A seismic shift in oil exploration

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An advanced computational method for processing seismic data developed by KAUST researchers allows the detailed structure of deep oil reservoirs to be imaged at unprecedented resolution, opening new possibilities in the increasingly challenging search for new reserves.

Oil exploration is both mysterious and technically challenging. Reserves often occur kilometers underground, with few hints at the surface as to what lies beneath. An important technique used in oil exploration to observe the hidden geological structures that potentially hold trapped oil and gas is the seismic survey. This involves pumping powerful shock waves into the ground and recording the weak sonic vibrations that return to the surface.

Seismic surveys are used as a first pass to identify promising structures, which are then drilled to confirm an oil strike. Drilling, however, remains extraordinarily expensive—sometimes tens of millions of dollars per hole—and so the oil exploration industry relies heavily on relatively inexpensive seismic surveys.

The vibrations recorded in a seismic survey hold a surprising amount of information. The outgoing shockwave—generated by a small detonation or heavy vibrating plate—bounces off the boundaries between different rock types and travels at different speeds through the different rock layers. This produces a complex sequence of vibrations at the surface that can reveal basic geological structures. Further analysis of the amplitude and phase of the recorded waveform, known as full waveform inversion, provides another level of structural detail to aid exploration.

With much of the Earth's easily discoverable oil reserves already exploited, and growing costs of exploration, the search for oil is increasingly challenging.

The team of Tariq Alkhalifah and doctoral student Zhen-dong Zhang at KAUST have now made a major advancement in seismic data processing that has the potential to redefine the process.

"Conventional reservoir characterization methods are mainly based on one-dimensional seismic inversion," says Alkhalifah. "Such methods are stable but rely on assumptions of geological properties and are dependent on the accuracy of the seismic imaging process. Our method, utilizing full waveform inversion, integrates more elaborate additional information to better constrain the results."

Building on full waveform inversion, the team added the capacity to incorporate into the inversion many parameters of the subsurface structure based on geological knowledge and experience or drillhole data.

"The key idea is a more complex physics description of the reservoir region with parameterization [additional parameters included] related to fluid content and fracture direction and density," says Alkhalifah.

With the right additional information, the new inversion method is capable of unprecedented structural resolution, resolving critical information like fracture density and orientation—information useful for drilling decisions and horizontal well placements.

"Although our method is computationally heavy and puts higher quality requirements on the seismic data, there is a lot of interest in this very hot topic within the oil exploration and production communities," says Zhang. "With the pace of advancement in computing power, we are well placed to benefit from the expected wave of interest in methods that can provide more accurate descriptions, particularly for fractured reservoirs."

More information: Zhen-dong Zhang et al. Multiparameter elastic full waveform inversion with facies-based constraints, *Geophysical Journal International* (2018). DOI: 10.1093/gji/ggy113

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