# Effects of available long offset and random noise on simultaneous-AVO inversion

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## Introduction

The aim of simultaneous-AVO inversion is to extract S-wave and density information from PP pre-stack seismic data. The availability of this information may be the key to discriminate reservoirs from the background in some geological frameworks, as the one shown in Fig. 1 that corresponds to a gas reservoir. The acoustic solution could not be enough to identify the reservoir. The P-impedance range of the reservoir overlaps with the background's P-impedance. For this reason, we need both S- and P-impedances to properly separate the reservoir from the background.

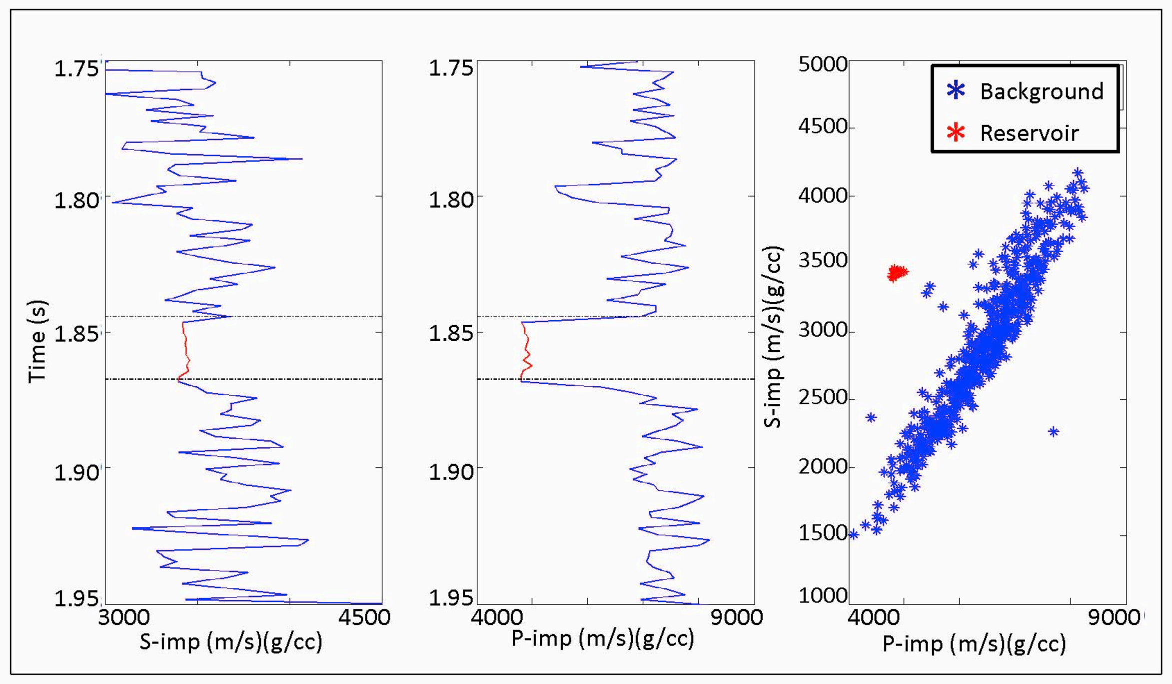


FIG. 1. Log data of a gas-producing well. Density, P- and S-wave velocity logs were used for this experiment.

The top and base reflection coefficient variations with angle, given by the Zoeppritz equation, are shown in Fig. 2. The reflection coefficient amplitude increases with angles. We know the relationship between offset and angle of incidence by using ray tracing.

