



# Borehole Seismic Services

Achieve understanding at every phase of your field development



Drilling



Evaluation



Completion



Production



Intervention

## Wireline services

- Borehole seismic services
  - Check-shot services
  - Microseismic services
  - VSP surveys
- Cased-hole
- Openhole
- Subsurface evaluation services

More options. Multiple services.  
Maximum value.



**Weatherford**<sup>®</sup>

# Maximize recovery with borehole seismic technology

Weatherford's borehole seismic services can help you achieve a better understanding of your field at every phase of development, make better decisions and, ultimately, maximize recovery.

Our capabilities include the planning, execution and interpretation of vertical seismic profile (VSP) and microseismic surveys in observation and treatment wells; we also offer permanent monitoring for producing wells. During the exploration phase, borehole seismic surveys complement other datasets to provide a holistic image of your reservoir; collectively that information can help you determine well placement and optimize completions. In the development phase, borehole seismic surveys play a critical role in improving the effectiveness of stimulation treatments. And, in producing wells, our permanent monitoring services contribute to maximizing life-of-well recovery.

Go deeper to acquire better data: Borehole seismic versus surface seismic.

A pertinent evaluation tool, borehole seismic surveys tie a true depth to surface seismic studies and typically yield higher quality data than you can acquire at the surface. Specifically, the extended frequency content in borehole seismic data increases the stratigraphic and structural definition of the formations around, below and away from the borehole.

# Get the most out of borehole seismic—the Weatherford way

Weatherford combines a breadth of sophisticated technologies, interpretation skills and a truly global presence to ensure that you get the most out of borehole seismic data. Covering all facets of the discipline, we are an industry leader in VSP and microseismic surveys, as well as permanent reservoir monitoring.

## Better Technology

Through internal development and strategic acquisitions, we have built an arsenal of sophisticated borehole seismic technologies. With such breadth, we can monitor seismic activity from both observation and treatment wells. In fact, using our SeismicSpear™ tool, we are uniquely positioned to provide our clients with microseismic data when an offset observation well is not available. Rounding out our portfolio, the sophisticated Clarion™ in-well optical system extends the application of seismic monitoring to producing assets, used specifically to maximize life-of-well recovery.

## Better Analysis

Drawing on extensive training and an array of specialized software, our borehole seismic support personnel can translate seismic data into meaningful recommendations. Among the applications we use, ZebraSeis™ software is available exclusively at Weatherford through an alliance with Zebra Geosciences Ltd. We can also leverage interpretative expertise in related disciplines (laboratory services, surface logging and wireline logging, for example) to provide you with a truly comprehensive understanding of your reservoir.

Get closer to the source: Borehole seismic in treatment wells.

Weatherford can perform seismic monitoring in treatment wells, which can reduce costs by eliminating the need to drill an observation well or to convert an existing well into one. Monitoring in treatment wells also tends to yield high-quality data that could not be obtained from the vantage point of an observation well.

## Better Reach

We serve the global oil and gas industry through approximately 900 locations in more than 100 countries. With such a large footprint, we can deploy borehole seismic equipment and personnel to your wellsite quickly, virtually anywhere you're operating.

### Weatherford's array of VSP capabilities

- Cross-well surveys
- Offset profiles
- Rig-side checkouts
- Salt-proximity surveys
- Three-dimensional spiral shoots
- Vertically incident profiles
- Walkaways

ZebraSeis is a trademark of Zebra Geosciences Ltd.



# Weatherford's borehole seismic service helps achieve understanding and enables decisions at every phase of your field development life cycle to improve production and recovery and, ultimately, your return on investment.

## Data Acquisition

Using high-quality downhole tools and sensors, we offer several data acquisition services, including check-shots, VSP, microseismic monitoring and permanent monitoring for all reservoir types, including shale-gas, tight-gas and coalbed methane. Our tools can be deployed in horizontal wells, thru-tubing, and slimholes and can successfully operate in hot environments, providing you with the high-quality data and information needed at the exploration, development and production phases of your field development life cycle.

### Assess

We can help you organize your well-development plan, whether it includes the entire cycle from exploration through abandonment, or just part of it. Improved quality of imaging in time and depth helps well placement and improves the surface seismic image for field exploration and development. Avoiding drilling hazards by using multicompetent downhole data minimizes risk and improves recovery. Our microseismic services monitor production and the efficiency of stimulation and injection programs.

