Research Paper

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Shale Gas an Unconventional Hydrocarbon Resource: Overview

Energy Resources

KEYWORDS : Unconventional, Shale gas, shale reservoir.

A. Boruah	Gujarat Energy Research and Management Institute, Gandhinagar, Gujarat-382007
Dr Md Abdul Rasheed	Gujarat Energy Research and Management Institute, Gandhinagar, Gujarat-382007
Dr Syed Z. Hassan	Gujarat Energy Research and Management Institute, Gandhinagar, Gujarat-382007

ABSTRACT

The commercial shale gas exploration requires exhaustive investigations of all the shale rock properties of hydrocarbon bearing shale beds having significant organic matter and maturity. This paper presents the systematic approach using integrated methodology of geological, geophysical, geochemical, geomechanical etc for shale gas resources evaluation. It also attempts to discuss the sedimentology of shale rock, gas generation and retention mechanisms within the shale rock. Thermal maturity, sorbed gas fraction, reservoir thickness and geographic extent, total organic content, mineralogy, water saturation, fracture types, reservoir heterogeneity etc which are the primary controlling factors of shale gas production. But all the parameters may show wide variations in different shale gas systems and even most of the world's commercial shale gas reservoirs exhibit wide range of these parameters which makes it difficult for establishing the sweet spots for shale gas exploration and exploitation.

INTRODUCTION

Shale gas is the insitu hydrocarbon gas present within the shale sedimentary rocks may be as free gas or adsorbed gas or both. Gas can be accumulated throughout the shale layer in three forms: Gas is stored on the shale as adsorbed gas, within the intergranular pores and the natural fracture system as free gas (Kent Perry and John Lee, 2007). In case of shale gas, the Shale rock itself acts as both the source rock and reservoir for the gas (fig 1). This may be due to two reasons either due to lack of micro- fracture for primary migration of gas or insitu cracking of oil into gas at greater depth and post mature zone due to higher geothermal gradient. When organic matter get converted into hydrocarbon its volume increases and exerts pressure on the surface of the source rock which creates micro- factures or pathways for oil or gas expulsion from source rock to reservoir. But in certain cases under different circumstances hydrocarbon cannot expel from source rock to reservoir. Hydrocarbon inside the source rock gets converted into oil or gas depending upon the organic matter types and the source rock acts as reservoir. It does not matter whether the shale rock is source, reservoir

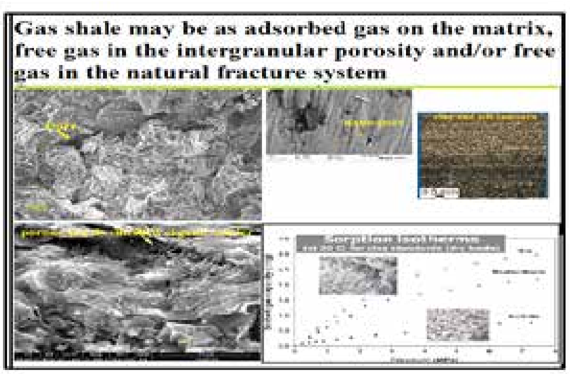

Fig1: Gas Storage Mechanism in the Shale. (Modified after Curtis, 2002; Law, 2002)

or seal. Shale gas can be generated throughout the shale horizon containing minimum 1% total organic carbon content (>3% TOC is preferable for commercial exploration) by thermogenic processes. The production viability of shale gas depends on these various characters of shale. This is due to: (i)local changes in permeability which is highly depends on the fracture intensity and fracture aperture width, (ii) sedimentology of shale, (ii) mechanical properties of shale etc. Moreover, the shale gas exploration and exploitation is governed by a numbers of factors such as the areal extent of shale layer, thickness, total organic carbon content, kerogen type, maturity, permeability, mineralogy, brittleness verses ductility etc. integrated studies of geological, geochemical, geophysical, petrophysical, geomechanical etc can help evaluating all these factors to identify the sweet spots for shale gas exploration and exploitation. The basic idea of this paper is to present the basic concept of shale gas generation, accumulation and integrated studies i.e. geological, geochemical, petro- physical, geophysical, geomechanical, technical etc for identification of sweet spots for shale gas exploration and exploitation. The work flow of shale gas research and development is given below:

Fig2: Work flow of Shale gas Prospect Identification (modified after Bowker 2007, Curtis 2002)

PETROPHYSICAL STUDIES

Petrophysical analysis includes both core analysis and log analysis. Core analysis is to investigate the physical rock properties of rocks.

