Paul Fulton Scholarship

Hydraulic Fracturing in Shale Formations

By: Paul Paslay

Abstract:

Shale formations can hold vast amounts of hydrocarbons and are currently very popular as producing formations. However, they must be stimulated in order to produce economically. The most prevalent stimulation technique is hydraulic fracturing. This paper explains the process of hydraulic fracturing and looks at the formation characteristics that must be considered for a proper fracture design. A fracture modeling software package, M-Frac from Meyer and Associates, is examined and examples of its outputs are given. Also, this paper discusses some hydraulic fracturing techniques and practices unique to shale formations. Emphasis is placed on the Marcellus Shale, located in western Pennsylvania.

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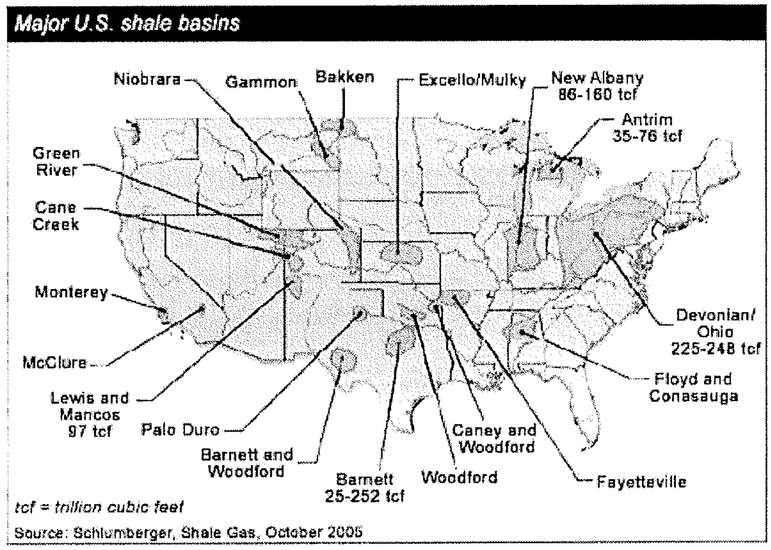
Hydraulic Fracturing in Shale Formations

Shale formations exist all across the United States and they can provide large amounts of production, but they must be treated differently than all other types of reservoirs. Unlike conventional reservoirs that may need stimulation, shale formations always require special techniques to make them produce economically. Many techniques are employed in shale, but the most prevalent is hydraulic fracturing.

Fig. 1 – Map of U.S. Shale Formations



Fundamentally, the process of hydraulic fracturing consists of pumping a fluid at high pressure into a well in order to break open the rock of the producing formation. The breaks in the rock increase the ability of fluids to flow through the rock. A "proppant" must be pumped in with the fluid to hold open the fractures.

The first things to understand when designing a hydraulic fracturing procedure are rock properties. The most important rock property, and the whole focus of the process, is permeability. Permeability is a measure of the ability of rock to transmit fluids (Ahmed, 2006). Shales have very low permeabilities. The vast amount of hydrocarbons trapped within them cannot be produced by traditional means because they cannot flow into the wellbore. The aim of hydraulic fracturing is to increase the permeability so that the formations can be produced in a traditional fashion.

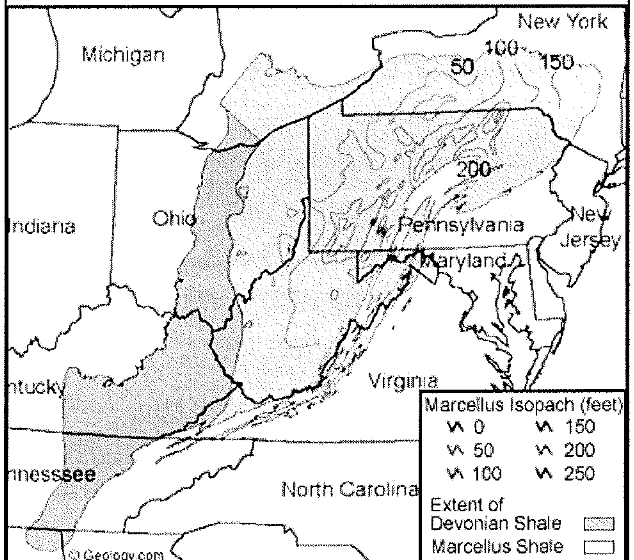
Another important rock property is porosity. Porosity is a measure of void space within the rock. It measures the storage capacity of the rock that is capable of holding fluids (Ahmed, 2006). This property determines how much oil and gas can be held within a formation. High porosity likely means high hydrocarbon content.

