



South Australia

EarthResources

Information Sheet



Unconventional gas in South Australia

Shale gas, tight gas, coal seam gas and regulation of activities

Where does oil and gas come from?

Oil and gas were formed over millions of years through organic matter being buried through time; the inorganic matter in which the material was buried transformed into rocks such as shale and sandstone, and with heat and pressure the organic matter is converted into oil and gas (typically at depths greater than 2 kilometres).

The gas and oil then migrates through the rock strata until it reaches a sealing layer where it becomes trapped and accumulates. A schematic diagram of oil and gas accumulation types is shown in Figure 1.

What is conventional gas?

Conventional gas resources occur as discrete accumulations in traps formed by folds and other structures in sedimentary layers. In these traps gas builds up in tiny connected spaces (high permeability and porosity) within rocks and is prevented from moving upward by impermeable barriers (seals) such as layers of different types of rock.

Conventional gas accumulations are significantly affected by hydrodynamic influences such as the buoyancy of petroleum in water, and require a process known as migration. This means that after the gas is expelled from its source rock, it moves slowly upwards through water filled pore spaces and fractures in porous and permeable sedimentary layers until it reaches a trap.

To access the gas, engineers drill holes 2–3 km below the earth's surface and install production equipment. While the drilling equipment looks large, the hole in the ground from which the well produces is typically smaller than the width of a standard A4 page. The quality of the rock that the oil and gas becomes trapped in influences how much oil and gas can be recovered and how quickly the well can produce.

The property of the rock that describes its productivity is known as permeability. In poorer quality zones which have low permeability rock, it is necessary to fracture stimulate to induce a fine fracture

network to improve the productivity. In the Cooper Basin several hundred wells, targeting conventional gas, have been fracture stimulated.

Oil and gas are naturally associated with the aquifers of the Great Artesian Basin. In the Eromanga Basin, which is part of the Great Artesian Basin, oil and gas has migrated upwards through the aquifer system, as described above, and conventional oil and gas accumulations typically have a basal contact with the aquifer, as shown in Figure 2. Conventional oil accumulations in the Eromanga Basin show evidence of water-washing, whereby more water

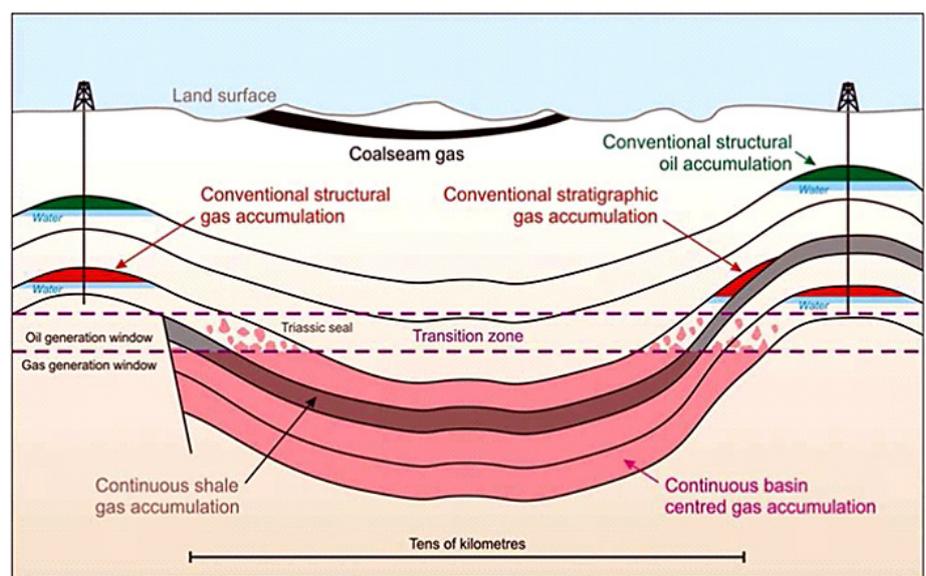


Figure 1 Schematic diagram showing conventional and unconventional oil and gas accumulation types (Source: Beach Energy Limited, AGM Presentation, November 2011. Amended from Schenk and Pallastro, 2002).

soluble hydrocarbons such as benzene and toluene are naturally removed by artesian fresh water flow.

Conventional oil and gas accumulations have been drilled and extracted from the South Australian Eromanga basin since the first discovery of economic gas in 1976. Gas was discovered in the underlying Cooper Basin in 1963 and has been produced from the Cooper Basin since 1969.

