

LWD Sonic Technology Focus of Emerging Technology Workshop

A technology designed to help drillers make improved real-time decisions in uncertain environments was the focus of an Emerging Technology Workshop (ETW), held 12–13 May in San Antonio, Texas. Seventy workshop participants representing drillers, petrophysicists, geophysicists, geologists, and tool/service providers discussed the current value and future potential of logging-while-drilling (LWD) sonic technologies to increase the quality and speed of downhole data measurement.

LWD sonic technologies use a wave propagator or signal source to send a sonic signal from the wellbore out into the formation, and receivers to pick up the return signals which are stored in memory. Derived formation-sonic-travel time measurements are sent through a telemetry mud pulse system to the surface in real time. LWD offers several benefits that enable nearly instantaneous data collection to improve the safety of drilling operations and create a more efficient business process by improving the speed and quality of geological interpretations and operational decisions, as Gopal Amruthapuri, Operations Geologist for Chevron and Chairperson of the ETW, explained.

“Drilling without any LWD tools on the bottomhole assembly is like walking in a dark tunnel, and as seismic resolutions are poor under salt, we need a flash light to better understand these complex structures,” he said. “Drilling activities continue to move into deeper waters and high-pressure/high-temperature (HP/HT) reservoirs... there are many uncertainties that cannot be determined with predrill seismic studies.

“A LWD sonic tool enables us to drill safely and efficiently in subsalt sections,” Amruthapuri continued, “and the velocity measurements let you predict borehole stability, understand rock mechani-

cal properties and time-to-depth seismic correlation while drilling, measure petrophysical properties like porosity determination, and even identify cement top. This allows us to prepare for or circumvent potential problems.”

Yet given this level of potential, there is still hesitation within the industry to more fully adopt the technology. A major aim of the ETW was to bring together the industry’s experts to openly discuss why this hesitation persists, and to address the technology gaps that must be filled before more widespread industry acceptance is possible.

Keynote Address Frames Potential

The keynote address was delivered by Brian Hornby, Geophysical Adviser for BP. “My aim in the keynote was to focus on what LWD sonic technology could realistically deliver. In my view, new technologies normally generate a lot of enthusiasm on introduction and this can lead to failure because of unrealistic expectations that are not fulfilled. A conservative approach where one focuses on initially achieving basic, robust deliverables followed by introduction of more exotic developments is recommended.”

Hornby started with the basic question of why a company would want to run LWD sonic in the first place. “The main pull for this technology is compressional-wave (P-wave) logging, so the key to introducing this technology to more of the industry is to focus on delivering a reliable P-wave logging service. On the business side, decision makers may ask if LWD sonic adds something in combination with a wireline tool, or if it can replace wireline outright.

“There is a pull from the drilling community to replace wireline with LWD sonic for extended reach wells and deep-water wells, where the total costs of rigs are running into several hundred-thou-

sand dollars per day,” Hornby continued. “LWD sonic may provide additional benefits in terms of lowering the risk to the well and providing real-time data for pore pressure calculations. However, there are some technology limitations that must be addressed before we can do this.”

One limitation is the technology’s potential to provide misleading data. “LWD sonic is not a tool that either works or does not. You will always get a waveform train, but unless you are an acoustics expert, you have no way of knowing how good the data are,” said Hornby.

Greater advances in the hardware are needed to alleviate the challenges of interpreting the waveforms that come back from the reservoir. “I worry that you cannot always see the P-wave data signal you are after,” he continued. “With the current technology, we are missing something in terms of signal-to-noise, source power, or receiver sensitivity. We are forced to interpret data sets that we would throw out if they came to us from wireline.”

Sessions Highlight Tool Specifics

With Hornby’s keynote setting the stage, the technical sessions that followed discussed specific aspects of the technology and allowed attendees to better understand the next development steps.

The first technical session highlighted physics and numerical modeling. Xiaoming Tang of Baker Hughes reviewed the history of acoustic physics for LWD compressional- and shear-wave measurements. He discussed the evolution of acoustic systems from monopole to quadrupole, as well as the excitation modes one can expect from each. Tang also reviewed the importance of designing sonic tools such that acoustic isolation is achieved, which minimizes measurement errors.

