Neural network inversion of λρ and μρ from post-stack seismic attributes

Rongfeng Zhang, Renjun Wen and Donghai Zhuang
Geomodeling Technology Corp.

Summary

λρ and μρ are the results of pre-stack inversion and they are very popular for seismic interpretation. In areas that AVO effects present, λρ and μρ are effective parameters to discriminate lithofacies and fluid types. However, λρ and μρ are not always available in practice for various reasons such as cost, time, data quality, skills etc. We present a new workflow of λρ and μρ inversion from post-stack attributes and well logs through a neural network approach. The neural network inversion workflow provides an alternative way to obtain λρ and μρ attribute volumes in areas where pre-stack inversion results are not available. We use the well-known Blackfoot data set in the Western Canada Basin to demonstrate the workflow. The results show that λρ and μρ derived from post-stack attributes are comparable with those from pre-stack inversion.

Theory and Workflow

Pre-stack inversion gives us P-impedance, S-impedance and density, from which λρ and μρ can be calculated and used for interpreting reservoir facies and fluid distribution. However, λρ and μρ are generally not derived from post-stack inversion, which only generates P-impedance We propose a neural network inversion workflow to predict λρ and μρ from post-stack attributes and well logs. The workflow consists of five steps:

Step 1: Calculate λρ and μρ logs from wells that have share sonic and density logs.

Step 2: Build a neural network between λρ, μρ logs and three conventional logs: gamma, compressional sonic, and density. The network is used to predict λρ and μρ logs in wells that do not have the share sonic log.

Step 3: Upscale λρ and μρ logs to seismic resolution

Step 4: Build a neural network between upscaled λρ and μρ logs and seismic attributes along the well path.

Step 5: Apply the neural network built in step 4 to create a seismic stratigraphic grid.

Results

We applied the neural network inversion workflow to the Blackfoot area in Western Canada. There are pre-stack inversion results from the same area (Dufour et al 2002). There are 12 wells available in the study area. Only four of twelve wells have shear sonic logs (Figure 1). We calculated λρ and μρ at these four wells from sonic, shear sonic and density logs. The results at well 08-08 are shown in Figure 4(track 4 and 5). Figure 2 shows a cross-plot between λρ and μρ at production well 08-08 and regional well 09-17 in the incised valley depth range. The figure shows a good separation. There are three incised valleys in the region, called upper, middle and lower valley respectively. If the depth range is limited to just upper valley, the separation could be even better.

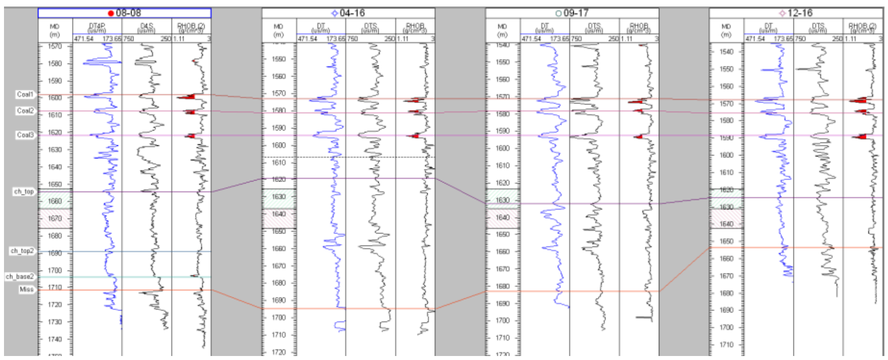

Figure 1 Wells that have shear sonic logs

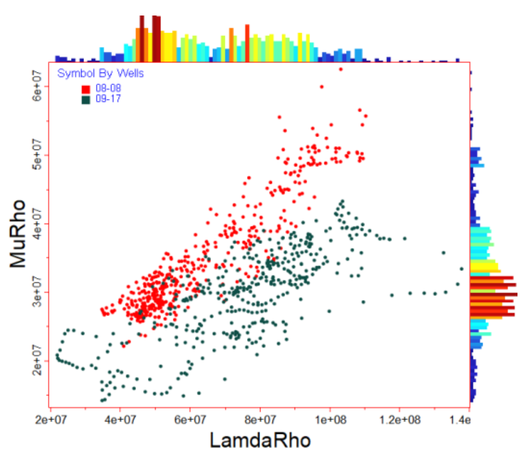

Figure 2 Cross plot between λρ and μρ at production well 08-08 (red) and regional well 09-17 (blue)

We then train a neural network using data available at four wells that have shear sonic logs. Figure 3 shows cross plots between known λρ and predicted λρ. Cross plot (labeled as Training) with blue dots shows data points used for training, and cross plot (labeled as Testing) with red dots is for blind test, which means those data points are not used during the training process. An excellent result with correlation 0.97 is achieved. Then the predictions on each well are made. Figure 4 shows the predicted λρ and μρ. From well 08-08 we can evaluate how good the predicted λρ (track 6) and μρ (track 7) comparing to the actual logs (track 4 and 5). In this example, the results are quite good, though some slight amplitude differences exist. Well 01-08 doesn't have shear sonic logs, so only the predicted results are displayed on track 4 and 5.

