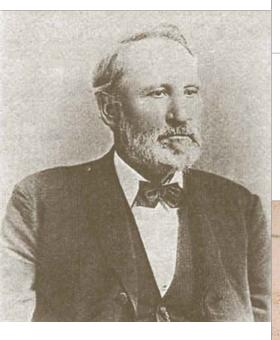
# SHALE FRACKING INNOVATION TIMELINE



ABOVE: As a reminder of where it all began in Fredonia, NY 1825. Located on West Main St. Courtesy of the Darwin-Barker Historical Museum

### 1821

Natural gas is first extracted from shale in Fredonia, New York



# 1865

Civil War veteran
Colonel Edward Roberts patents
technique to extract oil and gas from
rock using nitroglycerine explosives

BELOW: First experimental fracturing job conducted in 1947 by Stanolind Oil in the Hugoton gas field of southwestern Kansas.



# 1947

Hydraulic fracturing, using napalm, first used to extract natural gas from limestone in Kansas

# 1953

Water and gelling agents replace petroleum products in hydraulic fracturing



Hydraulic fracture created with a typical cross-linked gel with three stages of different colored sand.

Rock has been chipped away to show the distribution of colors and thickness of the resultant fracture, circa 1976.

Photo courtesy Norm Warpinski.

### 1954

The Supreme Court classifies natural gas producers as "natural gas companies" under the 1938 Natural Gas Act, allowing the Federal Power Commission to regulate wellhead prices

### Mid-1960s

Crude computer programs first used to simulate fracking operations



ABOVE: Scientists lower a 13-foot, 29-kiloton nuclear warhead into a well in New Mexico for the Project Gasbuggy experiment. Photo courtesy of Los Alamos National Laboratory.

# 1967

Project Gasbuggy tests atomic explosions for gas extraction in New Mexico

### 1971

Natural gas distributors warn of national gas shortages



# 1973

OPEC imposes an embargo on oil exports

General Electric develops diamondstudded drill bits, which it would improve with the Department of Energy later in the 1970s and 1980s

The Federal Power Commission (FPC) completes the first study of unconventional gas volumes



### 1974

President Ford and Congress create the Energy Research and Development Administration (ERDA) and the Federal Energy Agency (FEA)

# 1975

ERDA demonstrates massive hydraulic fracturing (MHF) technique

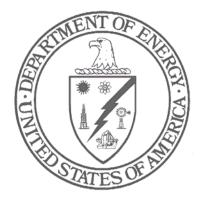
ERDA and the West Virginia
Kentucky Gas Corporation demonstrate
"directionally deviated drilling"

### 1976

ERDA launches the Eastern Gas Shales
Program (EGSP) and the Western Gas
Sands Program (WSGP) under the
Unconventional Gas Research Program (UGRP)

The Gas Research Institute (GRI), the "R&D arm of the gas industry," is founded, initially funded by a FERC-sanctioned surcharge on interstate gas pipelines

Two ERDA engineers patent early directional drilling technique



#### 1977

ERDA merges with FEA to form the US Department of Energy (DOE)



### 1978

Congress passes the Natural Gas Policy Act, allowing for higher price ceilings on unconventional gas

Mitchell Energy conducts largest contemporary MHF demonstration with DOE assistance

# **LATE 1970s**

EGSP demonstrates feasibility of foam-based fracking

### 1980

Congress creates the Section 29 tax credit for unconventional gas, which would last until 2002

Elf Aquitaine, a state-owned French company, drills four experimental horizontal wells in France and Italy

# SHALE FRACKING INNOVATION TIMELINE



ABOVE: The first Sandia microseismic receiver, circa 1980. Photo courtesy Norm Warpinski.

ABOVE: A cored hydraulic fracture from a Multiwell Experiment fracture created in 1983. Core was taken in 1988. The hydraulic fracture has many individual strands.

Photo courtesy Norm Warpinski.

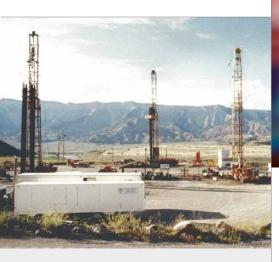
### 1984

Mitchell Energy switches from foam-based to gel-based fracks

### 1981

Sandia Laboratory initiates
the Multiwell Experiment, which
would last through 1986;
this includes the first-ever published
microseismic monitoring of
hydraulic fracturing operations

Mitchell Energy drills first well in Texas's Barnett Shale



ABOVE: Photo taken circa 1985, when activities were going on in all three of the close-spaced wells, the key of the Multiwell Experiment. Photo courtesy Dave Northrop.

### 1986

First multifracture horizontal well drilled in Wayne County, West Virginia, by DOE-private venture



circa 1992. Photo courtesy Norm Warpinski.

### 1989

Congress fully deregulates wellhead natural gas prices

### 1991

Mitchell Energy experiments with DOE and GRI on mapping and drilling in the Barnett Shale



1992

ABOVE: Installation of the first 5-level receiver array at the M-Site (same location as the Multiwell Experiment),

The DOE/GRI/industry "M-Site"
Experiment, which would run through 1996, successfully demonstrates the accuracy of microseismic monitoring



ABOVE: Senior management of Mitchell Energy.
This photo was taken after Bill Stevens took over
as president of the company in the mid-1990s.
Photo courtesy Dan Steward.

### 1998

Mitchell Energy, adapting a technique from Union Pacific Resources, successfully demonstrates slickwater fracking in the Barnett Shale



ABOVE: (Left to right): George Mitchell, Doug Mitchell (no relation), and Dan Steward at celebration commemorating 700th Barnett Shale well in Decatur, Texas, in the early 2000s. Photo courtesy Dan Steward.

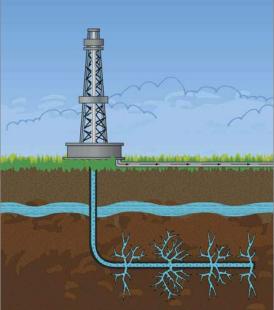
### 2000

Mitchell contractor Pinnacle and GRI-funded researchers successfully map the Barnett Shale using microseismic imaging

# 2002

Devon Energy buys Mitchell Energy for \$3.5 billion

For the first time, Devon Energy successfully combines its horizontal drilling techniques with Mitchell Energy's microseismic mapping and slickwater fracking in the Barnett Shale



## 2003

Southwestern Energy uses Mitchell's slickwater fracking techniques to extract oil

### Mid-2000s

Shale gas production grows steadily, initially led by Chesapeake Energy

Several companies including Continental, EOG, and Brigham begin applying fracking techniques to oil deposits in the Bakken Shale

# 2012

Natural gas prices drop to below \$2/mmBTU; natural gas reaches a record 30 percent of total US power generation

# 2013

Shale gas reaches 40 percent of US natural gas production, up from less than 2 percent in 2001



# 2014

Global oil prices crash by nearly 60 percent over 8 months, largely because of the boom in US shale oil production