- **Megascopic studies**
- Identification/ differentiation of lithology
- Identification of visible Fracture, partings
- Sedimentary structures such as laminations, beddings identification
- Facies identification

- Litholog preparation

- **Petrographic studies { scanning electron microscope (SEM)}**
- Identification/ differentiation of mineralogy
- Porosity, pore throats, Permeability, Lamination, rock fabric, fracture network

- **XRD**
- To identify the Clay mineralogy (percentage of kaolinite, Montmorillonite etc)

GEOPHYSICAL STUDIES

A typical shale gas log shows high gamma ray due, high resistivity and low photo electric effect. This characteristic log response is a function of the high concentration of kerogen, the insoluble organic material within the shale. Also, resistivity in gas shales is high due to low water saturations, usually irreducible, resulting from the expulsion of hydrocarbons. Gamma ray log can be used as proxy to predict TOC content. Natural Gamma Ray Spectroscopy (NGS) logs help in interpretation of lithology as well as environment. It is also used to differentiate between carbonaceous layers (uranium rich) and true shales (Thorium/Potassium rich) which may determine the probability of lateral continuity. FMI logs are useful for identifying the fractures and fracture network, structures, rock textures.

SEISMIC STUDIES

Seismic attributes in shale gas exploration can be used in a wide manner mainly to (i) delineation of shale gas bed, thickness, areal extent, (ii) estimation of closure stress in combination with AVO, (iii) identification of optimal area of hydro- fracturing,(iv) demarcation of zones of hydro- fracturing, (v) determination of brittleness versus ductility, etc. Researchers have been using different seismic methods/ attributes to study shale gas resources. Gupta (2012) in the Anadarko Basin and Guo et al. (2010) in the Arkoma Basin were able to map a network of lineaments that correlate to subtle faults seen on the vertical seismic data using coherence and most-negative principal curvature. Hill et al (2002) reported high spatial variability of petrophysical and petrochemical properties of Marcellus formation. Jaeger and Cook studied the mechanical properties of shale i.e. brittleness and ductility using seismic in 1976. Seismic properties of kerogen shows very low density (~1.3g/cc) and Very low velocity. It may cause high amplitude and low impedance reflections like coal in favorable conditions.

GEOCHEMICAL ANALYSIS

The hydrocarbon generation potential of shale is depend on: (a) presence of organic matter (at least 0.5% wt.), (b) types of organic matter (which will determine only gas or oil or both), (c) thermal maturity and time. Organic matter maturity depends on geothermal gradient, burial time, organic matter quantity & quality, rate of sedimentation, overburden pressure etc. Maturity can be determine with the help of different maturity indicators such as vitrinite reflectance, thermal alteration index, fluorescence, Lopatin's time temperature index etc. Vitrinite reflectance is one of the widely used methods and it measures the refection of light on the surface of vitrinite (one of the primary components of coals and kerogen derived from the cell-wall material or woody tissue of the plants) increases with increasing maturity.

Van Krevelen plots of atomic H/C-O/C are the best method for evaluating the quality and maturation state of the source rock in the subsurface (Hunt, p. 340).

DISCUSSION

The permeability of shale is negligible. The pore throats in shale are typically not large enough for even tiny methane molecules to flow through easily. Consequently, gas production in commercial quantities requires fractures to provide permeability. Horizontal wells are used in several gas shale formations. This is because natural fractures or joints in most of the shale are vertical. When vertical wells are drilled, the borehole does not intersect many vertical fractures. Horizontal wells are drilled down vertically to the target formation and then horizontally through the shale formation itself. Multistage stimulation treatments are performed on the wells to place hydraulic fractures around the borehole.

For commercial shale gas exploration, the wellbore must be stimulated or hydraulically fractured before a well can produce significant amount of gas. Proppant injection is an important job after hydro- fracturing to hold the fracture mouth open. During the life time of a well, it may effected by some cyclic changes in fracture closure stress. The changes in pressure and stress can cause the proppant to shift or rearrange, resulting in a decrease in fracture width. Therefore exhaustive investigation and experiments are required in selection of proppant. Slick water (a low-viscosity water-based fluid and proppant) is more commonly used in deeper high-pressure shale, while nitrogen-foamed fracturing fluids are commonly pumped on shallower shale and shale with low reservoir pressures. In the slick water fracturing is used in the Barnett shale, additives may include: friction reducers, biocides, surfactants and scale inhibitors. Hydrochloric acid is also used as part of the fracturing process.

CONCLUSION

Composition of shale rock varies from reservoir to reservoir. They are fine-grained sedimentary rocks consisting mostly of silt and clay. The more clay minerals contained in the rock, the more likely the rock is to be fissile. Heterogeneity of shale reservoir is the main controlling factors in commercial shale gas production. Technology is the key to successful development of Shale gas plays. Technology advances in fracturing and horizontal drilling were crucial in making Shale Gas a developable unconventional resource. Hydraulic fracturing is necessary in order to stimulate the shale and allow the gas to be extracted. Fracturing is not new to the industry, only the way it is implemented in the Shale play (multi- stage) is somewhat different. Integrated studies of geological, geophysical, geochemical, petrophysical and geomechanical etc can help to delineate the potential shale plays as well as sweet spots for shale gas exploration and exploitation.

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