Repercussions of available long offset, random noise and impedance contrast on AVO analysis

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Introduction

The amplitude variation with offset (AVO) response is sensible to several factors that may affect the feasibility of doing this kind of analysis. This work measures how the available long offset, level of random noise and impedance contrast between the reservoir and seal, impact on intercept, gradient and curvature estimations. Density, P- and S- velocity logs of and oil producing sand, were used for this experiment. Gas and water scenarios were reproduced by using the Gassmann theory (Fig. 1). The reflection coefficient variation with angle was modelled by applying Zoeppritz equations (Fig. 2). Fig. 3 shows the synthetic seismic gathers constructed by using the wavelet and well-logs in Fig. 1 and applying Zoeppritz equations.

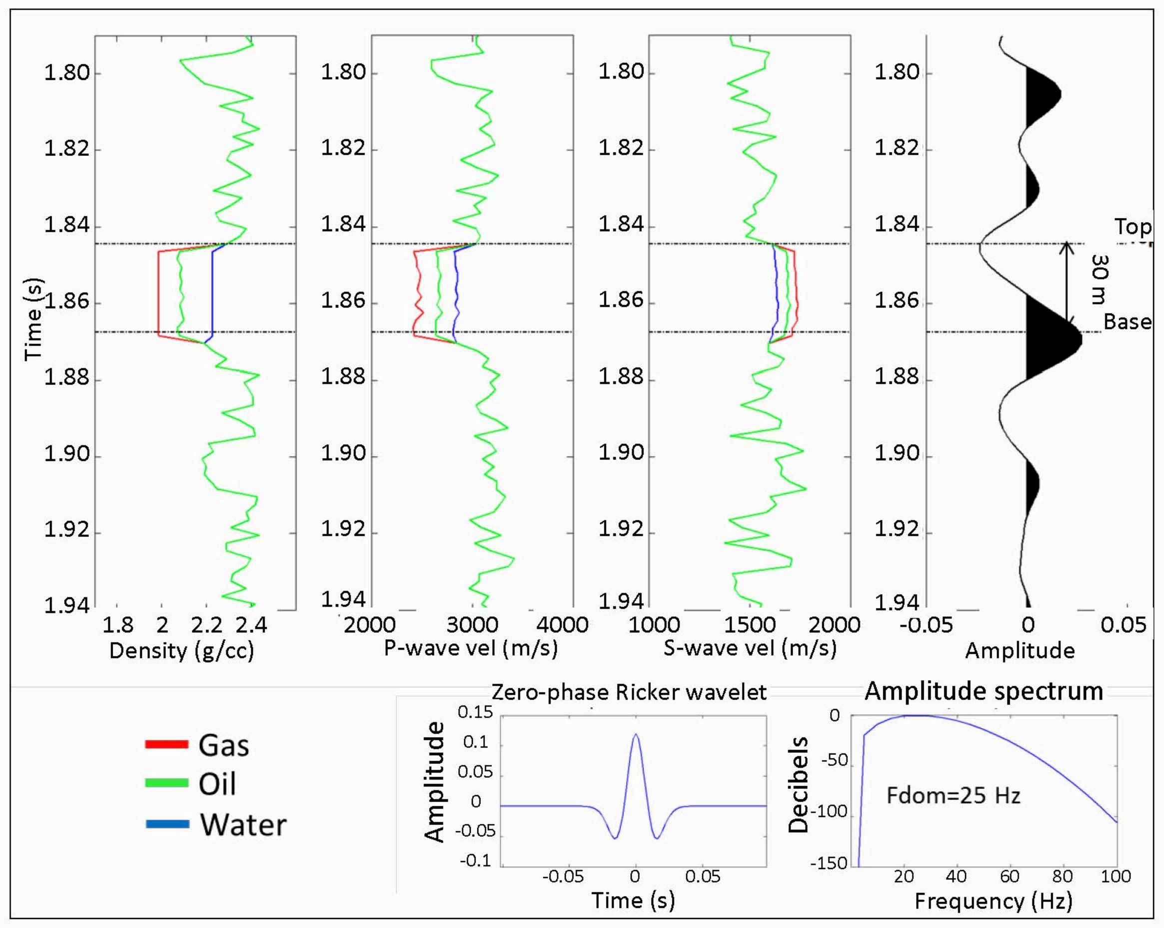

FIG. 1. Well log data of an oil-producing well. The original logs (green) correspond to oil filling the pore space. The red and blue lines correspond to gas and water, respectively. A zero-phase Ricker wavelet with dominant frequency of 25 Hz properly resolves the reservoir.

