U.S. DEPARTMENT OF ENERGY | Fossil Energy

Office of Oil and Natural Gas

Subsurface Science

Unconventional oil and gas (UOG) reservoirs present unique subsurface science challenges related to their low porosity and permeability, complex naturally-occurring fracture systems, or poorly understood fluid-rock and fluid-fluid interactions. To efficiently optimize recovery of UOG resources through environmentally sustainable best practices, it is crucial to develop technologies that better characterize the subsurface. Investments by the Department of Energy's (DOE's) Office of Fossil Energy (FE) and the National Energy Technology Laboratory (NETL) have led to substantial progress in developing data and technologies that reduce the subsurface footprint and mitigate environmental impacts associated with UOG production. Optimizing recovery and minimizing environmental risk of shale resources is also part of the DOE crosscutting R&D initiative named SubTER (Subsurface Technology and Engineering Research). SubTER has identified adaptive control of subsurface fractures and flow as a grand challenge that, if achieved, has the potential to transform all subsurface energy strategies. FE and SubTER support joint research efforts between DOE, industry, and universities leading to better design, monitoring, and control of fractures and stimulations. This research focuses on technology and practices that minimize the number of wells that must be drilled for a given volume of oil or gas production.

Goals

The goals of the ongoing and completed research are to:

- Improve our understanding of the basic physical properties of UOG reservoirs,
- Mitigate environmental risks,
- Provide public data sets that characterize current and future resources, and
- Enable responsible stewardship through more efficient utilization of resources via technology allowing more recovery from fewer wells.
- Help crosscutting DOE SubTER team achieve adaptive control of subsurface fractures and fluid flow. Through SubTER, FE's subsurface research supports research in geothermal energy, geologic storage of CO_2, and geologic storage and disposal of spent nuclear fuel.

What Is Known

Optimizing shale and other unconventional resources plays an important role in creating a safe and effective "all-of-the above" energy future. Shale resources have very low porosity and permeability, which makes it hard for oil and gas to flow into the well. They can also have complex naturally-occurring fractures, and poorly understood fluid-fluid and fluid-rock interactions. Furthermore, UOG reservoirs are not all the same, so mixed results occur from the use of common, standard practices. This variability means that more than one solution is needed to resolve both production and environmental challenges.

Research has led to an improved understanding of recovery behavior in hydraulically-fractured low-permeability reservoirs. Still, questions remain. For instance, many reservoirs that are under relatively low pressure and do not respond well to hydraulic fracturing. The ability to assess the area impacted by a well is limited. Also, the most up-to-date microseismic technology still cannot reliably distinguish between productive and non-productive fractures.

UOG recovery has delivered benefits to the economy and national security. Research in this area requires expertise in geosciences, remote sensing, engineering, and many other fields. The remaining challenges are best tackled with research that brings together experts from industry, academia, and research organizations.

Research Results

FE has sponsored research that has advanced understanding and technologies in the area of subsurface science, including the following projects.

- Texas A&M identified key factors, such as temperature and proppant concentration, that impede the productivity of fractures. Producers can use this information to maximize the amount of gas produced from each well.
- University of Texas at Austin found that using water is less effective than using foam without gels (which are used to help proppant move through the fracture) in increasing productivity. They found, specifically, that these foams create longer fractures in which the proppant settles and compacts less.
- Researchers at University of Texas at Austin improved re-fracturing designs. They determined the best amount of time between repeating a fracturing job on an unconventional well is usually months or years. This research also developed a re-fracturing technique known as "Texas 2-Step". This technique helps maintain economic production from a fractured well.

The following sections include more research results in this area.

Reducing Subsurface Impact

University of Texas at Austin and Paulsson Geophysical are developing a better way to map the placement of proppant in a fracture. This can help determine which fracturing methods leads to the longer-lived wells.

GroundMetrics, Inc., executed the first field-scale test that showed how combining two advanced technologies—microseismic and electromagnetic surveying—can help determine how much of the gas- or oil-bearing rock is being fractured.