### Acquire

Based on where your well is in its life cycle, our crews will expertly deploy and operate the survey tools and ancillary equipment you need for optimal data acquisition.

### In Action

With an accurate time and depth knowledge and a complete picture of the subsurface challenges, an integrated composite view makes difficult decisions easier and less costly. To give you a solid basis for your decisions, we work with you to create an integrated view of logs, drilling plans, formation logs, surface seismic, and microseismic and production data.

### Analyze

Processing VSP and microseismic data is our specialty. Only the most experienced and talented geophysicists, using the latest and most proven algorithms, process and distribute 2D and 3D VSP data to your key personnel. • Through our alliance with Zebra Geosciences Ltd., clients have access to highly sophisticated but user-friendly borehole seismic and log calibration software.

## Data Analysis

We teamed up with Zebra Geosciences Ltd. to offer world-class VSP data processing. Their ZebraSeis software is an innovative, intuitive, interactive suite for the processing and display of borehole seismic and log data. Available exclusively from Weatherford, this powerful software uses industry-standard formats, making it ideal for robust data processing and for viewing or reprocessing vintage data sets.

- We use the ZebraSeis suite in our data centers and also offer it for sale to our clients.
- With adequate training you can process and quality-check processing results yourself, in your office, on any Windows® based PC.
- The Divine 2D ray trace modeling package, from Semore Seismic, is included in the licensing of ZebraSeis and can be used for pre- and post-survey modeling. It is also used for ZebraSeis depth migration of VSP data and can be upgraded for full microseismic processing capability.

Windows is a registered trademark of Microsoft Corporation.



# Applying borehole seismic services through your field development life cycle

Weatherford's borehole seismic services can help you achieve a better understanding of your field at every phase of development, make better decisions and ultimately, maximize recovery. Our capabilities include vertical seismic profile (VSP), microseismic surveys (in observation and treatment wells) and permanent monitoring.

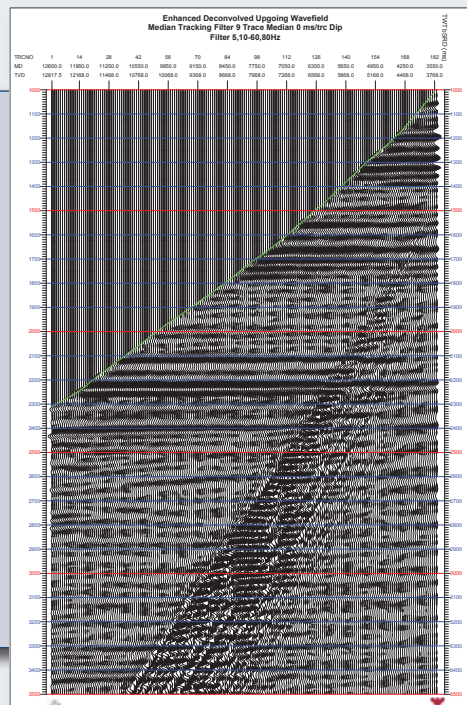


## Exploration

### Assess

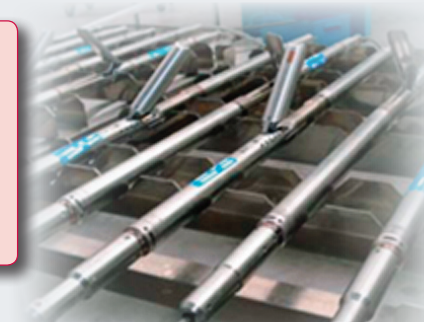
Our VSP surveys increase the value of your seismic data with a new dimension of information. They not only tie true depths to your surface seismic data; they image formations at high resolution and optimize your surface seismic processing and imaging.

- In exploratory wells, our VSP technology gives you a valuable look-ahead capability for more accurate drilling decisions and reduced nonproductive time. To successfully characterize your reservoir in three dimensions and at high resolution, we offer full 3D VSP planning, acquisition and processing services to illuminate the subsurface around the well.
- These 3D images are critical to planning sidetracks from the exploration well and identifying pay zones for future production wells.



### Acquire

In the field, our specialists position one of our multilevel downhole tools in a survey well and position the seismic source in predetermined locations to optimize the result. This source-target-sensor deployment gives VSP the capability at high resolution to image formations that are considerable distances away from and below the wellbore.

