of greenhouse gas generated per unit of heat delivered



* It is assumed that fuel is burnt at 70% efficiency
** It is assumed that electricity is used by a radiator or fan heater at 100% efficiency:
*** Greenhouse gases generated by electricity supply are averaged across Australia except for Tasmania where hydroelectricity generates little greenhouse gas.
, Transport of wood, and land clearing for timber harvesting, generate greenhouse gas emissions not included here.

Carbon dioxide from burning wood is not counted, as wood is a renewable resource; a natural cycle exists in which carbon is captured by growing trees, then released by burning or deay and again captured by growing trees.

New technologies. New technologies which make any of the processing, transportation and utilisation stages more efficient, will help to reduce emmissions. A practical consideration is whether the technologies are affordable and competitive. This will strongly dictate whether they will be used.

The future

Improving the efficiency of household appliances and industrial technology is one way in which the impact on the environment is being and will continue to be minimised. Improving the design of buildings will mean that less energy is required for space heating.

In the future, natural gas will be used more widely, in transport, air conditioning of buildings, cogeneration and as a chemical feedstock.

The wise use of Australia's non-renewable resources provides us with the opportunity to maintain our current way of life while answering the long term challenge of delivering economically and environmentally sustainable renewable energy resources.

References

The Australian Gas Association (1996). *Coal Seam Methane in Australia: An Overview*, April 1996. The Australian Gas Association. Canberra.

The Australian Gas Association (1997). *Cogeneration, January 1997.* Canberra, Australia.

The Australian Gas Association (1997). *Gas Statistics Australia 1997.* Canberra, Australia.

The Australian Gas Association (1998). *Gas Transmission Pipelines, February 1998.* Canberra, Australia.

The Australian Gas Association, Australian Liquefied Petroleum Gas Association Ltd., Australasian Natural Gas Vehicles Council (1997). *Gaseous Transport Fuels Policy Development, A Joint Submission on Alternative Transport Fuels*, January 1997. Australia.

The Australian Gas Association (1997). *Industrial Gas Demand October 1997.* Canberra, Australia.

The Australian Gas Association (1997). *Residential Gas Demand July 1997.* Canberra, Australia.

Australian Geological Survey Organisation (1998), *Oil and Gas Resources of Australia 1998*, Australian Geological Survey Organisation, Canberra.

Berger, B.D., & Anderson, K.E. (1978). *Modern Petroleum.* The Petroleum Publishing Company. Okalahoma.

Boden, A. (1986). *Chemtext.* Science Press. Marrickville, Australia.

Bradshaw, M.T., Bradshaw, J., Weeden, R.J., Carter, P., & de Vries, D.F.H., *Assessment—translating the future into numbers*, APPEA Journal, 1998.

Bureau of Resource Sciences (1996). Oil and Gas Resources of Australia. Bureau of Resource Sciences. Canberra, Australia.

Clark, I.F. & Cook, B.J., (1983). *Perspectives of the Earth.* Australian Academy of Science. Canberra, Australia.

Cope, G., *Have all the elephants been found?*, Petroleum Review, March 1998, Australia.

Encyclopaedia Britannica CD 97, Encyclopaedia Britannica Inc.

Environment Australia, (1997). See Pears, A., (1997).

Environment Australia WWW site. URL: http//www.environment.gov.au/portfolio/esd/climate/ggi/facts/fact4.html (Accessed 28 August 1998).

Exon, N.F., Dickens, G.R., Auzende, J-M., Lafoy, Y., Symonds, P.A. & Van de Beuque, S., (1998). *Gas hydrates and free gas on the Lord Howe Rise, Tasman Sea..*

Foster, R.J. (1975). *Physical Geology.* 2 Ed. Charles Merrill Publishing. Ohio.

Foster, J.D., & Hodgson, A.J, (1995). *Port Campbell reviewed: methane and champagne,* APPEA Journal, Volume 35, Part 1, Christopher Beck Books, Melbourne.

Gunner, C., *LNG/Gas Prospects for Northern Australia*, APPEA Journal, 1998 Part 2.

Hewitt, P.G. (1987). *Conceptual Physics.* Addisoon-Wesley Publishing Company, Inc. Sydney, Australia.

Lewis, G.B. (1995). *Climate Change - throughout Earth history.* Australian Geological Survey Organisation. Canberra.

Liquefied natural gas, Shell. WWW document. URL: http://www.shell.com/b/b1_01d8.html (Accessed 27 July 1998).

McGraw-Hill Encyclopaedia of Science and Technology, Vol 13 (1982). McGraw-Hill Book Company.

Messel, H. (1971). *Science for High School Students.* Vol 2. Science Foundation for Physics. Sydney.

National Greenhouse Gas Inventory Committee, Department of the environment, sport and territories (1996). *Energy—Workbook for Fuel Combustion Activities.*

National Strategy for Ecologically Sustainable Development, In Environment Australia Online: Ecologically Sustainable Development (WWW document).
URL: http://www.environment.gov.au/portfolio/esd/integ.html (Accessed June 15, 1998).

Oil and Gas Gazette: Ballera to Mount Isa pipeline on track for April gas flow. November 1997.

Pears, A., (1997), *Global Warming cool it!*, Environment Australia, Canberra, ACT.

Petroleum Review, (March 1998), *The future belongs to gas*, Australia.

Preparation of Acetylene: The Caving Helmet Description (WWW document).
URL: http://www.chemlearn.chem.indiana.edu/ (Accessed June 5, 1998).

Press, F. & Siever, R. (1978). *Earth.* 2 Ed. Freeman and Company. San Francisco.

QEPS, (1995). *Energy Efficiency and Alternative Energy*, Queensland Energy Policy Statement, February.

Schwartz , A.T., Bunce, D.M., Silberman, R.G., Stanitski, C.L., Stratton, W.J. & Zipp, A. P. (1994). *Chemistry in Context.* Wm.C. Brown Communications Inc. Dubuque, USA.

State of the Environment Advisory Council (1996). *State of the Environment Australia 1996.* CSIRO Publishing. Collingwood, Australia.

Swan, J.M., Neff, J.M. & Young, P.C. (Eds). (1994). *Environmental Implications of Offshore Oil and Gas Development in Australia. The findings of an Independent Scientific Review.* Australian Petroleum Exploration Association Ltd. Christopher Beck Books

Terrell, J., *Gorgon, bigger than the olympics*, Prospect, March 1998, Western Australia.

Troner, A., *Condensate market under development*, Petroleum Economist, February 1998, Australia.

Watson, G. (1996). *Science Works Book 1.* Oxford University Press. Australia.

Wilkenfeld, G. & Associates with Energetics Pty Ltd (1990). *Greenhouse gas emissions from the Australian energy system: the impact of energy efficiency and substitution, Report 1379,* National Energy Research, Development and Demonstration Program, Canberra.

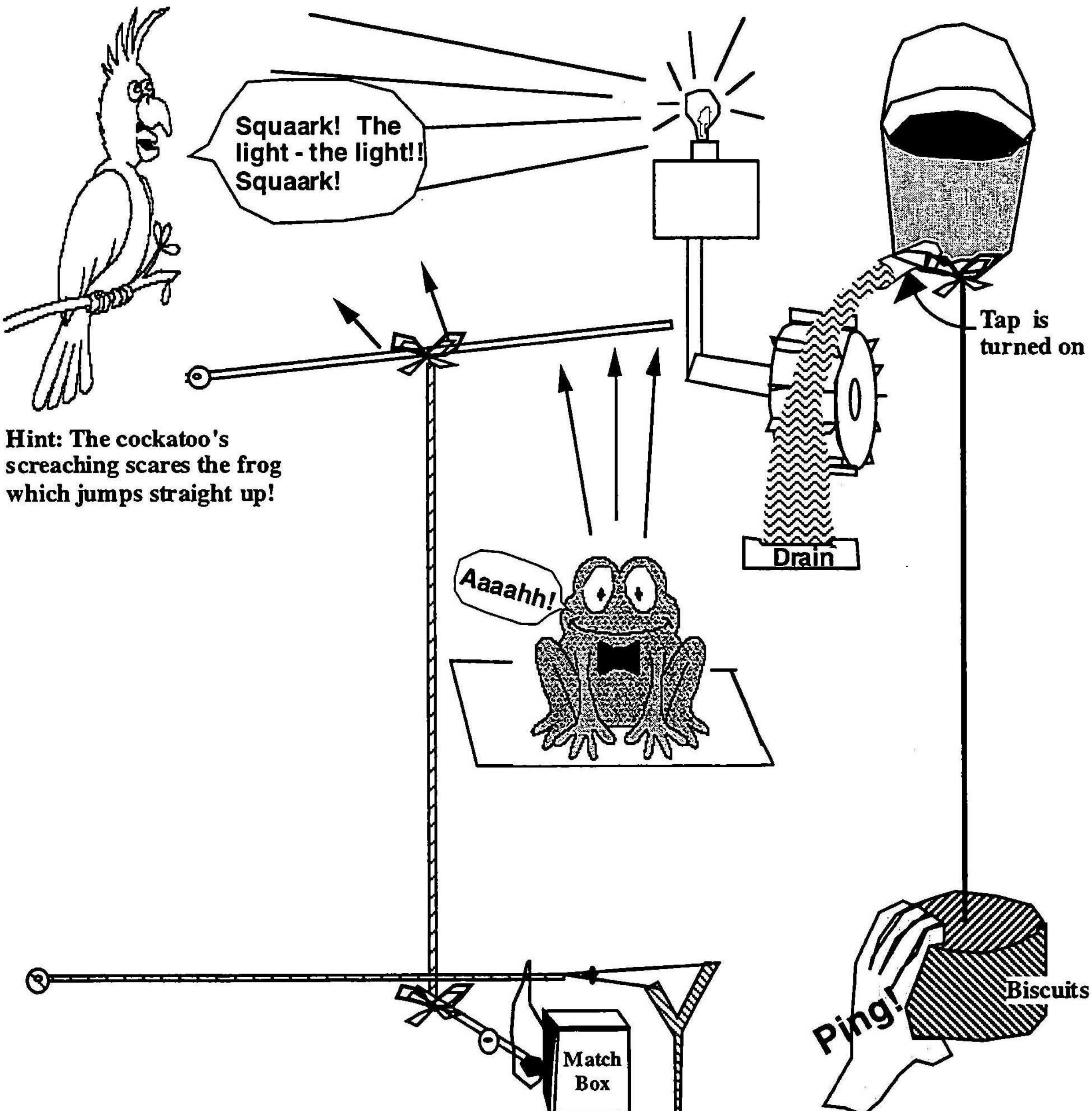
Geoscience
Education

Activities

Louise Mitchell
1998

Further Information
(02) 6249 9497

Energy and Change



Describe how the biscuit tin is kept safe from greedy hands! What energy changes are taking place?

____

____

____

____

In groups, come up with an idea similar to this one which shows how one form of energy can change into another form of energy and then another and so on. Illustrate your idea on a large sheet of paper and label the different forms of energy.

Out Bush!

Have you ever been camping? Did you have to really rough it — or was there a fridge in the back of the 4WD and a gas stove to save you from boiling the billy! Here is the story of a student your age who went hiking. Follow the story and where it asks you — give your answer!

Sammy Satchel went camping and in his pack he carried the following:

A change of clothes	Pasta and Rice	Billy
2 woolly jumpers	Dehydrated Meat	2L Water
Essentials First Aid Kit	Sauces	Sleeping Bag
Spare underwear	Crackers and Cheese	Fruit and Snacks
torch	Breakfast food	Chewing Gum
Matches	Tent Pegs and Ropes	Tent
Firelighters	Lighter	Hollow Tent Poles

He was camping in the bush nearby a flowing creek. How do you think he would cook his dinner?

____

What would he be using as a fuel for this?_______________

If your whole class was to join Sammy — each person carrying the same personal gear, what fuel would you all use to cook your dinner?_______________

What would an alternative source of fuel be?_______________

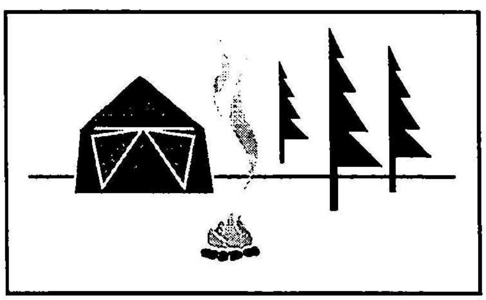
If you were all to stay there for a month (pretend you brought in enough food and your sense of smell is poor), what effect would using so much of this fuel have on the local area?_______________

____

____

If you were to become stranded in the bush with no immediate way out and you come across some gas, seeping out of a small hole in the ground,
with the equipment you have with you how might you use this fuel?_______________

____



Do you think you could sell it?_______________

How would you measure the amount you were able to collect?_______________

____

____

What safety issues should you consider?

Note: Do not try this as an experiment because of the risk of fire.

Appropriate Use of Fuels I

Different sources of energy — fuels — are used for different purposes. How long will a car continue to run if apples are put in the petrol tank? Not very far. If you tried to use wind as a fuel you would have a lot of trouble with your energy levels!

What fuel would you use to run these things?
Next to each item below fill in the appropriate source of energy from the list.
Note : There may be more than one answer.

Battery, Gas, Solar, Coal, Wind, Food, Mainline/Grid Electricity, Oil, Geothermal.

1. Car ____________
2. Light Globe ____________
3. Computer ____________
4. Radio ____________
5. Torch ____________
6. Marathon Runner ____________
7. Windmill ____________
8. Portable BBQ ____________
9. Electric Car ____________
10. Bunsen Burner ____________
11. Hair Dryer ____________
12. Whistle ____________
13. Building Heat ____________

Why do you think we have so many different types of fuels?
____
____

If you could run your body on any energy source you wished, which energy source would you chose? Explain why.____________________________
____
____
____

Appropriate Use of Fuels II

ACTIVITY:

Take a candle.

Light it.

Observe it closely.

What is actually burning? (solid wax, liquid wax or gas)

____

*How can you prove your observations?*______________________________

____

____

____

Flour explosions!

On December 14, 1785, an industrial explosion occurred in a flour warehouse at Turin in Italy. Flour, a harmless ingredient in so many of our food products, can build up as a dust in the air and when exposed to a spark it will explode!

Work out why:

Before the invention of batteries, miners used to use caving lamps to light their way. These lamps contained the chemical calcium carbide. To produce light, water from the lamp would drip onto the calcium carbide, causing a chemical reaction which would produce acetylene gas (C_2H_2). This acetylene gas was then burnt to produce a bright white light.

Why might this practice be dangerous in a coal mine?______________________________

____

____

____

____

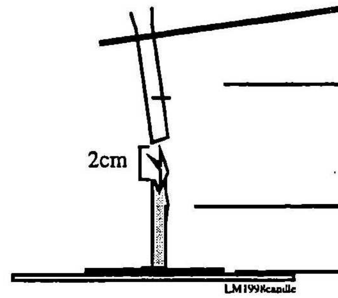
Fuel Efficiency

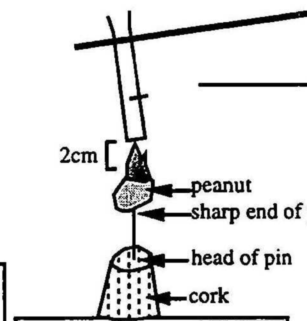
How could you measure the relative power of different fuels?

This experiment will enable you to compare the heat given off by two different fuels. (AIM)

Equipment (per group) :

1 peanut
1 cork and sewing pin
1 small birthday candle
matches or lighter
2 small containers (test tubes)
Test Tube holder
thermometer
glass plate or sturdy paper plate
small piece of blue tack or plasticine





Note : Instead of test tubes, aluminium cans cut in half could be used. This will reduce the washing up - the test tubes will go BLACK! However holes will need to be punched into the sides so that a glass rod can be inserted through the top of the can in order to hold it in place. Alternatively cover the bottom of all test tubes with foil.

WARNING — Room needs to be well ventilated — burning peanuts produce a lot of smoke.

Teacher instructions: Prepare some 15°C water for the whole class to use. Mix fridge water and tap water to achieve this temperature.

What to do:

1. Set up the equipment for your experiment. Secure the candle to the glass/paper plate with blue tack. Attach the pin to the cork and then carefully put the peanut onto the pin.
2. Measure room temperature and record it in the table.
3. Measure the mass of the candle and glass/paper plate. Do the same for the peanut, cork and pin. Record these numbers in the table.
4. Label both containers/test tubes A (to be heated by the candle) and B (to be heated by the peanuts).
5. Add exactly 20ml of 15°C water to both containers. Your teacher will have this water. You can leave the thermometer in the container.
6. Light the candle hold container A filled with water no more than 2cm above the flame. Keep an eye on the temperature as it heats.
7. Continue heating until the temperature rises to about 30°C.
8. When this has been reached, extinguish the flame. Continue to stir the water for a couple of minutes until the temperature stops rising. Record the highest temperature reached.
9. Once the candle has cooled, weigh it and the plate it is on.
10. Repeat the procedure from step 6 to 9, using the peanuts and container B. Try to get your temperatures as close to those of container A as possible.
11. Once the temperature has reached the same as that of the final temperature of container A, blow out the peanut so it is no longer burning. This is essential so that your results will be accurate. Make sure the peanut is cool before weighing.

Record of results:

	Container A heated by candle	Container B heated by peanuts
Room Temperature		
Initial temperature of water in container		
Final temperature of water in container		
Initial mass before burning		
Final mass after they have cooled		
Change in mass of candle/peanuts		

Comparison (calculations):

- The temperature of beaker A was raised by ___________°C when ___________g of candle was burnt.
- The temperature of beaker B was raised by ___________°C when ___________g of peanuts were burnt.

Discussion:

Write your ideas about the comparison of the fuel efficiency of candles versus peanuts.__________

____

____

____

____

What are the possible sources of error in your calculations and in this experiment?

____

____

____

____

Conclusion: (answer the aim).__________________________________

____

Once a Plant - now Natural Gas

The sequence of events that need to take place before gas and oil are produced consists of a large number of steps. Can you work out the right order?

What to do.

