How is Shale Gas Produced?

Shale gas formations are "**unconventional**" reservoirs – i.e., reservoirs of low "**permeability**."

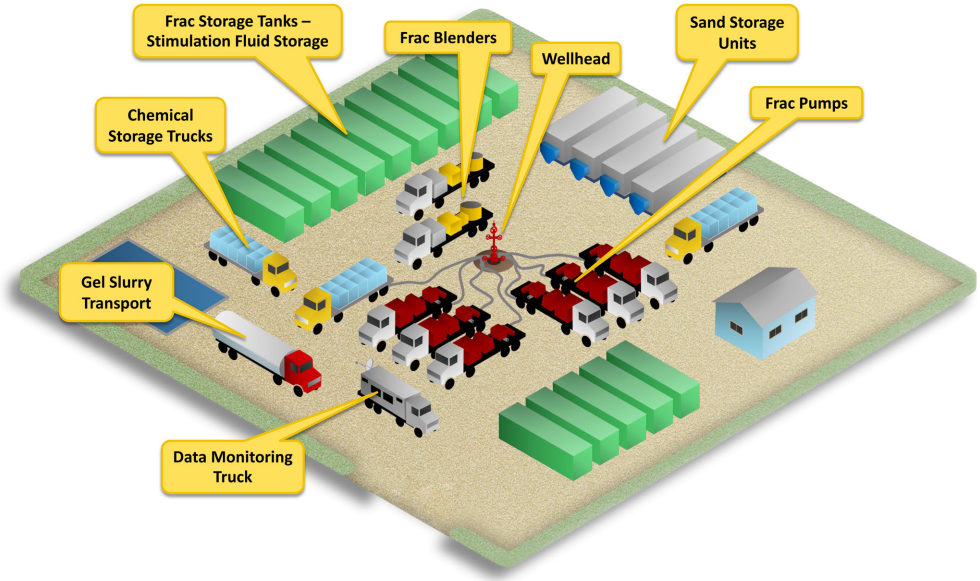
Permeability refers to the capacity of a porous, sediment, soil – or rock in this case – to transmit a fluid. This contrasts with a "**conventional**" gas reservoir **produced from sands and carbonates** (such as limestone).

Tight gas differs from shale gas in that it is trapped in sandstone or limestone, rather than shale formations.

The bottom line is that in a conventional reservoir, the gas is in interconnected pore spaces, much like a kitchen sponge, that allow easier flow to a well; but in an unconventional reservoir, like shale, the reservoir must be mechanically "**stimulated**" to create additional permeability and free the gas for collection. In addition to shale gas, other types of unconventional reservoirs include **tight gas** (low-porosity sandstones and carbonate reservoirs) and **coal bed methane** (CBM – gas produced from coal seams).

Hydraulic fracturing is a known technology and has been used for at least 60 years. It has helped produced more than 600 trillion cubic feet of natural gas and 7 billion barrels of oil.

Source: American Petroleum Institute, "Freeing Up Energy – Hydraulic Fracturing: Unlocking America's Natural Gas," July 19, 2010, page 4.

