Shale Gas Exploration and Production

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Abstract

Shale gas is natural gas from shale formations which acts as both the source and the reservoir for the natural gas. Each Shale gas reservoir has unique characteristics. Shale has low matrix permeability, so gas production in commercial quantities requires fractures to provide permeability . For a given matrix permeability and pressure, gas production are determined by the number and complexity of fractures created, their effective conductivity, and the ability to effectively reduce the pressure throughout the fracture network to initiate gas production. Understanding the relationship between fracture complexity, fracture conductivity, matrix permeability, and gas recovery is a fundamental challenge of shale-gas development. Shale gas reservoirs almost always have two different storage volumes(dual porosity) for hydrocarbons, the rock matrix and the natural fractures .Because of the plastic nature of shale formations, these natural fractures are generally closed due to the pressure of the overburden rock. Consequently, their very low, matrix permeability, usually on the order of hundreds of nanoDarcies (nD), makes unstimulated, conventional production impossible. Almost every well in a shale gas reservoir must be hydraulically stimulated (fractured) to achieve economical production. These hydraulic fracture treatments are believed to reactivate and reconnect the natural fracture matrix .

Introduction

Shales and silts are the most abundant sedimentary rocks in the earth's crust. In petroleum geology, organic shales are source rocks as well as seal rocks that trap oil and gas. In reservoir engineering, shales are flow barriers. In drilling, the bit often encounters greater shale volumes than reservoir sands. In seismic exploration, shales interfacing with other rocks often form good seismic reflectors. As a result, seismic and petrophysical properties of shales and the relationships among these properties are important for both exploration and reservoir management.

Another key difference between conventional gas reservoirs and shale gas reservoirs is adsorbed gas. Adsorbed gas is gas molecules that are attached to the surface of the rock grains . The nature of the solid sorbent, temperature, and the rate of gas diffusion all affect the adsorption . Presently , the only method for accurately determining the adsorbed gas in a formation is through core sampling and analysis. Understanding the effects of adsorption on production data analysis increase the effectiveness of reservoir management in these challenging environments. They contain natural gas in both the pore spaces of the reservoir rock and on the surface of the rock grains themselves that is referred to as adsorbed gas .This is a complicated problem in that desorption time, desorption pressure, and volume of the adsorbed gas all play a role in how this gas affects the production of the total system. Adsorption can allow for significantly larger quantities of gas to be produced. Shale gas reservoirs present a unique problem for production data analysis. The effects of the adsorbed gas are not clearly understood except that it tends to increase production and ultimate recovery. The phenomena of gas storage and flow in shale gas sediments are a combination of different controlling processes. Gas flows through a network of pores with different diameters ranging from nanometres (nm = 10^{-9}m) to micrometres (μm = 10^{-6}m). In shale gas systems, nanopores play two important roles. Petrophysical imaging employs first,second & third generation wavelet to delve deep into complex shale gas reservoir. Nanoscale gas flow in Shale gas sediments has scope to cope with research on dry nanotechnology(smartfluid/nanofluid).Anisotropy in sediments may develop during deposition or post deposition. In clastic sediments, anisotropy can arise both during and after deposition. In carbonates, anisotropy is controlled mostly by fractures and diagenetic processes, and so tends to arise after deposition. For anisotropy to develop during deposition of clastics, there needs to be an ordering of sediments-in essence, some degree of homogeneity, or uniformity from point to point. If a rock were heterogeneous in the five fundamental properties of its grains- composition, size, shape, orientation and packing- anisotropy cannot develop because there would be no directionality intrinsic to the material. Anisotropy at the bedding scale that arises during deposition therefore may have two causes. One is a periodic layering, usually attributed to changes in sediment type, typically producing beds of varying material or grain size. Another results from the ordering of grains induced by the directionality of the transporting medium. Anisotropy is therefore governed not only by variation in the type of material but also by variation in its arrangement and grain size.

