# The effects of seismic data conditioning on density estimates from PP-PS joint pre-stack inversion: An example from the Athabasca oil sands

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**Summary**

Density is a key attribute for differentiating lithologies and fluid compositions in Athabasca oil sands reservoirs, and estimates of density from PP-PS joint pre-stack inversion (Russell et al, 2005) in recent years have demonstrated the benefit of adding multi-component data to the inversion work flow (Zhang, and McMillan, 2018).

The degree of uncertainty in a density estimate is determined by several parameters, including seismic data quality, an existing geologically-representative low frequency model and petro-physical information. The objective of data conditioning is to enhance signal-to-noise ratio, to preserve AVO amplitude-variation and to expand useful angle range, all of which serve to improve matching seismic data with well-synthetic, to improve prediction accuracy and to reduce the uncertainty of inversion. This talk will demonstrate the effects of data conditioning on density estimates using a case study from the Athabasca oil sands.

**Introduction and Data Conditioning**

The test area for this study is the Jackfish project expansion, which lies within the Athabasca oil sands region, about 200 km south of Fort McMurray, Alberta. The target zone is the lower Cretaceous McMurray formation, which is a stratigraphically complex zone containing bitumen and water.

Density is known to be the best indicator of lithology and fluid variations in Athabasca oil sand reservoirs. Therefore, improving density estimates is a major goal in seismic reservoir characterization. Joint PP-PS pre-stack inversion has been widely applied to density estimates because it generally produces more accurate results compared to P-wave AVO inversion. However, joint PP-PS inversion does not automatically optimize density estimates; special care is needed at each step of inversion processing, and the results can be quite different, even with the same data and inversion methods.

As a major input for inversion, the quality of seismic data has a significant effect on joint inversion results, particularly density estimates. Seismic data quality is assessed by four criteria: 1) frequency bandwidth, 2) signal-to-noise ratio, 3) AVO amplitude preservation, and 4) useful angle range. The objective of data conditioning is to maximize the value of seismic data on each of the four points above, so it is a key part of the quantitative interpretation workflow, and leads to more reliable and accurate density estimate from joint PP-PS inversions.

Two sets of PP-PS joint pre-stack inversions were performed on the same input data (seismic, both PP and PS; wells and geologic data) by two different companies (Company A and Company B). No conditioning work was done by Company A, though Company B performed customized seismic data conditioning prior to inversion (Figure 1). *The comparison between input and conditioned gathers are shown in Figure 2.*

**Results and Conclusion**

Two density volumes (from Companies A and B, respectively) were compared at 35 well locations. Figure 3 clearly shows that the density volume from the conditioned gathers exhibits a stronger geological well tie and a better reservoir characterization. Approximately two-thirds of leads in the study area have been improved and cross-correlation with measured density well logs (n = 35) have been improved from 65% (in the case of Company A) to 86% (Company B). *Figure 3 shows an example of estimated density from the two inversion workflows.*

Since the inversion work was done by two different companies, the data conditioning workflow may not be the only cause of differences in the density estimates between these two versions; however, data conditioning is a very important step in inversion processing, and we believe it to be the primary cause of the differences in the two datasets.