Other properties to consider are the properties of proppants. When the pressure put on the formation by the fracturing fluid is removed, the newly created fractures will start to close. The purpose of the proppant pumped in along with the fluid is to hold these fractures open. However, sometimes the closing fractures can crush the proppant grains, creating fine, sandy material. This material can decrease productivity and possibly damage equipment. Therefore, it is necessary to choose proppants with properties suited for the formation and pressures to be encountered.

There is a wide variety of fluids available for use as fracturing fluids. Everything from fresh water to chemical gels can be used. Because of this, factors such as chemical reactivity must be taken into consideration when choosing fracture fluids.

Shale formations are currently very popular because of their large reserves of natural gas. Shale presents some unique production problems, but also presents some unique opportunities. One of the most important, if not the most important, shale formations in the country is the Marcellus Shale, located primarily in western Pennsylvania. The formation has an average thickness of 50 feet, but it varies from less than 50 feet on its western edge to 900 feet on its eastern edge. The total organic content ranges from 1% to over 11%. However, the most interesting characteristic of the Marcellus, and the one that presents to most unique opportunity, is its network of natural fractures. A system of closely-spaced fractures runs from northeast to southwest throughout the formation. These fractures provide some much-needed permeability to the otherwise impermeable shale. Conventional vertical wells may only intersect one of these fractures, but horizontal wells could possibly intersect a large number of fractures. If the drilling of horizontal wells from southeast to northwest, perpendicular to the fractures, is combined with hydraulic fracturing treatments, enormous natural gas production could be achieved.

