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Efficiency of seismic inversion methods for porosity estimation in sandy reservoirs with inter-bedded shale layers

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Seismic inversion methods that convert seismic amplitude to acoustic impedance provide not only better resolution and more accurate structural interpretations, but also allow the use of acoustic impedance as an attribute to estimate porosity and a more accurate quantitative interpretation of reservoir properties. In addition, seismic facies analysis is based on acoustic impedance and other seismic attributes. Therefore, acoustic impedance, containing nearly all the information of the seismic data without the complication of wavelet, is widely being used to estimate reservoir properties such as porosity. Since acoustic impedance is closely related to porosity, as well as to other lithological factors, it is common to establish an empirical transform function between them. Obviously, empirical functions differ from area to area and from one geological setting to another. Under certain geological conditions, such as sandstone with shale layers inter-bedded, finding an exact transform function is difficult.

In the present study, sand and shale layers have first been considered separately. Although a close relation between acoustic impedance and porosity for each lithology is relatively well established the empirical regression trend is considerably poorer for shale and sand reservoirs. This is due to the limited seismic resolution resulting in interference between sand and shale layers within the reservoir with different acoustic impedance and similar or slightly different porosity. As expected, different inversion methods give varying results in this situation. Other factors, such as signal to noise ratio of seismic data, the wavelet, and well-log data quality, need to be taken into account

in order to control the performance of the inversion methods. Therefore, the present study has been carried out on a good quality OBC (Ocean Bottom Cable) seismic and well-log data. Different methods of wavelet extraction have been tested and the optimum wavelet has been selected to generate synthetic seismograms and initial models. The validity of empirical functions for each case has been evaluated by comparison of estimated porosity with average well-log derived porosity in a blind well.

Results show that even though model-based inversion provides a band-limited acoustic impedance estimate that sparse spike inversion is more accurate on traces far from the control well, implying greater sensitivity of this method to the seismic data rather than the initial model. However, sparse spike inversion applied to noisy seismic data is not reliable for detailed modeling as shown by a correlation coefficient between calculated porosity and well-log derived porosity in a blind well at less than 0.25, compared to nearly 0.7 where the data quality is good. Furthermore, sparse spike inversion tends to average acoustic impedance. This averaging can be somewhat compensated for by using an empirical function based on multi-attributes for porosity estimation rather than an empirical function based only on acoustic impedance. In spite of these limitations, inversion of seismic data for reservoir property estimation between wells enables us to determine petrophysical anomalies and lateral variations within reservoir layers.