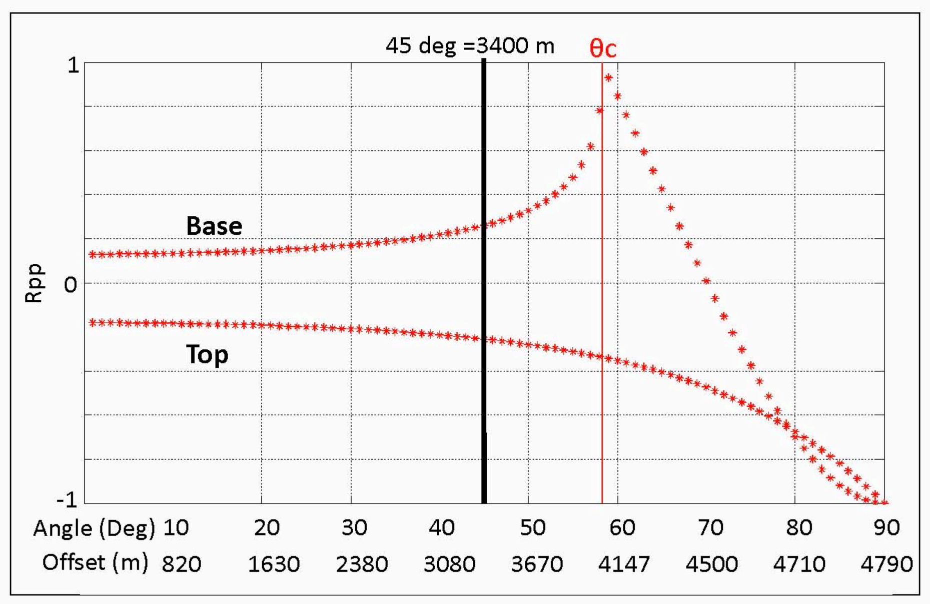


Fig. 2 Reflection coefficient variation with angle of incidence and offset. The critical angle is 58 degrees. Pre-critical angle traces smaller than 50 degrees were used in this experiment.

Figure 3 shows the synthetic gather with AVO response constructed by using the density, P-wave and S-wave velocity logs, the Zoeppritz equations, and a zero-phase Ricker wavelet with dominant Freq. of 25 Hz.

