

FROM HALLIBURTON

# UNCONVENTIONAL WISDOM

**Shale Challenges Are Different.**

**You Need Different Thinking To Solve Them.**

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## **Put Halliburton’s proven solutions, and unconventional wisdom, to work for you.**

Halliburton has played a key role in developing the solutions that have made shale hydrocarbon recovery economically viable for operators since 1980.

Success in shale plays is due to the application of horizontal drilling, multi-stage hydraulic fracturing solutions and other technologies. But technology alone is not enough, because no two shales are alike and success in one shale play does not guarantee the same approach will yield success in another. At Halliburton, we believe our combination of technology, experience, and teamwork provides the unconventional wisdom needed to get the best results. This wisdom comes from our expertise in almost every active shale play in the U.S., and we are taking that wisdom across the globe, Halliburton is ready to build collaborative partnerships to help operators get the most from their shale assets.



## **The Industry’s Health, Safety and Environment and Service Quality Leaders**

Health, safety and environmental (HSE) considerations, along with service quality, are critically important for successful shale resource operations. HSE leadership and accountability are instilled across all levels of our organization. And strict process adherence and constant monitoring of service delivery metrics pay dividends in fewer equipment failures, less non-productive time, increased production and a multitude of other efficiencies at every stage of development and production.

Through our Service Quality processes, we bring greater value to shale development by pushing the frontiers of innovation and efficiency. These processes were developed for all Halliburton field personnel and are strictly adhered to throughout the life cycle of a job. The processes essentially explain what each employee does, how each task is done, who is responsible, how we know we’ve done it, and how to make it better. It’s a continuous feedback loop to ensure that optimal efficiency is achieved on every job, every time.

## **A Culture of Safety**

Ask our employees and they will tell you that we live and breathe a culture of safety—doing whatever it takes to implement and execute our proven and proactive HSE programs. We focus on eliminating all potential HSE incidents through the implementation of our Risk Management Plan.

## What is Shale?

A strict geological definition of shale is any “laminated, indurated (consolidated) rock with > 67% clay-sized materials” (Jackson, 1997). Approximately 50% of all sedimentary rocks are classified as shale. Shales are often deposited in low-energy depositional environments where the fine-grained particles fall out of suspension.

## What is Organic Shale?

When organic matter is present in high concentrations in rocks such as shale, they can form a source rock from which most oil and gas contained in conventional reservoirs originated. A fine-grained, organic rich, sedimentary rock characterized by thin layers of clay or mud, organic shale has wide variations in geology, geochemistry, geo-mechanics and production mechanisms. These variations occur from one resource play to the next, sometimes even within the same organic shale. No two organic shales are alike. Each offers its own set of unique technical challenges and learning curves.

Shale is unique in that it often contains both free and absorbed gas, oil and liquid condensates. This results in initially high production rates, quick decline curves, and then long-term steady production.

And because shale typically has very low matrix permeability, the major challenge is obtaining economically viable production. Sustaining commercial production rates requires stimulation treatments to develop complex fracture systems to allow hydrocarbons to flow.

## Shale Gas

Natural gas is found in mature organic shale. Shale gas is one of several unconventional sources of natural gas. Conventional gas production is expected to peak in the U.S., and unconventional gas will be needed to meet growing demand. According to the EIA, the United States possesses many trillion cubic feet (Tcf) of potential natural gas resources. Natural gas from shale resources, considered uneconomical just a few years ago, accounts for most of this resource estimate. Growing interest in energy independence, both in the U.S. and across the globe, has attracted operators to shale.

## Shale Oil

Oil is also found in shale. Extracting oil from shale starts with a question: “Is it shale oil or oil shale?” There is much confusion about the two terms. They are often used interchangeably but, in fact, are very different. Oil shale is an organic-rich sedimentary rock that contains kerogen. Kerogen-rich rock must be heated at extremely high temperatures (950°F or 500° C) in order to “process” it into liquid oil. Oil shale is expensive to mine as the process is more complex than conventional oil recovery. That’s because the oil substances in oil shale are solid and cannot be pumped directly out of the ground. Although it has great potential, oil shale is not economically viable for most operators.

Shale oil, on the other hand, is a high organic content rock that contains free and adsorbed hydrocarbons derived from the geologic conversion of kerogen by temperature and pressure. Commercial production is achieved by drilling long horizontal wellbores and hydraulically fracturing the formation with many stages, allowing the oil and gas to flow from the large surface area created. The oil produced is crude, and is comparable, if not better in quality, than West Texas Intermediate, the U.S. crude standard. Shale oil can be found across the U.S. and Canada in such shale plays as the Bakken, the Niobrara and the Eagle Ford.

## Comprehensive Approach

In shale development, the technologies used are only as good as the people who design, plan, manage, operate the jobs and interpret the data collected. Halliburton has spent many years fine tuning this comprehensive approach where petrophysicists work with stimulation engineers to optimize production — and vice versa.

Halliburton’s regional technical team structure promotes collaboration between all disciplines and clients that enables a better environment for identifying the right solutions for continuous well improvement.