1. Cut out each box.
2. Read each of them and as you read, place them in order from the first step in the formation of gas and oil to the last. *HINT : The first box has to do with the formation of the original material and the last box has to do with extracting the gas or oil.*
3. Once you have your completed flow chart, stick it down on an A4 sheet of paper.
4. Compare your results with your neighbour. Are they the same? _______

Folding and faulting of the rocks must not be too severe. Traps may become breached and thus leak due to intense fracturing.

The oil and gas that is being produced in the source rocks has to move or migrate into very porous rocks in which they are stored. These are called reservoir rocks.

If the layers of rock containing the stored gas and oil are uplifted and then exposed to erosion, the gas/oil may be lost.

Folding or faulting of the sequence of rocks may occur leading to the formation of traps which will not allow the oil and gas to escape.

Burial of organic matter by sand and mud before being eaten by scavengers or destroyed by decay(oxidation).

The pore spaces of the storage rocks must remain clear so that the oil and gas can be pumped out (if necessary) of the reservoir rocks. Swelling clays or mineral cements deposited by groundwaters can fill the pores of resorvoir rocks and stop the recovery of all of the oil/gas.

Organic matter (made up of complex hydrocarbons and contained in living organisms) is in plentiful supply in the environment.

The deeper rocks are buried, the higher the temperature becomes. As the temperature increases gas will be formed instead of oil. But if the temperature is too high, instead of gas and oil, graphite, used in lead pencils, will be formed!

Chemical reactions occurring deep in the crust tranform the organic source material to oil and gas.

The sediments (sand, mud, etc.) containing the layers of organic matter are turned into rock.

1998LM Sequence#2activity

Chemical Changes Assignment

Plant → Gas → Energy

At the present time, chemical reactions produce over 90 % of the energy that we produce in our society! These reactions are principally the combustion of coal, petroleum products and natural gas. Some chemists have been trying to construct models so they can compare the creation of gas (from plants) to what happens when the fuel is burnt. Can you work it out?

Step 1 : Read through the information below and fill in the blanks.
The source of energy for all fossil fuels has come from the sun. In the case of oil and gas, microscopic marine plants, such as algae, living in the upper layers of the ocean adsorb the sun's energy to convert carbon dioxide and water into simple hydrocarbon compounds such as sugars. This process is called photosynthesis.

What happens in Photosynthesis??

Photosynthesis is the major means for changing solar energy into forms that can be used by living organisms. The reaction that occurs in the leaves of plants is the conversion of carbon dioxide and water into simple hydrocarbon compounds such as glucose, for example:

> Hint: When a number is in front of a molecule then you have to multiply each atom by that number e.g. if there is a 6 in front of CH_4 you will then have 6 carbon atoms and 6x4 = 24 hydrogen atoms.

- **Write the names of the reactants and the products underneath their chemical formulae. C is Carbon O is Oxygen H is Hydrogen**

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

__________ __________ __________ __________

- **Check that this equation is balanced — the number of each type of atom must be the same on both sides of the arrow.**

C — ______________ C — ______________

O — ______________ O — ______________

H — ______________ H — ______________

These simple hydrocarbons (i.e. glucose) within the marine plants can later be converted within the food chain to more complex hydrocarbons. For example when algae are eaten by fish the simple hydrocarbons are changed within the fish to more complex hydrocarbons. All living things are made up primarily of hydrocarbons, compounds containing carbon, hydrogen and oxygen — these are called organic compounds. It is these hydrocarbons that ultimately become the essential components of natural gas: methane, ethane, propane and butane.

How does the hydrocarbon (organic compound) become gas?

When these hydrocarbons are buried in rocks deep in the crust, they heat up and "cook" under the ground. The process is chemically and biologically very complicated.

What happens when we burn natural gas??

We all know that in order to burn something air is required. More particularly, the oxygen portion of air is essential to support combustion. So when natural gas is burnt, it reacts with oxygen in the air. The products are carbon dioxide and water. This can be represented by a chemical equation as follows:

$$CH_4 \quad + \quad 2O_2 \longrightarrow CO_2 \quad + \quad 2\,H_2O$$

__________ __________ __________ __________

- **Write the names of the reactants and the products underneath their chemical formulae.**
- **Check that this equation is balanced — the number of each type of atom must be the same on both sides of the arrow.**

C — __________ **C —** __________

O — __________ **O —** __________

H — __________ **H —** __________

The process changes methane, a **more active** greenhouse gas, into carbon dioxide, which is relatively **less active** as a greenhouse gas.

Step 2 : Construct each of the molecules inthe equation that shows the **formation of glucose.** In order to do this you will need to read and follow the rules sheet the points beneath it:

RULES :

CONSTRUCTING THE MOLECULES

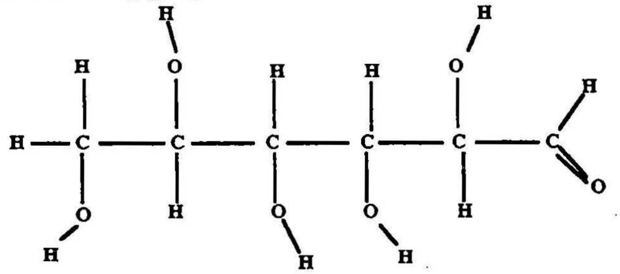
A ***molecule*** is made up of one or more elements or ***atoms***. These ***atoms*** can be the same or different.

e.g. O_2 — a molecule with two atoms that are the same.
CO_2 — a molecule with different atoms.

- Each atom can bond to other atoms.
- Carbon has four bonding sites (the arrows), oxygen has two bonding sites and hydrogen only one.
- Each arrows must join with another arrow to make a bond complete.

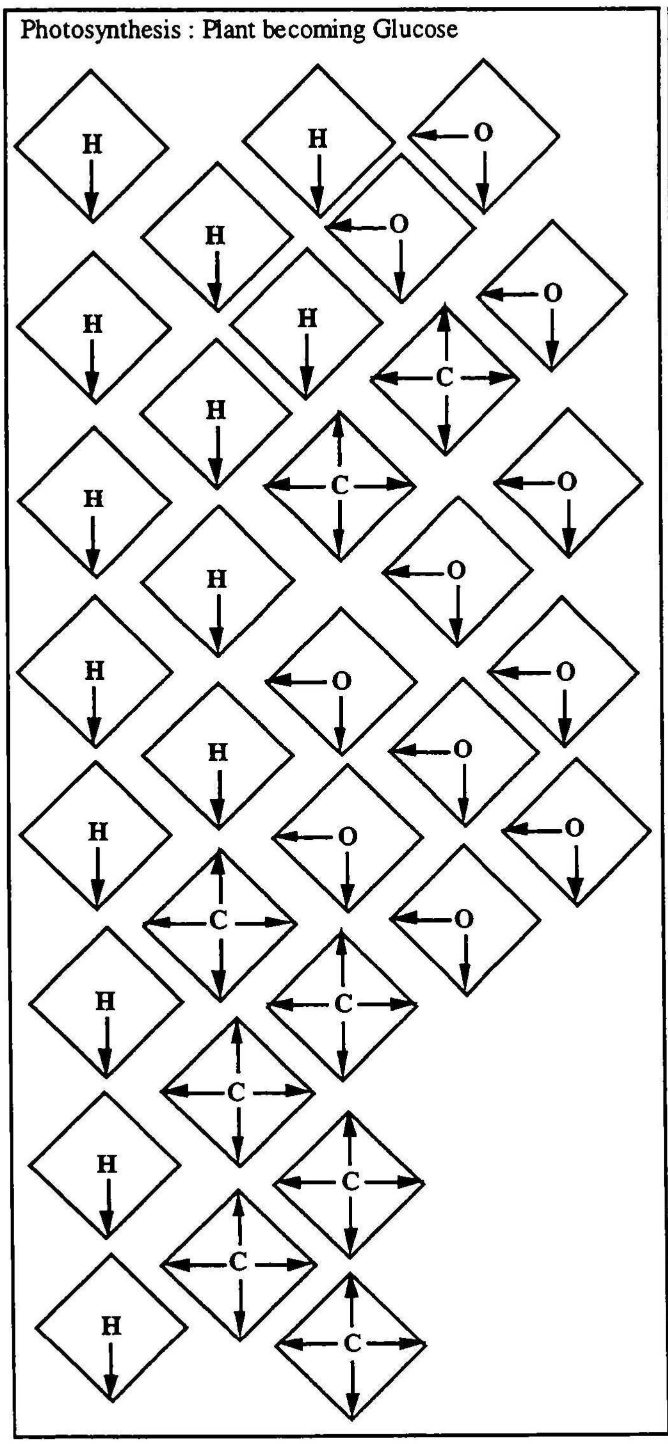
In order to make the molecules you may need to know the following:

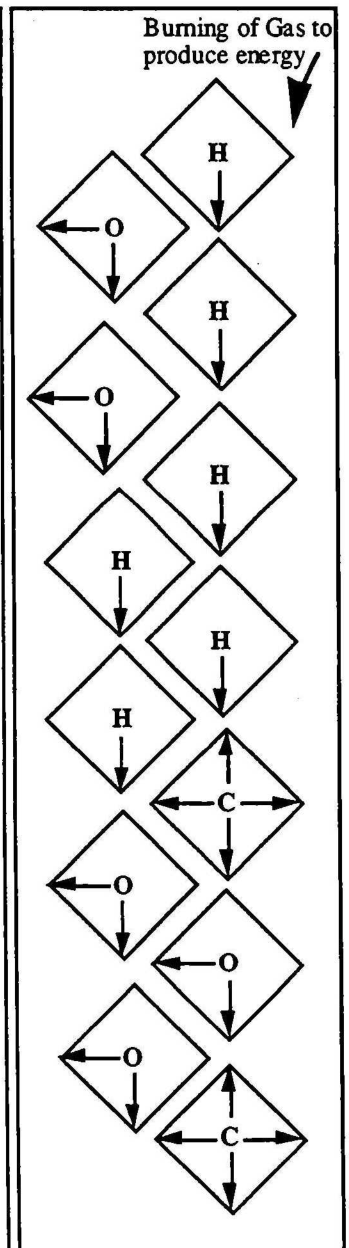
- CH_4 — the hydrogen atoms do not bond to each other.
- CO_2 —the oxygen atoms do not bond to each other.
- H_2O — the hydrogen atoms do not bond to each other.
- The carbohydrate (glucose) has a complex structure — to help you put it together use this diagram as a guide. There is only one place where one atom bonds twice with another atom (Carbon with Oxygen).



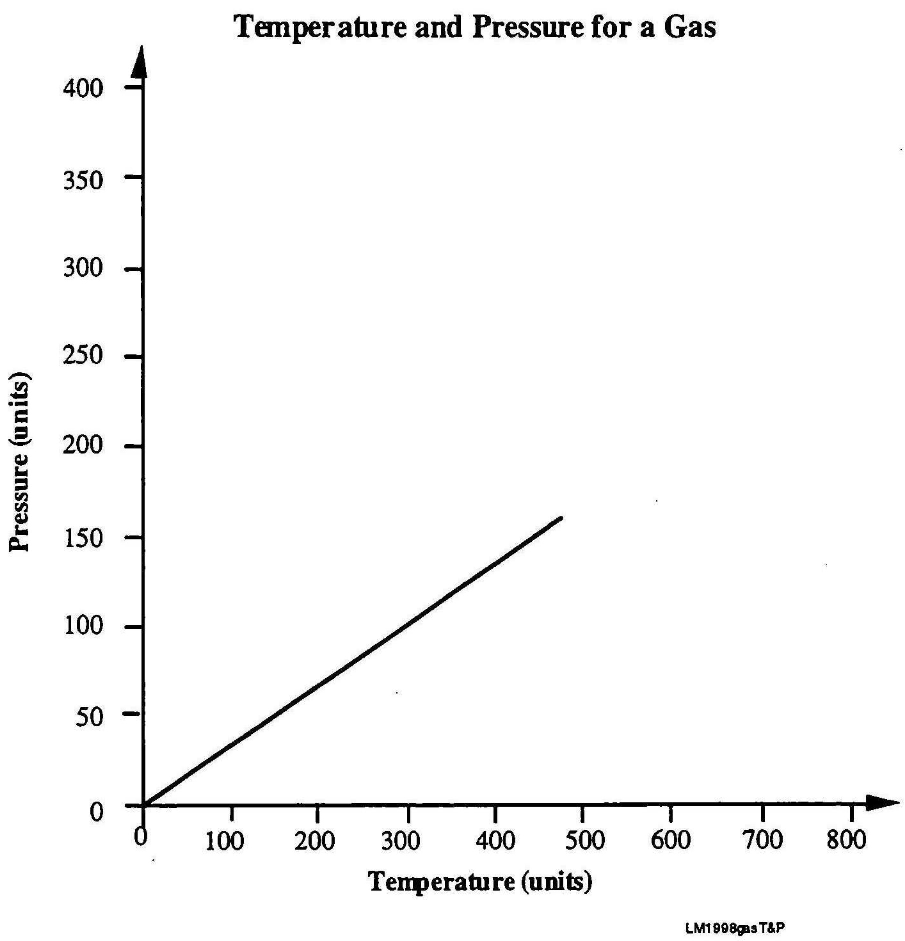
- Stick each molecule down on a large sheet of paper in the order of the equation. Add plus signs and arrows where needed.
- Make sure that there are the same number of carbon atoms one one side of the arrow as there are on the other side. Do the same for the oxygen and hydrogen atoms.
- If there are unequal numbers of the same atom you will need to make them equal by making more molecules to add to either side.

Step 3 : Construct each of the molecules in the equation that shows the a)**plant becoming glucose** and b)**burning of natural gas** and then complete the equation like you did in Step 2, only using the molecules you have constructed.





Gas and Volume Changes with Pressure & Temperature I



What will the ***temperature*** be if the pressure is 200 units? ______________

What will the ***pressure*** be if the temperature is 800 units? ______________

As the ***temperature*** of a gas increases, the ***pressure*** of a gas______________

What do you think would happen to the air ***pressure*** in a balloon if you took it from room ***temperature*** and put it into the freezer? ______________

____

____

Try this and see what happens to the volume.

What happens to the volume of the balloon when:

a) the temperature is reduced?______________

b) the pressure on the outside of the balloon is reduced?______________

Natural Gas under high pressures is sent through steel transmission pipes from the gas fields to the city. Why do you think that steel might be the best material for this purpose?______________

Gas and Volume Changes with Pressure & Temperature II

Find out : Does a gas meter take a measure of pressure or volume?____________________

What units does a gas meter measure in?____

How does a gas meter work?____

____

____

____

Would it be more advantageous to heat the gas pipes or cool them before the gas goes through the meter? ____

____

When gas is deep in the crust it is under a great deal of pressure. What do you think might be the cause of this pressure?____

____

What do you think will happen to the volume of gas as the gas is extracted to the surface, where the pressure is lower?____

____

Your teacher will supply you with a graph that shows the volume of the same amount of gas at depths from 1km to 5km (from chapter 6). Copy this diagram below.

Paying Your Gas Bill

Thomas just received his fortnightly pay cheque of $963.00. He did a "back of the envelope" calculation to determine how much he would have left after he puts aside money for food, rent and car expenses and it turned out to be $150.00. He has forgotten about his gas bill. By how much will Thomas have to cut back on his entertainment allowance of $150.00 in order to pay his gas bill?

Step 1

Work out how much Thomas still owes to the gas supplier from his last account by subtracting the "Payments received" from the "Last account" balance. Write your answer next to (a) the Balance, this appears twice on the page.

Step 2

Work out the charges for Natural Gas costs for this account by working through the following steps and filling in the amounts for (c), (d), (e), (f) and (g).

- To work out (c): When Thomas' gas meter is read it gives the amount of gas consumed in units. Read off the table how many units were consumed: ________________
- Convert units to Megajoules (MJ) using this equation (no decimal places necessary in answer)

Megajoules = units x 39.018838

Working:____Fill in (c).

- Work out (d) and (e) by multiplying the number of MJ consumed by the cost in cents/MJ. Fill them in on Thomas' gas bill.

- The cost of natural gas has increased. How many MJ will be charged at the new rate?

(f) = (c) - 185 MJ - 817 MJ

Working:____

- Work out (g) without any help.

Working:____

- The charges listed under cost will need to be added to get (h) the Total Natural Gas Costs. Fill this in in two places on the table. (Add d, e and g).
- Move up to the top section of the bill and fill in New Charges (h) in two places.
- Add up the total due (add (a) and (h) together) and write it in (b), in two places.

Now that the bill is complete, answer the following:

1.Will Thomas have to cut back on entertainment or will $150.00 pay off this bill?

____

2.How much will he have for entertainment this fortnight?__________________

3.Over what period of time is this bill for? __________________________

4.Should Thomas expect a bill like this every month? Why/Why not?

____

Thomas' Gas Bill

Customer Number
035595

Payment Reference Number	0103 5595 2001		☎
Invoice Number	00135		
Date of Issue	25 / 07 / 1998	Accounts and Service - 7am-8pm	132 707
Account Number	001	Appliance Repair - 24 hours	132 606
		Emergency - 24 hours	131 909
		Sales - 7 am-8pm	132 707
		Outside NSW and ACT call 1800 806 616	

Payment Due

Total Due
(b)

Last Account	**Payments Received**	**Balance**	**New Charges**
$129.40	$54.48	**(a)** DR	**(h)**

Natural Gas Costs (h)________

Balance (a) ____________

Total Due (b)____________

From 1 July 1998, the gas supply fee for Rate 2 customers (under 45GJ/annum) has increased by $1.25/quarter.
Usage rate for first tariff block has been reduced. Details 132 707.
Note: Of the total due, $74.92 is OVERDUE and must be paid immediately unless special arrangements have been made.
New charges of $48.47 should be paid by the DUE DATE of 08 /08 / 1998.