What is unconventional gas?

Unconventional gas refers to gas resources that are regionally pervasive, contained within underground formations such as coal, shale, and low permeability sand (tight gas). The term unconventional gas can also be used to refer to synthesis gas or syngas which is produced by converting coal into gas either while it is

still underground, or in a surface plant after mining. The gas that is contained within coal is often referred to as Coal Seam Gas (CSG), Coal Seam Methane (CSM) or Coal Bed Methane (CBM). Typically unconventional gas resources require specialised extraction technologies which have been developed to enhance production from conventional resources (e.g. dewatering of coal seams for CSG, fracture stimulation programmes for shale gas and tight gas, mining for some coal conversion projects).

In contrast to conventional gas sources some unconventional gas accumulations are the result of hydrocarbons generated by the source rock remaining trapped in the source rock, rather than migrating away. Shale gas and CSG accumulations are self sourced accumulations, where the adsorption of gas molecules to organic

matter is at least part of the trapping mechanism. For CSG accumulations, this adsorption of the gas molecules to organic matter is the primary trapping mechanism.

Why is unconventional gas important for South Australia?

As conventional sources of gas decline more unconventional sources are being explored for and developed and represent significant potential future supply sources, important for domestic energy security of supply and price regulation. In South Australia, several companies are exploring for shale gas, tight gas and shallow and deep CSG in the Cooper Basin. Coal deposits in other basins, including the Arckaringa Basin, are also being explored for CSG or assessed for possible coal gasification projects.