## Well Construction Efficiency

The most direct path to increasing service reliability and efficiency is to tailor the drilling process and technologies to the unique geology and mineralogy of each shale play. Some of the preventative actions employed to reduce drilling problems include:

- A. Monitoring borehole conditions to maintain the optimum mud weight, prevent shale sloughing and avoid formation damage
- B. Monitoring potentially destructive mechanical forces such as vibration to avoid bottom-hole assembly and bit failure
- C. Designing downhole equipment to address a specific set of conditions such as lithology, rock strength, temperature and pressure

**Reference:**  
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## Managing the Borehole

Shale formations are responsible for a majority of all drilling problems and non-productive time. Selecting the optimal drilling fluid compatible with the stresses and mineralogy of a shale play is critical to ensure borehole stability and shale inhibition. As part of the initial shale evaluation process, potential drilling fluids are tested for possible shale/fluid (mineralogical) interactions, reactivity and fines migration.

Shale strength is strongly related to the required chemistry of drilling fluid and fluid filtrates and the length of time shale formations can be exposed to these fluids. The current industry trend is to move away from oil-based fluid systems and move toward water-based drilling fluid systems. Water-based drilling fluids are cost efficient and can reduce the environmental impact.

## Well Integrity for Maximum Long-Term Production

Well integrity is a critical element in the process to optimize fracture design and production. Effective zonal isolation and elimination of crossflow improves stimulation effectiveness and contributes to maximizing production. Modern cement systems are engineered to meet specific geological and bottomhole conditions, e.g. temperature, pressure, carbon dioxide content and fracture placement.

The method used to place the fracture treatment is critical. Cement in perforations can inhibit fracture initiation, resulting in excessive tortuosity during stimulation that can significantly alter the fluid distribution and decrease stimulation effectiveness. Sometimes, acid-soluble cements are used to allow the cement to be removed from perforation clusters. This eliminates the tortuosity and fracture entry pressure effects that can affect the planned limited-entry fluid distribution, skin effects, reduced near-wellbore conductivity and perforation-plugging problems encountered during production that are associated with conventional cements.

## Hydraulic Fracturing

Fracture stimulation is critical to the viability of shale gas. Halliburton is at the forefront of fracture technology with products and services that provide the best environmental performance, are safe in their intended use, consume energy and natural resources efficiently and can be recycled, reused or disposed of safely. The emphasis is on developing services and technologies for optimized completion efficiency. To achieve this goal, Halliburton employs a workflow process that aids in the selection of the fluid systems, completion systems and pump-in tests required for the planning and execution of an optimal hydraulic fracture design.

In addition, precise multistage fracturing stimulates individual wellbore intervals to lower costs, reduce time to production and improve recovery. Halliburton also leads the industry with a variety of pinpoint stimulation processes for different types of completions.

And because shale typically has very low matrix permeability, the major challenge is obtaining economically viable production. Sustaining commercial production rates requires stimulation treatments to develop complex fracture systems to allow hydrocarbons to flow.

## Water Management

Fracturing a single shale gas well can use up to 20,000 m<sup>3</sup> water. As a result, development of a field can put significant stresses on regional fresh water supplies. Halliburton provides the technologies for treating the flow back and produced water to a standard suitable for reuse in fracturing or drilling fluids. In doing so, the volume of wastewater sent for disposal is minimized and water acceptable for use in fracturing or drilling fluids is returned to the operator, reducing overall demand for freshwater.

New frac-fluid components are geared towards creating frac fluids from treated produced water. By greatly reducing waste stream and maximizing reuse, Halliburton manages the water demands of the intensive fracturing schedules necessary to develop shale gas fields.

## Shale Experience

Halliburton formation evaluation, drilling, and stimulation programs are built on a thorough understanding of each specific shale play. At every step we collect and analyze data, which is used to improve our understanding. In the end, production and recovery rates are improved while associated costs and non-productive time are reduced.

With first-hand experience in practically every shale gas and oil play in the world, Halliburton knows how to assess the challenges each play presents. To answer these challenges, we provide proven capabilities through every phase of shale gas and shale oil development.

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## Get the Halliburton Advantage

Within Halliburton's shale network, best practices from around the world are shared to achieve the best results, regardless of geology or geography.

Halliburton's global technology research organization supports all of the company's product service lines and has specifically targeted research and development for the shale market. Halliburton has 15 R&D centers that service the shale unconventional resource market. Six of these centers have the majority of their technological developments focused on solving shale challenges. They are located very close to existing and new high-potential shale developments.

## The Shale Roadmap

Through the combination of technology, expertise and collaboration, the Halliburton shale road map was born. The shale road map is a workflow that addresses the central challenges in shale development. It also takes into account basin assessment, start-up exploration, mass production and reserve harvesting/cash flow throughout the life cycle.

## Logistics information

Halliburton is the market leader in materials supply and materials delivery. Through key partnerships with best-in-class suppliers and a strategic approach to ensuring continuity of supply and top materials performance, Halliburton delivers shale reservoir excellence.

The evolution of shale exploration has been paired with the evolution of a Service Intensity model that is essential to the economic viability of any given shale. It has been through Halliburton's significant investment in infrastructure and logistical expertise that we continue to deliver the technological solutions required for the economic recovery of shale resources around the globe. By boat, by rail, or by truck, Halliburton, through our extensive logistics network around the world, is prepared to offer a complete shale solution.



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