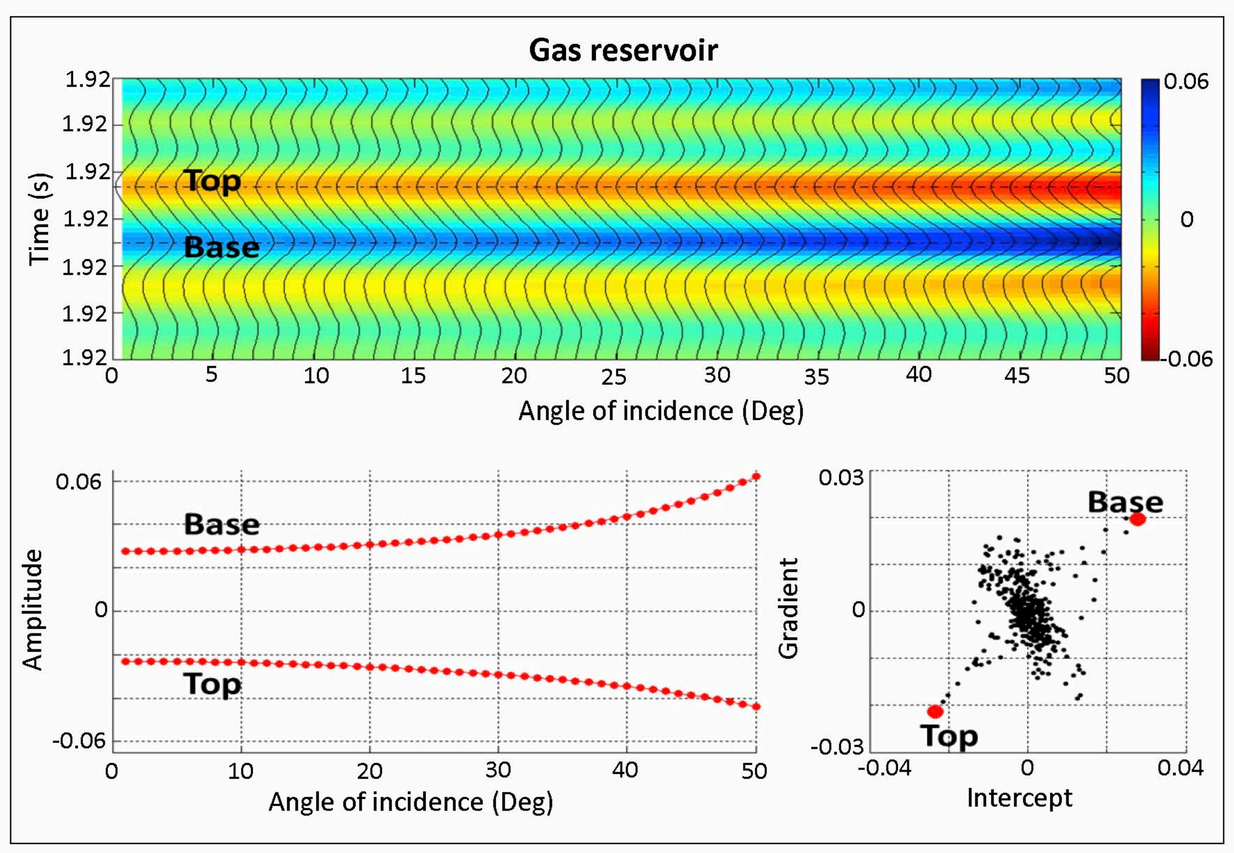


FIG. 3. Synthetic angle gather showing an amplitude increment given the presence of gas. The intercept vs gradient plot shows a typical class-III anomaly. We used this seismic angle gather to examine the effect of reducing the angle of incidence and the impact of varying the signal to noise ratio.

## Laboratory procedure and data analysis

We applied the simultaneous inversion approach given by Hampson et-al (2005). They use an initial impedance model which is iteratively perturbed until density, P- impedance and S-impedance are found. The algorithm applies a reformulation given by Fatti of the Aki and Richards' approximation for the Zoeppritz equations.

