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REVIEW

A review on multicomponent seismology: A potential seismic application for reservoir characterization

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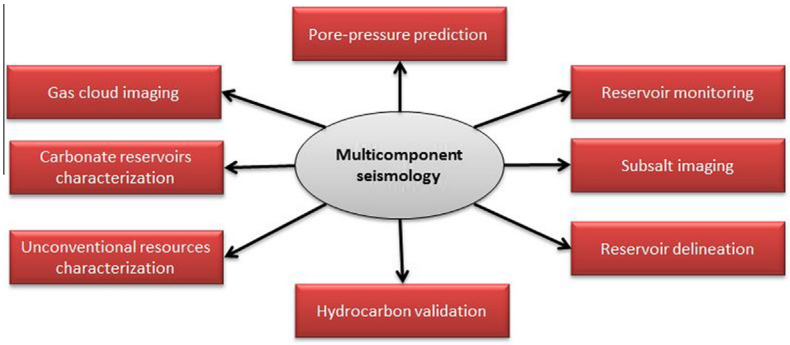
GRAPHICAL ABSTRACT



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ABSTRACT

Searching for hydrocarbon reserves in deep subsurface is the main concern of wide community of geophysicists and geoscientists in petroleum industry. Exploration seismology has substantially contributed to finding and developing giant fields worldwide. The technology has evolved from two to three-dimensional method, and later added a fourth dimension for reservoir monitoring. Continuous depletion of many old fields and the increasing world consumption of crude oil pushed to consistently search for techniques that help recover more reserves from old fields and find alternative fields in more complex and deeper formations either on land and in

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offshore. In such environments, conventional seismic with the compressional (P) wave alone proved to be insufficient. Multicomponent seismology came as a solution to most limitations encountered in P-wave imaging. That is, recording different components of the seismic wave field allowed geophysicists to map complex reservoirs and extract information that could not be extracted previously. The technology demonstrated its value in many fields and gained popularity in basins worldwide. In this review study, we give an overview about multicomponent seismology, its history, data acquisition, processing and interpretation as well as the state-of the-art of its applications. Recent examples from world basins are highlighted. The study concludes that despite the success achieved in many geographical areas such as deep offshore in the Gulf of Mexico, Western Canada Sedimentary Basin (WCSB), North Sea, Offshore Brazil, China and Australia, much work remains for the technology to gain similar acceptance in other areas such as Middle East, East Asia, West Africa and North Africa. However, with the tremendous advances reported in data recording, processing and interpretation, the situation may change.

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Introduction

We have come a long way since the 1920s when vibrations were first induced in the subsurface and transformed into interpretable information about oil reserves. Since then, great efforts were undertaken to understand the science behind seismology and integrate its use into oil industry which resulted in discovering giant oil fields in many basins in the world. The technology has evolved from two to three-dimensional and later to four-dimensional seismic where three-dimensional seismic data are recorded over time for comparison and monitoring bulk rock properties related to fluid changes (production/injection). With the increasing demand for new reserves to ensure the world energy supply, geoscientists started addressing objectives in deep onshore and offshore such as geological formations near salt domes, subsalt formations, tight sands, and source rocks (Fig. 1). In such environments, using one single component (P-wave) demonstrated numerous limitations. Thus, multicomponent seismology came to overcome these limitations and provide more complete image and characterization of subsurface.

Recording multimode data dates back to the early 1970s when Conoco began to test and demonstrate its horizontal vibrator. The development of the technology has slowed during the early 1980s. In the late 1980s, the technology gained attention from academia (e.g. CREWES Project at the University of Calgary, Canada; RCP Colorado School of Mines, United States (US); and Delphi at Delft University, Netherlands) and from a number of service and oil companies [1]. As a result, several case studies have been published from onshore US (e.g. [2,3]) and Canadian basins (e.g. [4,5]) where the technique was evolved and first applied, as well as from other geographical areas outside North America e.g. the North Sea (e.g. [6]). With the advent of land and marine seismic data acquisition and processing particularly the development of the digital multicomponent sensors, more successful applications have been reported in many new fields worldwide such as those in the Gulf of Mexico [7–9], Canada (e.g. [10,11]); the North Sea (e.g. [12–14]); China (e.g. [15–17]); the Caspian Sea [18]; the North Africa [19,20]; and the Middle East [21–23].

Multicomponent seismology: new information leads to new reserves

Seismic exploration for hydrocarbons starts by emitting a compressional P-wave using vertical vibrational truck or dynamite. The reflected wave's signal, once appropriately acquired and well processed, can carry information about structure, lithology, saturating fluids (water, oil, gas) of subsurface formations. As attention has been drawn to deeper, old and complex subsurface objectives, P-wave has encountered numerous