LF seismic improves E&P success

New hardware and software developments in low-frequency seismic technology are helping operators improve efficiency.

AUTHOR
***Brice Bouffard**, Spectraseis*

In the past two years, low-frequency (LF) technology, the tools that measure LF, and the software to process and analyze these new datasets have evolved. During the same period, there has been significant uptake among oil and gas operators that see LF seismic as a key tool for improving their E&P performance.

LF seismic technology draws on analysis of the passive seismic wavefield of the earth around 1 to 7 Hz to measure anomalies in the seismic wavefield – anomalies that are believed to be associated with multiphase fluid reservoirs, most commonly containing hydrocarbons.

In this way, LF seismic adds fluid information to structural information acquired with conventional seismic, providing a surface measurement of the reservoir fluid system.

Geoscientists generally develop an understanding of the reservoir potential of a prospect from reflection seismic and geological studies prior to drilling wells. LF seismic provides additional independent information on the reservoir fluid system and, when integrated with other geological and geophysical (G&G) data, becomes highly valuable in optimizing drilling programs, reducing risk, ranking prospects, and focusing conventional seismic efforts toward the most prospective areas.

There are clear operational benefits to LF seismic as well. Surveys can take place quickly and at a fraction of the cost of conventional seismic, with data acquisition from a 58-sq-mile (150-sq-km) survey requiring fewer than two weeks to complete. LF seismic also has virtually no negative environmental impact, allowing the economic development and production of reserves that previously were difficult to evaluate due to size, inaccessibility, or other reasons.

LF seismic partnership

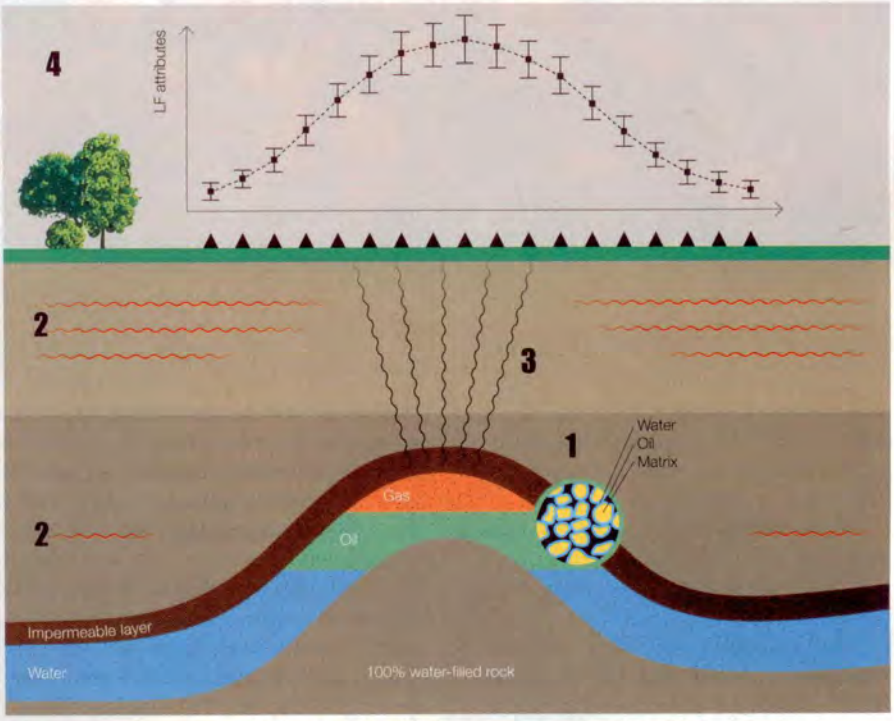
The last 12 months have seen a growing interest in LF seismic leading up to the October 2009 announcement of a multi-year joint-industry project – the Low Frequency Seismic Partnership (LFSP).

Among active participants to date are Cairn India, Chevron, GDF Suez, Pemex, and Petronas. The LFSP program is covering key application elements of LF seismic technology such as data acquisition and processing, as well as fundamental theoretical studies in partnership with the Swiss Federal Institute of Technology in Zurich and the University of Bern.

As part of the LFSP program, the most comprehensive research dataset acquired by Spectraseis has been completed over France's largest underground gas storage facility near Chemery. The field is operated by Storengy, a fully owned subsidiary of GDF Suez.

Among the many research objectives, data from the survey will provide a means of examining how reservoir characterization can be improved by relating LF seismic attributes to reservoir parameters. The survey also was designed – with a second data-acquisition phase planned for later this year – to acquire 4-D data under different gas-filled conditions in the reservoir.

The ability to derive subsurface reservoir properties such as hydrocarbon sat-



This image shows a multiphase fluid-filled pore system that has different seismic properties at low frequencies than surrounding 100% water-saturated rocks (1). The subsurface ambient wavefield primarily contains low-frequency Rayleigh waves and body waves (2). A fraction of the total wavefield at depth is redirected to the surface through interaction with a multiphase, fluid-filled reservoir (3). Wavefield decomposition and LF attribute analysis recover reservoir information from the wavefield recorded at the surface using sophisticated processing to remove contaminating surface noise (4). (Images courtesy of Spectraseis)

uration or pore pressure information from LF measurements has been observed on previous LF surveys. This survey in the well-controlled Chemery environment is designed to confirm initial observations and demonstrate its application in brownfield production optimization projects.

Western Egypt survey

The Chemery survey is one of 35 LF seismic surveys Spectraseis has carried out to date, demonstrating the applicability of LF in carbonates and sandstones for gas, oil, and heavy-oil reservoirs.

