frackingShaleGas280114rev2016

SHALE GAS and 'FRACKING'.

1. DEFINITIONS

a. Shale: Fine grained, fissile, sedimentary rock composed of clay sized and silt sized particles of unspecified mineral composition.

- **Clay** particles are less than 4 micrometres in size.
- **Silt** particles are between 4 micrometres and 62.5 micrometres in size.

Shale is widespread and plentiful. It occurs wherever ancient oceans, and particularly the shallower coastal waters, or still waters, existed with in-flows. And, sediments are subject to a constant 'rain' of organic material – plant and animal – which is buried under increasing pressure and exposed to heat at depth, in anoxic or low oxygen environments, forming liquid hydrocarbons and releasing gases.

Organic matter degrades to form **kerogens** [def: Kerogen – solid, bituminous, substance formed of fossil organic material in oil shales, which can yield oil by destructive distillation]**.** Shale is a good hydrocarbon and gas producing – source rock - medium; shales are generally impermeable and not good holding – reservoir - rocks, but *vide infra*.

b. Oil Shale: is dark grey or black shale containing organic substances that yield liquid hydrocarbons on distillation, but do not contain free petroleum.

- West Lothian has huge 'shale bings', the waste, dumped on the surface, of oil exploitation in the nineteenth and twentieth centuries, by 'Paraffin Young' and others, from the Carboniferous oil shales. [The West Lothian oil shale industry closed finally in the 1960s]
- The Moffat Shales are black shales, of Ordovician/Silurian age [between 488 and 419 Myr], but have never been exploited for oil or gas.

c. Natural Gas: gaseous hydrocarbons, chiefly *methane, ethane, propane* and *butane,* trapped in pore spaces in rocks with or without liquid petroleum. Methane estimated to constitute about 70% - 90% of shale gas. Small amounts of carbon dioxide, oxygen, nitrogen, hydrogen sulphide, radon and rare gases.

- Pure or near pure Methane reserves are referred to as **Dry gas** [90% + methane]. Much of the gas produced from shales in central and northern Pennsylvania is dry gas.
- Gas with butane and ethane – **Natural Gas Liquids [NGLs]** – is referred to as **Wet gas.** NGLs can be separated and provide important raw materials for the chemical industry. Gas extracted from the Marcellus Shale in south-west Pennsylvania is mainly Wet gas.
- Gas forms in old, deep, shales – about 3,000m +. This is the typical depth for thermogenic decomposition of organic matter into methane gas [Geological Society 2013], although US experience suggests 1,000 m plus may yield Shale gas. Of course, gas may have formed at much greater depth but shale strata are now closer to the surface due to erosion and uplift.
- The **Oil Window** occurs where kerogen has been heated to c. 60-160 degrees Celsius.
- The **Gas Window** where heating has been to c.150-200 degrees Celsius.

2. Natural gases are valuable products, burning with high heat value and without smoke or soot [unavoidable products of coal-gas]. They provide raw materials for the chemical industry in the manufacture of plastics, detergents, fertilisers etc.

- Oil and Gas, which may have been formed in Shale, under heat, migrate upwards to permeable overlying rocks and becomes trapped in reservoirs bounded by impermeable rocks. They can be exploited, by drilling to the reservoirs – these are **Conventional** oil and gas.

- Some oil and gas formed in Shale is unable to migrate; the overlying rocks are not permeable. They will occupy what little porosity and natural fractures there may be and also become adsorbed. [**Adsorption** is the process in which a gas or liquid layers on the surface of a solid, by ***chemisorption*** – a single layer of molecules, atoms or ions attached to the adsorbent surface by chemical bonds – or by ***physisorption*** – molecules held by van der Waals forces (*weak attraction of atoms to each other due to the interaction of electrons and nuclei; linkage called the van der Waals bond).*]

- Gas and Oil shales are estimated to be rich in organic material – 0.5% to 25% and have often been petroleum source rocks, in which heat and pressure have converted petroleum to natural gas. When exploited by fracturing, gas in fractures is released immediately, then adsorbed gas is released as pressure in the strata is released by the drilling

- To extract Gas or oil from such holding shales requires intervention, by mining the shale and heating it to extract oil, or by fracturing it – 'Fracking' – in situ and releasing Gas. The products are described as **Unconventional Gas or Oil.** Fracking requires horizontal drilling into target strata and the application of very high pressure water, sand and chemicals to fracture the shale. Horizontal drilling is up to 3,000 m laterally from the vertical bore.

- Oil trapped in shale or other minimally permeable beds, which may be sandstones or limestones, is referred to as **Tight Oil.**

- Shale strata being exploited for gas and oil extraction, usually in basins, are referred to as **Resource Plays.**

3. The US Energy Information Administration [EIA] monitors estimates of world resource. In a June 2013 report 'Analysis and projections: Technically recoverable Shale Oil and Shale Gas Resources: An assessment of 137 Shale Formations in 41 countries outside the US' there are 137 relevant formations, in 95 basins and estimates that technically recoverable resources <u>including</u> the US are:

    - 7,299 Trillion cubic feet of Shale gas
    - 345 billion barrels of Shale and Tight oil. [A 'barrel' is 42 imperial gallons.]
    - [On the **short scale,** *Billion* means a thousand million and *Trillion* means a thousand billion.]
    - About 35 cubic feet = one cubic metre.