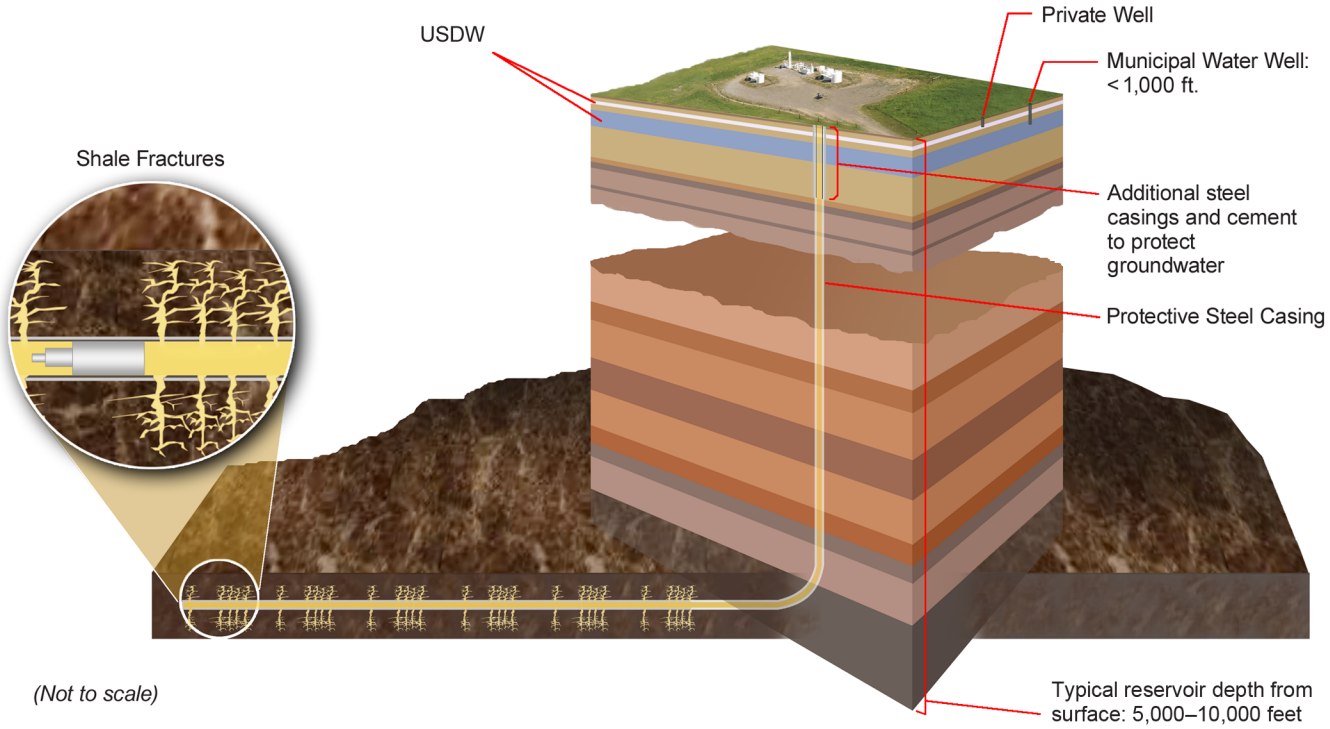


Representation of common equipment at a natural gas hydraulic fracturing drill pad.

For shale gas, **hydraulic fracturing** of a reservoir is the preferred stimulation method (*see graphic below*).

This typically involves injecting pressurized fluids to stimulate or fracture shale formations and release the natural gas. Sand pumped in with the fluids (often water) helps to keep the fractures open. The type, composition and volume of fluids used depend largely on the geologic structure, formation pressure and the specific geologic formation and target for a well. If water is used as the pressurized fluid, as much as 20 percent can return to the surface via the well (known as **flowback**). This water can be treated and reused – in fact, reuse of flowback fluids for subsequent hydraulic fracture treatments can **significantly reduce the volume of wastewater** generated by hydraulic fracturing.