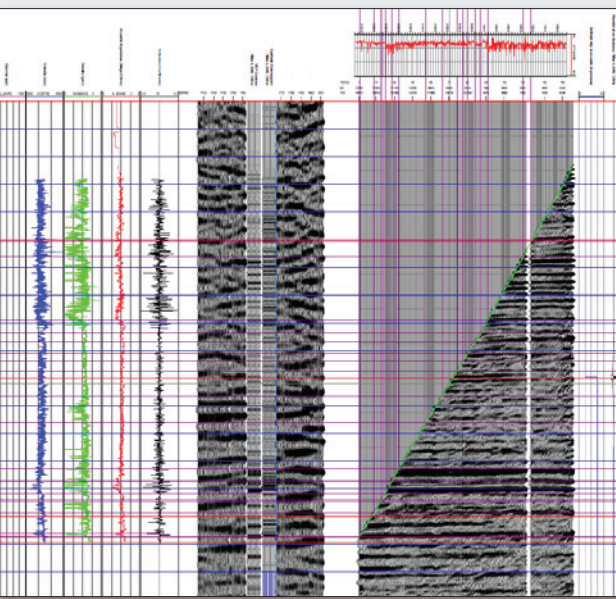


### Analyze

Survey results (available in 2D and 3D modes) are rich with needed information:

- Measure Q for improved surface-seismic imaging.
- Calibrate your de-multiple processing by identifying multiples with VSP data and eliminating them from your interpretation.
- Bring your petrophysical log data and seismic data together using a VSP, either as a composite PDF plot or in a 3D visualizer.

The processed data clearly reveal rock properties such as formation P- and S-wave velocities, velocity anisotropy, Poisson's ratio, porosity changes and fluid content. The data also help in refining the structural elements of thin-bed boundaries, bed dip, fault mapping and fracture density. Q and shear-wave analysis reveal further rock characteristics that help in identifying hydrocarbon-bearing layers and their extent.



### Advancement

We have commercialized the first slim digital array for VSP surveys, improving high-frequency response and providing improved access to difficult or narrow wellbores.

- We are introducing a revolutionary innovation in 3D salt-flank imaging to accurately map salt-flank boundaries in full 3D space.

### In Action

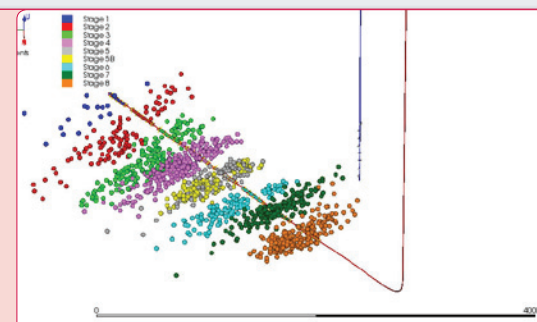
Seeing beneath the salt. An offset VSP survey was successfully reprocessed to image a salt flank in continuous 3D. We use proprietary reverse-time-migration algorithms to correctly image salt flanks, without the need for special hardware such as rigid interconnects or gyros.

## Appraisal

### Acquire

The field deployment of microseismic monitoring instrumentation is like VSP. Our specialists position a multilevel tool in a monitoring well.

- For microseismic surveys, however, we use sensors designed for picking up microseismic activity.
- These sensors detect the real-time opening and closure of microfractures in rock and, by locating the point of origin of these microseismic sources, we produce fracture maps and look at fluid-front movements.



### Acquire

Client choice is a large factor in our microseismic surveys. We usually monitor the frac job from a well other than the one being treated, but we do have the technology to monitor from the same well that is being treated.

- Deployed in the treatment well, rather than in an offset, the SeismicSpear™ system can be moved and oriented during the survey to monitor the near-field signal from close-up, revealing high levels of detail. We follow the microseismic activity for excellent control of frac height.
- To maximize capabilities in shale plays, the SeismicSpear system can be deployed in high-pressure or horizontal wells via e-coil.



