WS09

4D Seismic - Some examples of repeated seismic and Permanent Reservoir Monitoring

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Summary

Seismic monitoring or 4D has started onshore on a few cases more than 30 years ago but has really developed over the last two decades, first in offshore fields where seismic image is generally of good quality, then onshore with more difficulties to achieve similar repeatability. In this presentation, several case studies of offshore and onshore 4D seismic form CGG's experience are presented. The techniques used for monitoring, permanent or not, are adapted to the degree of complexity of the objectives and provide valuable support to reservoir engineers for tracking production related changes in the reservoir in order to economically optimize oil recovery. Although the economic objectives are often the same, production schemes and reservoir characteristics are different from case to case.

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Abstract

Seismic monitoring or 4D has started onshore on a few cases more than 30 years ago but has really developed over the last two decades, first in offshore fields where seismic image is generally of good quality, then onshore with more difficulties to achieve similar repeatability. In this presentation, several case studies of offshore and onshore 4D seismic form CGG's experience are presented. The techniques used for monitoring, permanent or not, are adapted to the degree of complexity of the objectives and provide valuable support to reservoir engineers for tracking production related changes in the reservoir in order to economically optimize oil recovery. Although the economic objectives are often the same, production schemes and reservoir characteristics are different from case to case.

The various studies presented here were performed in fields having different maturity, permanent systems installed before production for steam assisted gravity drainage or deployed over offshore fields after decades of complex production. The cases presented cover also classical repeated acquisitions, both on land and offshore but also evolution from repeated surveys to a permanent system enabling seismic on demand and can be compared in terms of repeatability.

The complexity of the monitoring depends on the production objectives, whether to track the movements of injected steam or water, or to determine areas of by-passed production, or to identify the movement of the OWC (oil-water contact) across vintages in a thin oil column in order to plan an optimum continuation of the horizontal well trajectory. The monitoring difficulties depend on the complexity of the geology and the resolution of the seismic compared to the heterogeneities of the reservoir but also on the complexity of the production scheme with natural depletion, water or gas injection or both alternatively (WAG) or steam injection. These production schemes will cause different physical phenomena to occur affecting the seismic measurement. The response is the combination of pressure and saturation changes with non-negligible changes in temperature or even salinity, but also geomecanical responses with compaction or expansion leading to thickness and porosity changes.

The understanding of the different effects and the ability to predict their seismic effect through petro-elastic models are key to be able to separate them from the seismic measurements. In some complex cases, different combinations of production-induced changes can have a similar seismic response. Solutions are adapted to the complexity of the predicted seismic response and are illustrated through the different cases presented, from very simple cases where single seismic attribute changes like amplitude variations or time shifts are directly interpreted into saturation changes showing where injected water is going to very complex cases where the seismic 4D response alone cannot remove the ambiguity in the changes that occur within the reservoir. 4D feasability, 4D seismic inversion and 4D petrophysical analysis linking the flow model with the seismic measurements are key to understand the problems.