On the Inversion of Seismic Amplitudes for Lithology, Fluid and Pressure Analysis

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Abstract

Reservoir description using seismic data has two major components: inversion of seismic data to extract attributes such as P- and S-wave velocities and bulk densities, and relate those parameters to reservoir properties, such as rock and fluid types, fluid saturation, porosity and pore pressure through fundamentals of rock physics. Implicit in the process are two key assumptions: the seismic data quality must be good enough for inversion, and the inversion algorithm must be robust and fast enough to yield reliable and consistent results economically with acceptable non-uniqueness. We have seen much progress in both areas. In seismic acquisition, we have seen considerable advancement that contributed to the quality of the seismic data, especially in the prestack domain. These are: single sensor recording (a large number of channels/offset), accurate and calibrated source and receivers and their positions, digital group forming, and towing cables at shallow water depths to minimize swell noise. All of these enable us to access surface seismic data with high S/N and fidelity that often rivals the fidelity of the Vertical Seismic Profiles (VSP). Seismic inversion algorithms also reached new heights. The advent of high-speed digital data processors and cluster technology impacted significantly the performance of various inversion algorithms; we are now inverting routinely seismic data in the *full* offset domain and just not restricting ourselves to the stacked data.

In this paper we discuss the advances in seismic inversion technology that utilizes the amplitude information along with data consistent velocity analyses. First, we briefly review the basic assumptions behind the AVO, EI and full waveform inversion techniques in the prestack domain. While the users of the AVO and EI technology have focused on carrying out inversions using "large angle" assumption- presumably for extracting bulk density information, we show that this may not be feasible due to the neglect of various physical effects, such as interbed multiples, mode conversions and reflection and transmission losses which are omnipresent.

Full waveform prestack inversion (FWPI) is currently the highest level of inversion technology in the industry. Unlike prestack inversion methods such as AVO, the FWPI technique uses a finite-difference elastic model to compute the entire seismic waveform. This provides an advantage over AVO methods in capturing thin-bed effects in data and increasing the potential resolution of the process. The process is computationally intensive and discussed in detail by Mallick (1999). Rock physics-based constraints are applied to speed convergence as well as to reduce ambiguities. Nonetheless, results from this as well as any non-linear inversion process tend to be sensitive to the quality of the a-priori model. However, given a good rock physics model and a-priori information, the output resolution exceeds that produced by other inversion techniques. We have also found that the ambiguities associated with the inversion process can be further reduced if the prestack data has high S/N.

The FWPI technique is computer intensive. Currently this is used in the 1D mode to create pseudo-logs of Vp, Vs and density at selected points in a 3D data volume. These pseudo-logs are then used in the hybrid inversion technique (Mallick (1999) to propagate the benefits of FWPI inversion over 3D volumes. In its current form, hybrid inversion involves computation of pseudologs from full-offset seismic data at selected pilot points in the 3D volume using the FWPI technique, as well as AVO p-intercept and pseudo-shear data over the entire volume. Shear-wave output from FWPI pilot points are used to calibrate the AVO pseudo-shear data. Then both p-wave and pseudo-shear data are independently inverted using a poststack algorithm. Poisson's ratio and other elastic attributes for lithology discrimination are computed from the poststack inversion results. The hybrid inversion process requires input of a 3D a-priori model and a geologically consistent rock physics model, calibration of 3D attribute volumes, and interactive 3D visualization.

We illustrate the entire procedure with examples from several basins.

References

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