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Topical Perspective

Shale gas and fracking: exploration for unconventional hydrocarbons

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ABSTRACT

Geological perspective and discussion of shale reservoired hydrocarbons (shale gas and shale oil) and the emotive process used to produce them, hydraulic fracturing or fracking in colloquial parlance, is timely, in view of the current debate on the potential for exploitation of shales in the UK. Fracking is a long-standing oil industry process which has recently allowed unconventional hydrocarbons to dominate much of the world oil industry. This is particularly so in the USA where their development has dramatically overturned the decline in domestic production, with the current attainment of near self-sufficiency in both oil and gas production. Exploration for, and production of, shale-reservoired hydrocarbons requires a very different approach and mind-set from that required for conventional oil and gas resources, as well as raising widespread concerns around environmental aspects of fracking. The aim of this paper is to discuss the geology of shale resources and the techniques developed for their exploration and exploitation and place the environmental issues in their geological, not socio-economic context.

1. Introduction

The aim of this "Topical Perspective" is to objectively discuss the geological and technical aspects of the exploration and production of hydrocarbons from shales, including hydraulic fracturing ("fracking"). This is unashamedly presented from a hydrocarbon exploration geologist's perspective and whilst the potential environmental issues and risks are outlined, this paper does not seek to fully examine or discuss these important topics which are ably and further discussed elsewhere (King, 2012; Zuckerman, 2013; Hester and Harrison, 2015; Stephenson, 2015; Kaden and Rose, 2015). It should be noted that this paper is derived and adapted from a fuller, previously published treatise on shale resources and their exploitation (Scotchman, 2014).

In a world where the human race is ever more energy-hungry and dependent, sources of low carbon energy should be at a premium, particularly as Governments world-wide endeavour to limit carbon emissions and make the transition to renewable or nuclear energy sources. Natural gas is currently seen as a transitional energy source to displace high carbon energy sources such as coal or heavy oil. In the USA, the boom in shale-gas production over the last 10–15 years has hastened this process, displacing the previously high coal-burn for electricity generation. However, in the United Kingdom and much of Europe, potential for the exploration and development of shale gas resources is only occurring at a slow to virtually non-existent pace, due to a number of complex factors. While this can mostly be attributed to the widespread public concerns over the safety and potential environmental effects of the hydraulic fracturing (fracking) process required to produce gas from shale (Engelder, 2014), the lack of drilling activity, development of infrastructure, limited licencing and, importantly, the slow development of regulatory frameworks are also major factors.

In the USA, shale gas (and shale oil) has been extracted extensively and has not only enriched both individuals and communities but has also been instrumental in reducing US carbon dioxide emissions by replacing much coal-fired electricity generation. In the UK the position is different as all hydrocarbons are owned by the state with a Government controlled hydrocarbon licensing system with devolved local authority planning controls on actual exploration activities (DECC, 2013). Nevertheless the potential for shale gas and shale oil production in the UK (and Europe) is clear, and it could play an important role in meeting rising energy demands in the face of rapidly declining internal UK production and reserves and the increasing need for imports. However, after an initial start in the mid-2000s, the possibility of hydrocarbon production from shales, as either shale gas or shale oil, has since been be met with widespread public opposition leading to moratoria and regulatory stagnation.

Much has been made of the potential for poorly engineered and executed wells and fracking procedures to potentially result in gas

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leakage, contamination of ground-waters and minor earth-tremors, based on largely unattributed Internet-sourced information with no rigorous scientific basis. However, scientific and engineering data collected on the many thousands of wells drilled for both shale gas and shale oil in the USA over the recent years indicates fracking is inherently safe and does not cause widespread environmental damage when properly engineered and executed (Hitzman et al., 2013; Engelder, 2014; Committee on Climate Change, 2016). The challenge therefore falls to both industry and Government to communicate this reality to the public, in the face of a vast array of incorrect information (e.g. The Times, 2015), spread uncontrollably on the internet and social media by opponents of the process to support their views.

2. Unconventional hydrocarbon resources – what are they?

Until the mid-1990s, the world's hydrocarbons were almost totally produced from porous and permeable rocks such as sandstones and limestones sealed in individual geological traps by shales or salt. These are now known as "conventional" hydrocarbon resources and the bulk of the known reserves in the world occur in these reservoirs. Unconventional hydrocarbon resources, as suggested by the name, are very different, although the actual hydrocarbons (oil and gas) are the same. Most unconventional hydrocarbon reservoirs occur in the same basins as conventional reservoirs, where they also form the source rocks for the "conventional" hydrocarbons and, potentially, the seal. A further key difference from conventional reservoirs is that unconventional hydrocarbons are trapped within the whole of the reservoir rock unit, due to its inherent very low or negligible permeability. Thus these resources are limited only by the stratigraphical extent of the reservoir and economic considerations, hence the need for delineating the most prospective areas with the best reservoir parameters and hydrocarbon content, the so-called "sweet spots". Indeed, shale reservoirs can cover very large areas, for example the US Marcellus Shale Formation extends over much of the state of Pennsylvania and adjoining areas of New York, Ohio, Kentucky and West Virginia. However, due to lateral variations in lithology, mineralogy, organic-richness and thermal maturity, only areas of northern and south-western Pennsylvania and northern West Virginia contain economic volumes of shale-gas (e.g. Wang and Carr, 2012).