Understanding Reservoir Behavior

An improved understanding of how fluids, the formation, and the wellbore behave can be used to optimize production and decrease the number of wells.

Missouri University designed and fabricated a tool that can be used to explain how fluids in the subsurface interact with each other and the formation at the nano-scale. This makes it more clear how different fluids move within low-permeability formations.

The University of Pittsburgh and West Virginia University monitored hydraulically-fractured shale in Pennsylvania. This project showed that while some fractures grew beyond the targeted formation, no fluid movement into aquifers was detected.

The University of Pittsburgh also evaluated how the microbiology of produced water can cause scaling and corrosion in wells and in the formation. Actions based on this knowledge can help ensure long-term well productivity and can mitigate environmental impacts.

Characterizing UOG Resources

Understanding the nature and scale of UOG resources will help ensure that recovery is efficient and environmentally sustainable.

A Colorado School of Mines project led to the development of a computer model to optimize production in the Bakken Petroleum System by identifying likely “sweet-spots” of the play. This research and model can ultimately result in greater resource recovery with less environmental impact by drilling fewer wells.

A Gas Technology Institute (GTI) project assessed the recoverability potential in the New Albany shale play, specifically noting that due to the richness of clay, some techniques used in other plays are not applicable. Another GTI project characterized emerging Alabama shale gas plays using outcrops, cores, well logs, and seismic data, showing that these plays may contain enough natural gas to have a major impact on domestic gas resources (see Figure 1).

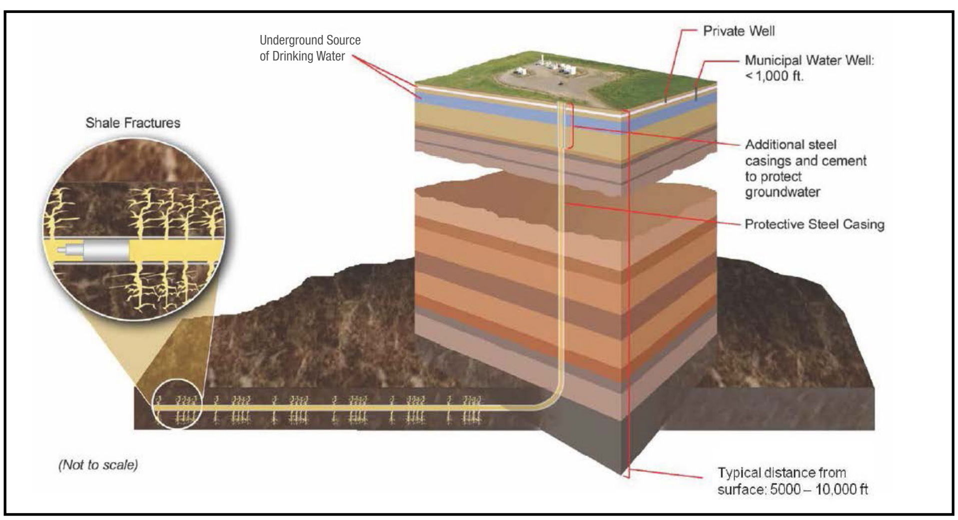

Figure 1. NETL schematic of hydraulically-fractured shale gas system. It is important to understand not only the characteristics and behavior of the target formation but also the overlying layers through which the well is drilled. Conducting this type of subsurface research and technology development can ensure safer and more efficient production in an environmentally sustainable manner.

Direction for Future Progress

Technology development and research opportunities include better characterization of the subsurface, as well as technologies or practices that reduce the environmental footprint of UOG resource development. Research should also focus on improving estimates of resource size, both in-place and technically recoverable resources. Research to improve imaging and understanding of the subsurface in terms of geophysical, geochemical, and other characteristics is also needed, and could help with the adaptation of development plans to specific locations contributing to the efficiency of use of this resource. Finally, research into alternative stimulation approaches, including the advancement of analytical models that support these approaches, can improve resource stewardship and result in more efficient and effective resource recovery using fewer wells.