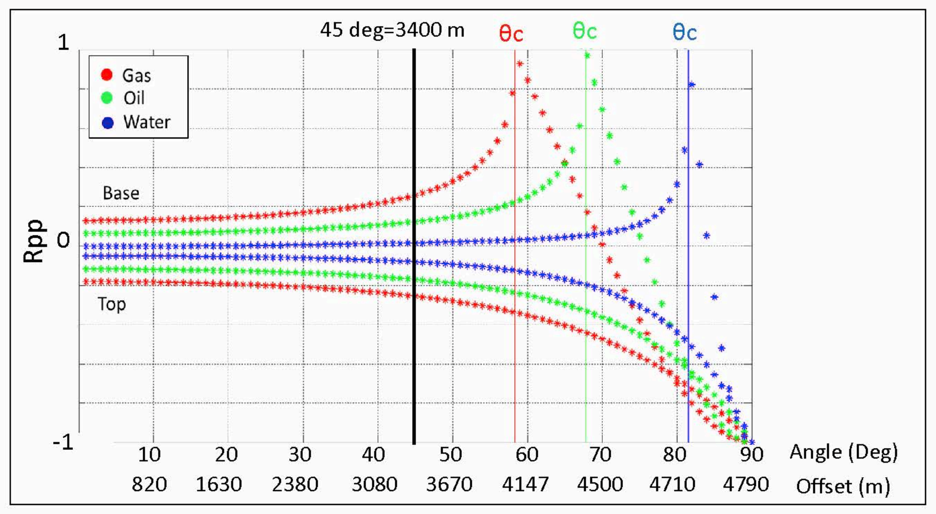

FIG. 2. Reflection coefficient variation with angle of incidence (or offset) for the three fluid scenarios. Pre-critical angles smaller than 45 degrees were used in this experiment

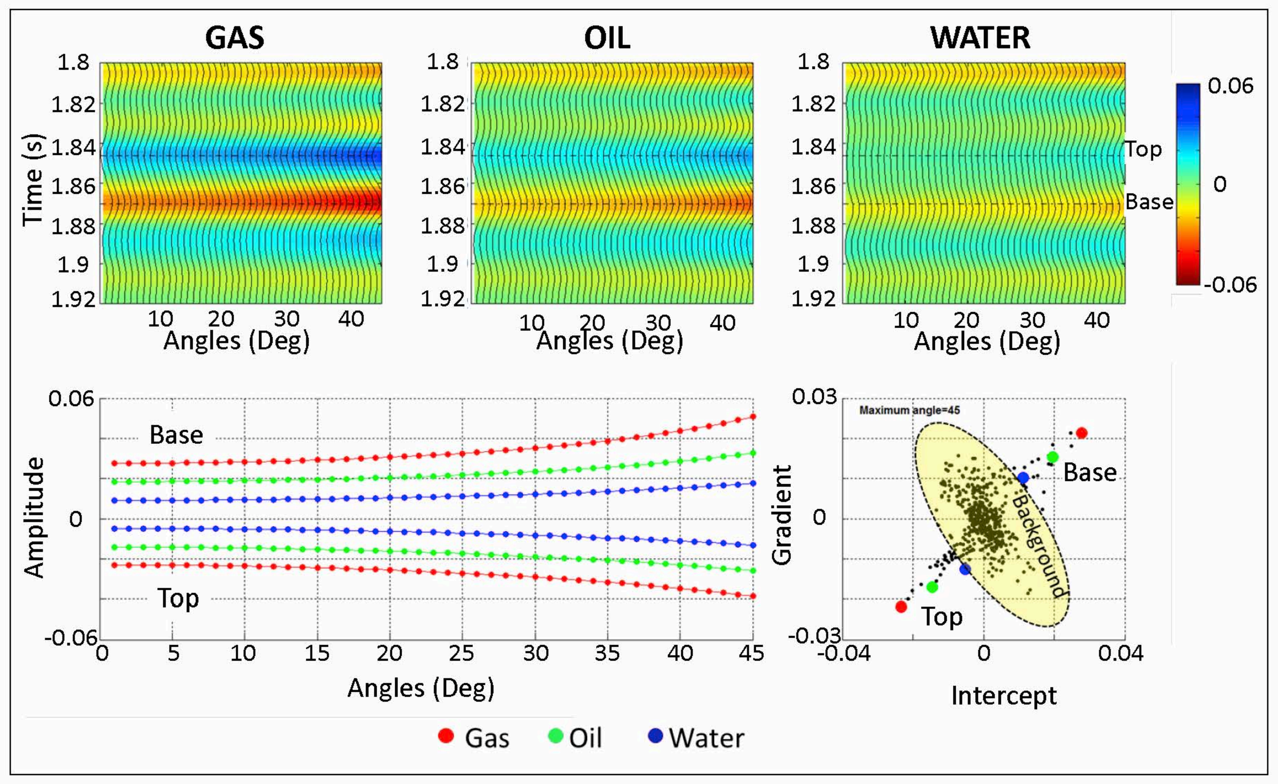

FIG. 3. Synthetic seismic gathers with AVO response for gas, oil and water sands. The intercept and gradient parameters are derived by fitting equation 1 to the amplitude vs angle points. The intercept vs gradient plot discriminates fluids.