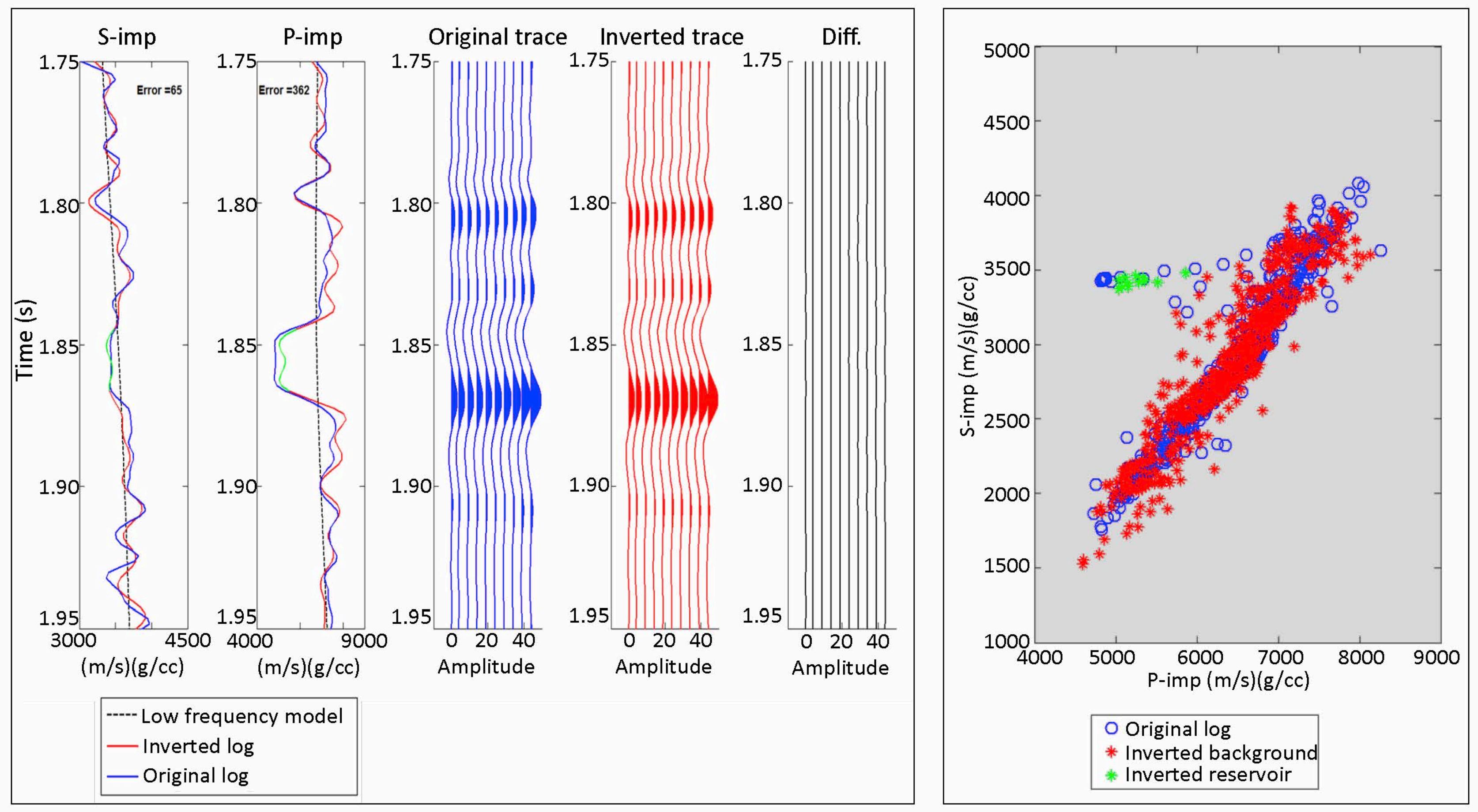


FIG. 4. Simultaneous-AVO inversion applied to the synthetic gather of Fig. 3. No noise was added. We used an angle range from 1 to 45 degrees. A comparison between the inverted and original P- vs S-impedance plot in shown on the right. The reservoir (in green) is well discriminated from the background in this case which corresponds to maximum angles of 45 degrees, without noise.

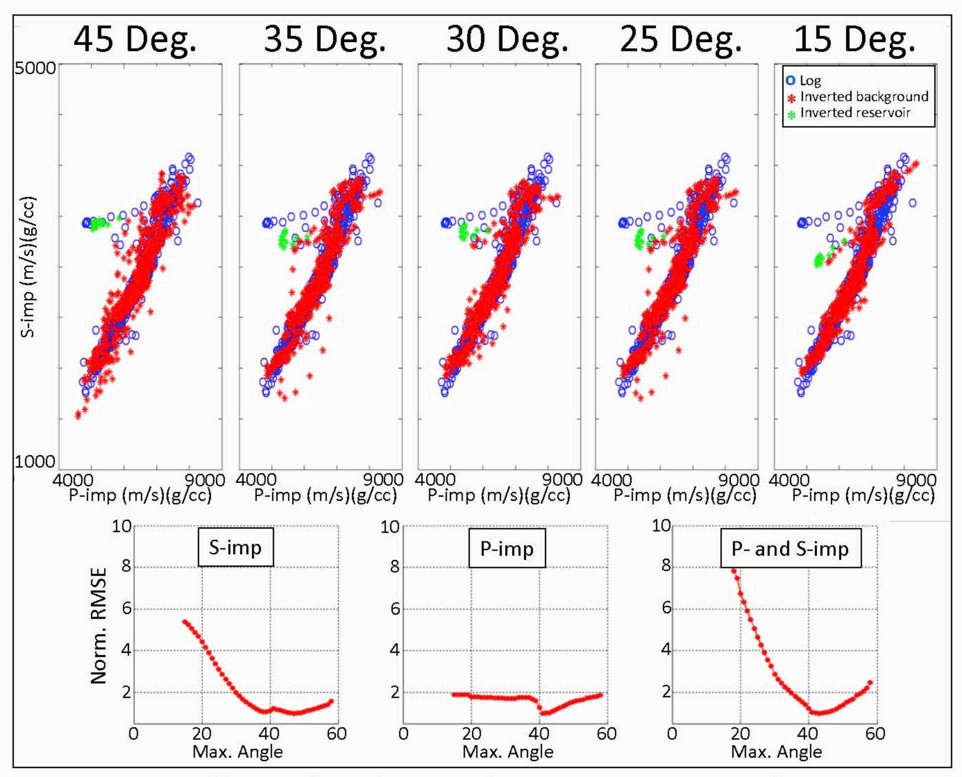


FIG. 5. Effect of reducing the maximum angle on simultaneous-AVO inversion.