Shihong Chi of ConocoPhillips next discussed LWD sonic modeling and physics with a review of experimental studies comparing monopole, dipole, and quadrupole systems. Chi said that quadrupole tools are better at measuring fast and slow shear waves in anisotropic formations, and dipole tools are more affected by tool waves, which dominate at frequencies below 3 kHz. Choosing and controlling operating frequencies are important in reducing this tool wave effect.

Chi also briefly reviewed the differences between LWD and the more established wireline sonic tools, which Amruthapuri reiterated. "The LWD sonic tool does not perform like a wireline sonic tool, even with regards to the frequencies involved. However, with the wireline tool we are seeing everything after it happens rather than in real time. This is an important advantage that LWD has over wireline."

The next technical session presented some of the tools currently available on the market, as representatives from Baker Hughes, Schlumberger, Halliburton, and Pathfinder each described in candid terms the relative strengths and weaknesses of their different tools. Many attendees found this openness on the part of technology providers, many of whom are competitors, to be refreshing.

"It was definitely the most valuable workshop I have been to in terms of the mix of people that actively and openly shared their experiences and ideas," said Larry Wisniewski, one of the founders of sonic tool developer SensorWise and Cochairperson of the session. "As a tool developer, it was valuable to see feedback from both our customers, the service companies, and their customers, the production companies."

"In this session, there were many questions to the presenters regarding the robustness of their tools," Amruthapuri added. "This is only natural, since you are putting the tool downhole and expecting it to provide relevant data for real-time analysis on things like pore pressures, wellbore stability, and time to seismic depth correlation while drilling under aggressive conditions of temperature and pressure. But to their credit, the tool providers were very open about service ratings, present state of the tool's performance standards with hardware and software, what future tools they might release, and the benefits these future tools will have."

For Arthur Cheng of Cambridge Geosciences, one of the pioneers of LWD sonic processing with a background in the physics behind the technology, this discussion on current tools highlighted one of the gaps that remain. "Getting a reliable, real-time shear-wave measurement is partly limited by the hardware. There was some discussion about using the next generation of wired drillpipe to circumvent telemetry speed limitations of the mud column, but that raises a question of expense... do people

want to invest in wired drillpipe that can achieve high rates of telemetry?"

"It is a 'chicken-and-egg' scenario," Cheng continued. "You need to demonstrate the economic potential of using this new wired drillpipe in order to get greater adoption in the industry, but you cannot demonstrate this until you have run it a few times."

The next session focused on processing the acquired data and assuring quality control. Representatives from Halliburton, Schlumberger, Baker



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acre × 4.046 873	E+03= m ²
acre × 4.046 873	E-01= ha
acre-ft × 1.233 489	E+03= m ³
ampere-hr × 3.6*	E+03= C
Å × 1.0*	E-01= nm
°API 141.5/(131.5+°API) = g/cm ³	
atm × 1.013 250*	E+05= Pa
bar × 1.0*	E+05= Pa
bbl × 1.589 873	E-01= m ³
Btu × 1.055 056	E+00= kJ
Ci × 3.7*	E+10= Bq
cp × 1.0*	E-03= Pa•s
cycles/sec × 1.0*	E+00= Hz
dyne × 1.0*	E-02= mN
eV × 1.602 19	E-19= J
ft × 3.048*	E-01= m
ft ² × 9.290 304*	E-02= m ²
ft ³ × 2.831 685	E-02= m ³
°F (°F - 32)/1.8 = °C	
°F (°F + 459.67)/1.8 = K	
gal (U.S. liq) × 3.785 412	E-03= m ³
hp × 7.460 43	E-01= kW
hp-hr × 2.684 520	E+00= MJ
in. × 2.54*	E+00= cm
in. ² × 6.451 6*	E+00= cm ²
in. ³ × 1.638 706	E+01= cm ³
kip × 4.448 222	E+03= N
knot × 5.144 444	E-01= m/s
ksi × 6.894 757	E+03= kPa
kW-hr × 3.6*	E+06= J
lbf × 4.448 222	E+00= N
lbm × 4.535 924	E-01= kg
mL × 1.0*	E+00= cm ³
mho × 1.0*	E+00= S
mile × 1.609 344*	E+00= km
oz (U.S. fl) × 2.957 353	E+01= cm ³
psi × 6.894 757	E+00= kPa
psi ² × 4.753 8	E+01= kPa ²
sq mile × 2.589 988	E+00= km ²
stokes × 1.0*	E-04= m ² /s
ton × 9.071 847	E-01= Mg
ton (metric) × 1.0*	E+00= Mg
tonf × 8.896 444	E+03= N
tonne × 1.0*	E+00= Mg

*Conversion factor is exact.