Supply Address:

Type	**Meter Number**	**Current Date**	**Current Reading**	**Previous Date**	**Previous Reading**	**Units Consumed**	**Megajoules Consumed**
Gas	EA05073 2	24/07/1998	2337	24/06/1998	2227	110	(c) MJ

To convert Gas Units to megajoules, multiply the Units by 39.018838
NOTE: The Industrial and Commercial Rate changed in price on 01/07/98

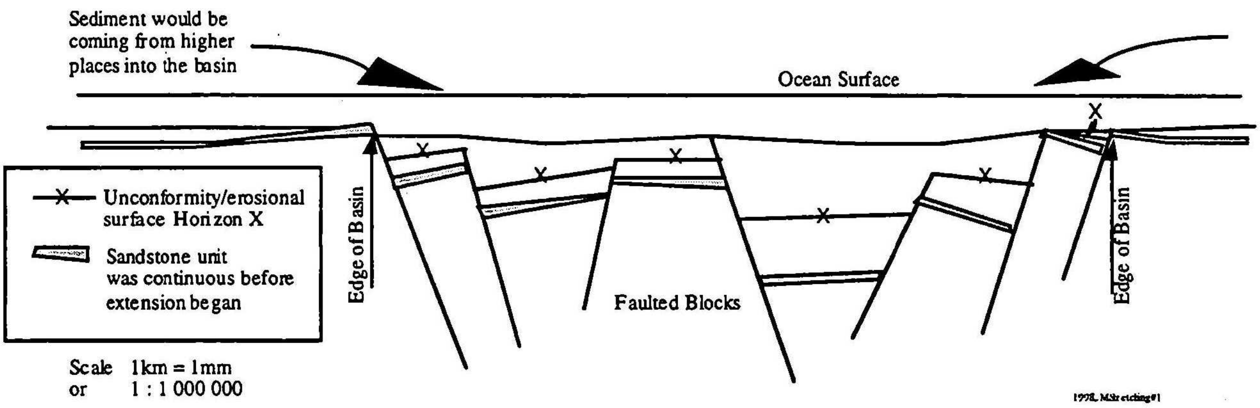
Natural Gas Costs:	Tariff - Industrial and Commercial Rate	
Old Rate (7 days):	817 MJ, charged at 1.1725c per MJ	(d) ______
	185 MJ, charged at 1.1192c per MJ	(e) ______
New Rate (23 days): (f)	____ MJ, charged at 1.1192c per MJ	(g)
Total for 30 days:	MJ **Natural Gas Costs =**	**(h)**

How far has the crust stretched?

You are the structural geologist on a contract for the local council and you have been assigned the following task: You have been asked to assess the rate of extension of the crust in the Basinda area. It is planned to lay some large transmission pipes across the length of the basin for transportation of gas to the coastal town of Le Basin. The council wants you to tell them whether they will need to be concerned about replacing or extending the pipes in the next 150 years.

Background Information

When basins are forming, due to crustal extension, large fault structures usually occur. These fault structures will extend deep into the earth's crust. A result of the tensional force and faulting is that the crust will have been stretched.



Step 1

Measuring how much the crust has stretched.

- With your ruler measure the distance between the two points at the east and west edges of the basin that appear not to have moved:(a) ________________ mm.

  To convert this to the actual distance in kilometres use this formula

$$\text{Distance across the basin in km} = \frac{\text{Distance across the basin today(mm)(a)}}{\text{Length of 1km (mm)}}$$

Answer A: ____________.

- Measure the length of the sandstone unit before it was extended. To do this you will need to measure the length of the sandstone unit in each fault block and then add them all together. The total is (b) ________ mm Convert this measurement to kilometres using the formula above.

  Answer B: ____________.

- Find the difference between distances A and B.

  Answer C: ____________.This is how much the crust has stretched.

Why do you think horizon X may not be as good a marker to use for determining the distance stretched?____

____

____

Step 2

Work out the rate of extension of the crust.
Geological evidence suggests that this basin is relatively young and possibly still growing. Evidence from the rock layers, fossils and cross-cutting veins indicate the basin began forming, near the base of the sandstone unit, around 5 million years ago. If we assume that stretching is occurring at a constant rate, what is this basins rate of stretching?

Do your calculation here:

Rate of stretching = $\dfrac{\text{Distance stretched, C (km)}}{\text{Number of years of stretching}}$ =

Answer D: ______________km/year

Step 3

Using the rate of extension of the crust work out how much more extension will occur over the next 150 years.

Do your calculation here:

Stretching distance (km) = Rate of stretching, D (km/yr) x Number of years

= __________________ x 150 years

= __________________km

Answer E: ______________km over 150 years

To answer the question below you will need to convert this to mm/year.

1 km = 1000 m = 100 000 cm = 1000 000 mm

Stretching distance (mm) = Stretching distance, E (km) x 1000 000 mm/km

= x 1000 000

=

Answer F :______________mm over 150 years

If the pipes can cope with extension of up to 300 mm, do you think they will need to replace them or extend them in the next 150 years?________________________

So how long would it be before the crustal stretching would have an effect on the pipes?

Use the following formulas to work this out —

Number of years for basin to reach 300mm = $\dfrac{\text{300mm}}{\text{Rate of Stretching in mm/year}}$

Rate of stretching (mm/year) = Rate of Stretching (D) km/year x 1000 000 mm/km

= mm/year

Working :

The number of years it will take to stretch the crust the allowable distance = years

In order to work out the answer above — what is the big assumption we are making?__________

____

____

How might this assumption be incorrect?________________________________

____

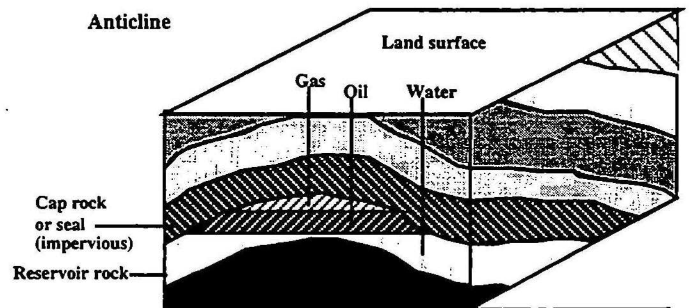
____

This is an extremely young basin. Most basins take tens of millions of years to form.

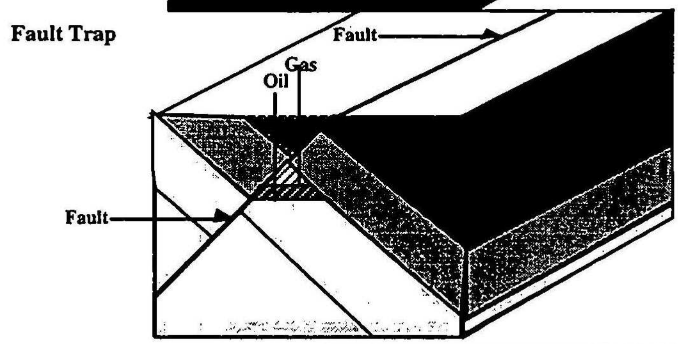
Can you find the traps?

A trap, as the name suggests, is a structure which prevents the petroleum from escaping to the surface. The major forms of structural traps are anticlines, faults and salt domes.

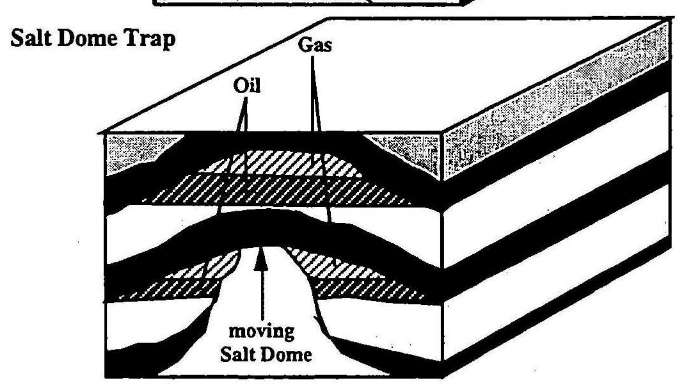
Anticline
An anticline is simply a fold shaped like an arch or an elongated dome. Oil fields may extend for many kilometres along the crest of an anticline.



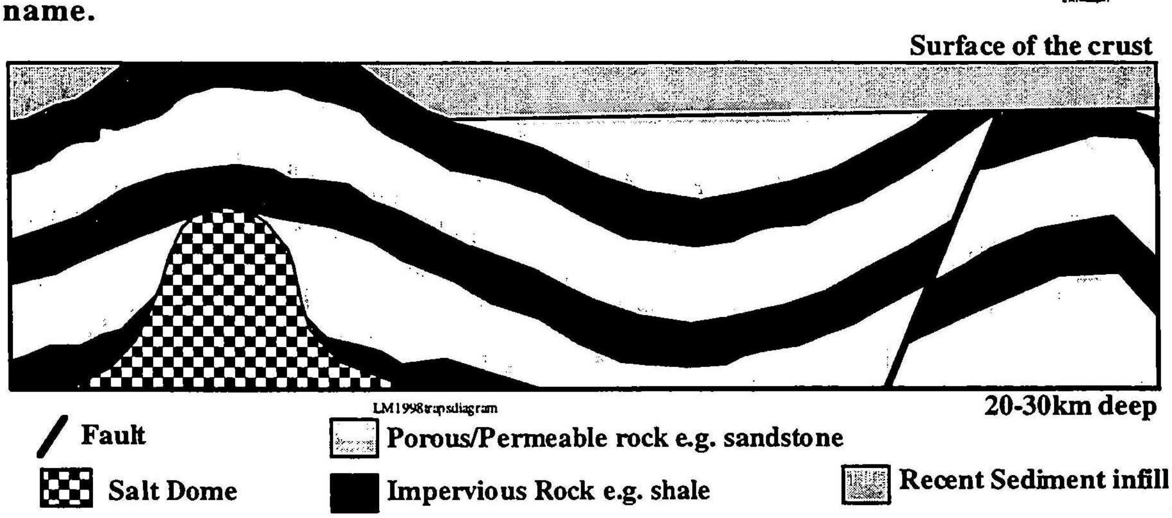
Fault
Traps can form where a reservoir rock and impermeable cap rock are moved by a fault to allow porous rocks to collect oil and gas underneath the trap. The impermeable material must lie above the reservoir rock. Sometimes small amounts of oil and gas can leak up the fault and reach the surface. Over very long periods of time this minute leakage could eventually empty the trap.



Salt Domes
Salt domes are structures which formed by a moving mass of salt. Deeply buried beds of salt (called evaporites) were formed in the past by evaporation of sea water and subsequent burial. These are structures which can move upwards because of density differences. The rising domes bend the surrounding sediments upwards producing reservoirs in porous beds cut off by the salt. Remember the salt is a cap rock as well as the clay/shale that the salt dome pushes.



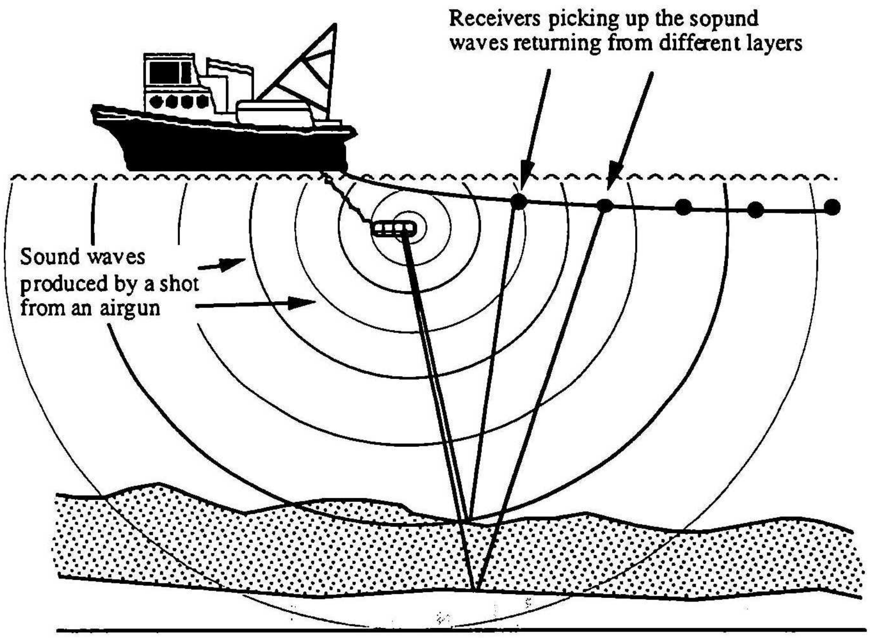
In the diagram below, draw where you think there may be a possible trap — use a bright pen or pencil so that it will be obvious. Label the trap with its correct name.



Measuring Depth with Time

When a company decides to explore for petroleum, the first thing it must do is research information about the potential of the area. Once the company decides to explore in a particular area it will buy an exploration permit for that area and then it will begin by "shooting" some seismic. This will enable the geologists to map the structure of the rocks at depth and predict where oil and gas might be found.

A seismic cruise has just been completed and some raw data has been handed to you. The depths of some of the horizons needs to be worked out accurately so that drilling costs can be estimated. Can you work out how time relates to depth?



During seismic exploration a shot is fired at the surface, it creates sound waves which bounce off particular layers and then return to the surface. What is recorded is the time it takes a wave to travel from the shot to the layer and back up to the detector.

1. Plot depth vs two way time for the Yampi vertical section on graph paper. Put depth on the y axis (the vertical axis). The data you will need is in a table on the next page.

2. Draw the line of best fit through the points.

How deep is a unit that is recorded at 2.1 seconds? ______________

How long would it have taken for a sound wave to travel from the airgun to a layer that is 1750m deep and back up to the receiver?

How long would it have taken for that sound wave to travel to the depth of the layer at 1750m, but not back again?

Yampi Vertical Section

Horizon Name	Depth metres below sea level	Two Way Time seconds
A	473	0.450
B	785	0.708
C	825	0.745
D	922	0.822
E	1013	0.893
F	1060	0.930
G	1100	0.960
H	1147	0.995
I	1550	1.289
J	1948	1.613
K	2379	1.924
L	2572	2.044
M	2827	2.169
N	3238	2.375
O	3390	2.454
P	3459	2.484
Q	3592	2.542
R	3915	2.681
S	4010	2.720

3. If you were to redraw the graph so that depth was plotted against one way time, not two way time, sketch what the graph would look in the space below.

Interpreting a Seismic Section
Major Assignment - Challenging

The chief exploration geologist working on a section of the Basinda Basin has suddenly left the company. You have been working with her and now the company wants you to complete the report and recommend where to do further drilling.

This is the information you have at this stage:
Three Exploration Wells have already been drilled and gas or oil has been found in particular rock units. The table below summarises the findings.

Well Name		**Yampi**		**Prudhoe**		**Buccaneer**	
Rock Type	**Horizon Name**	**Depth metres**	**TWT sec**	**Depth metres**	**TWT sec**	**Depth metres**	**TWT sec**
sandstone	**A** *	473	0.450	575	0.506	589	0.531
limestone	**B**	785	0.708	716	0.663	710	0.640
mudstone	**C**	825	0.745	750	0.732	820	0.740
shale, sandstone	**D** *	922	0.822	990	0.887	1015	0.883
shale	**I** *	1550	1.289	1797	1.470	1880	1.503
shale	**II**						
shale, sandstone	**J** *	1948	1.613	2392	1.890	2600	2.008
shale	**L** *	2572	2.044	2718	2.080	2840	2.151
shale, sandstone	**M**	2827	2.169	2895	2.167	2970	2.214
volcanics, sandstone	**N** *	3238	2.375			3261	2.360
shale, sandstone	**Q**	3592	2.542				
shale	**R**	3915	2.681	2955	2.198		
sandstone	**S**	4010	2.720				
shale	**T**						

TWT — two way time.
Depth in metres measured from the sea floor.
* — These are the horizons that will be mapped.

During seismic exploration a shot is fired at the surface, it creates sound waves which bounce off particular layers or horizons and then return to the surface. What is recorded is the time it takes a wave to travel from the shot to the layer and back up to the detector. It travels down and then back up and so is called two way time.

Note to the Teacher — Diagram "Generating a Seismic Image" in Chapter 4 can be turned into an OHT.

Equipment :

Coloured Pencils
Calculator
Ruler

What to do:

1. Interpret the seismic section

- The exploration wells are marked at the top of the section and two way time is marked down the side. Draw a straight line in lead pencil,straight down from each well, so that you can trace where the drill went!

From the table above, pick a horizon with an asterisk (*).

We'll do the first one, horizon A, for you.
From the table you can see that A is a horizon of sandstone and this horizon is at a different depth (=Two Way Time) under each drill hole. Horizon A is detected at a

— two way time of 0.450 seconds in the Yampie exploration well
— two way time of 0.506 seconds in the Prudhoe exploration well
— two way time of 0.531 seconds in the Buccaneer exploration well

So for horizon A we need to convert these times in seconds to millimetres in order to put a red coloured mark under each of the wells at the correct depths.

In order to work out what the seconds are equivalent to in millimetres, measure how far 1.000 second is in millimetres. If on your seismic section 1.000seconds = 33mm. Multiply the number of seconds in the table by 33mm/sec to give you your measurement.

Formula					
	Two Way Time for particular horizon	x	33mm/sec	=	Measurement (mm) from 0.000 sec line to reach horizon

NB. Make sure that 1.000 seconds measures 33mm. If it does not — use the measurement that you make.

For example: Horizon A in the Yampie drill hole
0.450 sec x 33 mm/sec = 15 mm

In red pencil you would mark 15mm on your section under the YampieWell. This is the horizon A.

Do the same for the Prudhoe and Buccaneer Wells.

Calculations:	
Horizon A in Prudhoe Well	Horizon A in Buccaneer Well

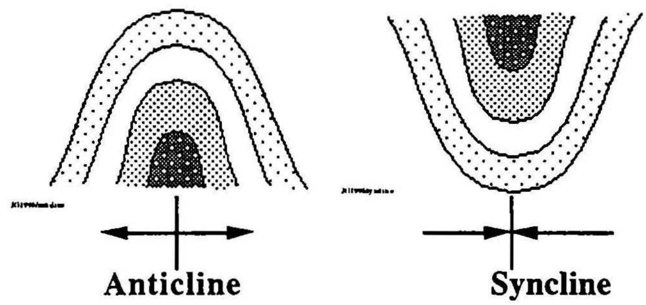
- Now that the layer has been marked underneath each well, you will have to complete the seismic section. Look side on at the seismic section so that your head is almost on the table and your eye is glancing down the length of the layer. As best you can, follow the layer horizon A from one side of the page across to the other side. Carefully draw this in with your red pencil. It may not be a straight line — DO NOT USE YOUR RULER!
- Do exactly the same thing for the other horizons with an asterisk *, but make sure you choose a different coloured pencil — otherwise your horizons might become confused. Make sure you set out your working clearly as above.
- On the right hand side of each horizon, write the name of the rock type that makes up the horizon.