Fig. 5 shows the effect of reducing the maximum angle of incidence in the performance of simultaneous-AVO inversion. The normalized RMSE is shown at the bottom. When the combined error decreases, the discrimination of the reservoir improves. This happens with maximum angles between 40 and 45 degrees.

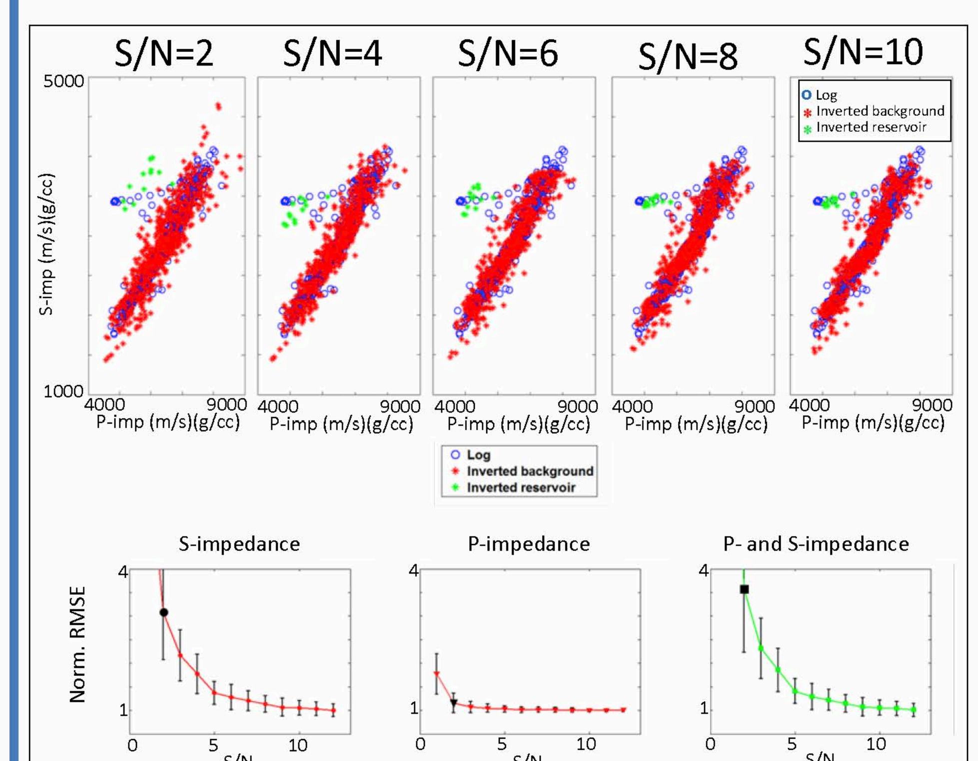


FIG. 6. Effect of random noise on simultaneous-AVO inversion.

Fig. 6 shows the inverted P- and S- impedance crossplot compared to the original impedances from the well and the impact of random noise. The reservoir points disperse as the S/N decreases. The normalized RMSE, for the inverted P- and S-impedances and the combined effect of them, is shown at the bottom of Fig. 7.

## Results

The combined S- and P-impedance RMSE as a function of S/N and maximum angle is shown in Fig. 7. We defined four zones based on the separation of the reservoir from the background. We can use this kind of plots to choose the maximum offset when designing a seismic survey or to check the feasibility of applying simultaneous inversion in old seismic data. Fig. 8 shows examples of the inversion performance from the four zones defined in Fig. 7.