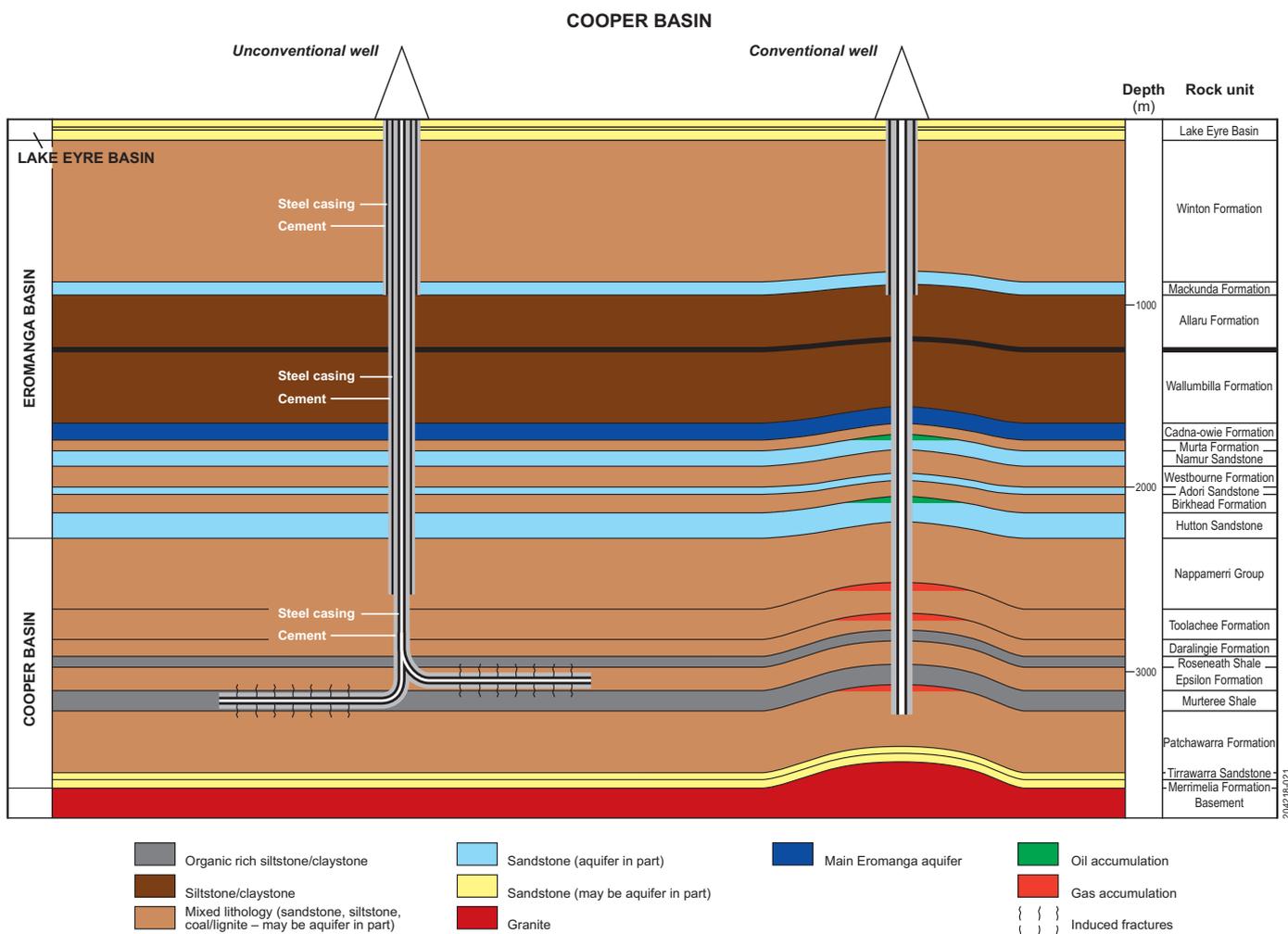


Figure 2 Schematic diagram showing both an unconventional well and a conventional well in the Cooper Basin.



How is unconventional gas extracted?

Unconventional gas resources require technologies such as horizontal drilling and hydraulic fracturing to access the gas.

Horizontal drilling

Most conventional gas wells in South Australia are drilled vertically down from the surface into gas accumulations in porous, permeable gas reservoirs. The high pressure gas in the reservoir flows through the pore spaces in the rock to the well bore and then up to the surface. However, unconventional gas reservoirs are less porous and permeable and the gas therefore flows at very low rates. The best way to access the gas is to drill horizontally so that the well follows the target layer, as shown in the image below. This maximises the exposure of the rock surface area to the well bore and therefore increases gas production rates. Horizontal wells can also be oriented so that they intersect natural fracture systems resulting in increased gas flow rates.

The wells are drilled vertically at first to a predetermined depth above the target layer and are then deviated from vertical to horizontal by the use of directional drilling equipment. The directional drilling equipment enables the well to be drilled horizontally for hundreds of metres within the target layer. In the same way that conventional vertical wells are constructed, the steel casing in horizontal wells is cemented in place to seal all aquifers that the well passes through and to prevent cross flow between them. Figure 2 illustrates how several strings of cemented steel casing are used to isolate the well bore.

It is possible for more than one horizontal section or 'lateral' to be drilled from the same vertical pilot hole, most likely for mature field developments that have moved beyond the exploration stage toward production. This is termed either a bi- or multi-lateral well. Therefore another benefit of horizontal drilling is that multiple wells can be drilled from one surface location reducing the overall surface footprint of the operation.

Hydraulic fracturing

Hydraulic fracturing or fracture stimulation (often colloquially called 'fracking') is a technology used to induce fractures and fissures in rock, providing paths with increased permeability for fluid flow within hydrocarbon reservoirs. Firstly the

cemented steel casing is perforated using specialised downhole perforation guns. Water is then pumped down the well under high pressure, passing through the perforations into the target reservoir zone to create or enlarge fractures in the rock. Viscosity modifying agents (such as guar gum) and other chemical additives are then added in low concentration to enable proppants, typically sand or ceramic beads, to be carried from the surface to the underground zone to 'prop' the newly created fractures open and prevent them from closing up after pressure is released. This allows the trapped oil or gas to flow through the induced fracture system to the production well.

When the well is flowed back to the surface after the stimulation is completed, some of the injected stimulation fluid is recovered and some remains trapped in the rocks below the ground. The water that is flowed back is commonly contained in ponds for evaporation or collected in the gathering system for disposal at the production facility.

The shallow potable aquifers that may be passed through when the well is drilled are isolated from the fractured reservoir and the fracture stimulation fluids by the cemented steel casing which lines the well. The casing provides a mechanical barrier between the inside of the well and geological formations. The cement provides zonal isolation behind the casing between geological formations and also protects the casing.

Geomechanical modelling of the stress contrast between various strata underground is used to assist in design of fracture stimulation treatments.