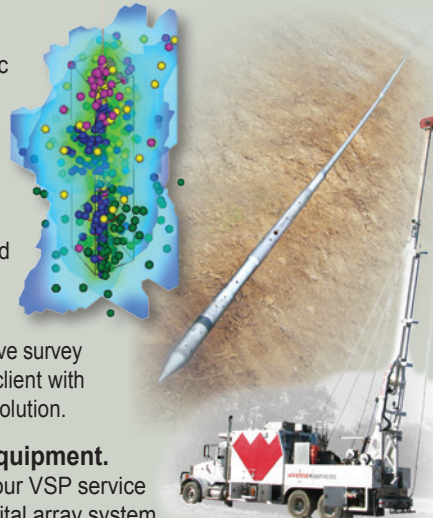
## Development

### In Action

Better pays with fewer wells. For a client operating in a tight-gas reservoir in the Piceance basin shale, our microseismic service provided understanding of the frac height, azimuth and containment—proving invaluable for the hydraulic stimulation programs across the entire field and reducing the number of wells that had to be drilled.

Slim tool, big results. An openhole obstruction had stopped drilling for an operator in a U.S. shale play. Although open-ended drillpipe was deployed past the obstruction, the logging company's tools could not pass through the drillpipe.

- We deployed our compact slim-profile tools, including the SlimWave survey tool, through the drillpipe, surveyed the well, and provided the client with a full suite of logs and VSP data for developing a workaround solution.



### Superior acquisition with less equipment.

For a client operating in a shale play, our VSP service acquired the data from a multilevel digital array system together with Vibroseis trucks using a single recording truck at the wellhead.

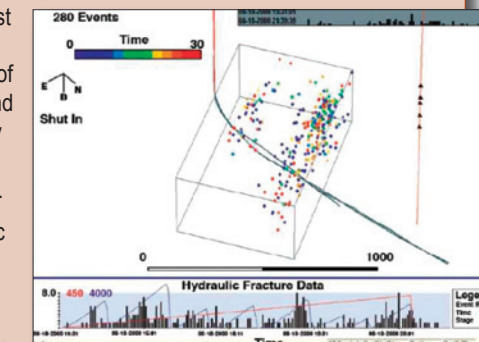
- The usual requirement for a second crane truck or other vehicle was avoided, minimizing additional costs and environmental impact because our units are equipped with a mast.



### Analyze

Real-time microseismic data gathered during fracturing operations can be used to monitor the progress of the treatment and to adjust fracturing parameters on the fly for optimal results.

- It reveals the most data obtainable about the quality of the completion and provides the only 3D view of the drainage network.
- Our microseismic surveys form the key technology for the economic development of an unconventional reservoir; can reduce the time and costs of fracturing operations; and can lead to higher production rates, lower decline rates in hydrocarbons and less water incursion.



### Assess

The powerful combination of our VSP and microseismic surveys helps operators increase their production, turning condemned acreage into prolific unconventional reserves, while decreasing lost-time and drilling expense.

- Our VSP surveys help to identify faults for more effective drilling and mapping of reservoir networks for drainage.
- Our microseismic monitoring service produces frac maps and can provide a view of fluid-front movements.
- We apply monitoring services to hydraulic fracturing, carbon capture and storage, production monitoring, and other applications that require short- or long-term monitoring of microseismic activity.

### Assess

Long-term field monitoring is another service that we provide to ensure optimal levels of field economics. By permanently deploying the Clarion™ optical seismic accelerometer in a monitoring well, we deliver time-lapse VSP, calibration of 4D surface seismic surveys, and continuous seismic monitoring.

- We can put this service to work in high-pressure/high-temperature wells with vertical, deviated or horizontal wellbores.



### Acquire

#### Exclusive: Our Clarion optical accelerometer.

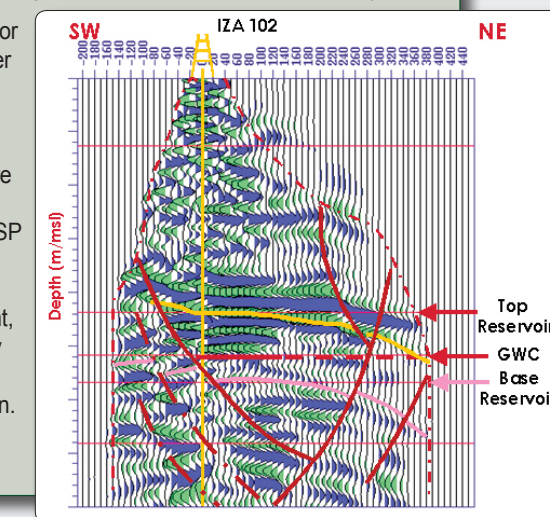
We are the only company to offer this patented, fiber-optic/accelerometer combination. This rugged, miniature optomechanical device delivers high performance for long-term deployment in hostile well environments and is suitable for vertical, deviated or horizontal wells.