By definition, unconventional hydrocarbons comprise oil and gas resources trapped in any "non-conventional" reservoir (i.e. not the porous and permeable sandstones and limestones which comprise "conventional" reservoirs), and encompass gas hydrates, shale gas, shale oil, coal-bed methane (CBM) and so-called "tight gas and oil" (reservoired in low permeability sandstones and limestones) (Fig. 1). However, in general, the term "unconventional hydrocarbons" has come to mean shale resources (shale gas and shale oil), both characterised by very low matrix permeability reservoirs with natural fractures, the former generally comprising organic-rich shales containing both free and adsorbed gas (Montgomery et al., 2005) (Fig. 2). Extraction of hydrocarbons from these rocks requires the creation of an artificially permeable reservoir using hydraulic fracturing of horizontal well bores drilled within the near-impermeable shale.

3. Hydraulic fracturing – what is it?

Hydraulic fracturing, or "fracking", is a long established oil-field stimulation technique used since the late 1940s to increase the production of hydrocarbons from poor quality, low permeability (often known as "tight") reservoirs. The process involves the multi-stage injection of fluids, generally water, into the well-bore at sufficient pressure to fracture the reservoir rock by exceeding its fracture gradient. Surface equipment is used to pump hydraulic fracturing fluid ("frack fluid") down-hole into the reservoir, which results in the formation of an artificial fracture network radiating out from the horizontal well-bore (Fig. 3). The fracturing fluid comprises 99.95% water as discussed below, the remaining fraction being proppant particles, usually quartz sand or ceramic material used to keep the fractures open after the injection process has ceased, and very small (0.05%) amounts of gels, friction-reducers, cross-linkers, and surfactants. These additives, commonly found in cosmetics, household cleaners and other similar products, are

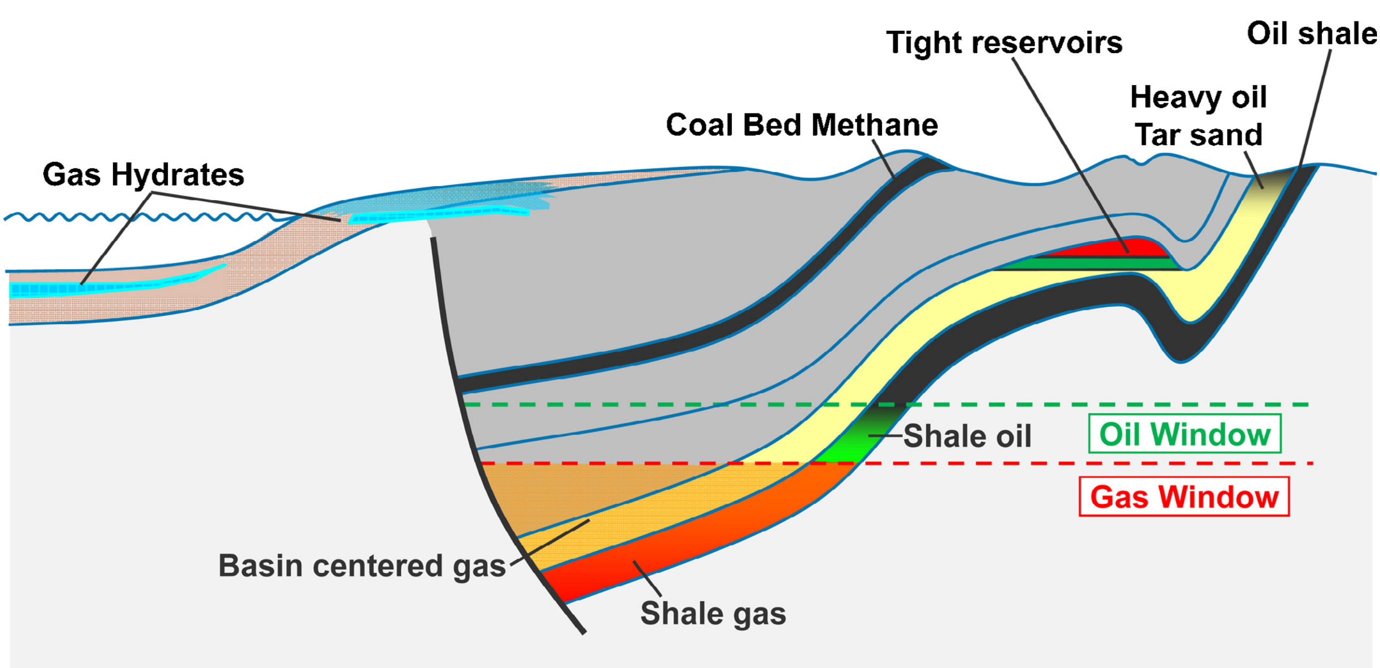

Fig. 1. Geological sketch illustrating the various forms of unconventional hydrocarbon systems and their relationships to conventionally reservoired hydrocarbons, showing the relationship to thermal maturity as defined by the oil generation window (green line) and gas generation window (red line). CBM is coal bed methane.