Fig. 2 – Map of Marcellus Shale



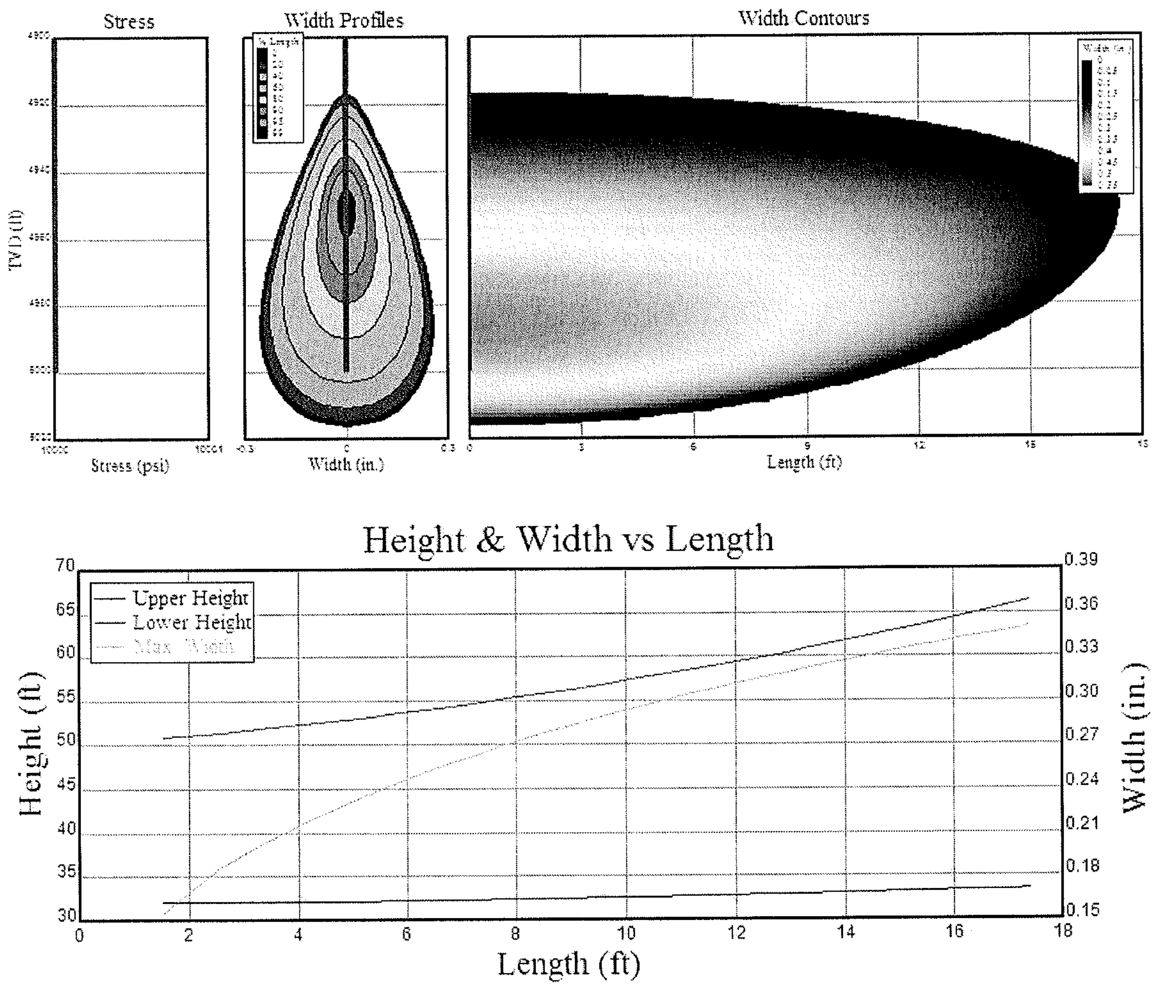
Source: www.geology.com

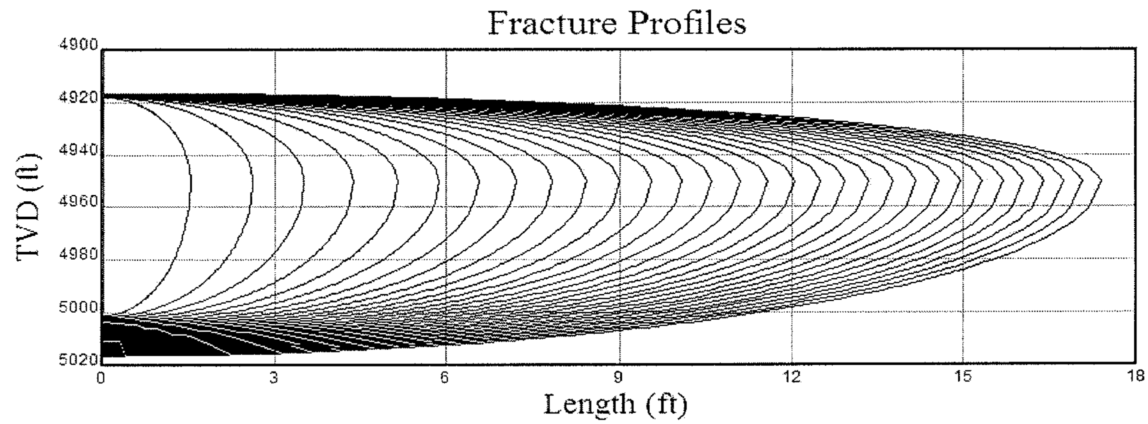
Of course, vertical Marcellus wells are not without their uses. They can also be profitable. Horizontal drilling is extremely expensive and, depending on gas prices, may not be economical. Vertical wells can have significant production, but they can also be used to evaluate formation properties. From vertical, fractured wells, the behavior of the formation under a fracture treatment can be analyzed. Data from these wells can provide models of fracturing within the formation. These models can then be applied to the design for horizontal, fractured wells, which will have the largest production. These horizontal wells also have the largest expenditure, so the models become even more important to the fracture design.