- At World level, EIA estimates the contribution of Shale Oil and Gas to world resources as:
    - Crude Oil – 345 billion barrels, 10% of total estimated resources
    - Wet natural gas – 7,298 [?rounding] trillion cubic feet, 32% of total estimated resources

- Big Winners [selected] with estimated reserves:

- **China** – 32 bn barrels of Shale oil, 1,115 trillion cubic feet of shale gas
- **US** – 58 bn barrels of Shale oil, 665 trillion cubic feet of Shale gas
- **Argentina** – 27 bn barrels of Shale oil, 802 trillion cubic feet of Shale gas
- **Russia** – 75 bn barrels of Shale oil, 285 trillion cubic feet of Shale gas.

- Not as great in Europe…but not negligible.

4. The extent of unconventional natural resource recovery is largely influenced by the relative costs of recovering conventional and unconventional natural resources, the demand for gas and oil and its final market price; climate considerations are a strong secondary influence. Demand for gas and oil was on a strong upward trajectory as economies grew, coupled with controls on output by international producers leading to some steeply rising final prices up to 2015. At the same time, governments are concerned to try to control prices paid by consumers [also voters] and to encourage reduction of greenhouse gases and global warming. Shale gas, although 90% is estimated to be Methane, a greenhouse gas, is cleaner than conventional hydrocarbons.

5. In early 2016 – supplies of oil and gas on the market were plentiful, principally, it is believed, because:

- Chinese demand has fallen, as the Chinese economy's growth has slowed
- Oil and gas producers under US influence have flooded the market, as opposed to their former strategy of restricting supply to maintain higher prices, as part of sanctions strategy against Russia
- Diplomatic détente with Iran is likely to further increase supplies on the world market.

In consequence, prices fell markedly [oil c.$30 - $40 per barrel compared with prices in excess of $140 per barrel a couple of years previously] but currently [late 2016] are at about $60 per barrel and for the UK – as Sterling is falling against the US$ - we are seeing quite sharply rising prices. Whilst there is no end in sight to generally lower global prices, they could rise again just as quickly as they have fallen, in the space of a year or two.

5. Fracking[1] has been around for some time, originating in shale gas extraction in the US as early as the 1820s; by the late 1930s horizontal drilling technology was available. The first well was fracked in 1947. This method of gas recovery has increased exponentially since the 1990s, when the US, the world's main producer, was concerned to cap natural gas prices and reduce greenhouse gas emissions – the US was also one of the world's worst polluters. Shale gas is estimated, currently, to account for about 20% of US gas production and is expected to rise to nearly 50% by the 2030s. To date it has not been a major source of natural gas in Europe, but that is changing, fast.

5. In the UK shale gas exploitation is in its infancy. Some very recent research has been done and research continues.

- The Royal Society and Royal Academy of Engineering, June 2012 – 'Shale Gas Extraction in the UK: a review of hydraulic fracturing' – mainly focuses on technical issues and processes. Concludes – seismicity not a great problem; potential for ground water contamination should be assessed and managed carefully; leakage of GHGs should be monitored.

[1] [1]['Fracking' is not to be confused with 'Fragging'. Fragging was an interesting process adopted by US servicemen, late in the Vietnam war, to rid themselves of unpopular superiors by tossing fragmentation grenades amongst them.]

- Tyndall Centre for Climate Change Research, 2013 – 'Shale Gas: an updated assessment of environmental and climate change impacts' – concern over ***potential*** climate change effects of unavoidable GHG releases from Shale Gas exploitation….up to 15% of UK's emissions budget to 2050. Suggests UK Government focuses on other low-carbon energy supplies [wind? Water?, OK for electricity generation, but not much help in the chemicals industry]
- The Geological Society, 2013 – 'Shale Gas: challenges and opportunities'. Probably significant on-shore resources in large sedimentary basins most likely:
    - Lower Carboniferous [c.359-330 Myr], around the Pennines
    - Jurassic [201 – 145 Myr] layers in the Weald and Wessex
    - Upper Cambrian [542-488 Myr] in the Midlands
    - Possibly lower Palaeozoic black slate of Wales and South-West England
- British Geological Survey, DECC, 2012 – 'The Unconventional Hydrocarbon Resources of Britain's Onshore Basins – Shale Gas'.
    - Potentially great reserves. Estimates, based on US Shale gas play yields –
    - Jurassic Play of the Weald basin, perhaps 200 billion cubic feet
    - On shore Wessex basin petroleum system, perhaps 30 billion cubic feet
    - Carboniferous Upper Bowland Play – up to 4.7 trillion cubic feet
    - Cambrian Shale gas Play of the Midland Micro-craton – potentially up to 300 billion cubic feet

- But, basically much sitting on the fence, pending more research and licensed prospecting. Best bets are thought to be the Bowland Shales and The Weald [Lias, Kimmeridge Clay, Oxford Clay].

- Criteria identified in US for successful Shale gas plays [key selected]

    - Shales with more than 2% Total Organic Carbon
    - Thickness greater than 40 metres
    - 1,000 – 3,500 metre depth
    - Overpressured zones
    - High percentage of non-clay minerals
    - Area of more than 100 sq km, avoiding towns
    - Areas unaffected by orogeny [mountain building]
    - Presence of conventional gas fields
    - Presence of gas shows in shales.

- Risk of induced-seismicity, from high pressure fracking…probably quite high; *Cuadrilla* seem to have set off tremors around Blackpool in 2011 [1.5 and 2.3 magnitudes]. Did the tower fall down? No. Did large parts of Blackpool fall down? No. Do we get small magnitude earthquakes on this scale every year? Yes, 'undreds. Fracking can trigger movement on faults but risk is generally low.

- Risk of ground-water contamination may be greater, unless techniques are well regulated and bores through aquifers are fully lined and protected.

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