Integrating Seismic Imaging and Inversion

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The current need to find ways to reduce project costs along with the increasing number of geologically complex reservoirs makes the perfect scenario to change the way the O&G industry works. For years, seismic acquisition, processing, and characterization were linked only by the tape or media used to store the data. Today an efficient business must understand the needs of the entire production chain from seismic processing to quantitative reservoir characterization. The principal goal of geophysical studies is the creation of an accurate dynamic reservoir model. Precision is required from the beginning to the end of the geophysical process encompassing both imaging and inversion stages. The only way to achieve this goal is with an integrated team, leading edge software, and technical innovations.

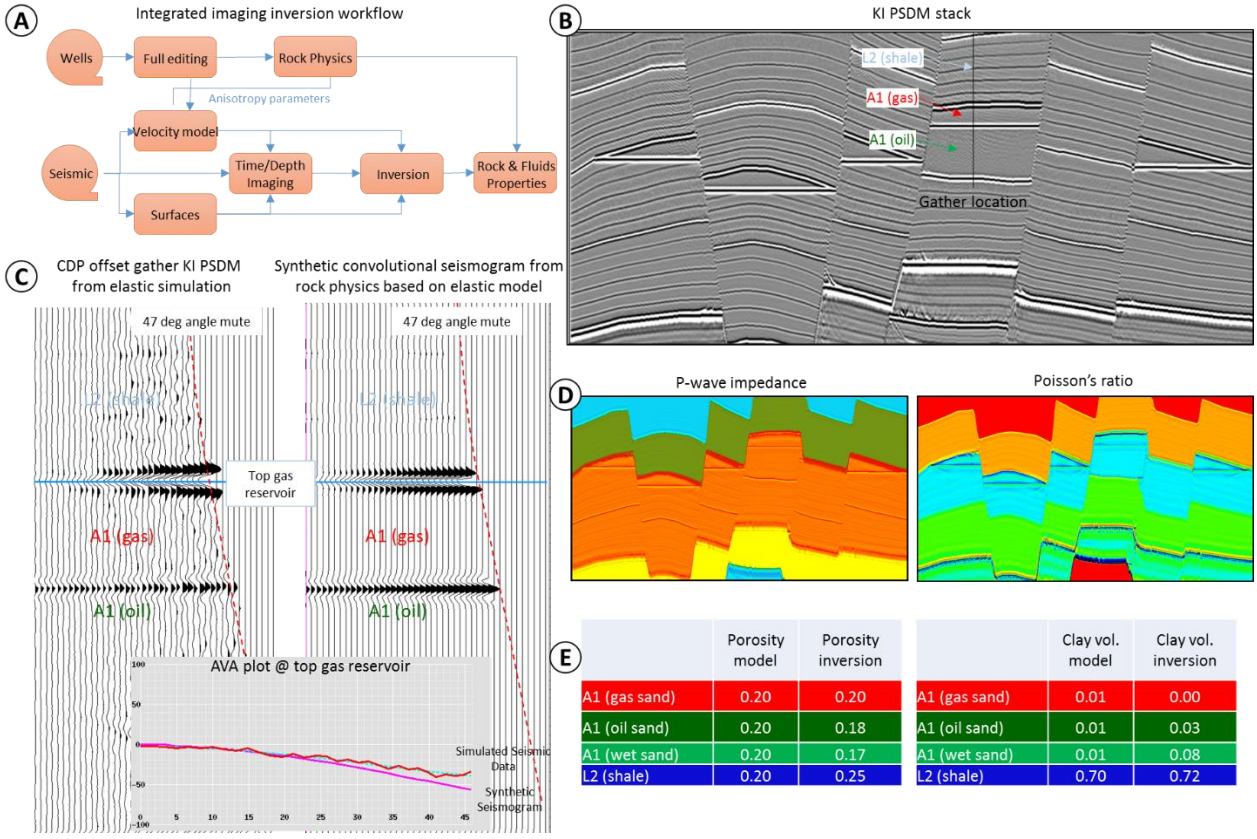
Ultimately we aspire to combine multi-physics workflows (for example including both seismic and electromagnetic data) with dynamic reservoir simulations for optimum development decision making. As a first step towards this goal, we started with the integration of seismic imaging and inversion workflows with the goal of optimizing the time to solution of a seismic characterization project, while maintaining or improving, the quality of rock property prediction and vertical positioning. Depth seismic imaging and pre-stack seismic inversion workflows were successfully linked and tested on a synthetic model, using the following workflow:

1) A geologically realistic faulted model including wet and pay scenarios was constructed using values obtained from rock physics models.
2) Using VTI anisotropic geology, an elastic model was generated and used as an input to elastic simulation. The anisotropic elastic simulation was done using recursive-operator algorithms.
3) A set of simulated shots generated using elastic simulation was then migrated (Figure1-B and C). The migration algorithm used was wave-front reconstruction Kirchhoff summation PSDM.
4) Depth-migrated PSDM gathers were conditioned to remove undesirable signal or noise.
5) A low frequency model using values at brine-saturated conditions was constructed based on the input model. Alternatively, the initial model could have been derived from the PSDM tomographic model and the horizons used during the PSDM model building.
6) The conditioned seismic gathers and initial low frequency model were then used in a pre-stack simultaneous inversion (Figure 1-D).
7) The seismic inversion results were transformed to rock properties through a multi-attribute rotation scheme and compared to the values used to construct the model.

Observed misfit of the predicted reservoir property values in comparison to the actual model are small (Figure 1-E). These are mainly due to the limitations of using only elastic measurements to predict rock properties. Fluid and lithology responses move in non-orthogonal directions when only seismic inversion derived attributes are used. Therefore, there will always be a fluid imprint on the lithology measures and vice versa. In this case, the transform used was estimated using all fluid phases (wet, oil and gas). As a consequence, the volume of clay prediction in a location with only two fluid phases, wet and oil, will trade off the lack of separation from the background with a decrease of the reservoir rock quality (increase of volume of clay).

Results indicate that PSDM preserved the relative amplitude of the data (Figure 1-C) and, therefore, rock properties can be successfully predicted and positioned in the space using a robust seismic reservoir characterization technique (Figure 1-D and E).

Further studies under the current phase of this project plan to use integrated imaging and inversion on a more complex model to set a criterion of confidence in the amplitude responses underneath fast layers such as basalt or salt bodies, with the aim of estimating reservoir properties in such challenging scenarios.



	Porosity model	Porosity inversion
A1 (gas sand)	0.20	0.20
A1 (oil sand)	0.20	0.18
A1 (wet sand)	0.20	0.17
L2 (shale)	0.20	0.25

	Clay vol. model	Clay vol. inversion
A1 (gas sand)	0.01	0.00
A1 (oil sand)	0.01	0.03
A1 (wet sand)	0.01	0.08
L2 (shale)	0.70	0.72

Figure 01. ***A***- *Integrated imaging inversion workflow which ensures consistency throughout the imaging and inversion processes. Significant efficiencies are achieved in the combination.,* ***B***- *Kirchhoff PSDM full angle (3-48) stack,* ***C***- *raw KI PSDM CDP offset gather and convolutional synthetic from elastic vertical profile created using rock physics model convolved with theoretical 30 Hz Ricker wavelet from left to right respectively. At the bottom, comparison of the AVA extraction at the top of the gas reservoir,* ***D*** *– P-wave impedance and Poisson's ratio section from simultaneous pre-stack seismic inversion and* ***E*** *– rock properties used in the model and recovered from the multi-attribute rotation scheme for porosity and volume of clay from left to right respectively.*

For more information on integrating seismic imaging and inversion please contact Francisco Bolivar or visit Rock Solid Images in booth 2941 at SEG.