Congratulations! You have interpreted the seismic section!

2. Finding traps for oil and gas.
When extension or compression occur within the earth, faulting or folding will most probably accompany it. When looking for traps, a good place to start is to look for faulting or folding.

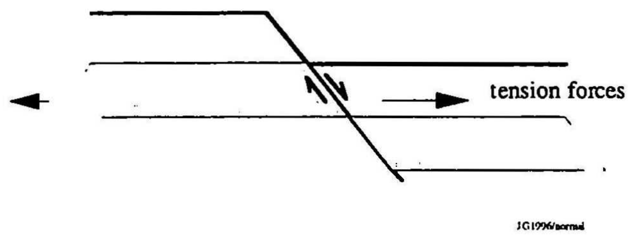
Here are some examples of the structures that result from faulting or folding:

Anticline, syncline — these are geological structures where the rocks have been folded.

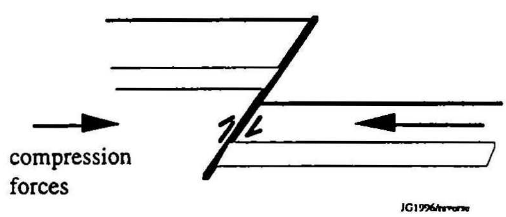


Fault — a break in the rocks along which the rocks move when they are put under stress. An earthquake occurs when the rocks slide past each other along a fault. However, most faults are currently inactive. There are two main types of faults: normal faults and reverse faults.

Normal fault — due to tension pulling rocks *apart,* the rocks on the top of the fault have slipped down.



Reverse fault (thrust) — due to compression forces, causing one rock body to be pushed up over the top of another.



With different coloured pencils, draw in any folds or faults that you can see in the seismic section. If you can, determine the type of fold or fault and label each one.

Can you see any structures that would make good traps? Circle them with a different colour.

3. An unconformity is a geological boundary which indicates that a large amount of time has elapsed between the erosion of the older layers of rock and the deposition of younger rocks. The older rocks may have been folded and tilted, then eroded. After millions of years a new layer of rocks is deposited on top.

The unconformity is a layer that you have already traced in colour.

Which layer do you think it is?________________

All sedimentary rocks are laid down horizontally (or very close to horizontal), as sediment is washed into a basin or low lying area.

Describe the structure of the rocks above the unconformity. ______________________________

____

Describe the structure of the rocks below the unconformity. ______________________________

____

What might have happened to give the rocks at depth the structure they now have?____________

____

4. The exploration wells showed some indications of oil and gas in particular horizons. These horizons are:

J — oil
M — oil
N — oil and gas
Q — oil and gas
S — oil and gas

Which rock type would you suggest has the ability to contain the oil or gas? ____________

At what depths is the oil being found?

At what depths is the gas being found?

Does the gas sit above or below oil in a reservoir rock?______________________________

Why do you think that only oil is found in some places and both gas and oil in others?__________

____

____

In a paragraph, write a possible explanation for how the gas and oil got there! Also include why you think the gas and oil have remained trapped.______________________________

____

____

____

____

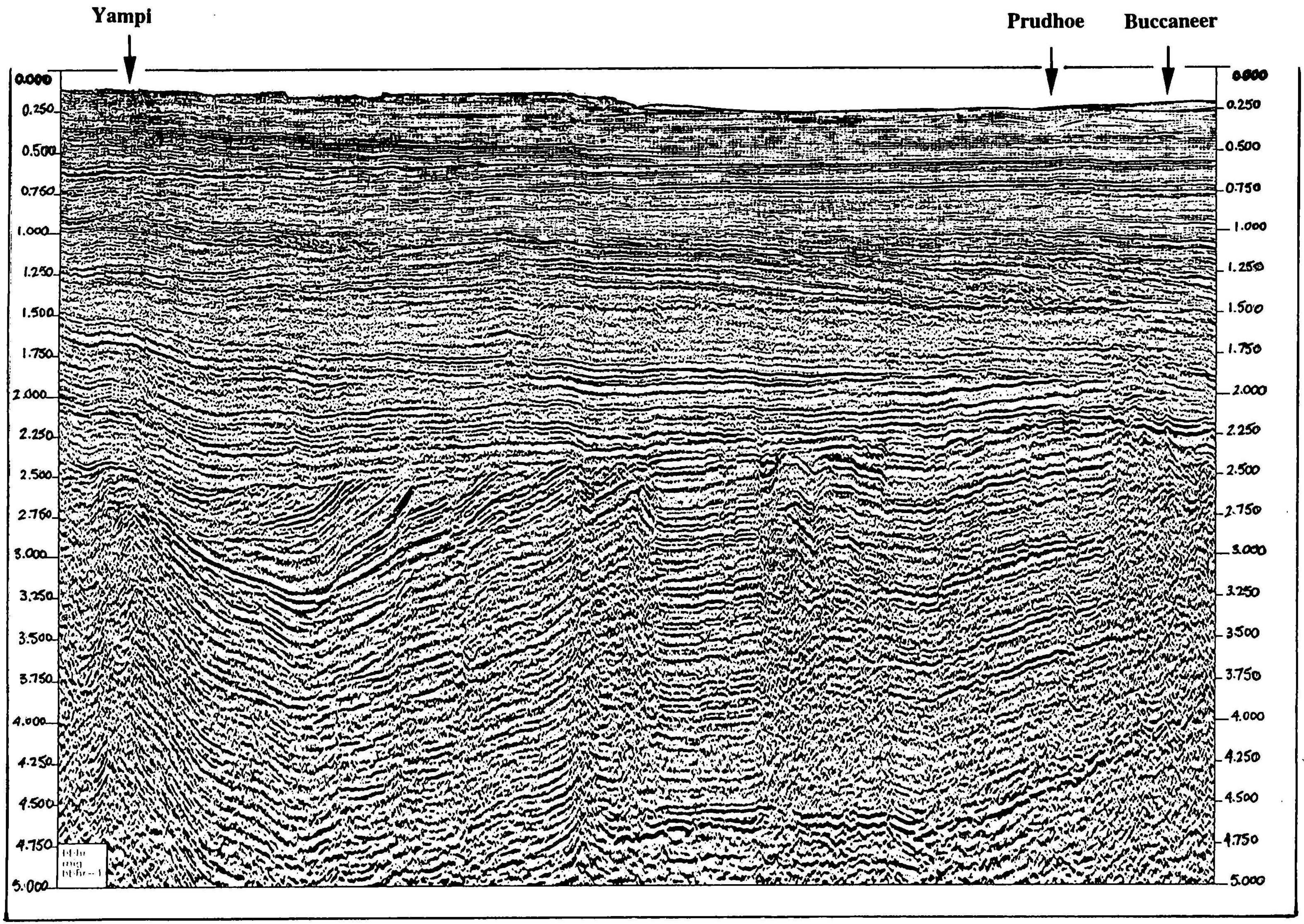
Can you see any of these traps elsewhere, where drilling has not taken place? Draw some drill holes where you think it would be possible to expect to find oil or gas. Remember that there has to be a reservoir rock below the drill holes.

Pick your most favoured position and write a small paragraph recommending where to drill next and explaining why. (Remember it costs from $10 million to $30 million to drill one well offshore). Also predict how deep you will have to drill to reach the oil (& gas).

____

____

____



Basinda Basin Seismic Section

Erratum

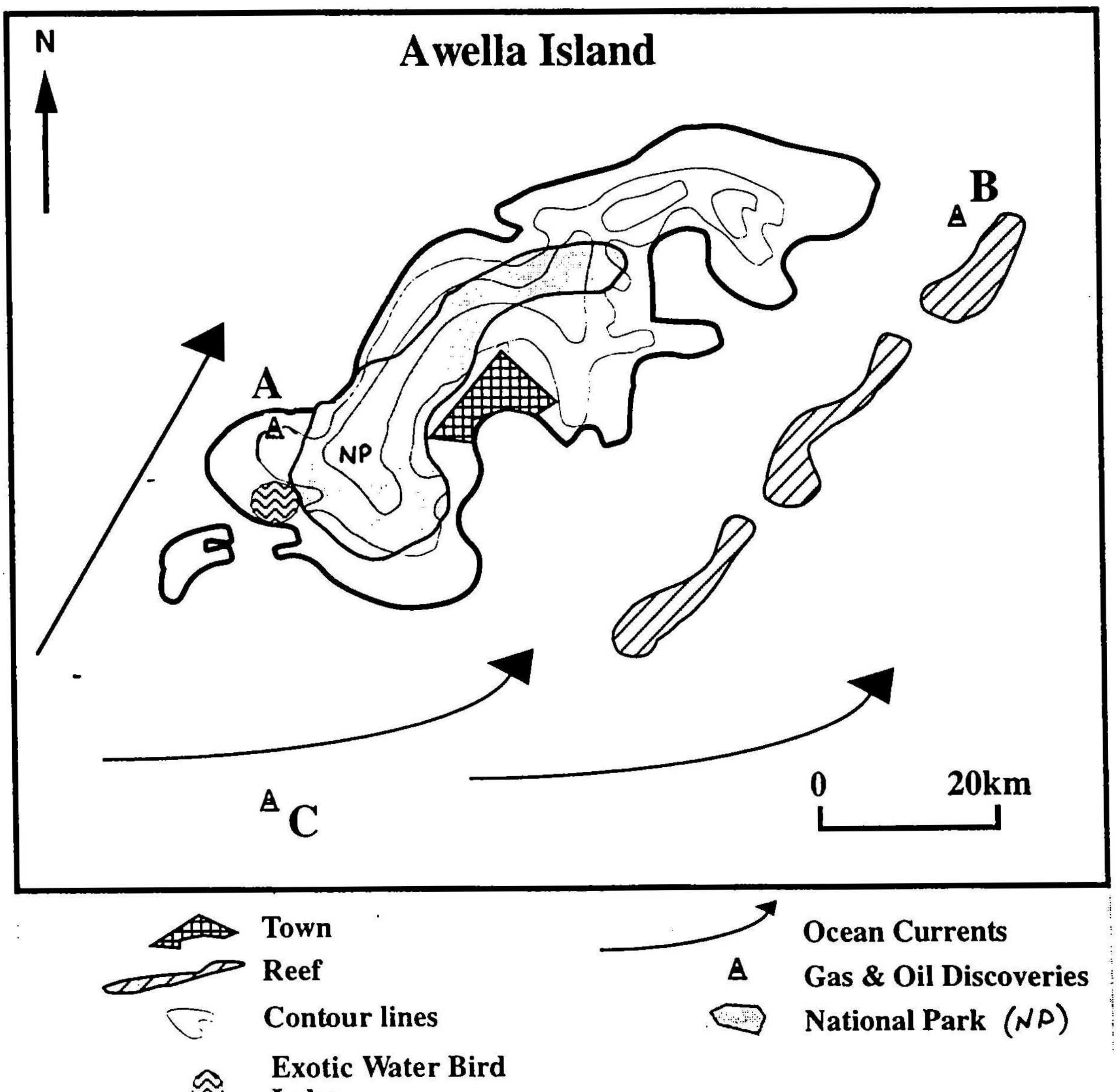
The map of Awella Island on this page should be used with the AWELLA ISLAND ASSIGNMENT rather than the map in the book.

AWELLA ISLAND ASSIGNMENT

It is the year 2070 AD, 20 years after the discovery of the planet Drillaron in the solar system of Sunagasan (in a distant galaxy). Drillaron is an exact replica of the Earth in all respects, proximity to their sun Sunagasan, climate, plant and animal life, rocks and inner planet structure. Humans travelled from Earth to make the planet their new home just 20 years ago. In order to live quite comfortably on this planet, the people need to find sources of energy and materials to sustain their way of life. At the same time, they don't want to damage the extraodinary environment that exists on the planet.

Three discoveries of oil and gas deposits (A, B & C) have been made just near the planets equator on and around Awella Island. You have been assigned the task of assessing the potential impact that extracting the gas and oil from each of these wells would have on the environment. You will then have to assess from which of the sites it is the best to obtain fuel and whether in the long term alternative energy sources should be developed.

Awella island is known as a tourist destination and its economy is based on eco-tourism. It features national parks with great walks and rare species, a freshwater lake that is an a breeding ground for many species of exotic waterbird, coral reefs with abundant life and a very comfortable tropical climate.

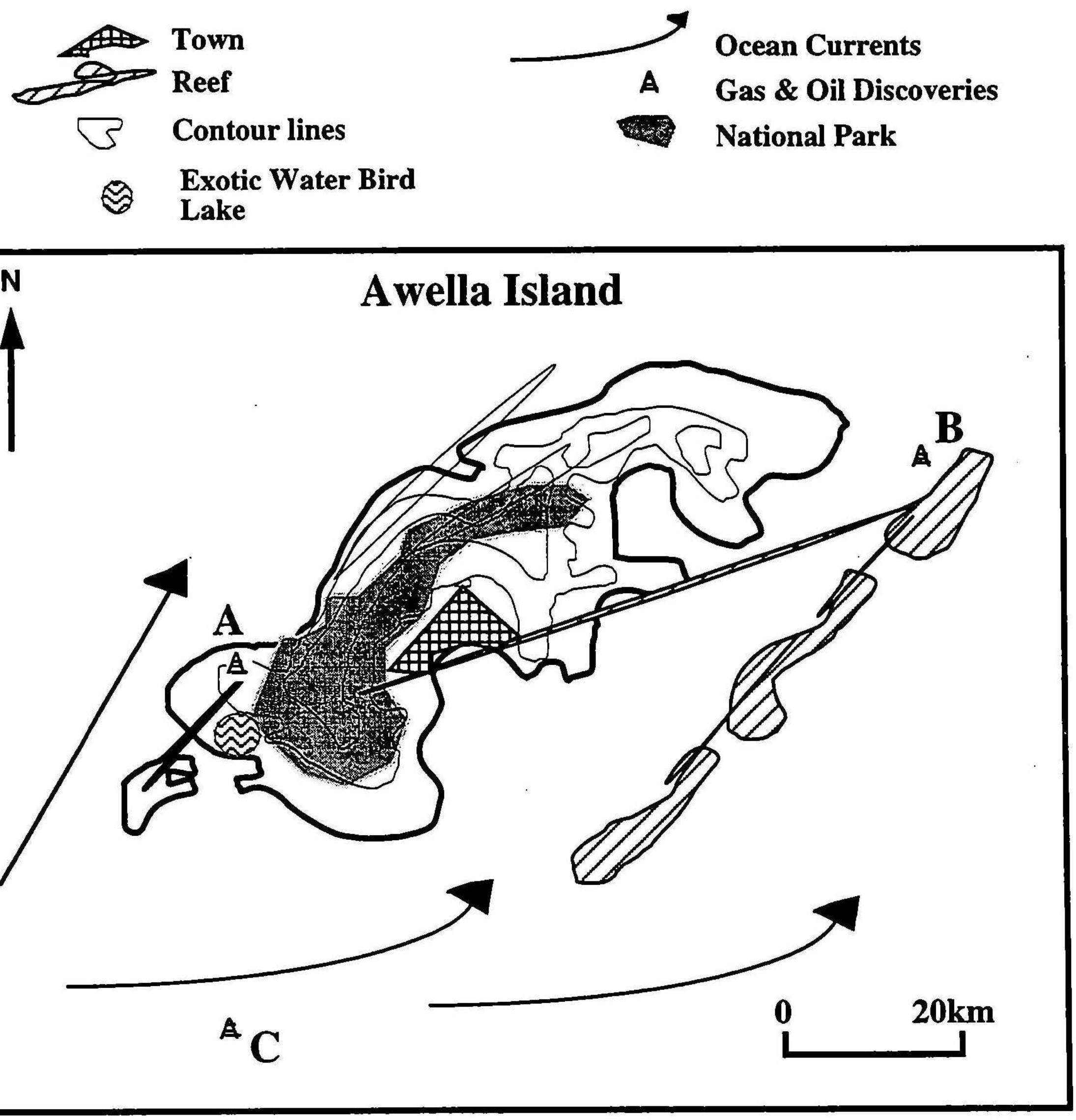


AWELLA ISLAND ASSIGNMENT

It is the year 2070 AD, 20 years after the discovery of the planet Drillaron in the solar system of Sunagasan (in a distant galaxy). Drillaron is an exact replica of the Earth in all respects, proximity to their sun Sunagasan, climate, plant and animal life, rocks and inner planet structure. Humans travelled from Earth to make the planet their new home just 20 years ago. In order to live quite comfortably on this planet, the people need to find sources of energy and materials to sustain their way of life. At the same time, they don't want to damage the extraodinary environment that exists on the planet.

Three discoveries of oil and gas deposits (A, B & C) have been made just near the planets equator on and around Awella Island. You have been assigned the task of assessing the potential impact that extracting the gas and oil from each of these wells would have on the environment. You will then have to assess from which of the sites it is the best to obtain fuel and whether in the long term alternative energy sources should be developed.

Awella island is known as a tourist destination and its economy is based on eco-tourism. It features national parks with great walks and rare species, a freshwater lake that is an a breeding ground for many species of exotic waterbird, coral reefs with abundant life and a very comfortable tropical climate.



Some preliminary costs have been drawn up so that you can compare the cost of producing from each well. This table also includes the amount of gas that is expected to be recovered from the well.

Costs and Production from Awella Island Exploration Wells

"per barrel equivalent" — gas is not measured in barrels but can be converted to the number of barrels.
"ppm" — parts per million, a measure of the concentration.

Activity / Reserves	**Well A**	**Well B**	**Well C**
Drilling	$2 750 000	$ 3 million	$ 4 million
Gas Transportation : Pipes (direct - as the crow flies!)	$30 per barrel equivalent/km	$40 per barrel equivalent/km	$80 per barrel equivalent/km
Processing	$14 per barrel equivalent	$17 per barrel equivalent	$12 per barrel equivalent
Harmful components released during processing	0.080 ppm	0.110 ppm	0.070 ppm
Estimated number of barrels	100,000	130,000	150,000

The economic cost of production

In order to assess the whole situation, you might like to start by comparing individual items:

From the table, which is the least expensive production well to drill? ______________________

Which is the least expensive production well to transport from, through pipes? __________

Why do you think this is the case? ____

____

Add the processing costs to the transportation costs and fill in this table.