Seismic monitoring techniques can be used to monitor fracture propagation during the stimulation process to confirm the treatments work as designed. Fracturing into water zones is actively avoided for production purposes as water production can slow or stop gas production resulting in poor commercial outcomes. Where there are aquifers in close proximity to the stimulation interval, such as the aquifer immediately underlying the Barnett shale in Texas, microseismic monitoring during stimulation can determine when to stop pumping to prevent fracturing into the water.

Seismic monitoring techniques can also be used to provide assurance that there is no impact from stimulation on overlying potable aquifers, as shown for example in Figure 3. The figure shows the separation in this area between the fracture extent and surface water aquifers in the Barnett shale. In the Cooper Basin the Great Artesian Basin aquifers are underlain by the thick Nappamerri Group siltstones which provide isolation. Additionally stress contrast modelling between the gas bearing units and the Nappamerri group further suggest containment of stimulation treatments.

A recent additional technology to show promise to delineate the extent of effective fracture stimulations are magneto-telluric measurements of changes during the placement of fracture stimulation fluids. This measurement is a proxy for changes in rock conductivity and so may be able to detect the stimulation fluid¹.

¹ Thiel, S., 2011. *First Results of Monitoring Fluid Injection in EGS Reservoirs using Magnetotellurics*. Proceedings of the AGEA-AGEG Australian Geothermal Energy Conference, Melbourne.

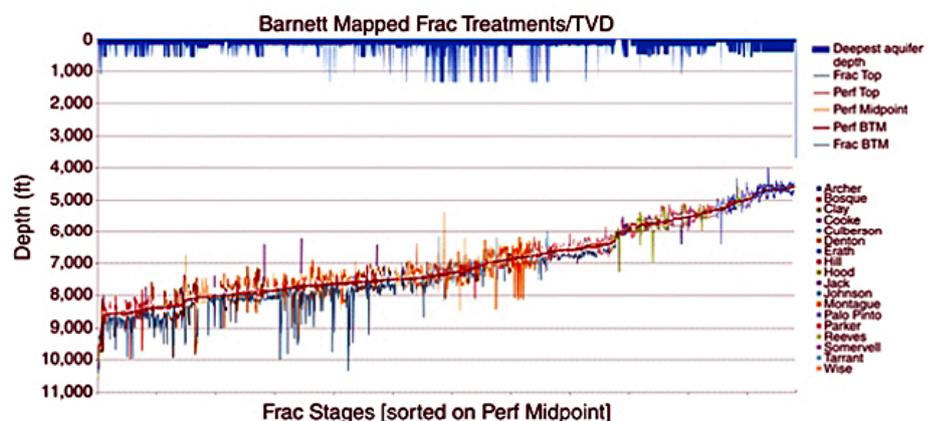


Figure 3 Schematic diagram showing fracture heights measured with seismic monitoring sorted by depth compared with the deepest shallow aquifer depths shown in blue, for the Barnett Shale, Texas. (Source: Fisher and Warpinski, 2011, Figure 2. SPE 145949).

Why are chemicals sometimes used in hydraulic fracturing?

Chemicals may be added to the hydraulic fracturing water for a variety of purposes, such as:

- to carry the proppant,
- to reduce the friction between the water and the pipe or casing in the well,
- to stop the growth of bacteria in the well and underground intervals,
- to clean the well and increase permeability near the base of the well,
- to prevent scaling, and
- to remove oxygen and prevent corrosion of the casing.

Any chemicals in the stimulation fluid are diluted to a high extent. The additives can have ingredients that are also found in commonly used household products²; which doesn't mean that they are all harmless, but with appropriate control their use can be managed. In all cases with good well design, construction and maintenance the risk of cross flow between the stimulated reservoir and aquifers can be reduced to as low as reasonably practicable, avoiding the introduction of any of these chemicals into aquifers. In addition with good work practices all chemicals will also be contained at the surface and disposed of appropriately.

An example of the proportions of different additives used in fracturing fluids is shown in Figure 4.

² *Modern Shale Gas: A Primer*, 2009, US Department of Energy.