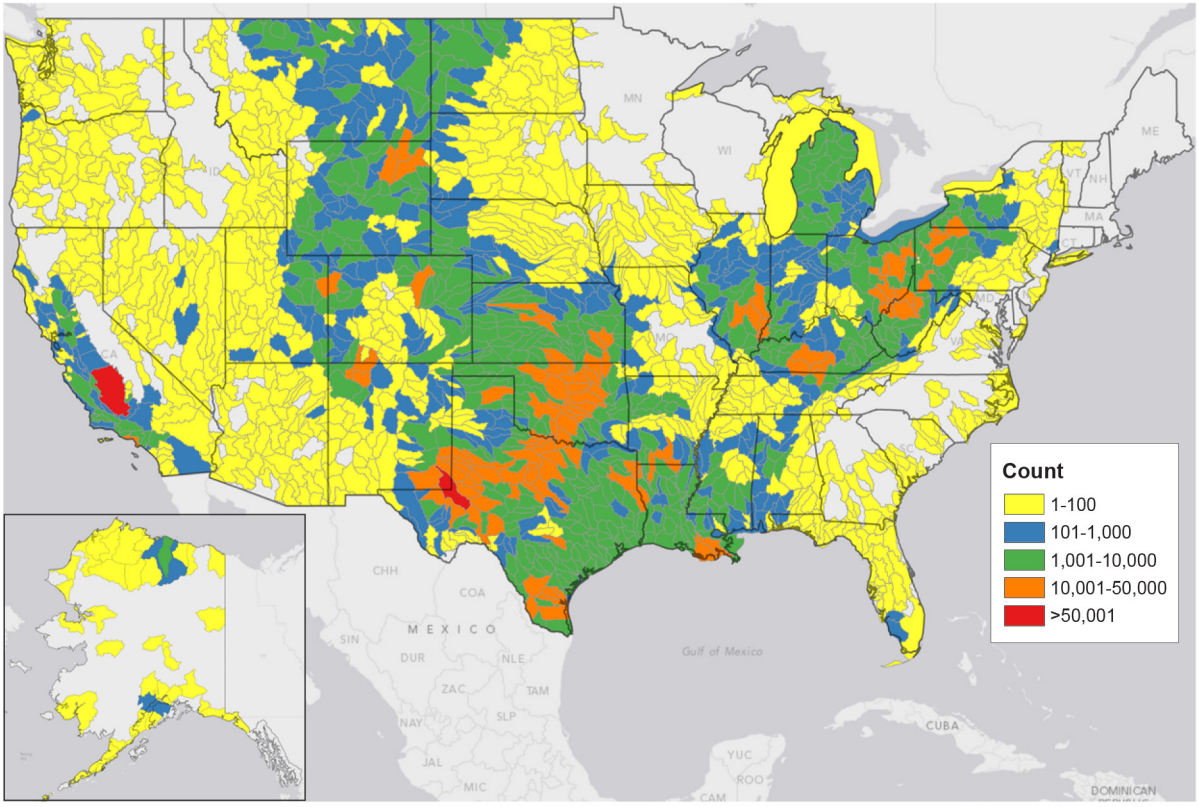
Fine-grained silica sand is mixed with chemicals and water before being pumped into rock formations to prevent the newly created artificial fractures from closing after hydraulic fracturing is completed. Photo: Bill Cunningham, U.S. Geological Survey



Producible portions of shale gas formations are located many thousands of feet below the surface, well below groundwater aquifers. Modern hydraulic fracturing technology involves sophisticated engineering processes designed to create distinct fracture networks in specific rock strata. Experts continually monitor all aspects of the process, which must comply with local, state and federal laws and regulations.

The hydraulic fracturing process was used in conventional limestone and sandstone reservoirs for decades before the onset of the shale revolution. But it was not until the 1970s that significant attempts to apply the technology to gas shale were made, pioneered by **DOE research** and demonstration project cost-sharing with industry in such ventures as the **Eastern Gas Shales Project** (1976-92).[1]

Another major technology often employed in producing natural gas from shale is **horizontal drilling** *(see graphic on previous page)*. The shallow section of shale wells are drilled vertically (much like a traditional conventional gas well). Just above the target depth – the place where the shale gas formation exists – the well deviates and becomes horizontal. At this location, horizontal wells can be oriented in a direction that maximizes the number of natural fractures intersected in the shale. These fractures can provide additional pathways for the gas that is locked away in the shale, once the hydraulic fracturing operation takes place.



More than 4 million oil and gas related wells have been drilled in the United States since development of these energy resources began nearly 150 years ago. At least 2 million of these have been hydraulically fracture-treated, and up to 95 percent of new wells drilled today are hydraulically fractured, accounting for more than 43 percent of total U.S. oil production and 67 percent of natural gas production.

Sources: U.S. Geological Survey Powell Center for Analysis and Synthesis (graphic), http://pubs.usgs.gov/fs/2012/3049/FS12-3049_508.pdf; "Hydraulic Fracturing – A Historical and Impact Perspective," presentation by Kent F. Perry, Gas Technology Institute, College Station, Texas, November 18, 2010, slide 33, http://www.rpsea.org/attachments/contentmanagers/3328/Natural_Gas_The_Path_to_Clean_Energy_Forum_Hydraulic_Fracturing_a_Historical_and_Impact_Perspective_Kent_Perry_111810.pdf; and National Petroleum Council, "Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources," 2011, page 205.

[1] See http://www.netl.doe.gov/publications/descriptions.html for a DVD archive of the DOE/NETL Unconventional Gas Resources Program, containing reports and logs related to the Eastern Gas Shales Project.