- The unit is free of downhole electronics and has a specialized decoupling system built for decades of monitoring.
- The high-tech optical sensors are compatible with Clarion seismic instrumentation and can be multiplexed to form in-well arrays without the use of downhole electronics.

### In Action

Only the best would do. A national oil company in the Asia-Pacific region required a leading-edge permanent seismic installation and in-house software solution for long-term monitoring. The choice was the installation of our Clarion seismic system on location, and the installation of licensed ZebraSeis software on the client's network. The client's in-house personnel can now retrieve and manipulate the data. We also provide geophysical data-processing services to further support the project.

Production continues. A major operator installed the Clarion system in a deepwater Gulf of Mexico sub-salt well. While the well was in full production, a 3D VSP was acquired by a surface-seismic vessel that was working in the area, and the data were processed in-house by the oil company. This project was the first time that a 3D VSP had been acquired in this manner and is what the operator calls a "drive-by-shoot." Because the VSP installation is permanent, a high-resolution time-lapse repeat survey could be acquired to monitor the change in seismic response caused by production. The VSP had no impact on the well's operations and incurred no rig-time costs.



## Production

## Abandonment

Legend

### Assess

Before we begin a borehole seismic job, we review your well-development plan (in its entirety or relevant sections) to formulate a strategy that governs critical aspects of the operation, such as tool and support personnel selection.

### Acquire

With a team of borehole seismic support personnel available for worldwide deployment, we install and operate monitoring technologies in your wells to obtain high-quality borehole seismic data.

### Analyze

Drawing on a core group of highly experienced, in-house geophysicists, we offer expert interpretation of borehole seismic data to inform field-development decisions.

### In Action

With subject matter experts in a wide range of disciplines, we turn your borehole seismic data into actionable information with an end goal of maximizing recovery.

### Advantages Weatherford VSP surveys

- Are available in 1D, 2D and 3D modes
- Provide higher resolution than surface seismic data for more accurate reservoir characterization
- Give you 3D VSP—for accurate sidetracks and much more
- Measure Q for the restoration of lost high frequencies in surface seismic
- Remove potentially costly inaccuracies with multiple-free data
- Avoid problems and save time by looking ahead of the drill bit

Borehole Seismic Tool	OD (in.)	Hole Size (in.)	Temperature Rating (°F/°C)	Pressure Rating (psi/MPa)	Features
Slim digital array	1-11/16	2 to 13	304° 150°	14,500 100	Fully digital array with gamma and CCL* options
Standard digital array	3	3 to 22	354° 180°	20,000 138	Fully digital array with gamma option
Advanced digital array			392° 200°		Dual analog with gamma option
SeismicSpear system	2-5/8	3-1/2 to 9	320° 160°		Three-level digital with gyro, CCL* and gamma options
Super multilevel digital	3-1/3	9	302° 150°	15,000 103	100 digital levels with CCL* and gamma options

\*Casing collar locator

### Advantages Weatherford microseismic monitoring

- Reveals the most data obtainable about the effectiveness of the stimulation operation
- Provides the only 3D view of the drainage network
- Is the key technology for the economic development of an unconventional reservoir
- Reduces the time and costs of fracturing operations
- Enables higher production rates and lower decline rates in hydrocarbons
- Means less water incursion
- Provides OFDM telemetry for high sample rates, improving sensitivity and data accuracy

Weatherford provides worldwide service and support from more than 900 facilities in approximately 100 countries. To find out more, contact an authorized Weatherford representative, or visit [weatherford.com/boreholeseismicervices](http://weatherford.com/boreholeseismicervices).



**Weatherford**<sup>®</sup>

[weatherford.com](http://weatherford.com)

© 2011 Weatherford. All rights reserved. 7834.01

Weatherford products and services are subject to the Company's standard terms and conditions, available on request or at [weatherford.com](http://weatherford.com). For more information contact an authorized Weatherford representative. Unless noted otherwise, trademarks and service marks herein are the property of Weatherford and may be registered in the United States and/or other countries. Weatherford products named herein may be protected by one or more U.S. and/or foreign patents. For more information, contact [patents@weatherford.com](mailto:patents@weatherford.com). Specifications are subject to change without notice. Weatherford sells its products and services in accordance with the terms and conditions set forth in the applicable contract between Weatherford and the client.