These conversion factors are from *The SI Metric System of Units and SPE Metric Standard*, SPE, Richardson, Texas (1984).

Hughes Inteq, and ConocoPhillips presented various aspects of achieving tighter quality control of LWD acoustic data. For example, Inteq's Derek Buster discussed some of the important upfront points to consider in planning a real-time acquisition, such as reviewing the particular geoscience application, analyzing offset well slowness and seismic interval velocity data, analyzing the bottomhole assembly design, and maintaining good communication with the client. He also discussed various aspects of post-acquisition data processing, with particular emphasis on acquisition diagnostics, which are required before any interpretation of waveform processing results can begin.

The second day was devoted to case studies on the topics of pore pressure measurement and evaluation, wellbore stability, and formation evaluation from companies including ConocoPhillips, Chevron, Devon, Schlumberger, BP, Baker Hughes, and ExxonMobil. "I appreciated the willingness of the companies to share so much of their experiences in these case studies," Wisniewski said. "Seeing more detail on instances in which tools did and did not work well, and specific problems they had, will be useful as we further develop these tools."

Future Work Discussed

The final session of the workshop was a wrap up and summary of what was discussed over the two days and what topics should be addressed in the next 2 years. "There were several points that came up from the operators, including a desire to put the sonic tool as close to the bit as possible," said Hornby. "Tool providers expressed some concern that the noise would dampen out the signal."

In Wisniewski's experience, there are several factors that must be considered to get a sharper signal. "The data's quality is all about the signal-to-noise ratio, which can be affected by acoustic noise downhole that is influenced by the composition of the formation, the borehole size, and where the tool is located in the borehole. There are some things that tool developers can do to make tools more acoustically reliable, but the other borehole environmental factors require a comprehensive understanding of the physics and how to process the data."

Hornby suggested that tool developers should experiment with different types of drill bits to minimize noise effects. "Some of my own studies suggest that PDC bits, which run much quieter downhole than roller cone bits, would eliminate this signal-to-noise problem. I suggested new noise measurements be conducted with the tool placed near a PDC bit."

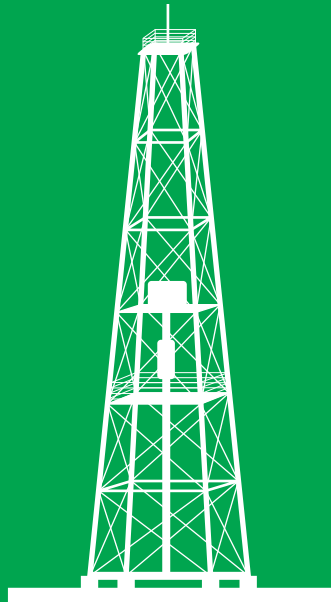
Other operator requests included having error bars on the processed data sets, developing tools that can better handle HP/HT environments for deeper drilling, and eliminating black boxes such that operators understand the physics and methodologies employed in a tool's measurement sequence.

Better training of field engineers in the basics of acoustics was also highlighted. "We have very bright field engineers, but they may not have any fundamental training in borehole acoustics," said Hornby. "I recommended a university training course that provides a background on how data change with frequency, how waves propagate around the borehole, and so on."

The final session was also a chance for attendees to discuss Hornby's keynote address, which included a so-called traffic-light format that presented Hornby's impression on the current level of development for certain components of LWD sonic and how they will progress in the next few years. "I suggested that the possibility of using LWD sonic to get meaningful real-time P waves right now is a yellow light, meaning that we're getting close but more hardware and software work is needed. In another 5 years, I think this will be a green light."

"For robustly measuring P-wave velocity using stored data, I also see a yellow light," Hornby added, "though this should change to green in less than 5 years. We still have many situations where we simply cannot acquire usable data where we expect to receive it."

Hornby gave red lights (significant work needed) for measuring real-time shear waves and for processing signals for shear waves from stored data. "I have seen many cases where we seem to have a signal buried in noise, we do a good deal of processing, and then we still cannot see it. I think that in 5 years, these should turn green with further technology developments." **JPT**



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