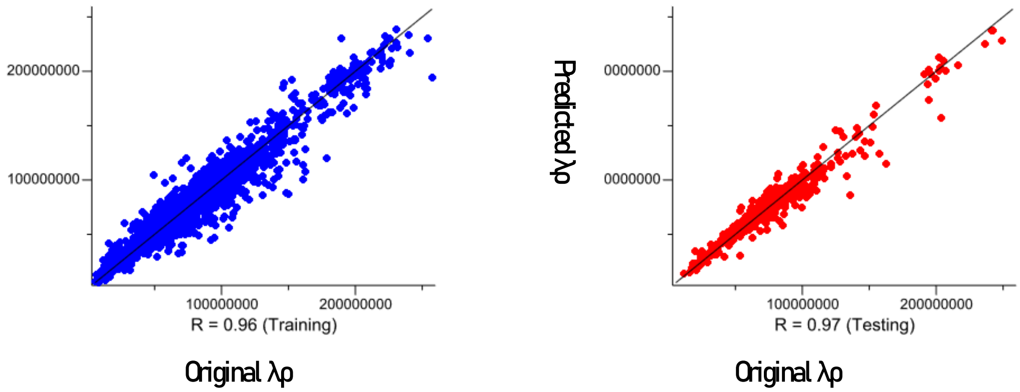

Figure 3 Cross plots from neural network training for λρ log prediction at wells

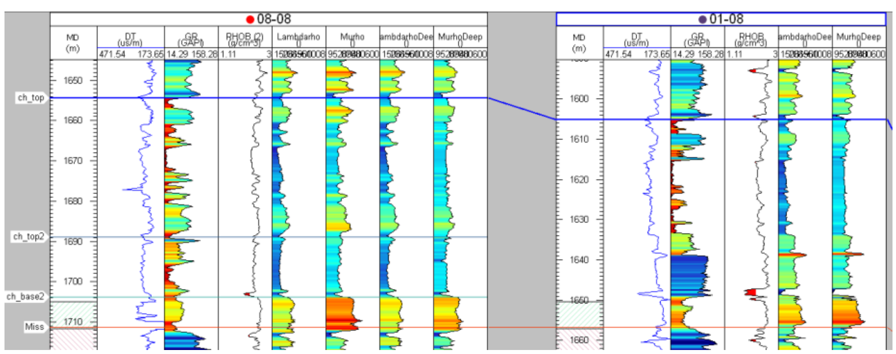

Figure 4 Compare λρ and μρ between the predicted (track 4 and 5) and the calculated (track 6 and 7)

Once λρ and μρ at every well in the region are predicted, they are upscaled in the interest zone according to seismic resolution. The results are shown in Figure 5. Then, another neural network is trained between the seismic attributes (26 in total) at each well location and λρ or μρ. A correlation coefficient of 0.75 overall is achieved. λρ and μρ volumes are subsequently predicted using the trained neural network. A map view of λρ from the upper valley interval is shown in Figure 6 where area with lower λρ value within the incised valley system corresponds to gas sand zone. They match the results from pre-stack inversion quite well.

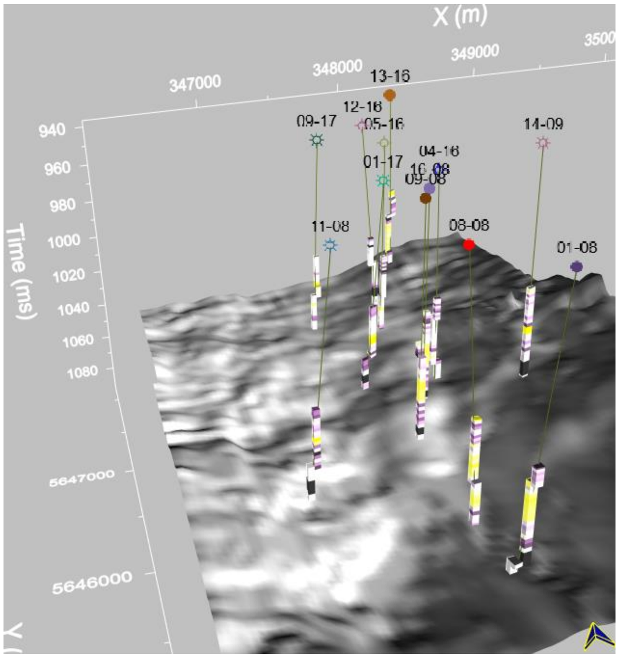

Figure 5 Upscaled λρ and μρ at each well

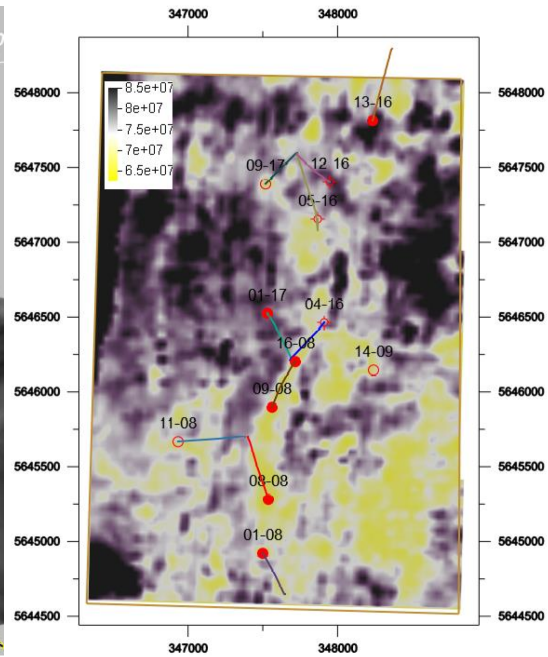

Figure 6 Map view of predicted λρ in the upper valley interval

Acknowledgements

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2. Integrated geological and geophysical interpretation case study, and Lamé rock parameter extractions using AVO analysis on the Blackfoot 3C-3D seismic data, southern Alberta, Canada, Jocelyn Dufour, Jason Squires, William N. Goodway, Andy Edmunds, and Ian Shook
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