Another high-profile survey took place for Shell Egypt NV in the North East Abu Gharadig Basin in the Western Desert in Egypt.

The location for the LF seismic survey was a remote, unpopulated area of Egypt, nearly 60 miles (100 km) from the nearest field camp. The project area covered 23 sq miles (60 sq km) and took place with logistical support from Ardiseis, a regional joint venture between CGGVeritas and TAQA in the Middle East. The size and remoteness of the area, the geological complexity, and the need to reduce exploration risk made this an ideal location for an LF seismic survey.

The project involved 110 data points with synchronous recordings taking place in only four days. It saw the mobilization of 120 sensors – the largest equipment shipment for a single LF seismic survey by Spectraseis at that time – and was designed to apply the company's time reverse imaging (TRI) technique in 3-D.

TRI spatially localizes the source of hydrocarbon microtremors by time-reversing measured signals into the velocity model, numerically identifying the origin of spectral anomalies. The result is a 2-D or 3-D subsurface image that localizes the hydrocarbon reservoirs at depth.

While the results are still being analyzed, Ahmad Saleh, GeoSolutions Manager at Shell Egypt NV, commented that LF seismic's "ability to cover such a broad area in a short time and without recourse to heavy field equipment can prove to be quite beneficial for our future exploration activities."

Advances in data management, visualization, analysis

A number of software advances also have taken place for LF seismic. For example, commercial customers now are provided with an integrated software toolset that simplifies the management and analysis of LF seismic data. This software suite contains a variety of data-specific viewers needed to handle LF data efficiently, including a 3-D map viewer, measurement timeline viewer, photograph viewer, raw data-trace viewer, and synchrogram viewer.

Through the synchrogram and other viewers, users can browse, search, and view their acquisition and processing data – from survey points to data analyst quality assessments and spectrograms for each recorded measurement.

As LF data increasingly are used by operators, close integration with conventional G&G data becomes critical to exploit this new data type optimally. To this end, Spectraseis is developing

The field team prepares 115 broadband sensors for deployment.

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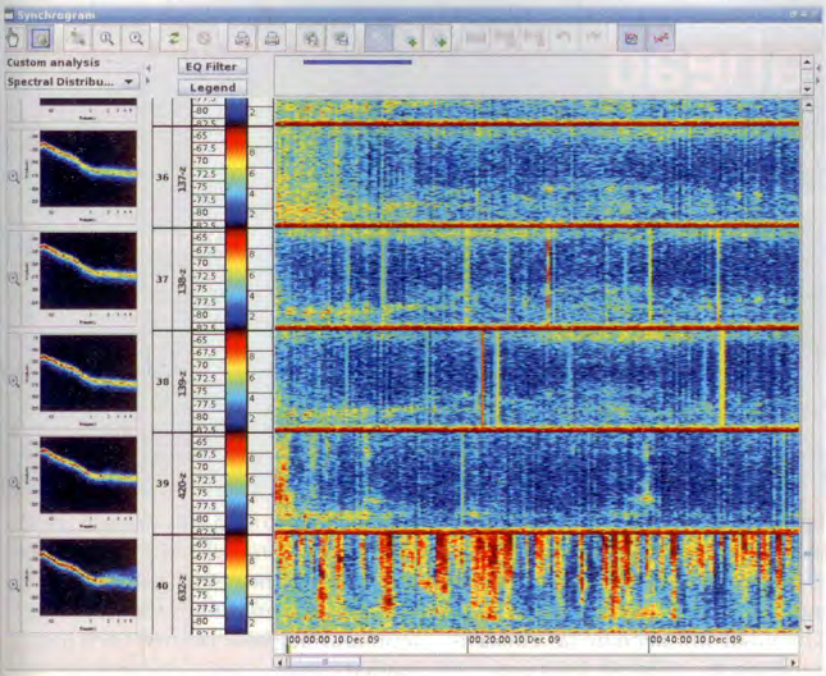

The software module provides a synchronous display of multiple spectrograms, showing spectral variations for several stations. The variations in color show variations in the measured energy at different stations over time. The left-hand column includes spectral distribution analysis plots for each measurement.

extensions to industry-standard workstation applications.

Later this year, the company will release the first version of an LF seismic plug-in for Schlumberger's Petrel software. The plug-in will allow Petrel users to integrate Spectraseis' data, analysis, and results with conventional E&P data types such as 2-D and 3-D seismic data and structural models within the Petrel framework.

Hardware developments

LF seismic also has seen hardware and instrumentation developments, exemplified by a new borehole receiver array for LF and microseismic measurements.

The broadband, multilevel receiver array provides a highly sensitive, safe, and flexible downhole tool that can be used in a wide range of geophysical applications, such as for measurements in multiple well bores and combined with surface LF data acquisition.

Scheduled for delivery in October 2010, the 4.4-in. OD tool can acquire three-component broadband measurements from 0.1 to 1,000 Hz, allowing for both LF and microseismic applications. It uses highly sensitive, active geophones capable of recording wavefields to -190 dB and can be used in a multicomponent configuration to fully sample weak, ambient, or induced seismic activity.

A promising future

The LF segment has experienced technical and commercial developments over the last two years as it continues to invest resources into accelerating the development of LF seismic. The development effort is matched by the increased value of information provided by LF, in particular, with the ability to create 3-D images that integrate seamlessly in the geoscientist environment, providing new information and a better understanding of the earth model.

LF seismic is a cost-effective geophysical technology delivering highly valuable new information about operators' reservoir fluid systems that has potential to increase exploration and production performance. E&P