Total Transportation and Processing Costs per barrel equivalent

Well A	**Well B**	**Well C**
$44		

Taking into account drilling, transportation and processing, list the wells in order from the cheapest well to produce from to the most expensive. ____

____

The environmental cost of production:

Look carefully at the map of Awella Island and the information about the island. Which well would you produce from so that the enviromental risk is minimised? State why.

____

____

____

____

____

The gas will have to be processed before it can be used. The processes involved will release some gases like sulphur dioxide and carbon dioxide into the atmosphere. The monitoring regulations for gas purification (or processing) plants are stringent back on Earth.

Hint: Air currents are usually the same as ocean currents in this area.

Using a red pencil, draw on the map where you would locate the purification plant for the gas being produced from the well you chose.

State any particular reasons for positioning it there.________________________

____

____

____

Using a blue pencil, draw on the map the location of the pipeline that would be laid down so that gas could be transported from the well to the processing plant to the town. State anything you considered when designing the pipelines route.________________________

____

____

____

____

What other information might you need to gather before you can design the pipeline route:?______

____

____

____

Given the amount of gas each well will deliver, and their relative economic and environmental costs, decide on your recommendation as to which well should be used for production. State in point form the reasons for your choice.

Well ______

Reasons ______________________________________

____

____

TEACHERS NOTES to accompany AWELLA ISLAND ASSIGNMENT:

How is the environment affected?

Here are some of the impacts on the environment at the different stages development and utilisation of this resource :

- Trapping
- Exploration
- Extraction
- Processing
- Delivery

Trapping

When petroleum is forming in the first instance, and moving from the source rocks to the reservoir, it travels along some pathway through the rocks. If this pathway does not exist, it will not move. Alternatively, if this pathway leads to the surface of the earth, the oil and gas will seep out at a rate dependent on the size of the pathway. This is something that has occurred naturally throughout geological time and is the how humans first discovered oil and gas. The environmental effects would depend on the local area; however, the rate of seepage is *usually* too slow to cause major environmental problems.

Exploration

In offshore exploration for hydrocarbons the environment is scarcely affected, if at all. Marine seismic surveys no longer use dynamite as the source of the shock waves; sources used today, such as air guns, do not harm marine life. In exploration drilling, as in development drilling, oil blowouts are the greatest potential source of environmental damage. Blowouts can occur when the pressure in a hydrocarbon reservoir exceeds the pressure of the mud column in the drill hole and control by various safety devices is not maintained. The oil or gas then escapes uncontrolled to the surface. Since people's lives and equipment worth millions of dollars are endangered, as well as the environment, great care is taken to avoid blowouts. The only occurrence of this sort in Australia was a gas blowout at the Marlin A-21 well in 1968, but no lives were lost and it was quickly controlled so no damage was done to the environment.

Extraction and Processing

Detailed planning and monitoring are adopted by companies at all stages of development and production to protect the plant and animal life in coastal zones and deep offshore environments. When drilling is taking place, it is important to extract as much water from crude oil as possible to maximise the efficiency of the process. There is no point transporting water that will not fetch the oil price. Likewise, it is important to extract all of the oil from the water. Water produced in this way is only discharged after removing remaining oil. Drilling muds are released in the area — these would be similar to sedimentation caused by a river entering the sea.

The monitoring regulations for gas plants and crude oil processing plants are stringent .

Delivery

There are two ways of delivering gas to the population centres. The first is by transporting the LPG by road, rail and sea. The second is through pipelines. There are two types of pipelines — transmission and distribution. The effects, of transporting the gas from the well to the user, on the environment are discussed further in Chapter 7.

Economic Considerations

To understand the amounts of capital involved in developing a gas field: extracting the gas and building a processing plant, compare the Sydney 2000 Olympics with the Western Australian Gas project Gorgon.

<u>The Sydney 2000 Olympics, NSW</u>

- the biggest single event in Australia's history
- Add $7.3 billion to Australia's gross domestic product
- $3.5 billion will go directly to Sydney with another $1 billion going to people and companies throughout NSW.
- create 150, 000 full and part time jobs
- bring an extra 1.3 million visitors to Australia

<u>The Gorgon LNG Project, WA</u>

- a giant offshore gas gathering and liquid natural gas processing project.
- estimated it will generate $375 million in export income in its first year of operation in 2003, rising to $750 million in 2004 and doubling to $1.5 billion in 2006 when four LNG trains are expected to be fully operational.
- Annual operating costs will be $150-160 million (salaries, maintenance and supplies).
- create jobs for up to 4000 people during construction (1999 - 2003) and several hundred full-time jobs once operational
- expected to be in operation for 20-30 years
- the construction component of Gorgon will be 25% greater in dollar terms than that of the Sydney 2000 Olympics.

Is there any further information you require before you can compare the two projects?__________

____

____

____

Summarise your ideas on how the projects compare:

____

____

____

Is it fair to compare the two projects on a purely economic basis? Why/Why not?__________

____

____

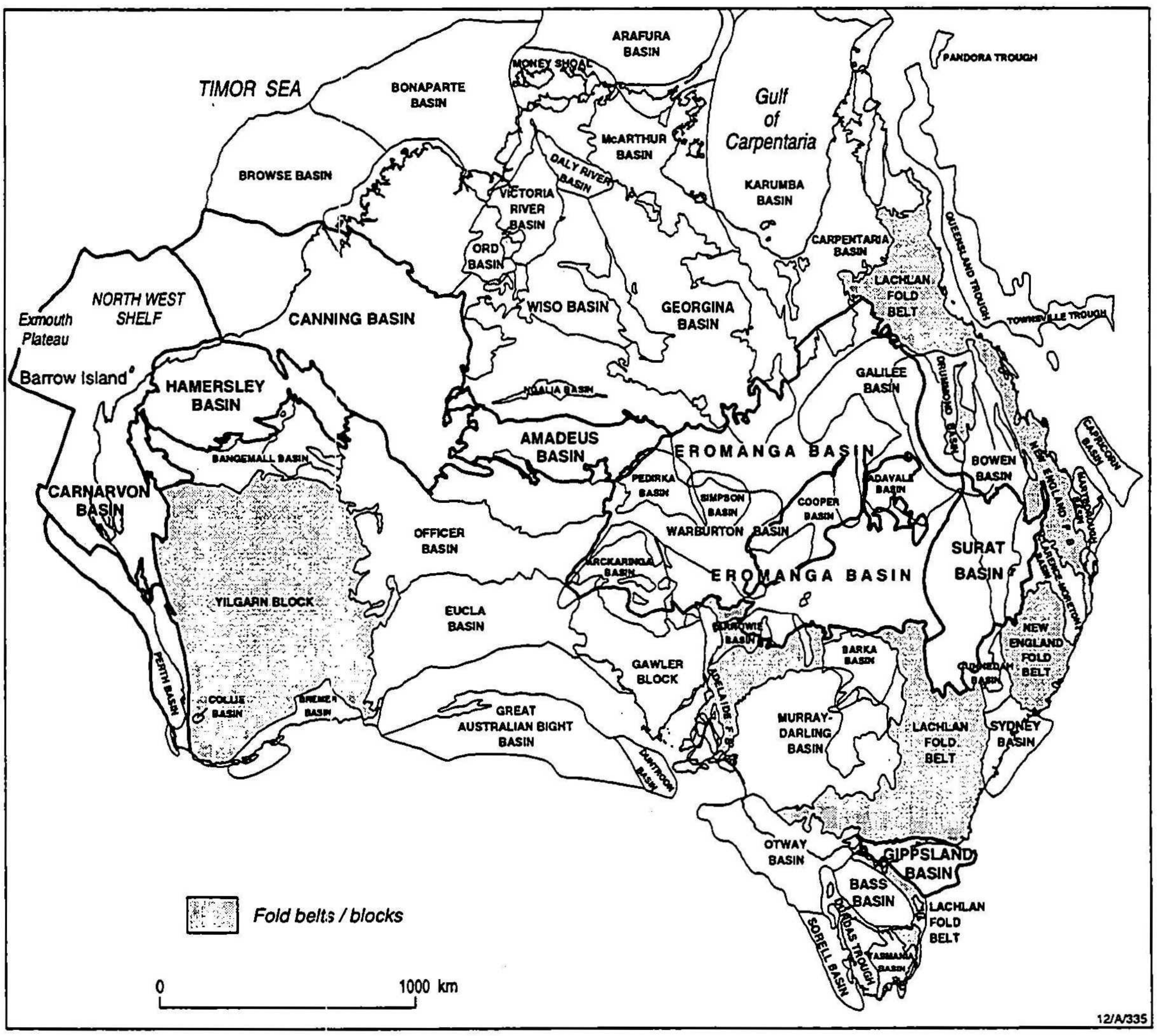
____

Further research questions:
Where does most of our gas come from?
Who are our main suppliers?
What would happen if there was a monopoly on gas supply?

Basins of Australia Assignment

The Australian Geological Survey Organisation heard about your superior skills in fieldwork and interpretation and they need your help. From the rocks they found in a drill hole they have found what might be a possible gas field. But their data became mixed up and they can't work out which basin "drill hole E" belongs to! Which basin should they go back to in search of GAS?

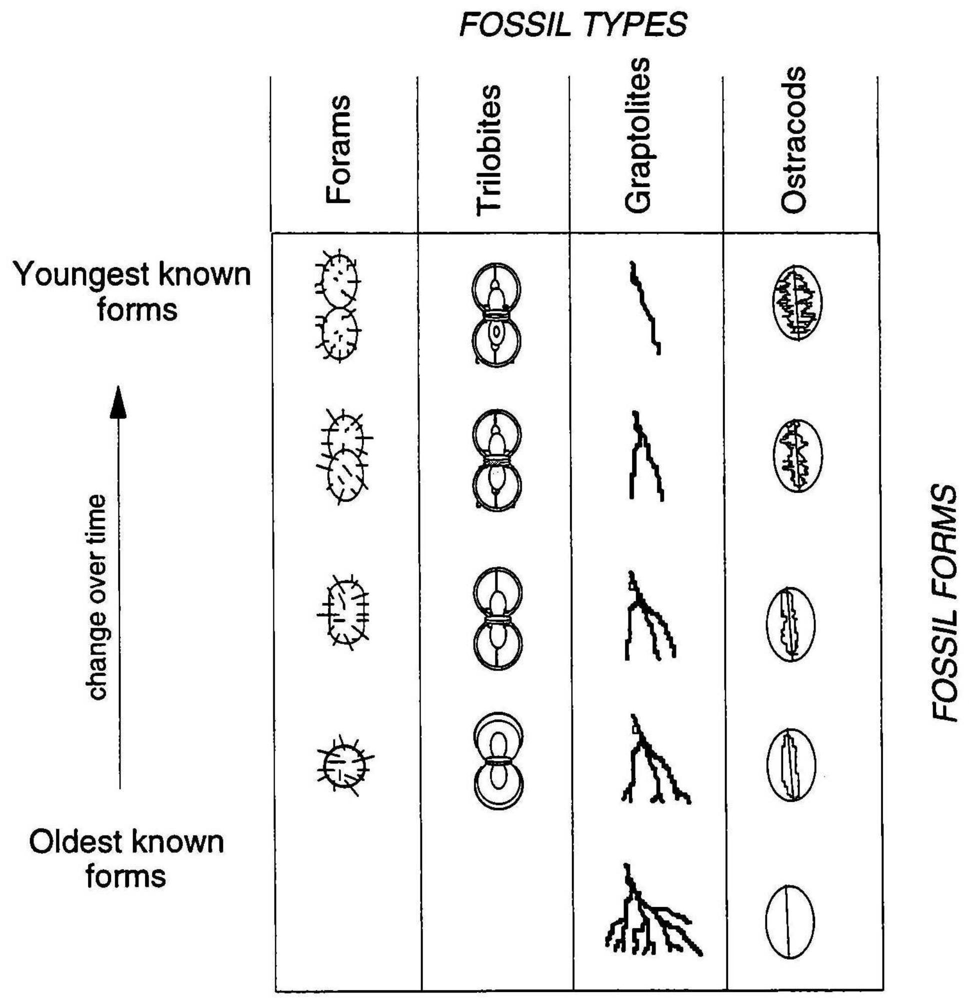
You know that one drill hole comes from each of the following basins — Gippsland Basin, Canning Basin, Cooper Basin, Adavale Basin and Barrow Island on the NW Shelf. Find and colour each of these basins on the map below.



In order to work out which drill hole belongs to which basin, you will have to

- work out the relative ages of the fossils identified from rocks in each drill hole
- use the fossils that have been dated to give approximate absolute ages to the drill holes
- compare these ages to the geological time line in order to assign each drill hole to a particular basin.

Background Information
The fossil types identified by the geologist are trilobites, graptolites, forams and ostrocods. Each of these types have a number of different forms, which have evolved over time. Research you have already undertaken gives the relative ages of each member of the fossils types. You have summarised these in a table :



Your table does not compare ages of fossils types with other fossil types, only the known ages between different forms of the same fossil i.e.. the form of graptolite at the bottom is older than the form of graptolite above it, but it may be older or younger than the form of ostracod at the bottom.

What to do
1. You have been given information about the fossils contained in five drill holes (A, B, C, D and E). Cut out each of the drill holes on the separate page into strips (do not cut between the fossil layers). In each drill hole, the fossils at the bottom are older than the fossils at the top.

2. Line up like fossils. Note that **in some cases fossils of different types will have the same age**. You may have to swap the strips around so you get the best amount of information you can from each drill hole.

3. Give each layer of the same age a number, the youngest layer at the top being 1 with the layer below being 2 and so on until you find the layer containing the oldest fossil. These numbers represent relative ages for the layers. Paste your correct version on to paper.

4. Now compare the oldest fossil to the youngest by answering the following questions—
Describe the youngest fossils

____

____

How does this form differ from other forms of the same fossil type

____

____

Which drill hole(s) contains the youngest fossil at the bottom?______________

Describe the oldest fossil form(s)

____

____

How do these differ from other forms of the same fossil type

____

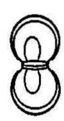
____

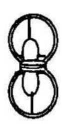
Which drill hole(s) contains the oldest fossil at the bottom?____________

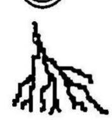
The following fossils have been dated.

Upper and lower limits on ages of particular fossils (Ma means millions of years ago)

 40-60 Ma

 210-250 Ma

 70-120 Ma

 360-410 Ma

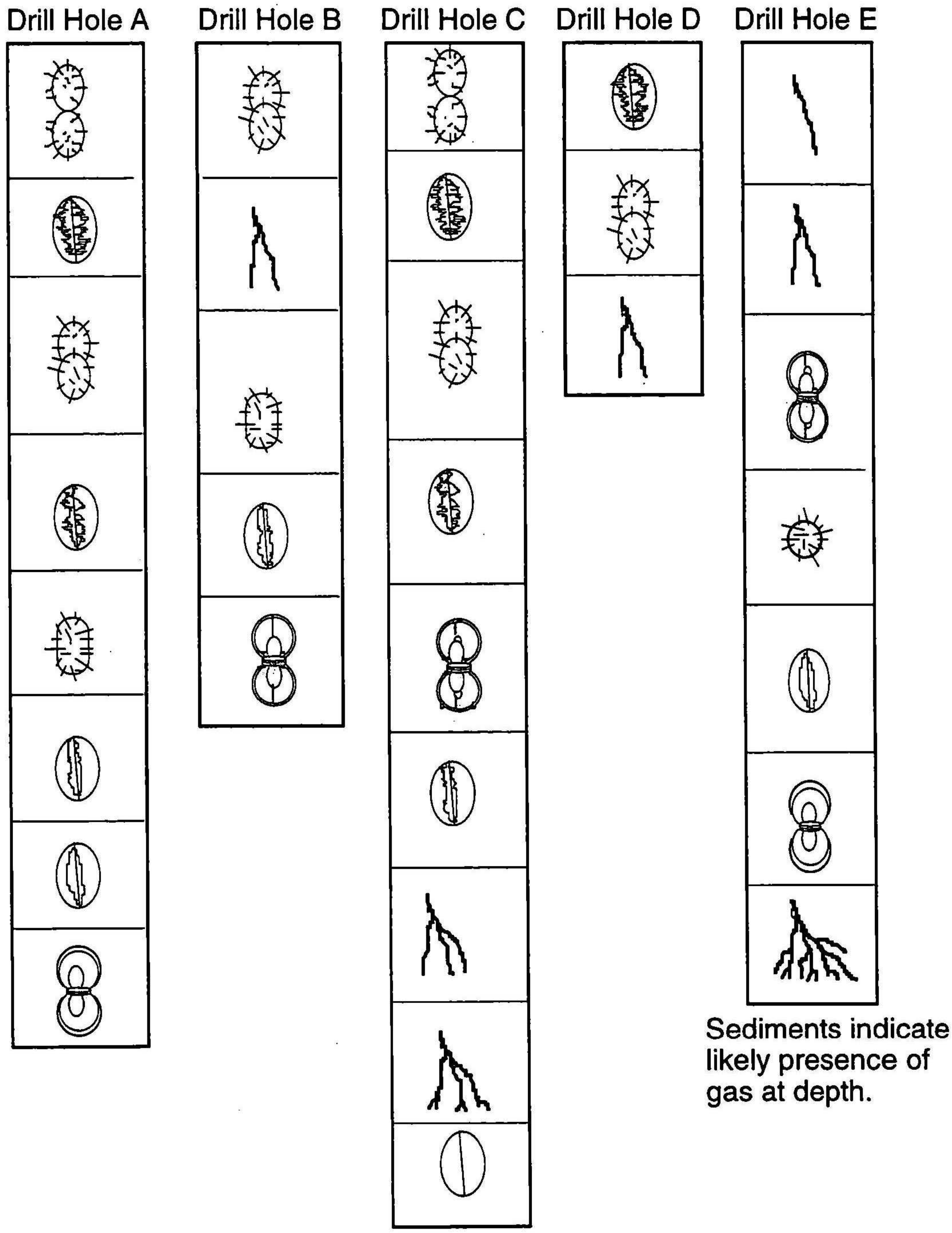
Put an age range next to the **oldest** fossil in each drill hole.Compare the ages at the bottom of each drill hole to the ages of the basins on the timeline in order to work out which drill holes are most likely to have come from which basins—