$$R_P(\theta) = R_{AI} + G\sin^2\theta + R_{VP}\sin^2\theta\tan^2\theta$$

Intercept Gradient Curvature

Eq. 1. Wiggins' reformulation for Aki-Richards' approximation of Zoeppritz equations (Aki and Richards, 2002; Russell and Hampson, 2006).

Laboratory procedure and data analysis

Fig. 4 shows the effect of random noise on the amplitude vs angle plot and intercept vs gradient plot. Figure 5 shows the impact of reducing the maximum angle. Both factors produce instability when estimating the AVO parameters. We can observe the actual effect of noise by repeating several times the parameter estimation for a fixed S/N and maximum angle (Fig. 6 and 7). The standard deviation of these measurements provides a sense of the quality of the AVO-parameter estimations (Fig. 8). The reference for measuring the error was the case with no noise and using angle traces up to 45 degrees.

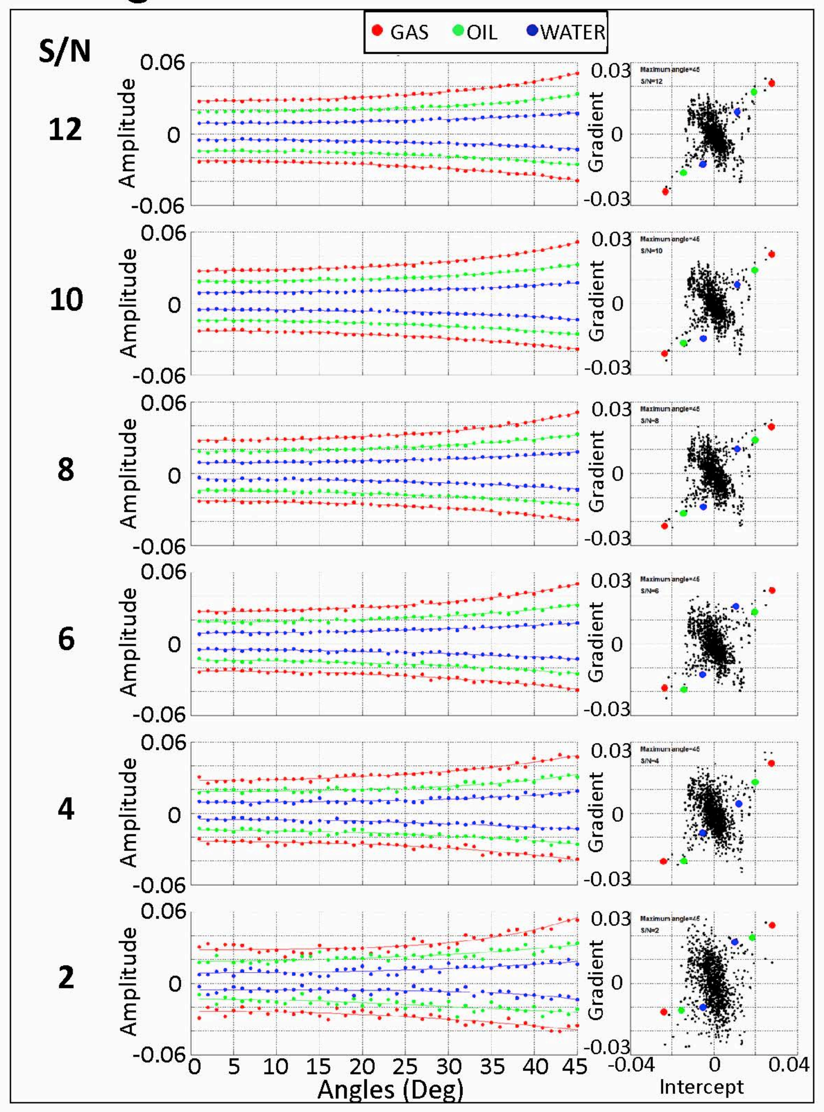

FIG. 4. Effect of random noise. Max Ang=45 deg.

