the ENERGY lab

R&D FACTS

Geological & Environmental Systems

Geomechanical Impacts of Shale Gas Activities

Background

During hydraulic fracturing of unconventional resources, large quantities of fracturing fluids are injected at high pressures for the express purpose of creating large fractures to improve hydraulic connectivity and produce additional gas. The vertical extent of these fractures and their ability to produce conduits into underground sources of drinking water (USDW) remains a topic of debate. Recent simulation studies have suggested that hydraulic fractures may extend outside of the target shales, but that the vertical extent of these fractures is not large enough to reach USDW for deep shale deposits. Microseismic studies of the Marcellus and other shales have also shown that vertical fractures do sometimes extend outside of the shales, but have not detected any microseismic events within hundreds or thousands of feet of USDW. Thus, the main area of interest is not to determine if hydraulic fractures will reach USDW, but if they will extend to permeable overlying formations that could connect to other conduits to USDW, such as abandoned wellbores that are not completed to surface, and thereby create pathways for gas migration.

The potential shallow system effects of hydraulic fracturing highlight the need for a detailed understanding of whether hydraulic fracture evolution could result in induced seismic events. Stress changes due to these hydraulically-induced fractures have been alleged in some situations to induce seismic activity that may cause a public nuisance or property damage. While the recent NAS report on induced seismicity suggests that seismic events due to hydraulic fracturing are of low probability, it mentions that the likelihood of seismic events due to water disposal with shale gas is more prevalent. Hydraulic fracturing uses much less injected fluid at one location in a much shorter span than other shale gas related activities, such as wastewater disposal. That, and the infrequency of induced seismic events, have led several to suggest that the risks of induced seismicity due to hydraulic fracturing are small. However, pressures associated with hydraulic fracturing are much higher than those seen in other activities, and there have been a couple of felt events due to HF worldwide.

Goals and Objectives

Goal - a science-based assessment for propagation of hydraulically-induced fractures under a range of conditions and materials properties in order to define likely maximum extents of induced fractures

Objective 1 - Identification of rock physics and petrophysics properties and operation envelopes to use for modeling of Marcellus and overburden formations; collection of Marcellus cores

Objective 2 - Constructing models to simulate the propagation of fractures within the formation and overburden; measurements of Marcellus core properties

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Objective 3 - Complete initial model of fracture propagation in Marcellus shale.

Objective 4 - Simulate behavior of Marcellus shale under different operational and in situ conditions

Project Description

Our goal is to produce a science-based assessment for propagation of hydraulically-induced fractures under a range of conditions and materials properties in order to define likely maximum vertical extents of induced fractures. DOE-NETL will conduct coupled geomechanical and flow studies on the Marcellus shale under in situ conditions to evaluate the potential for extension of fractures beyond the Marcellus and its seal rock into overlying formations and/or wells and fractures that could connect to drinking water. Detailed rock properties will be used to create predictive models, which will be validated with microseismic monitoring data, where available. Prior work resulted in a baseline assessment, but future efforts need to apply more comprehensive models and scenarios to ensure representation of more realistic scenarios. Ground-truthing can be performed through use of field data being collected, and using existing data sets (e.g., Pinnacle).

NETL is gathering data from literature sources, as well as data collected from industrial partners to develop a database of properties for the Marcellus shale and the surrounding formations. This data is being used to populate existing models that we will use to simulate the growth of hydraulic fractures in the Marcellus and overlying formations based on a variety of operational scenarios and within the measured variability of in situ properties. These models will be used to predict the height, extent, and permeability of stimulated fractures.

As microseismic monitoring data is collected, this data will be used to help calibrate the fracture growth models. Additionally, statistics of stimulated microseismic activity and background microseismic activity both before and after the stimulation will be measured and compared to help determine if there is any change in the seismic activity induced by the stimulation event. Coupled flow and geomechanical models will be used to help take this field data and use it to predict such events in the future.

Benefits

This comprehensive study will allow us to produce validated tested models of fracture growth in the Marcellus shale at specific sites and use those models to predict behavior at a range of sites across the resource area. Similar models will also be able to aid in the understanding and prediction of induced seismic events associated with hydraulic fracturing.

Accomplishments

In 2012, NETL developed a database of parameters of the Marcellus shale and surrounding layers that include petrophysical properties such as permeability and porosity and geomechanical properties such as Youngs modulus and Poisson's ratio.

A 2-D heterogeneous model of hydraulic fracturing in shales was developed to study the vertical growth of fractures in the Marcellus shale (see Fig. 1). Comparisons to microseismic data from a field project have been made.

A 3-D Marcellus-specific layered model for hydraulic fracturing for simulating hydraulic fracturing was developed. Modifications were made to this model to account for the presence of existing fractures in the overburden. Simulations have been made to predict fracture growth under different injection rates and for varying subsurface parameters.

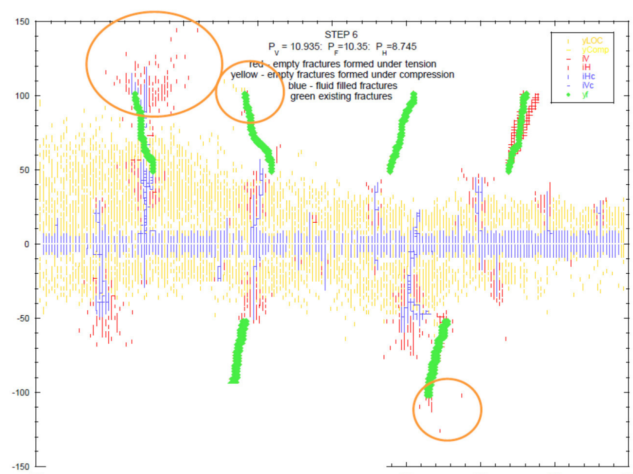

Figure 1. Preliminary results of 2-D hydraulic fracturing model; blue dots are induced pathways; red dots are microseismic events.

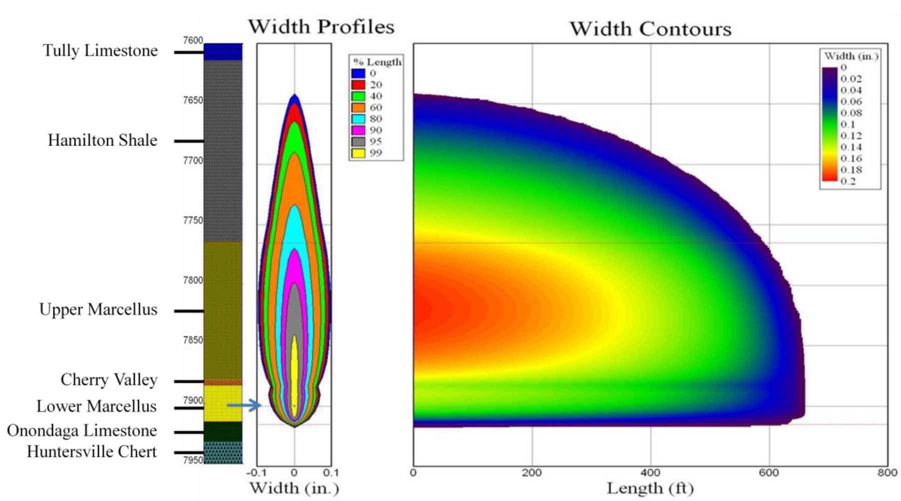

Figure 2. Example simulation of fracture width and height during a hydraulic fracturing event.