Drill Hole	Basin
A	____________________
B	____________________
C	____________________
D	____________________
E	____________________ —(likely presence of gas at depth)

From which basin might they be able to produce **GAS** in the future?__________

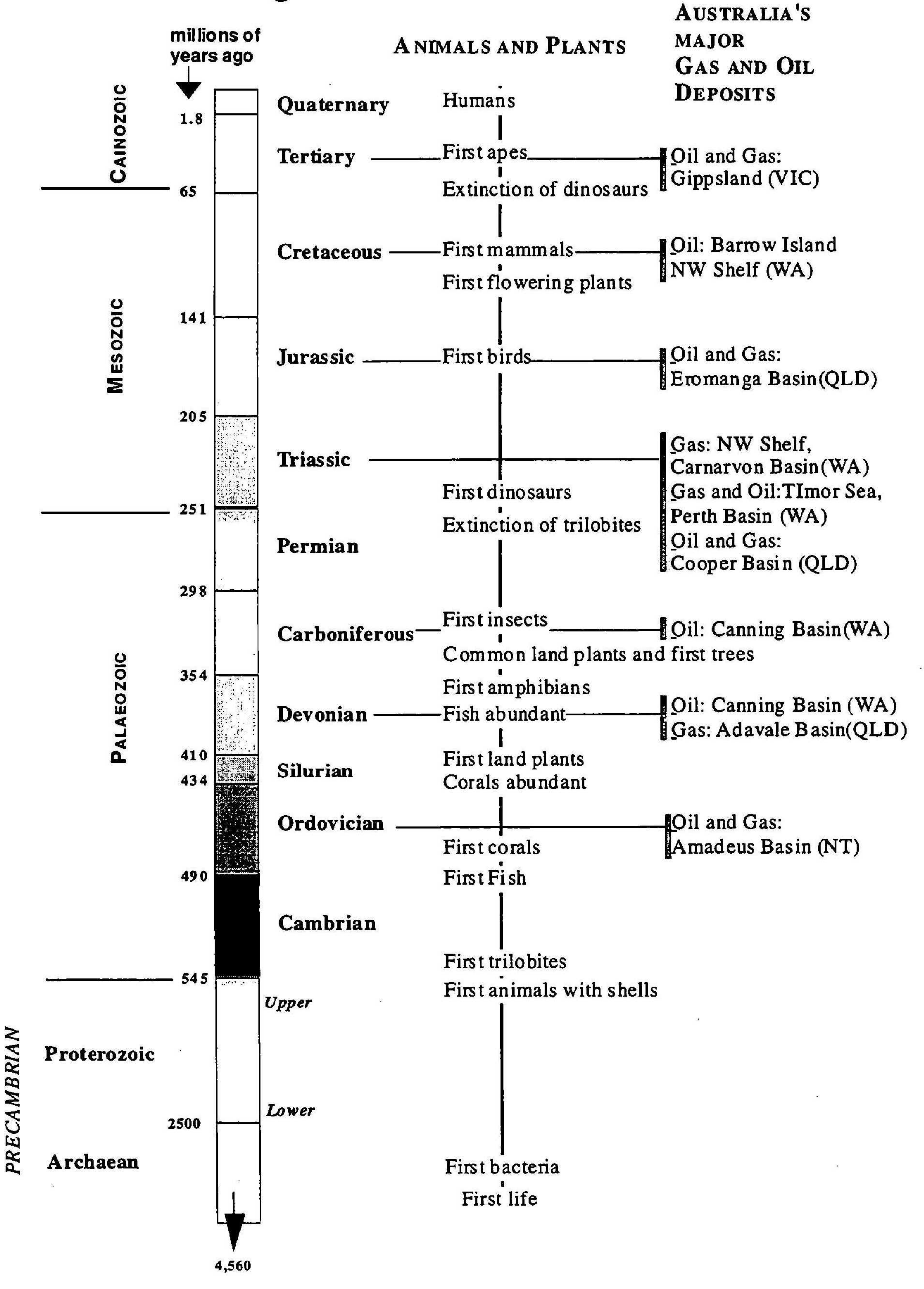
The ages cited in this exercise are not precise. What is factual is that most of our gas and oil has formed in rocks that have formed in the last 545 million years. The age of the earth is 4560 million years old. In what fraction of the **total age** of the earth do we find most of our gas and oil?_____
Why do you think this might be so?____

DRILL HOLES



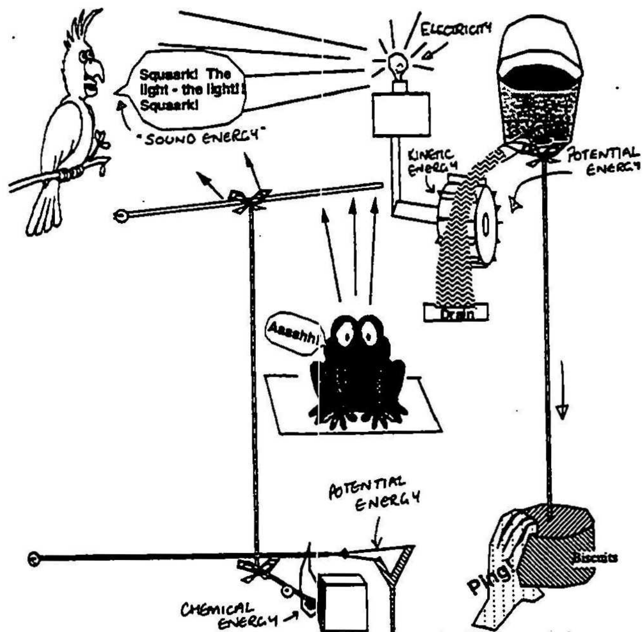
Drill Hole A
Drill Hole B
Drill Hole C
Drill Hole D
Drill Hole E
Sediments indicate likely presence of gas at depth.

Geological Time Line



Suggested Answers to Activities

Energy and Change



Describe how the biscuit tin is kept safely from greedy hands! What energy changes are taking place?

As the "greedy hand" goes to pull the biscuit tin, the string it is attached to pulls the tap down, which starts the water running over the paddle wheel. This drives a turbine which provides electricity to light the globe. The cockatoo is alarmed by the light and "squarks". This frightens the frog, who jumps, hits the lever, pulls the string which strikes the match.

In groups come up with an idea similar to this onw which shows how one form of energy can change into another form of energy and then another and so on. Illustrate your idea on a large sheet of paper and label the different forms of energy.

The match burns through the string releasing the sling shot which hits the "greedy hand".

Out Bush!

Have you ever been camping? Did you have to really rough it — or was there a fridge in the back of the 4WD and a gas stove to save you from boiling the billy! Here is the story of a student your age who went hiking. Follow the story and where it asks you — give your answer!

Sammy Satchel went camping and in his pack he carried the following:

A change of clothes	Pasta and Rice	Billy
2 woolly jumpers	Dehydrated Meat	2L Water
Essentials First Aid Kit	Sauces	Sleeping Bag
Spare underwear	Crackers and Cheese	Fruit and Snacks
torch	Breakfast food	Chewing Gum
Matches	Tent Pegs and Ropes	Tent
Firelighters	Lighter	Hollow Tent Poles

He was camping in the bush nearby a flowing creek. How do you think he would cook his dinner? Light a fire using nearby wood, boil rice in the billy . . .

What would he be using as a fuel for this? WOOD

If your whole class was to join Sammy — each person carrying in the same personal gear — with what fuel would you all cook your dinner? Nearby Wood

What would an alternative source of fuel be? metho or kerosene for a fuel stove.

If you were all to stay there for a month (pretend you brought in enough food and your sense of smell is poor), what effect would using so much of this fuel have on the local area? There would be very little "scrap" wood around, this might affect ground dwelling life.

If you were to become stranded in the bush with no immediate way out and you come across some gas, seeping out of a small hole in the ground, with the equipment you have with you how might you use this fuel? pipe it to a fuel stove using hollow tent poles + chewing gum

Do you think you could sell it? Yes - to your friends!

How would you measure the amount you were able to collect? A volume measure e.g. a full sleeping bag worth (f.s.b.w)

What safety issues should you consider? FIRE.

Appropriate Use of Fuels I

Different sources of energy — fuels — are used for different purposes. How long will a car continue to run if apples are put in the petrol tank. A car would not go very far if apples were put in the petrol tank and if <u>you</u> tried to use petrol as a fuel you would become extremely sick.

What fuel would you use to run these things?
Next to each item below fill in the appropriate source of energy from the list.
Note : There may be more than one answer.

Battery, Gas, Solar, Coal, Wind, Food, Mainline/Grid Electricity, Oil, Geothermal.

1. Car — Oil
2. Light Globe — Electricity
3. Computer — Electricity
4. Radio — Battery
5. Torch — Battery
6. Marathon Runner — Food
7. Windmill — Wind
8. Portable BBQ — Gas / Solar
9. Electric Car — Battery / Electricity
10. Bunsen Burner — Gas
11. Hair Dryer — Electricity
12. Whistle — Wind
13. Building Heat — Geothermal

Why do you think we have so many different types of fuels? Different fuels are used for different purposes.

If you could run your body on any energy source you wished, which energy source would you chose? Explain why. Various Answers.

Appropriate Use of Fuels II

ACTIVITY:
Take a candle.
Light it.
Observe it closely.
What is actually burning? (solid wax, liquid wax or gas)
The wax becomes a gas which burns.
How can you prove your observations? Blow out the candle and light the smoke.

Flour explosions!

On December 14, 1785, an industrial explosion occurred in a flour warehouse at Turin in Italy. Flour, a harmless ingredient in so many of our food products, can build up as a dust in the air and when exposed to a spark it will explode!

Work out why:
Before the invention of batteries, to light their way miners used to use caving lamps containing the chemical calcium carbide. To produce light, water from the lamp would drip onto the calcium carbide, causing a chemical reaction which would produce acetylene gas (C_2H_2). This acetylene gas was then burnt to produce a bright white light.

Why might this practice be dangerous in a coal mine? Coal dust is explosive just like flour can be.

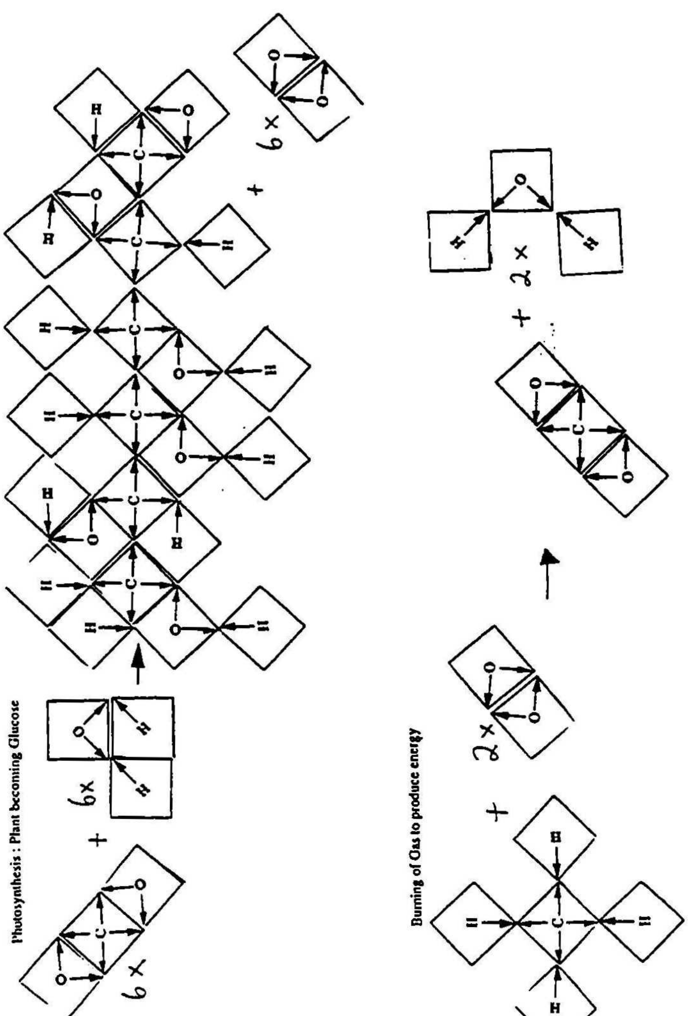
Once a Plant - now Natural Gas

The sequence of events that need to take place before gas and oil are produced consists of a large number of steps. Can you work out the right order?

What to do.

1. Cut out each box.
2. Read each of them and as you read, place them in order from the first step in the formation of gas and oil to the last. *HINT : The first box has to do with the formation of the original material and the last box has to do with extracting the gas or oil.*
3. Compare your results with your neighbour. Are they the same? ______
4. Once you have your completed flow chart, stick it down on an A4 sheet of paper.

Folding and faulting of the rocks must not be too severe. Traps may become breached and thus leak due to intense fracturing.	7
The oil and gas that is being produced in the source rocks has to move or migrate into very porous rocks in which they are stored. These are called reservoir rocks.	8
If the layers of rock containing the stored gas and oil are uplifted and then exposed to erosion, the gas/oil may be lost.	10
Folding or faulting of the sequence of rocks may occur leading to the formation of traps which will not allow the oil and gas to escape.	6
Burial of organic matter by sand and mud before being eaten by scavengers or destroyed by decay(oxidation).	2
The pore spaces of the storage rocks must remain clear so that the oil and gas can be pumped out (if necessary) of the reservoir rocks. Swelling clays or mineral cements deposited by groundwaters can fill the pores of resorvoir rocks and stop the recovery of all of the oil/gas.	9
Organic matter (made up of complex hydrocarbons and contained in living organisms) is in plentiful supply in the environment.	1
The deeper rocks are buried, the higher the temperature becomes. As the temperature increases gas will be formed instead of oil. But if the temperature is too high, instead of gas and oil, graphite, used in lead pencils, will be formed!	4
Chemical reactions occurring deep in the crust tranform the organic source material to oil and gas.	5
The sediments (sand, mud, etc.) containing the layers of organic matter are turned into rock.	3



Chemical Changes Assignment

Plant → Gas → Energy

At the present time, chemical reactions produce over 90 % of the energy that we produce in our society! These reactions are principally the combustion of coal, petroleum products and natural gas. Some chemists have been trying to construct models so they can compare the creation of gas (from plants) to what happens when the fuel is burnt. Can you work it out?

Step 1 : Read through the information below and fill in the blanks.
The source of energy for all fossil fuels has come from the sun. In the case of oil and gas, microscopic marine plants, such as algae, living in the upper layers of the ocean adsorb the sun's energy to convert carbon dioxide and water into simple hydrocarbon compounds such as sugars. This process is called photosynthesis.

What happens in Photosynthesis??
Photosynthesis is the major means for changing solar energy into forms that can be used by living organisms. The reaction that occurs in the leaves of plants is the conversion of carbon dioxide and water into simple hydrocarbon compounds such as glucose, for example:

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

Carbon Dioxide — Water — Glucose — Oxygen

- **Write the names of the reactants and the products underneath their chemical formulae.**
  C is Carbon O is Oxygen H is Hydrogen
- **Check that this equation is balanced — the number of each type of atom must be the same on both sides of the arrow.**

C —	6	C —	6
O —	18	O —	18
H —	12	H —	12

When a number is in front of a molecule then you have to multiply each atom by that number e.g. if there is a 6 in front of CH_4 you will then have 6 carbon atoms and 6x4 = 24 hydrogen atoms.

These simple hydrocarbons (i.e. glucose) within the marine plants can later be converted within the food chain to more complex hydrocarbons. For example when algae are eaten by fish the simple hydrocarbons are changed within the fish to more complex hydrocarbons. All living things are made up primarily of hydrocarbons, compounds containing carbon, hydrogen and oxygen — these are called organic compounds. It is these hydrocarbons that ultimately become the essential components of natural gas: methane, ethane, propane and butane.

How does the hydrocarbon (organic compound) become gas?
When these hydrocarbons are buried in rocks deep in the crust, they heat up and "cook" under the ground. The process is chemically and biologically very complicated.

What happens when we burn natural gas??
We all know that in order to burn something air is required. More particularly, the oxygen portion of air is essential to support combustion. So when natural gas is burnt, it reacts with oxygen in the air. The products are carbon dioxide and water. This can be represented by a chemical equation as follows:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

Natural Gas (methane) — oxygen — Carbon dioxide — water

- **Write the names of the reactants and the products underneath their chemical formulae. Check that this equation is balanced — the number of each type of atom must be the same on both sides of the arrow.**

C —	1	C —	1
O —	4	O —	4
H —	4	H —	4

The process changes methane, a more active greenhouse gas, into carbon dioxide, which is relatively less active as a greenhouse gas.

Step 2 : Construct each of the molecules inthe equation that shows the formation of glucose. In order to do this you will need to read and follow the rules sheet the points beneath it:

RULES :

CONSTRUCTING THE MOLECULES

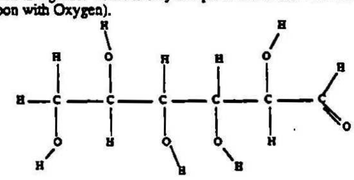
A *molecule* is made up of one or more elements or *atoms*. These *atoms* can be the same or different.

e.g. O_2 — a molecule with two atoms that are the same.
CO_2 — a molecule with different atoms.

- Each atom can bond to other atoms.
- Carbon has four bonding sites (the arrows), oxygen has two bonding sites and hydrogen only one.
- Each arrows must join with another arrow to make a bond complete.