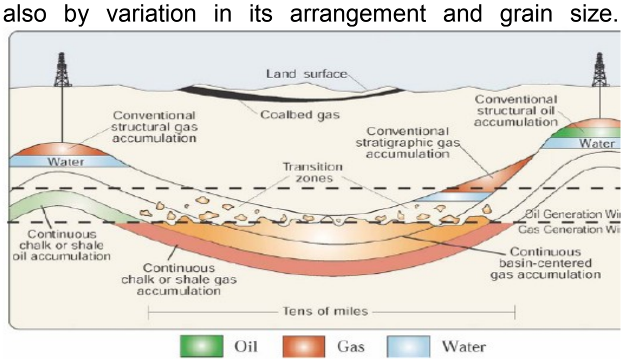

Fig1: Diagram Showing the Area of Occurrence of Shale Gas

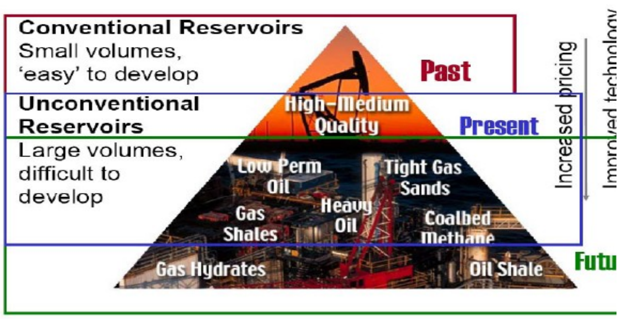

Fig2: The resource triangle unconventional resources

The main cause of elastic anisotropy in shales appears to be layering of clay platelets on the micron(micrometer) scale due to geotropism -turning in the earth's gravity field – and compaction enhances the effect.Shale, with its inherent heterogeneity and anisotropy, has always been problematic in many operations ranging from seismic exploration, well-log data interpretation, well drilling and well-bore stability problems, to production. Research work focus at bridging the gap between invariant characteristics at nano scale of sedimentary rocks and their macroscopic properties. 3D seismic is becoming successful because of the ability to identify fracutre and fault trends. Surface geochem cannot identify in the subsurface where the frac or fault systems will be intersected by the drill bit. This is why 3D is now being used aggressively and successfully.

Method

Unconventional reservoirs require some form of stimulation to obtain commercial production. Shale gas reservoirs require fracture stimulation to unlock gas from extremely low-permeability formations. As fracture stimulation is an important aspect of well completions, production companies need to know basic information about fractures such as whether they will open (and stay open), direction of fracture propagation, dimensions and type of fracture, and whether they will stay in zone. Increasingly, seismic is utilized to provide such information and guide drilling and completions. Three types of information extracted from seismic are useful in optimizing drilling locations: fracture characterization, geomechanical properties, and principle stress measurements (vertical maximum and minimum horizontal stresses). Given the target depth of formations in shale gas basins that are being exploited today, the maximum principle stress is vertical, giving rise to HTI (horizontal transverse isotropy). This means that the fracture system is comprised of vertical fractures which cause anisotropic effects on seismic waves as they pass through. These anisotropic effects are observed on 3D seismic data as changes in amplitude and travel time with azimuth. In multicomponent data shear wave splitting can be observed.

The relationship between changes in P-wave amplitude with azimuth in anisotropic media to invert the observed seismic response and predict fracture orientation and intensity. This information is of great value to production companies because it indicates the optimum horizontal drilling azimuth and offers the prospect of subsequent fracture stimulation as a solution to tap into existing natural fracture systems.A clear understanding of the geomechanical properties and their distribution explains the reservoir heterogeneity and thus the variation in economic ultimate recovery (EUR) between wells. Geophysicist derives a host of geomechanical properties from migrated CDP gathers, including Young's Modulus, Poisson's Ratio, and shear modulus, by first inverting the data for P- and S-wave velocities and density. With this information, fracture dimensions can be predicted and wells drilled in the most brittle rock.Linear Slip Theory for geomechanical properties is used to calculate stress values.

Generally, the stress state is anisotropic leading to the estimation of both the minimum and maximum horizontal stress. As the seismic data measure dynamic stress, results are then calibrated to the static stress that is effectively borne by the reservoirs at depth, making it possible to predict the hoop stress and the closure stress as key elements defining the type and motion of fractures. At locations where the differential horizontal stress ratio (DHSR – the ratio of the difference between the maximum and minimum horizontal stresses to the maximum horizontal stress) is low, tensile fractures will form in any direction, creating a fracture swarm. If the maximum horizontal stress is much greater than the minimum, then fractures will form parallel to the direction of maximum horizontal stress.

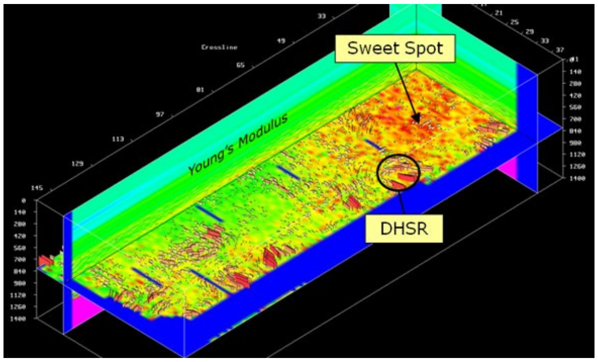

Fig.3: colour represents estimates of Young's Modulus, while the small vertical plates show DHSR. Large plates correspond to large values of DHSR. The prospect locations are where Young's Modulus values are high (rock is most brittle) and DHSR plates are small (fracture swarms will form). (Image courtesy of CGGVeritas)

Examples

Hydraulic fracturing is a process that results in the creation of fractures in rocks, the goal of which is to increase the output of a well. The hydraulic fracturing is used to increase or restore the rate of fluid flow within the shale reservoir and horizontal drilling creates maximum borehole surface area in contact with the shale.