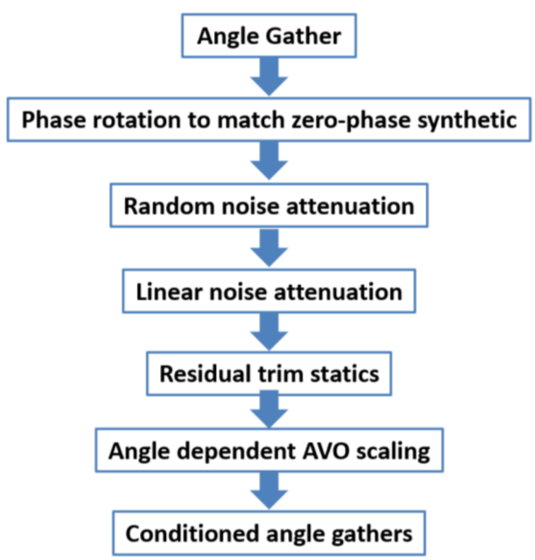
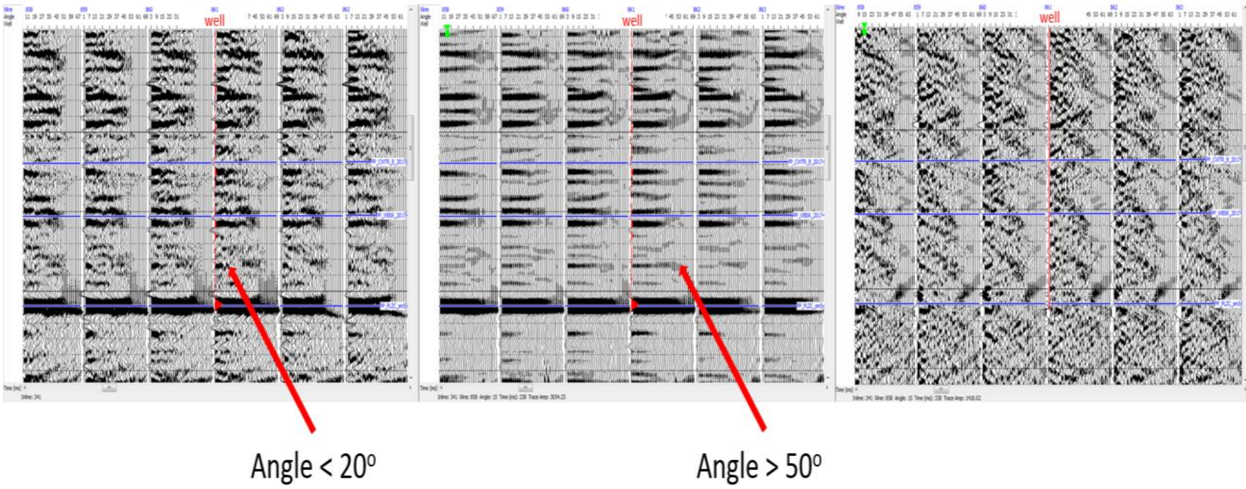



*Figure 1. Company B data conditioning workflow.*

a) Input PP angle gathers for joint inversion

Input gathers (before conditioning) Output gathers (after conditioning) Difference




b) Input PS angle gathers for joint inversion

Input gathers (before conditioning) Output gathers (after conditioning) Difference

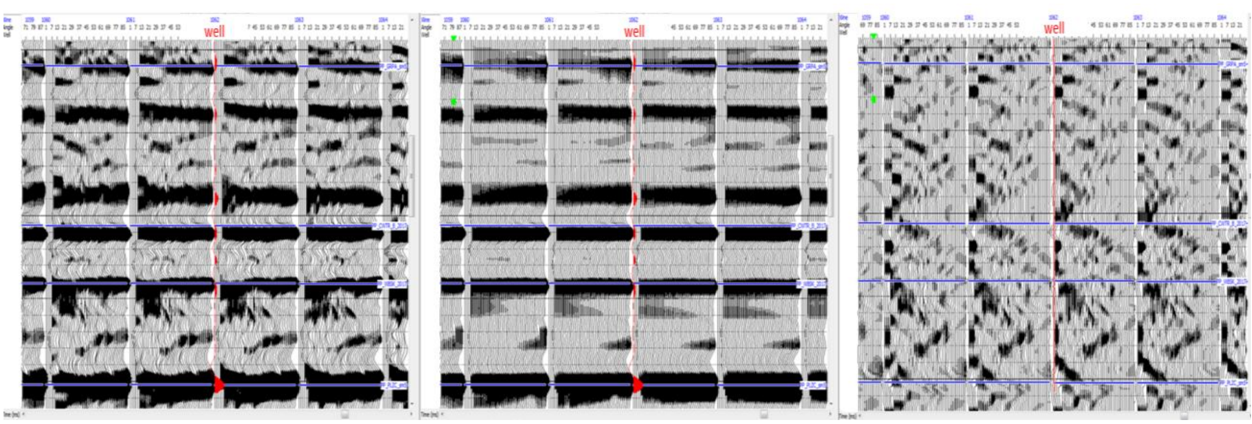



*Figure 2. Input and conditioned PP & PS angle gathers for two sets of joint PP-PS inversion. In each case, PP angle gathers are shown above (a) and PS angle gathers are shown below (b). Input angle gathers are shown in the left two frames, Company B's conditioned gathers are shown in the middle two frames, and the difference between the two are shown to the right. Data conditioning was found to enhance signal-to-noise ratio, preserve AVO amplitude variation and expand the useful angle range.*