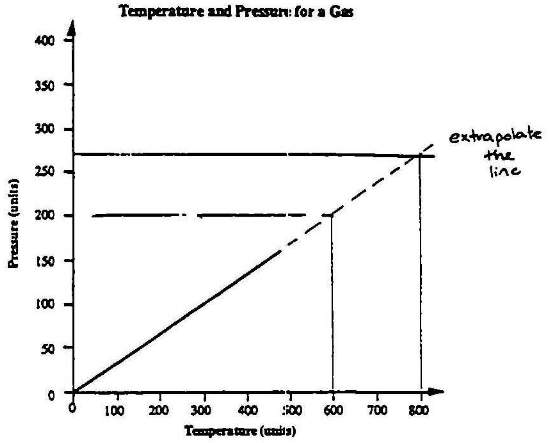
In order to make the molecules you may need to know the following:

- CH_4 — the hydrogen atoms do not bond to each other.
- CO_2 —the oxygen atoms do not bond to each other.
- H_2O — the hydrogen atoms do not bond to each other.
- The carbohydrate (glucose) has a complex structure — to help you put it together use this diagram as a guide. There is only one place where one atom bonds twice with another atom (Carbon with Oxygen).



- Stick each molecule down on a large sheet of paper in the order of the equation. Add plus signs and arrows where needed.
- Make sure that there are the same number of carbon atoms one one side of the arrow as there are on the other side. Do the same for the oxygen and hydrogen atoms.
- If there are unequal numbers of the same atom you will need to make them equal by making more molecules to add to either side.

Gas and Volume Changes with Pressure & Temperature I



What will the *temperature* be if the pressure is 200 units? 600 units

What will the *pressure* be if the temperature is 800 units? 275 units

As the *temperature* of a gas increases, the *pressure* of a gas increases

What do you think would happen to the air *pressure* in a balloon if you took it from room *temperature* and put it into the freezer? Because the temperature is decreasing the pressure would decrease inside the balloon.

Try this and see what happens to the volume.

What happens to the volume of the balloon when:

a) the temperature is reduced? it decreases

b) the pressure on the outside of the balloon is reduced? it increases

Natural Gas under high pressures is sent through steel transmission pipes from the gas fields to the city. Why do you think that steel might be the best material for this purpose? Strength + other answers.

Gas and Volume Changes with Pressure & Temperature II

Find out : Does a gas meter take a measure of pressure or volume? VOLUME

What units does a gas meter measure in? CUBIC METRES (m^3)

How does a gas meter work? See chapter 8 - end.

Would it be more advantageous to heat the gas pipes or cool them before the gas goes through the meter? If you cooled the pipes and the gas before it goes through the meter a greater amount of gas would be in the same volume.

When gas is deep in the crust it is under a great deal of pressure. What do you think might be the cause of this pressure? The gas is trapped. See end of chapter 7 :- water under the force of gravity.

What do you think will happen to the volume of gas as the gas is extracted to the surface, where the pressure is lower? It increases.

Your teacher will supply you with a graph that shows the volume of the same amount of gas at depths from 1km to 5km (from chapter 6). Copy this diagram below.

Paying Your Gas Bill

Thomas just received his fortnightly pay cheque of $963.00. He did a "back of the envelope" calculation to determine how much he would have left after he puts aside money for food, rent and car expenses and it turned out to be $150.00. He has forgotten about his gas bill. By how much will Thomas have to cut back on his entertainment allowance of $150.00 in order to pay his gas bill?

Step 1
Work out how much Thomas still owes to the gas supplier from his last account by subtracting the "Payments received" from the "Last account" balance. Write your answer next to (a) the Balance, this appears twice on the page.

Step 2
Work out the charges for Natural Gas costs for this account by working through the following steps and filling in the amounts for (c), (d), (e), (f) and (g).

- To work out (c): When Thomas' gas meter is read it gives the amount of gas consumed in units. Read off the table how many units were consumed: 110
- Convert units to Megajoules (MJ) using this equation (no decimal places necessary in answer)

Megajoules = units x 39.018838

Working: = 110 x 39.018838 = 4292 Fill in (c).

- Work out (d) and (e) by multiplying the number of MJ consumed by the cost in cents/MJ. Fill them in on Thomas' gas bill.
- The cost of natural gas has increased. How many MJ will be charged at the new rate?

(f) = (c) - 185 MJ - 817 MJ

Working: = 4292 MJ - 185 MJ - 817 MJ = 3290 MJ

- Work out (g) without any help.

Working: 3290 MJ x 1.1192 c/MJ = 3682 ¢

- The charges listed under cost will need to be added to get (h) the Total Natural Gas Costs. Fill this in in two places on the table. (Add d, e and g).
- Move up to the top section of the bill and fill in New Charges (h) in two places.
- Add up the total due (add (a) and (h) together) and write it in (b), in two places.

Now that the bill is complete, answer the following:

1.Will Thomas have to cut back on entertainment or will $150.00 pay off this bill?
He will have to cut back He will have $26.61 left

2.How much will he have for entertainment this fortnight? $26.61

3.Over what period of time is this bill for? 30 days or 1 month

4.Should Thomas expect a bill like this every month? Why/Why not?
No because once he has paid back this bill his new charges each month should only be around $50.

Thomas' Gas Bill

Customer Number
035595

Payment Reference Number	0103 5595 2001
Invoice Number	00135
Date of Issue	25 / 07 / 1998
Account Number	001

	☎
Accounts and Service - 7am-8pm	132 7[illegible]
Appliance Repair - 24 hours	132 6[illegible]
Emergency - 24 hours	131 9[illegible]
Sales - 7 am-8pm	132 7[illegible]
Outside NSW and ACT call 1800 806 616	

Payment Due

Last Account	Payments Received	Balance	New Charges	Total Due
$129.40	$54.48	(a) 74.92 DR	(h) $48.47	(b) $123.39

Natural Gas Costs (h) $48.47

Balance (a) $74.92

Total Due (b) $123.39

From 1 July 1998, the gas supply fee for Rate 2 customers (under 45GJ/annum) has increased by $1.25/quarter.
Usage rate for first tariff block has been reduced. Details 132 707.
Note: Of the total due, $74.92 is OVERDUE and must be paid immediately unless special arrangements have been made.
New charges of $48.47 should be paid by the DUE DATE of 08 /08 / 1998.

Supply Address:

Type	Meter Number	Current Date	Current Reading	Previous Date	Previous Reading	Units Consumed	Megajoules Consumed
Gas	EA050732	24/07/1998	2337	24/06/1998	2227	110	(c) 4292 MJ

To convert Gas Units to megajoules, multiply the Units by 39.018838
NOTE: The Industrial and Commercial Rate changed in price on 01/07/98

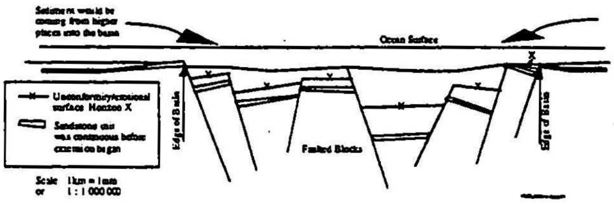
Natural Gas Costs: Tariff - Industrial and Commercial Rate

Old Rate (7 days):	817 MJ, charged at 1.1725c per MJ	(d) 958
	185 MJ, charged at 1.1192c per MJ	(e) 207
New Rate (23 days):	(f) 3290 MJ, charged at 1.1192c per MJ	(g) 3682
Total for 30 days:	(c) 4292 MJ	Natural Gas Costs = (h) 4847 cents.

How far has the crust stretched?

You are the structural geologist on a contract for the local council and you have been assigned the following task: You have been asked to assess the rate of extension of the crust in the Basinda area. It is planned to lay some large transmission pipes across the length of the basin for transportation of gas to the coastal town of Le Basin. The council wants you to tell them whether they will need to be concerned about replacing or extending the pipes in the next 150 years.

Background Information
When basins are forming, due to crustal extension, large fault structures usually occur. These fault structures will extend deep into the earth's crust. A result of the tensional force and faulting is that the crust will have been stretched.



Step 1
Measuring how much the crust has stretched.

- With your ruler measure the distance between the two points at the east and west edges of the basin that appear not to have moved:(a) 97 mm.

  To convert this to the actual distance in kilometres use this formula

Distance accross the basin in km =	Distance across the basin today(mm)(a) / Length of 1km (mm)

Answer A: 97 km.

- Measure the length of the sandstone unit before it was extended. To do this you will need to measure the length of the sandstone unit in each fault block and then add them all together. The total is (b) 74 mm Convert this measurement to kilometres using the formula above.

  Answer B: 74 km.

- Find the difference between distances A and B.

  Answer C: 23km .This is how much the crust has stretched.

Why do you think horizon X may not be as good a marker to use for determining the distance stretched? It has been an erosional surface i.e. parts of it no longer remain therefore it is not a complete indication of what was there before the basin started forming.

Step 2
Work out the rate of extension of the crust.
Geological evidence suggests that this basin is relatively young and possibly still growing. Evidence from the rock layers, fossils and cross-cutting veins indicate the basin began forming, near the base of the sandstone unit, around 5 million years ago. If we assume that stretching is occurring at a constant rate, what is this basins rate of stretching?

Do your calculation here:

Rate of stretching = Distance stretched, C (km) / Number of years of stretching = 23 km / 5000 000 year

Answer D: 0.0000046 km/year

Step 3
Using the rate of extension of the crust work out how much more extension will occur over the next 150 years.

Do your calculation here:

Stretching distance (km) = Rate of stretching, D (km/yr) x Number of years
= 0.0000046 x 150 years
= 0.00069 km

Answer E: 0.00069 km over 150 years

To answer the question below you will need to convert this to mm/year.

1 km = 1000 m = 100 000 cm = 1000 000 mm

Stretching distance (mm) = Stretching distance, E (km) x 1000 000 mm/km
= 0.00069 x 1000 000
= 690

Answer F : 690 mm over 150 years

If the pipes can cope with extension of up to 300 mm, do you think they will need to replace them or extend them in the next 150 years? YES

How long before the crustal stretching will have an effect on the pipes?

Number of years for basin to reach 300mm = 300mm / Rate of Stretching in mm

Rate of stretching (mm) = Rate of Stretching (D) km x 1000 000 mm/km
= mm

Working :
0.0000 046 km/yr x 1000 000 mm/km
= 4.6 mm / year.
No years = 300mm / 4.6 mm/year = 65.2 years

The number of years it will take to stretch the crust the allowable distance = 65

In order to work out the answer above — what is the big assumption we are making? That stretching is occurring at a constant rate.

How might this assumption be incorrect? The earth's crustal movements do not necessarily occur like this. The earth may move metres in one year and then not move for another hundred years!

This is an extremely young basin. Most basins take tens of millions of years to form.

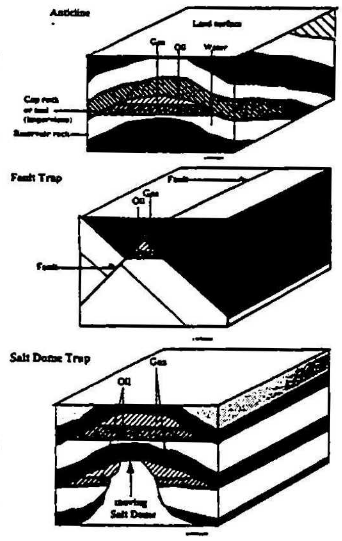
Can you find the traps?

A trap, as the name suggests, is a structure which prevents the petroleum from escaping to the surface. The major forms of structural traps are anticlines, faults and salt domes.

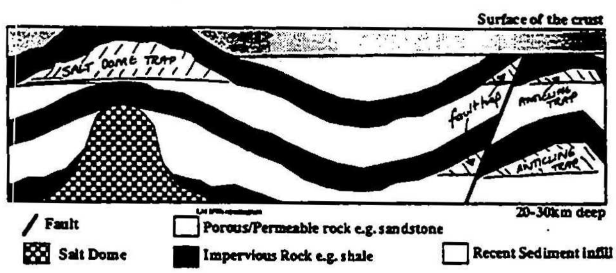
Anticline
An anticline is simply a fold shaped like an arch or an elongated dome. Oil fields may extend for many kilometres along the crest of an anticline.

Fault
Traps can form where a reservoir rock and impermeable cap rock are moved by a fault to allow porous rocks to collect oil and gas underneath the trap. The impermeable material must lie above the reservoir rock. Sometimes small amounts of oil and gas can leak up the fault and reach the surface. Over very long periods of time this minute leakage could eventually empty the trap.

Salt Domes
Salt domes are structures which formed by a moving mass of salt. Deeply buried beds of salt (called evaporites) were formed in the past by evaporation of sea water and subsequent burial. These are structures which can move upwards because of density differences. The rising domes bend the surrounding sediments upwards producing reservoirs in porous beds cut off by the salt. Remember the salt is a cap rock as well as the clay/shale that the salt dome pushes.



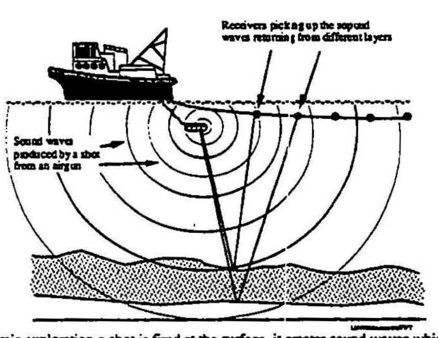
In the diagram below, draw where you think there may be a possible trap — use a bright pen or pencil so that it will be obvious. Label the trap with its correct name.



Measuring Depth with Time

When a company decides to explore for petroleum, the first thing it must do is research information about the potential of the area. Once the company decides to explore in a particular area it will buy an exploration permit for that area and then it will begin by "shooting" some seismic. This will enable the geologists to map the structure of the rocks at depth and predict where oil and gas might be found.

A seismic cruise has just been completed and some raw data has been handed to you. The depths of some of the horizons needs to be worked out accurately so that drilling costs can be estimated. Can you work out how time relates to depth?



During seismic exploration a shot is fired at the surface, it creates sound waves which bounce off particular layers and then return to the surface. What is recorded is the time it takes a wave to travel from the shot to the layer and back up to the detector.

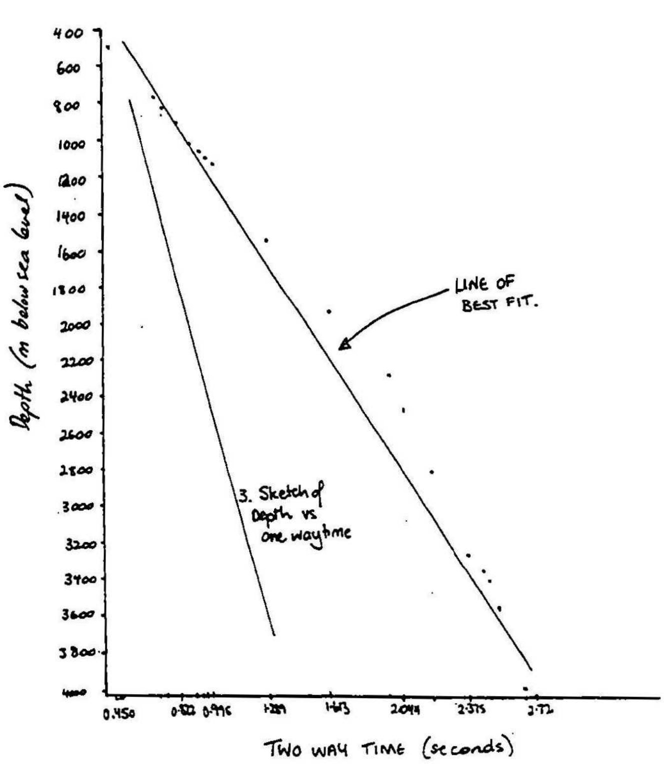
1. Plot depth vs two way time for the Yampi vertical section on graph paper. Put depth on the y axis (the vertical axis). The data you will need is in a table on the next page.

2. Draw the line of best fit through the points.

How deep is a unit that is recorded at 2.1 seconds? ~ 2700 m .

How long would it have taken for a sound wave to travel from the airgun to a layer that is 1750m deep and back up to the receiver? ~ 1.45 seconds .

How long would it have taken for that sound wave to travel to the depth of the layer at 1750m, but not back again? 1.45 ÷ 2 = ~ 0.73 seconds



Interpreting Seismic: a Seismic Section
Major Assignment

The chief exploration geologist working on a section of the Basinda Basin has suddenly left the company. You have been working with her and now the company wants you to complete the report and recommend where to do further drilling.

This is the information you have at this stage:
Three Exploration Wells have already been drilled and gas or oil has been found in particular rock units. The table below summarises the findings.

Well Name		Yampi		Prudhoe		Buccaneer	
Rock Type	**Horizon Name**	**Depth metres**	**TWT sec**	**Depth metres**	**TWT sec**	**Depth metres**	**TWT sec**
sandstone	Tlmio A	473	0.450	575	0.506	589	0.531
limestone	Tmmio B	785	0.708	716	0.663	710	0.640
mudstone	Temio C	825	0.745	750	0.732	820	0.740
shale, sandstone	Teoc * D	922	0.822 (27.0)	990	0.887 (29)	1015	0.883 (29.0)
shale	Ktur * I	1550	1.289 (42.5)	1797	1.470 (48.5)	1880	1.503 (49.5)
shale	Kalb II						
shale, sandstone	Kapt * J	1948	1.613 (53.0)	2392	1.890 (62.0)	2600	2.008 (66.0)
shale	Kval * L	2572	2.044 (67.5)	2718	2.080 (68.5)	2840	2.151 (71)
shale, sandstone	Kbase M	2827	2.169	2895	2.167	2970	2.214
volcanics, sandstone	Jcal * N	3238	2.375 (78)		=	3261	2.360 (78)
shale, sandstone	Trmid Q	3592	2.542				
shale	P R	3915	2.681	2955	2.198		
sandstone	Pearly S	4010	2.720				
shale	Cnam T						

answers in circles are in mm

TWT — two way time.
Depth in metres measured from the sea floor.
* — These are the horizons that will be mapped.

During seismic exploration a shot is fired at the surface, it creates sound waves which bounce off particular layers or horizons and then return to the surface. What is recorded is the time it takes a wave to travel from the shot to the layer and back up to the detector. It travels down and then back up and so is called two way time.

Note to the Teacher — Diagram "Generating a Seismic Image" in Chapter 6 can be turned into an OHT.