Hydraulic fracture complexity is the key to unlocking the potential of shale plays. Microseismic monitoring suggests that complex fracture network can be developed in some shale plays. Microseismic monitoring is a proven technology and has been widely used to monitor and evaluate the effectiveness of hydraulic fracture treatments in various formations, including shale. Theoretically, in shale plays, a complex fracture should produce better compared to bi-wing planer fractures as a result of increased fracture surface area. The value of the microseismic data is that it provides operators with 3D visualization of where the hydraulic fracture process is impacting the rock in the reservoir. When real-time monitoring is used, the micro-seismic information can be used to prevent fracture growth out of zone. Micro-seismic hydraulic fracture monitoring is another of these new technologies. One of the principal costs in extracting natural gas is the hydraulic fracture process. The rock must undergo extensive fracturing to create the permeability required to allow gas to flow into the wellbore. "Micro-seismic methodologies arguably offer industry the best method to determine the efficiency of the fracture stimulation process, as it applies to making contact with the gas resource locked in the rock.

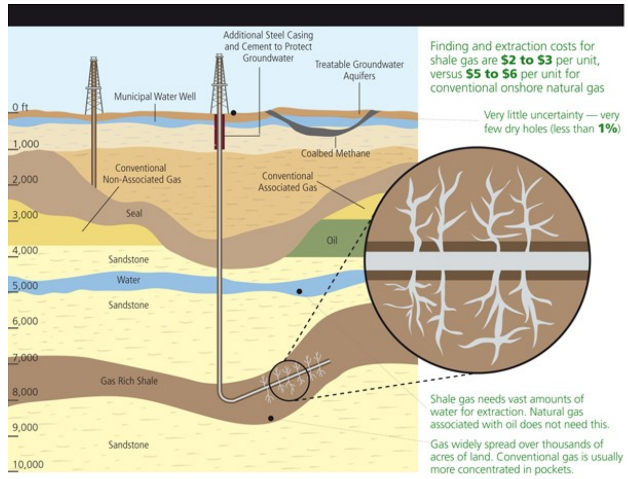

Fig.4: Introduction of horizontal drilling & Hydrofracturing in Shale

Results

Real-time monitoring of micro-seismic events allows operators to immediately optimize the hydraulic stimulation process by modifying the fracture stage design while pumping into the formation. The operator used the real-time data to experiment with how different perforation patterns impacted fracture propagation. The firm also used the data to make real-time changes in the fracture program. At one point, the data showed an absence of growing micro-seismic activity geometry, alerting the operator to stop pumping proppant and flush the well with water to avoid a potentially costly sanding-off of the fractures. Recording micro-seismic events to monitor rock fracturing in 3D space and time during the stimulation process allows operators to confirm the rock volume and formation geometry being stimulated. As a result, operators can optimize future well placement and completion designs, for cost-effective drainage of unconventional reservoirs.

Dual Porosity:Dual porosity model consists of two different media. These two media are fracture system and matrix system. The fracture system contains very little fluid (gas/oil) with low storage capacity but possesses a high conductive path for fluid compared to the matrix system. The other medium which is the matrix system has a high storage capacity but a poor fluid conductive path. Presently, there are many models that characterize natural fractures already existing in reservoir and artificial hydraulic fractures based on dual porosity.

At the core of the shale story is the stunning progress in the technology used to extract the gas from 'tight' rocks, through a process of hydraulic fracturing. This involves bombarding the rocks with millions of litres of chemically treated water to force the gas to flow. Shale gas is no different from the regular natural gas (primarily methane), and its presence over a wide area of thousands of acres has been known for years. But it was not pursued vigorously due to the difficulties of extracting it.

Conclusions

With a view to energy security of the world ,unconventional energy resources - coalbed methane (CBM) , Methane GasHydrate,shale gas, tight gas,oil shale and heavy oil- exploration and exploitation is pertinent task before geoscientist . According to geologists, there are more than 688 shales worldwide in 142 basins. Shale Gas exploitation is no longer an uneconomic venture with availability of improved technology as the demand and preference for this clean form of hydrocarbon have made Shale Gas, an energy in demand. The reserve accretion, production & development of shale gas from one basin to another around the world are rapidly increasing. Real-time monitoring of micro-seismic events allows operators to immediately optimize the hydraulic stimulation process by modifying the fracture stage design while pumping into the formation. The operator used the real-time data to experiment with how different perforation patterns impacted fracture propagation. The firm also used the data to make real-time changes in the fracture program. At one point, the data showed an absence of growing micro-seismic activity geometry, alerting the operator to stop pumping proppant and flush the well with water to avoid a potentially costly sanding-off of the fractures. Recording micro-seismic events to monitor rock fracturing in 3D space and time during the stimulation process allows operators to confirm the rock volume and formation geometry being stimulated. As a result, operators can optimize future well placement and completion designs, for cost-effective drainage of unconventional reservoirs.

Acknowledgments

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