Two density estimates from joint PP-PS inversion

Density (Company A) Density (Company B)

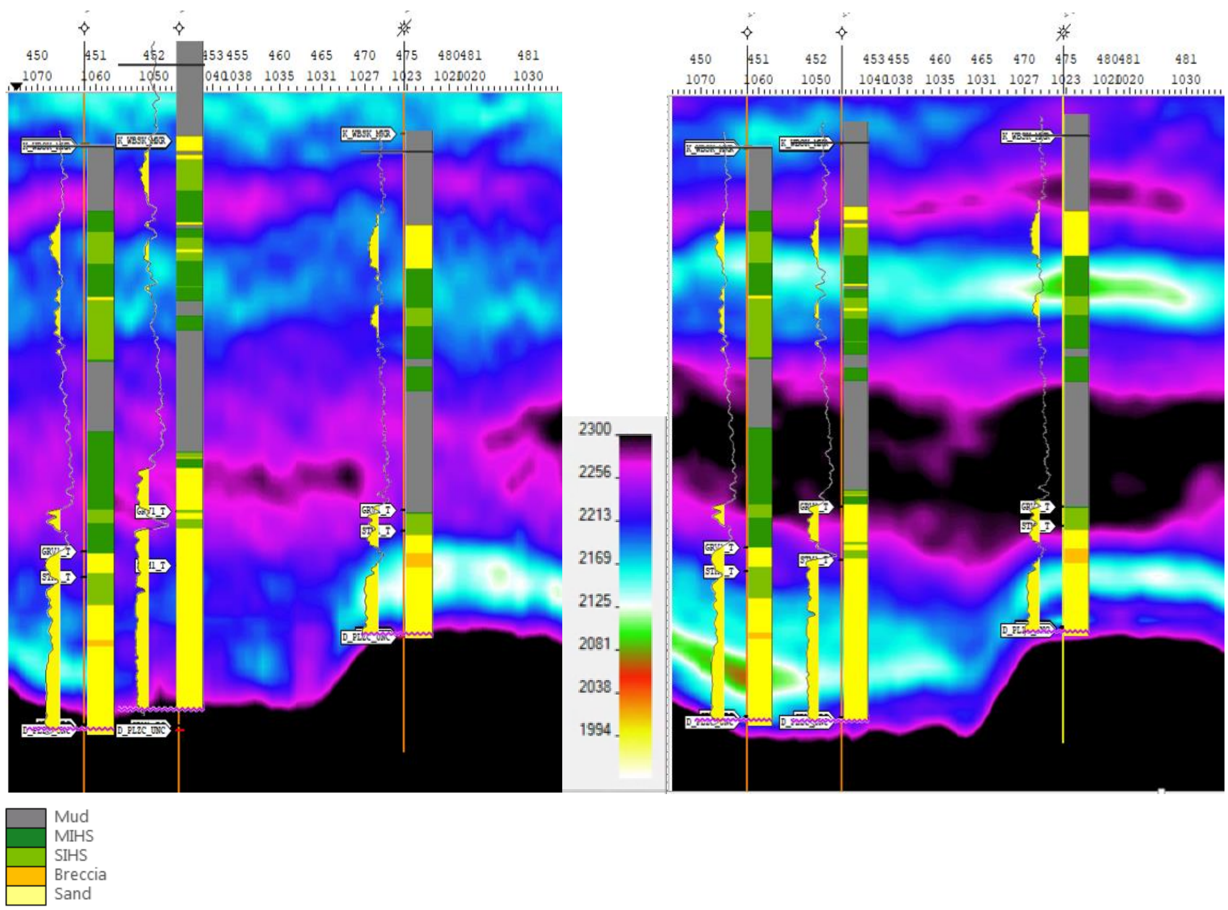



*Figure 3. Two density estimates from joint PP-PS inversion (Company A (left), and Company B (right)). Density volumes are superposed with gamma log curves and facies, the results were compared at 35 well locations. Approximately two-thirds of leads in the study area have been improved and cross-correlation with measured density well logs (n = 35) have been improved from 65% (in the case of Company A) to 86% (Company B).*

**Acknowledgments**

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**References**

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