Equipment:
Coloured Pencils
Calculator
Ruler

What to do:
1. Interpret the seismic section
- The exploration wells are marked at the top of the section and two way time is marked down the side. Draw a straight line in lead pencil, straight down from each well, so that you can trace where the drill went!

- From the table above, pick a horizon with an asterisk (*).

We'll do the first one (Horizon A) Tlmio for you.
From the table you can see that Tlmio is a horizon of sandstone and it has a different two way times which correspond to different depths in each drill hole :
— two way time of 0.450 seconds in the Yampie exploration well
— two way time of 0.506 seconds in the Prudhoe exploration well
— two way time of 0.531 seconds in the Buccaneer exploration well

So for Tlmio (Horizon A) we will put a red coloured mark under each of the wells at the following depths:
— Yampie : 0.450 seconds
— Prudhoe : 0.506 seconds
— Buccaneer : 0.531 seconds

In order to work out what these are equivalent to in millimetres so that you can measure them, measure down to 1.000 seconds. If on your seismic section 1.000seconds = 33mm. Multiply the number of seconds in the table by 33mm/sec to give you your measurement.

Formula				
Two Way Time for particular horizon	x	33mm/sec	=	Measurement (mm) from 0.000 sec line to reach horizon

NB. Make sure that 1.000 seconds measures 33mm. If it does not — use the measurement that you make.

For example: The tlmio horizon (A) in the Yampie drill hole
0.450 sec x 33 mm/sec = 15 mm

In red pencil you would mark 15mm on your section under the YampieWell. This is the tlmio horizon.

Do the same for the Prudhoe and Buccaneer Wells.

Calculations:
Tlmio horizon (A) in Prudhoe Well: $0.506 \times 33 = 16.698$; sec × mm/sec = 17mm
Tlmio horizon (A) in Buccaneer Well: $0.531 \times 33 = 17.523$ ≈ 17.5mm

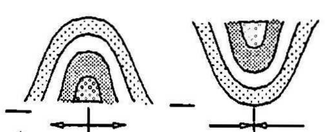
- Now that the layer has been marked underneath each well, you will have to complete the seismic section. Look side on at the seismic section so that your head is almost on the table and your eye is glancing down the length of the layer. As best you can, follow the layer tlmio (horizon A) from one side of the page across to the other side. Carefully draw this in with your red pencil. It may not be a straight line — DO NOT USE YOUR RULER!
- Do exactly the same thing for the other horizons with an asterisk *, but make sure you choose a different coloured pencil — otherwise your horizons might become confused. Make sure you set out your working clearly as above.
- On the right hand side of each horizon, write the name of the rock type that makes up the horizon.

Congratulations! You have interpreted the seismic section!

2. Finding traps for oil and gas.
When extension or compression occur within the earth, faulting or folding will most probably accompany it. Folding will occur when the crust is ductile, but as it becomes more brittle because of composition or lower temperature or pressure, faulting will occur.

Here are some examples of the structures that result from faulting or folding:

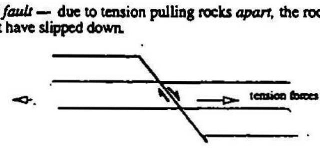
Anticline, syncline — these are geological structures where the rocks have been folded.



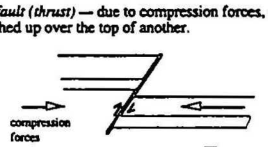
Anticline   Syncline

Fault — a break in the rocks along which the rocks move when they are put under stress. An earthquake occurs when the rocks slide past each other along a fault. However, most faults are currently inactive. There are two main types of faults: normal faults and reverse faults.

Normal fault — due to tension pulling rocks *apart*, the rocks on the top of the fault have slipped down.



Reverse fault (thrust) — due to compression forces, causing one rock body to be pushed up over the top of another.



With different coloured pencils, draw in any folds or faults that you can see in the seismic section. If you can, determine the type of fold or fault and label each one.

Can you see any structures that would make good traps? Yes - See Sketch of Section.

3. An unconformity is a geological boundary which indicates that a large amount of time has elapsed between the erosion of the older layers of rock and the deposition of younger rocks. The older rocks may have been folded and tilted, then eroded. After millions of years a new layer of rocks is deposited on top.

The unconformity is a layer that you have already traced in colour.
Which layer do you think it is? (Jcal) N

All sedimentary rocks are laid down horizontally (or very close to horizontal), as sediment is washed into a basin or low lying area.

Describe the structure of the rocks above the unconformity. Near horizontal layers, not faulted or folded.

Describe the structure of the rocks below the unconformity. Faulted, nearly all normal faults to right, large reverse structure to the left.
What might have happened to give the rocks at depth the structure they now have? A compression event followed by an extension event (normal faults to right)

4. The exploration wells showed some indications of oil and gas in particular horizons.
These horizons are:
Kapt — oil
Kbase — oil
Jcal — oil and gas
Trmid — oil and gas
Pearly — oil and gas

Which rock type would you suggest has the ability to contain the oil or gas? sandstone
At what depths is the oil being found? J 1948-2600m, M 2827-2970m, also answer for N, Q and S
At what depths is the gas being found? N 3238-3261m, Q 3592m, S 4010m
Does the gas sit above or below oil in a reservoir rock? above
Why do you think that only oil is found in some places and both gas and oil in others?
① oil breaks down to gas with depth due to temperature increase with depth.
② Source rocks sourcing the reservoirs may be gas or oil prone source rocks, ie. contain material of different composition.

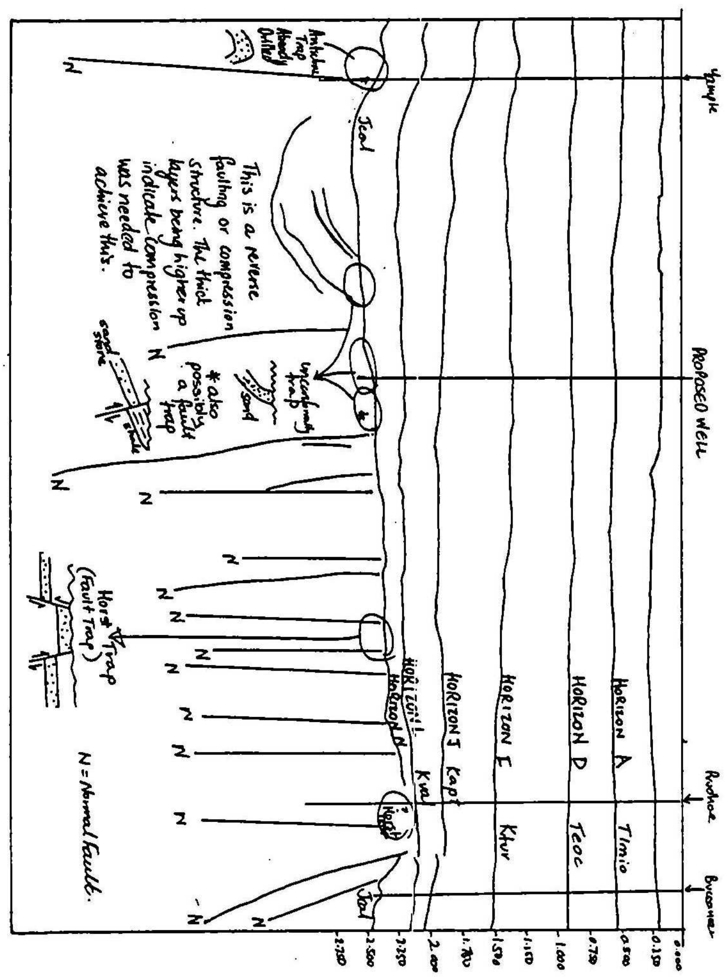
In a paragraph, write a possible explanation for how the gas and oil got there! Also include why you think the gas and oil have remained trapped. [how] moved from syncline to anticline, from higher pressure to lower pressure areas in reservoir, from deep to shallower levels due to bouyancy. [Remained Trapped] - There are no faults in rocks above the unconformity - so hydrocarbons cannot escape up faults, the shale sequence above N seals the reservoir.

Can you see any of these traps elsewhere, where drilling has not taken place? Draw some drill holes where you think it would be possible to expect to find oil or gas. Remember that there has to be a reservoir rock below the drill holes.

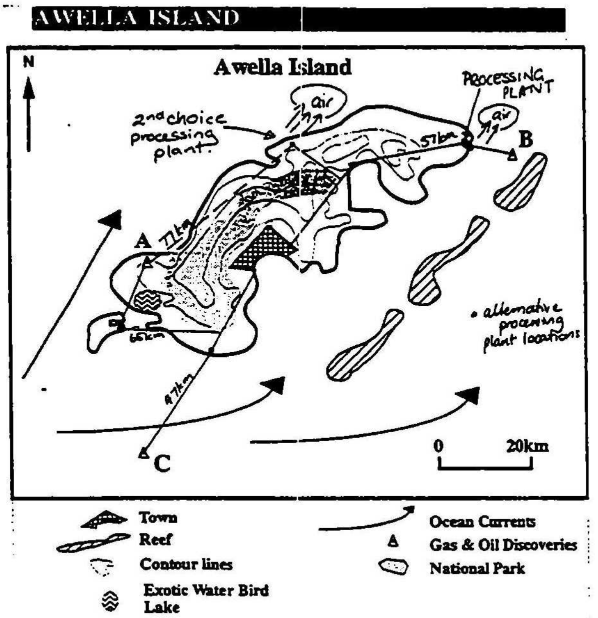
Pick your most favoured position and write a small paragraph recommending where to drill next and explaining why. (Remember it costs from $10 million to $30 million to drill one well offshore). Also predict how deep you will have to drill to reach the oil (& gas).
Proposed well on section: This location would be good because ① There is a structure at both L + M level where oil has been removed, ② In the same hole there would be another target below the N; at Q level where oil has been found + sands are present.
To reach oil: about 2800m for , 3200m for M
To reach gas: 3450-3500m for Q
(If it is there?!!)

VARIOUS ANSWERS WITH GOOD REASON SHOULD BE ACCEPTED.

Basinda Basin Seismic Section



AWELLA ISLAND



AWELLA ISLAND ASSIGNMENT

Some preliminary costs have been drawn up so that you can compare the cost of producing from each well. This table also includes the amount of gas that is expected to be recovered from the well.

Costs and Production from Awella Island Exploration Wells

Activity / Reserves	Well A	Well B	Well C
Drilling	$2 750 000	$ 3 million	$ 4 million
Gas Transportation : Pipes (direct - as the crow flies!)	$30 per barrel equivalent/km	$40 per barrel equivalent/km	$80 per barrel equivalent/km
Processing	$14 per barrel equivalent	$17 per barrel equivalent	$12 per barrel equivalent
Harmful components released during processing	0.080 ppm	0.110 ppm	0.070 ppm
Estimated number of barrels	100,000	130,000	150,000

"per barrel equivalent" — gas is not measured in barrels but can be converted to the number of barrels.
"ppm" — parts per million, a measure of the concentration.

The economic cost of production

In order to assess the whole situation, you might like to start by comparing individual items:

Which is the least expensive production well to drill? Well A

Which is the least expensive production well to transport from, through pipes? Well A

Why do you think this is the case? Land based pipelines are less costly

Add the processing costs to the transportation costs and fill in this table.

Total Transportation and Processing Costs per barrel equivalent

Well A	Well B	Well C
$44	$57	$ 92

Taking into account drilling, transportation and processing, list the wells in order from the cheapest well to produce from to the most expensive. Cheapest is Well A, then Well B, Most expensive is Well C.

The environmental cost of production:

Look carefully at the map of Awella Island and the information about the island. Which well would you produce from so that the enviromental risk is minimised? State why.

VARIOUS ANSWERS. One possible answer: Well B is the least risky as any spill would flush hydrocarbons to the north away from the reef. Well A could contaminate the national park and pond. Well C would contaminate the whole reef.

The gas will have to be processed before it can be used. The processes involved will release some gases like sulphur dioxide and carbon dioxide. The monitoring regulations for gas purification plants are stringent back on Earth. Assume that the direction of air currents are usually the same as ocean currents for this area.

Draw on the map where you would locate the purification plant for the gas being produced from the well.

State any particular reasons for positioning it there. Shortest pipeline possible out at sea to minimise damage to reef and cost of pipeline. It is also important to have the processing plant on the coast for shipping out hydrocarbons. You don't want gases released from the processing plant being taken over national park + town by air currents

Draw on the map the location of the pipeline that would be laid down so that gas could be transported from the well to the processing plant to the town. State anything you considered when designing the pipelines route. It is safer to have pipeline on land, you can bury it, shortest possible path to town to minimise cost, designed so as not to go through national park.

What other information might you need to gather before you can design the pipeline route:? Elevation of the land, access to the land, cost of compression stations + location approval for these.

Given the estimated lifetime of each of the wells, their relative economic and environmental costs, decide on your recommendation as to which well should be used for production. State in point form the reasons for your choice.

Well B

Reasons The higher cost of Well B would be offset by the "Ecotourism" dollars which could remain due to the lowest risk on environmental impact on the island. Well A is too environmentally sensitive and costly due to the processing plant needed at the other side of the island. Well C is too risky due to the currents and the reef.

Economic Considerations

To understand the amounts of capital involved in developing a gas field: extracting the gas and building a processing plant, compare the Sydney 2000 Olympics with the Western Australian Gas project Gorgon.

The Sydney 2000 Olympics, NSW	The Gorgon LNG Project, WA
• the biggest single event in Australia's history • Add $7.3 billion to Australia's gross domestic product • Half of this $3.5 billion will go directly to Sydney with another $1 billion going to people and companies throughout NSW. • create 150,000 full and part time jobs • bring an extra 1.3 million visitors to Australia	• a giant offshore gas gathering and liquid natural gas processing project. • estimated it will generate $375 million in export income in its first year of operation in 2003, rising to $750 million in 2004 and doubling to $1.5 billion in 2006 when four LNG trains are expected to be fully operational. • Annual operating costs will be $150-160 million (salaries, maintenance and supplies). • create jobs for up to 4000 people during construction (1999 - 2003) and several hundred full-time jobs once operational • expected to be in operation for 20-30 years • the construction component of Gorgon will be 25% greater in dollar terms than that of the Sydney 2000 Olympics.

Is there any further information you require before you can compare the two projects?

* Environmental impact of both Projects.
* Benefits to society and to Australia as a nation. + other answers.

Summarise your ideas on how the projects compare:

Various Answers.

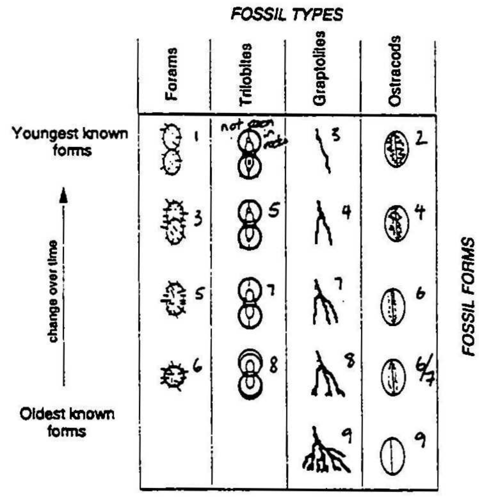
Is it fair to compare the two projects on a purely economic basis? Why/Why not?

Various Answers.

Further research questions:
Where does most of our gas come from?
Who are our main suppliers?
What would happen if there was a monopoly on gas supply?

Basins of Australia Assignment

Background Information
The fossil types identified by the geologist are trilobites, graptolites, forams and ostrocods. Each of these types have a number of different forms, which have evolved over time. Research you have already undertaken gives the relative ages of each member of the fossils types. You have summarised these in a table :



Your table does not compare ages of fossils types with other fossil types, only the known ages between different forms of the same fossil i.e. the form of graptolite at the bottom is older than the form of graptolite above it, but it may be older or younger than the form of ostracod at the bottom.

What to do

1. You have been given information about the fossils contained in five drill holes (A, B, C, D and E). Cut out each of the drill holes on the separate page into strips (do not cut between the fossil layers). In each drill hole, the fossils at the bottom are older than the fossils at the top.

2. Line up like fossils. Note that in some cases fossils of different types will have the same age. You may have to swap the strips around so you get the best amount of information you can from each drill hole.

3. Give each layer of the same age a number, the youngest layer at the top being 1 with the layer below being 2 and so on until you find the layer containing the oldest fossil. These numbers represent relative ages for the layers.

4. Use the layer numbers to give each fossil in the table above a relative age.

Describe the youngest fossils

The youngest fossil is a foram. It has two oval segments to its shell with spines which are slightly wriggly

How does this form differ from other forms of the same fossil type

The other forms have straight spines, the next youngest also has two segments but they are much closer together. Older forms have only one segment.

Which drill hole(s) contains the youngest fossil at the bottom? Drill hole D.

Describe the oldest fossil form(s)

Two fossils are equally the oldest ① Ostracod is a simple oval with a line running from across the widest point. ② The graptolite has numerous (10) branches.

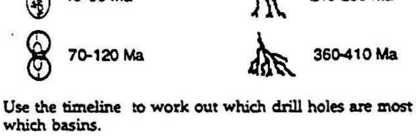
How do these differ from other forms of the same fossil type

① The Ostracod evolved with an ever increasingly complex set of lines between the widest point. ② The graptolite evolved with younger forms having fewer branches.

Which drill hole(s) contains the oldest fossil at the bottom? Drill hole C + D.

The following fossils have been dated.

Upper and lower limits on ages of particular fossils (Ma means millions of years ago)



Use the timeline to work out which drill holes are most likely to have come from which basins.

Drill Hole	Basin
A	COOPER BASIN
B	BARROW ISLAND, NW SHELF
C	CANNING BASIN
D	GIPPSLAND
E	ADAVALE BASIN —(likely presence of gas at depth)

Which basin should they target for further GAS exploration? ADAVALE.

The ages cited in this exercise are not precise. What is factual is that most of our gas and oil has formed in rocks that have formed in the last 545 million years. The age of the earth is 4560 million years old. In what fraction of the total age of the earth do we find most of our gas and oil? The last 12% = 545/4560 ≈ 1/10

Why do you think this might be so? Plants and marine life creates our source rocks which produced the oil + gas. These evolved later in the earth's history. Older forms of life were less complex + abundant.

DRILL HOLES