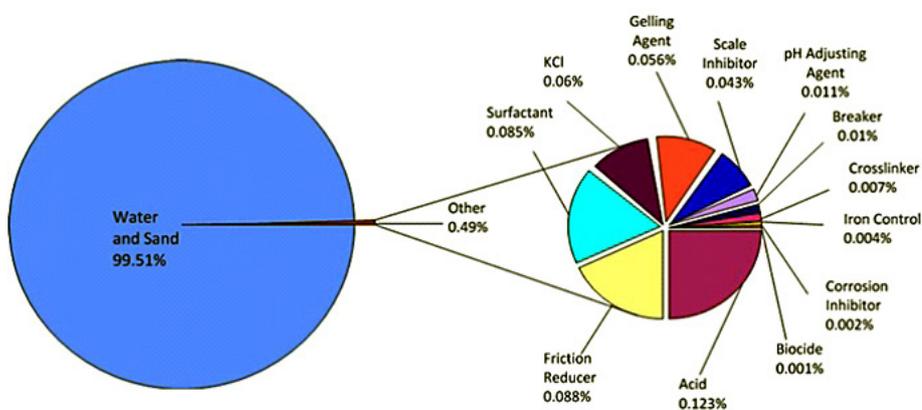


Figure 4 Schematic diagram with representative proportions and the purpose of different additives used in stimulation fluid. (Source: *Modern Shale Gas: A Primer*, 2009, US Department of Energy).

Has hydraulic fracturing been used in South Australia?

Hundreds of wells (>700) have been safely fracture stimulated to increase flows from hydrocarbon (both oil and gas) reservoirs over decades in South Australia (since 1969). Fracture stimulation in South Australia has largely been undertaken on reservoirs at depths far greater than the potable fresh water aquifers.

Where is de-watering required?

Many coal seams contain water and gas within them. The gas, generally methane, is generated as peat is converted to coal during burial. The methane remains adsorbed or attached to the coal and is held in the coal underground by pressure from the water within the seam. This means that to extract the gas in the seam some of the water must be pumped out first to reduce pressure. This is referred to as de-watering. As water production declines, gas production increases.

Some CSG operations produce a significant amount of water (generally a small percentage of the total water contained in the aquifer), which must be disposed of in an appropriate manner. Water management may differ greatly between projects depending on the local environment, the quality of the produced water, and any potential uses.

CSG is typically developed in shallow environments less than 1 km in depth. Permeability of the coal, particularly for large CSG plays in Queensland, is very good at this depth. For the deep coal seam gas targets present in the Cooper Basin permeability is expected to be very low.

How are unconventional gas exploration and development activities regulated in South Australia?

In South Australia, all operations associated with upstream petroleum operations – including coal seam, shale and tight gas exploration, development, production and transport in pipelines, are regulated under South Australia's Petroleum and Geothermal Energy Act 2000 (P&GE Act) and the accompanying Petroleum and Geothermal Energy Regulations 2000. The P&GE Act and its Regulations can be readily accessed through the South Australian legislation website www.legislation.sa.gov.au.

Key objectives of the P&GE Act and its Regulations are to ensure that all risks to the health and safety of the community and to the environment are either completely avoided, or managed and reduced to a level that is low or as low as reasonably practicable while also meeting community expectations for nett outcomes.

The grant of petroleum exploration, petroleum retention, petroleum production and petroleum pipeline licences pursuant to the P&GE Act, does not provide an automatic entitlement to conduct regulated activities under the P&GE Act.

Before regulated activities under the P&GE Act can be carried out there must be an approved Statement of Environmental Objectives (SEO) in place, prepared on the basis of an Environmental Impact Report (EIR). In addition an activity notification must be provided for all activities detailing the planned operations, risk management processes, operator capabilities and the applicable SEO.

- The EIR identifies all potential risks relating to the activity and the appropriate risk mitigation and monitoring strategies.
- The SEO identifies the environmental objectives to be achieved to address the risks identified in the EIR and the criteria to be used to assess achievement of the objectives.

Through the P&GE Act approvals process, all activities that might pose risks of potentially harmful crossflow and contamination are required to be undertaken such that the risks of crossflow and contamination is minimised to a level that is low or as low as reasonably practicable between hydrocarbon reservoirs and aquifers, either potable or

saline. This can be ensured through a fit for purpose well design that includes engineered casing and cementing designs in all wells with ongoing well integrity monitoring.

All SEOs and associated EIRs are public documents found on the SA Department for Manufacturing, Innovation, Trade, Resources and Energy (DMITRE) website www.petroleum.dmitre.sa.gov.au. Go to Environment and Land Access, Environmental Register.

What information is provided to stakeholders and land owners?