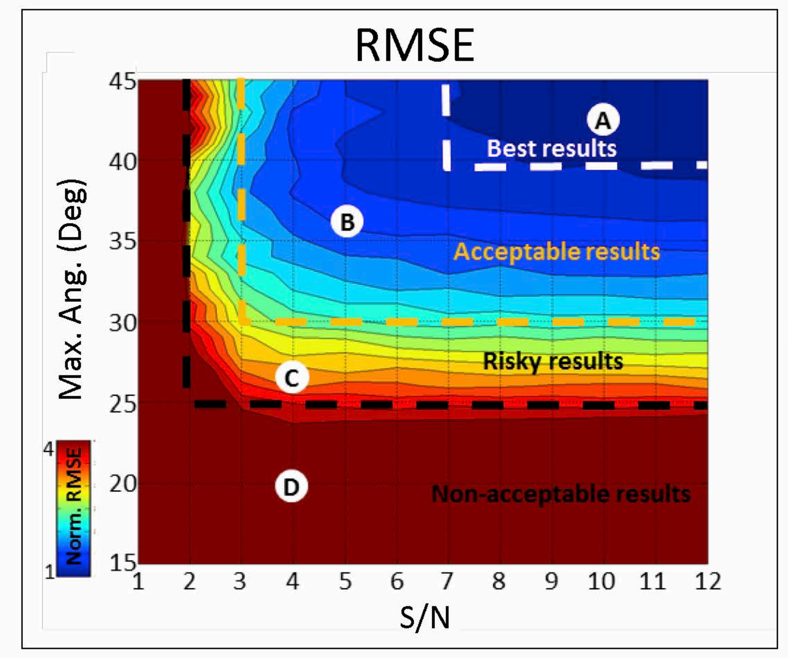


FIG. 7. Combined RMSE of inverted S- and P- impedances. Low error represents better reservoir discrimination.

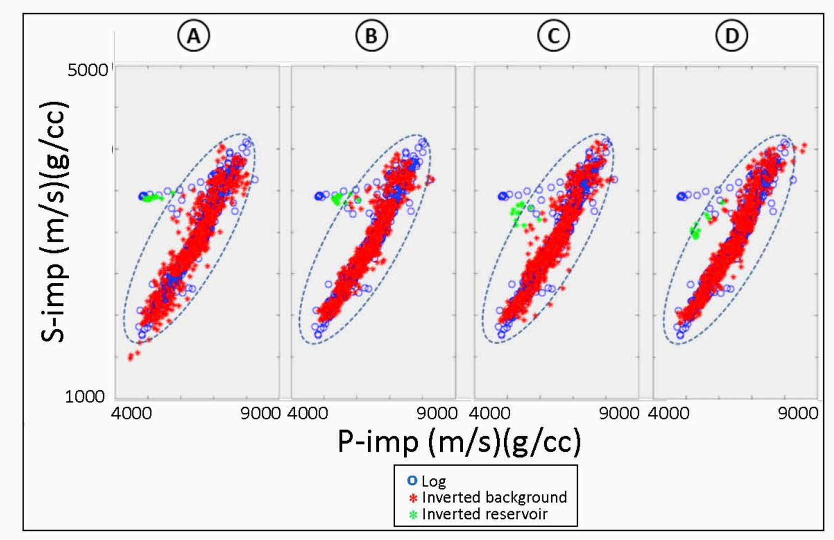


FIG. 8. Reservoir discrimination examples from the four zones defined in Fig. 8. Noise and maximum angle impact on the reservoir discrimination.

## Conclusions

Random noise and the maximum long offset affect the performance of simultaneous-AVO inversion. The best inversion results for the gas reservoir at a 2280-m depth correspond to angles between 40 and 45 degrees with S/N>7. This scenario properly discriminates the reservoir from the background in a P- vs S-impedance crossplot.

## Acknowledgements

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## References

Hampson, D. P., Russell, B. H., and Bankhead, B., 2005, Simultaneous inversion of pre-stack seismic data. In 2005 SEG Annual Meeting: Society of Exploration Geophysicists.