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4D Finite Difference Forward Modelling Within a Redefined Closed-Loop Seismic Reservoir Monitoring Work-Flow

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Abstract

Chimera is used to illustrate, in detail, the full-field 4D image-modelling workflow. The results of a Sim-to-Seis workflow are presented first, followed by the results from the full-field 4D image-modelling workflow, and the resultant predicted 4D-responses are compared. As Sim-to-Seis workflows do not address any geomechanical effects, and to ensure a valid comparison with the redefined forward modelling workflow, the material presented focuses on the reservoir. The geomechanics will be included in a later publication.

One component of the redefined closed-loop seismic reservoir monitoring workflow is Full- Field 4D Image-Modelling. Full-field 4D image-modelling incorporates the geologic, reservoir simulation, and reservoir geomechanical models into an integrated full-field coupled dynamic integrated earth model to surface. From which 3D grids of petro-elastic parameters for a range of reservoir simulations are derived via the rock-physics model for input into finite-difference forward-modelling and imaging. By including 3D wave propagation, acquisition geometry, overburden illumination, near surface effects and calibrated noise the seismically measurable 4D-response predicted via full-field 4D image-modelling is more robust, and of a higher fidelity than is achievable via the more traditional Sim-to-Seis type workflows.

Full-Field 4D Image-Modelling workflow:

- Integrates the reservoir, geologic and geomechanical models into a dynamic integrated earth model. From this model all aspects of the 4D-response, time-shifts, amplitude changes, AVO changes, compaction and subsidence to surface can be modelled into future time for a range of production scenarios.
- Noise free forward-modelling provides a qualitative understanding of the nature, magnitude and distribution of the 4D-response into future time, and ties reservoir changes to the corresponding seismically measurable 4D-response.
- With the inclusion of calibrated noise the forward-modelling models the seismically measurable 4D-response, from which the optimal measurement method and acquisition design can be determined; so as to record the seismically measurable 4D-response at the required time-steps for proactive seismic reservoir monitoring.
- Moreover, with the advent of modern computer architectures the elapsed time for the full-field 4D image-modelling is measured in single digit months.

Full-Field 4D Image-Modelling is necessary to fully understand the complexities of reservoir property changes over time, to assess whether those changes are seismically detectable and to make informed decisions on the 4D time-lapse measurement method, design, and reservoir monitoring strategy. Such an in depth understanding cannot be achieved using one of the more traditional Sim-to-Seis type workflows.