Through the stakeholder consultation requirements of the P&G Act, stakeholders including landholders are required to be informed of the potential risks associated with proposed activities, and management strategies to be deployed to minimise such risks to an acceptable level. This is undertaken at two stages of an activity approval, firstly during the development of the EIR and SEO and secondly when Notice of Entry is provided, at which point landholders have the right to object to the licensee's proposed entry. Landholders are also entitled to compensation for any deprivation or impairment of the use of the land, or damage or disturbance to the land.

In addition, licensees are required to submit annual reports detailing activities undertaken within each licence area during the respective licence year, as well as the activities proposed for the ensuing licence year. An important part of this reporting is to ensure that each licensee regularly reviews, assesses and reports on their performance and compliance with the P&G Act and the relevant environmental objectives. Once reviewed by DMITRE, licensee annual reports are made publicly available on the DMITRE website www.petroleum.dmitre.sa.gov.au. Go to Environment and Land Access, Environmental Register.

Where can I find out more?

For more information on the *Petroleum and Geothermal Energy Act 2000* and Regulations, and activities in South Australia, please visit the Petroleum section of the DMITRE website. Go to www.petroleum.dmitre.sa.gov.au, Legislation and Compliance.

To find out where current licence areas are, you can view the 'P1 sheet' which is also on the DMITRE website. This has a list of all licences, licence operators and

maps locating licences. Go to www.petroleum.dmitre.sa.gov.au, Licensing and Applications, Licence Register, and then scroll down for the link to the Earth Resources Information Sheet P1.

More information on hydraulic fracturing and the fluids used can be found on a US site supported by the individual states Frac Focus, which is a hydraulic fracturing chemical disclosure registry website which has sites for the US and Canada. See <http://fracfocus.org>. In particular the 'how it works' page gives a good overview of the technology.

Many companies that provide hydraulic fracturing services also have dedicated information pages on their websites. For example, the Halliburton [hydraulic fracturing site](#) also has [fluids disclosure](#) information including MSDS sheets, for typical operations in Australia (click on the map of Australia) and for operations in some US states.

There are also a number of useful websites where you can learn more about oil and gas terms and technology, including the [Schlumberger Oilfield Glossary](#).

Glossary

Adsorption – The property of some solids and liquids to attract a liquid or a gas to their surfaces.

Casing – Casing is generally steel pipe that is inserted into a well after it is drilled and held in place with cement. Casing must be designed to withstand all of the various forces that the well may be subject to including internal pressure from the gas or oil reservoir that the well is intersecting, external pressure from the well walls and different formation layers, and tension, compression and torsion as the well heats or cools or the earth moves.

Casing string – Casing is manufactured in lengths of about 12 to 15 metres, each length or joint being joined to another as casing is run in a well. The entire length of the casing is called the casing string³.

Migration – The movement of hydrocarbons from their source into reservoir rocks. The movement of newly generated hydrocarbons out of their source rock is primary migration, also called expulsion. The further movement of

the hydrocarbons into reservoir rock in a hydrocarbon trap or other area of accumulation is secondary migration. Migration typically occurs from a structurally low area to a higher area because of the relative buoyancy of hydrocarbons. Migration can be local or can occur along distances of hundreds of kilometres in large sedimentary basins².

Permeability – Permeability is a measure of how easily or how well a porous rock, sediment, or soil volume will allow fluids to flow through it.

Porosity – Porosity is a measure of the empty spaces within a material and is calculated as a ratio of the volume of empty space (or fluid or gas filled space) divided by the total volume of the material. In geological scenarios the material is rock or sediments and the pore space is where oil, gas, water or a mixture of these can be stored.

Proppant – Proppant is the name used for particles that are suspended in and carried by fracturing fluid to hold fractures open after a hydraulic fracture treatment, and provide pathways for gas to more easily flow through. The particles can be sand grains, or man-made particles such as resin coated sand grains or high strength ceramic beads. The materials are sorted by size and shape to enable selection of the most efficient proppant design for the particular stimulation operation.

Source rock – A rock rich in organic matter which, if heated sufficiently, will generate oil or gas.

Trap – A configuration of rocks suitable for containing hydrocarbons and sealed by a relatively impermeable formation through which hydrocarbons will not migrate. Traps are described as structural traps (in deformed strata such as folds and faults) or stratigraphic traps (in areas where rock types change, such as unconformities, pinch-outs and reefs)².

³ "The Oil and Gas Glossary", 1st Edition, May 2009.

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