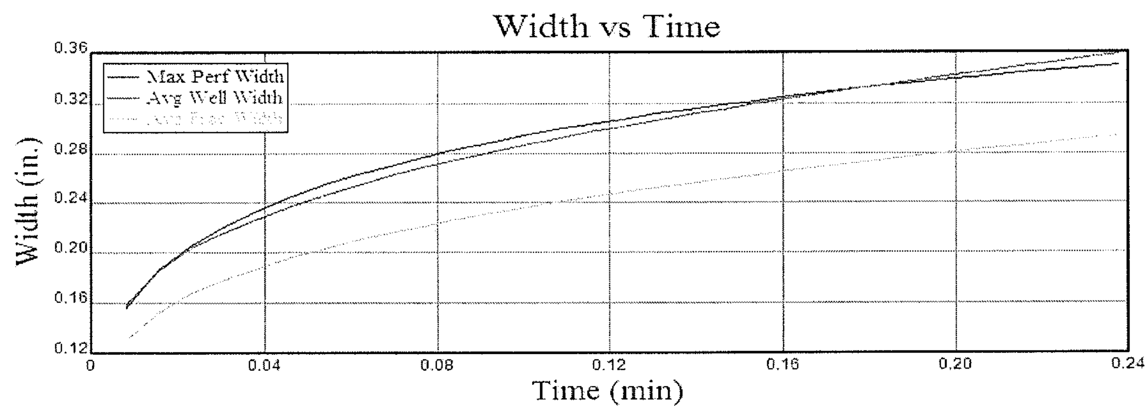
It is important that engineers do not think of shale formations as all being the same and, therefore, treat them the same. Each formation is different and certain properties must be considered before designing a fracture process. Some important properties are brittleness, closure stress, and chemical properties. A brittle shale is a good reservoir, while a ductile shale is a good seal. Ductile shales are more likely to try to close any fractures made in them. Of course, this makes them a good seal to trap hydrocarbons. Brittle shales are more likely to possess natural fractures and are more receptive to hydraulic fracturing treatments. This makes them better suited to become producing reservoirs. Brittleness can be calculated using Poisson's ratio and Young's modulus, which are rock properties measuring the rock's ability to fail under stress and its ability to maintain a fracture, respectively (Rickman et al, 2009). The closure stress of the formation can be used to determine the proper proppant for a fracturing treatment. As closure stress increases, a stronger proppant is needed, or else the proppant can be crushed by the formation. Chemical characteristics of the rock can be used to determine proper types of fracturing fluids. Mineral composition and acid solubility must be determined to avoid using a fluid that may damage the formation.

Engineers use advanced computer software to design fracture processes and model the results. One such software is M-Frac from Meyer and Associates. The aforementioned rock properties are entered into the program as well as desired fluid and proppant types and volumes. The program is then able to model the fractures that would result if the inputted design were implemented. These models are valuable tools for deciding on fluid and proppant types and for creating the overall plan of a fracture process. The M-Frac software is able to plot graphs of many different fracture characteristics, including height, width, length, and width profiles. Producers in the Marcellus are not eager to give out their well data, as they do not want to give a possibly hugely profitable opportunity to someone else. Therefore, the following graphs were created using entirely fictional well data in order to generate an example of M-Frac's output. The following graphs are just a sampling of the M-Frac programs output data. These plots show the width profiles and contours of the fractures, the height and with of the fractures versus length, and the width of the fractures versus time.

Fig. 3 – Sample M-Frac Plots







Source: Meyers and Associates M-Frac Software

The program can also plot many other characteristics such as pressures and fluid loss data. Engineers using the program can also view an entire report outlining the input data and the output models. Over the next year, actual shale well data will be obtained in order to create fracture models that better represent real world shale formations. These models will provide a significant analysis of how hydraulic fractures behave in shale formations.

The future looks bright for production from shale formations, especially because engineers are working everyday to adapt and develop production techniques to these unconventional reservoirs. A new development in hydraulic fracturing for shale is "simul-frac" technology. With this technology, multiple parallel horizontal wells are fractured simultaneously with the goal of creating a more complex fracture network. A more complex network of fractures creates more surface area for the wellbore to contact and can, therefore, greatly increase the recovery factor for the shale. Not only does this technique increase production, but it saves time and money because more than one well can be completed at the same time (Hume et al, 2009). However, to test the effective of this new strategy and other new techniques, the reservoir and the fractures should be modeled, using a tool such as the M-Frac software.

In conclusion, shale formations will continue to be important in the United States and the techniques for producing them may soon become important in the rest of the world (Schein and Mack, 2007). However, they must be hydraulically fractured to effectively produce gas. A great deal of time and money goes into the preparation for and the design of fracturing processes, but, for shale, the profits can be well worth the investment. Engineers will continue to develop more effective techniques for stimulating shale, but not as much money will be spent on this research as there would be if gas prices were higher. Realistically, should gas prices rebound from their current low prices, shale could become the most important reservoir rock there is.

Works Cited

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