2017 1Q, 2Q Distinguished Lecturer

Getting more for less: Frequent low-cost seismic monitoring solutions for offshore fields

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Time-lapse seismic reservoir surveillance is a proven technology for offshore environments. In the past two decades, we have seen this technology move from novel to necessary and enable us to monitor injection wells, water influx, compaction, undrained fault blocks, and bypassed reserves. Value is generated by influencing the management of our field operations and optimizing wells to reduce cost, accelerate production, and increase ultimate recovery.

Significant advances in technology are improving the quality of our data. Errors in acquisition repeats are nearly eliminated using permanently installed systems or dedicated ocean- bottom nodes. We now routinely obtain surveys with such a high signal-to-noise ratio that we can observe production-induced changes in the reservoir after months instead of years. This creates a demand for frequent seismic monitoring to better understand the dynamic behavior of our fields. Increasing the frequency of seismic monitoring will have a proportionate cost implication, and a challenge is how to design a monitoring program that maximizes the overall benefit to the field.

Reducing individual survey costs is important to enable frequent monitoring. Several techniques are considered for lowering these costs such as:

- Reducing the number of shots and/or receivers to minimize offshore vessel time. This includes shooting targeted (i4D-style) surveys on a frequent basis in between full-field surveys that are acquired infrequently.
- Use of smaller source arrays towed by less-expensive vessels.
- Semi-permanent ocean-bottom nodes that can be left on the seafloor for multiple on-demand surveys.
- Time-lapse VSPs that use permanent distributed acoustic sensors (DAS) in well bores.
- High-resolution 4D surveys that monitor shallow reservoirs cost effectively using low-cost vessels towing arrays of short-streamer cables (e.g., P-cable).

There is no single solution that works for every field, and we need to understand the pros/cons of the various technologies to select the best option for a specific field. Some results of applying these techniques to offshore fields will be discussed.

See below for alternative talks.

Seismic amplitude fidelity and its impact on 3D and 4D seismic interpretation

How much trust should we place in seismic amplitudes and the interpretations we make from them? In a textbook world, seismic amplitude interpretation will tell us not just about the structure of the earth but also provide additional information about the rocks in the subsurface such as fluid-fill, porosity, and lithology. We use quantitative interpretation tools such as amplitude versus offset, frequency decomposition, and seismic inversion to extract a great deal of information from 3D and 4D seismic surveys.

In the real world, seismic amplitudes show significant complexities that challenge textbook assumptions. Transmission through the earth creates multiple raypaths and distortions that impact the phase and amplitudes of the seismic waves. This complexity is evident when we examine first arrival amplitudes recorded by downhole receivers or look at the offset dependence of reflection seismic images. It is common that these amplitude distortions are larger than signals predicted from changes in lithology and/or fluids from idealized rock physics models.

In the time-lapse seismic arena, we try to measure typically small changes in 3D seismic data acquired before and after the production of oil and gas. If we compare two 3D seismic surveys that are acquired using dissimilar acquisition geometries, we find large differences (up to 40%) between the surveys that have nothing to do with the production effects we are looking for. This isn’t because of defects in the individual acquisition designs but rather the sensitivity of the seismic amplitudes and phase to the raypaths used to generate each seismic image. If we repeat either of these surveys using near identical geometries, we can reduce the difference to less than 10%. One of the key learnings from time-lapse seismic is that the transmission noises are repeatable.

So how much do you trust your favorite 3D seismic survey?

Time-lapse seismic monitoring of reservoir deformation

Seismic imaging is a technology used worldwide by the oil industry to look into the subsurface and determine underground structures and their potential for oil and gas production. Time-lapse seismic monitoring is a relatively new technology that consists of carefully repeating a seismic image months to years after production starts and looking for changes that indicate where production did or did not occur to help guide future operations.

Production of oil and gas often is accompanied by a large reduction in the reservoir fluid pressure that in some cases leads to compaction as large as several meters. The deformation of the reservoir layers is coupled to the adjacent rocks and leads to changes in the stress and strain fields that extend a great distance away from the reservoir. Time-lapse seismic measurements through these rocks show large variations that are useful for monitoring the distribution of deformation within the reservoir.

The compaction induces seismic velocity changes that are observed on many different wave types including conventional P-P reflection seismic, P-S mode converted seismic, and surface waves such as the Scholte wave and refracted compressional waves. Using geomechanical models that predict changes in stress and strain fields within the earth we can start to understand the factors that control the changes in seismic velocities. We find that simple nonlinear relationships between velocity and strain produce forward models that match many of our observations.

Biography

Paul Hatchell joined Shell in 1989 after receiving his PhD in theoretical physics from the University of Wisconsin. He began his career at Shell's Technology Center in Houston and worked on a variety of research topics including shear-wave logging, quantitative seismic amplitude analysis, and 3D AVO applications. Following a four-year oil and gas exploration assignment in Shell's New Orleans office, Paul returned to Shell's technology centers in Rijswijk and Houston where he is currently a member of the Areal Field Monitoring team and Shell's principal technical expert for 4D reservoir surveillance. His current activities include developing improved 4D seismic acquisition and interpretation techniques, seafloor deformation monitoring, and training the next generation of geoscientists.

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