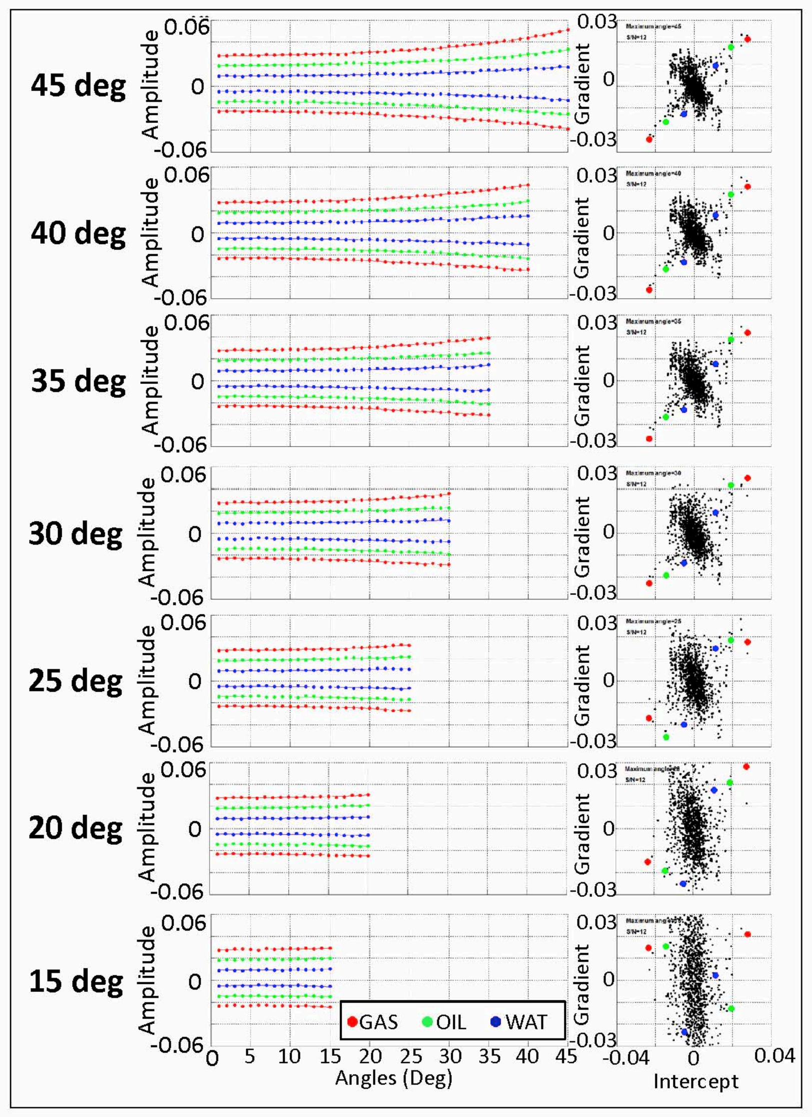

FIG. 5. Reducing Max. available angle. S/N=12.

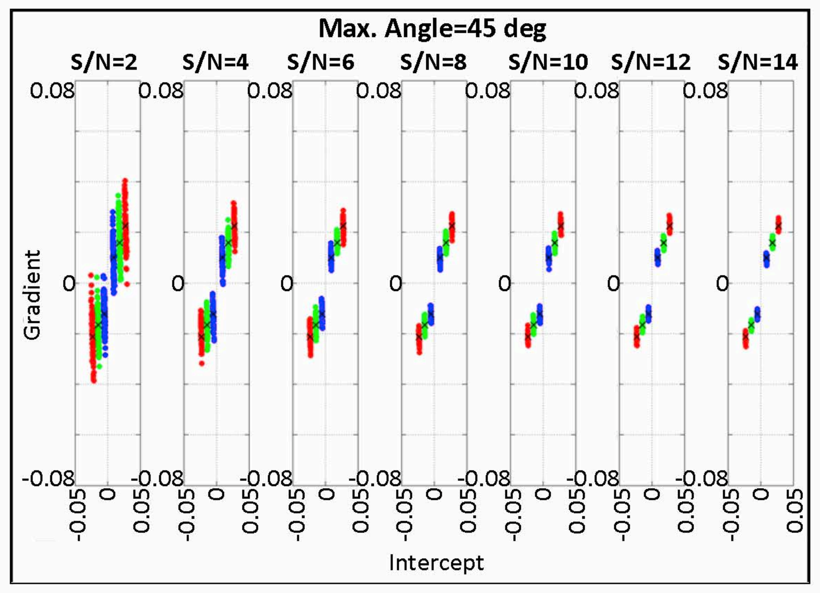

FIG. 6. Dispersion of the AVO-parameters produced by different levels of noise.

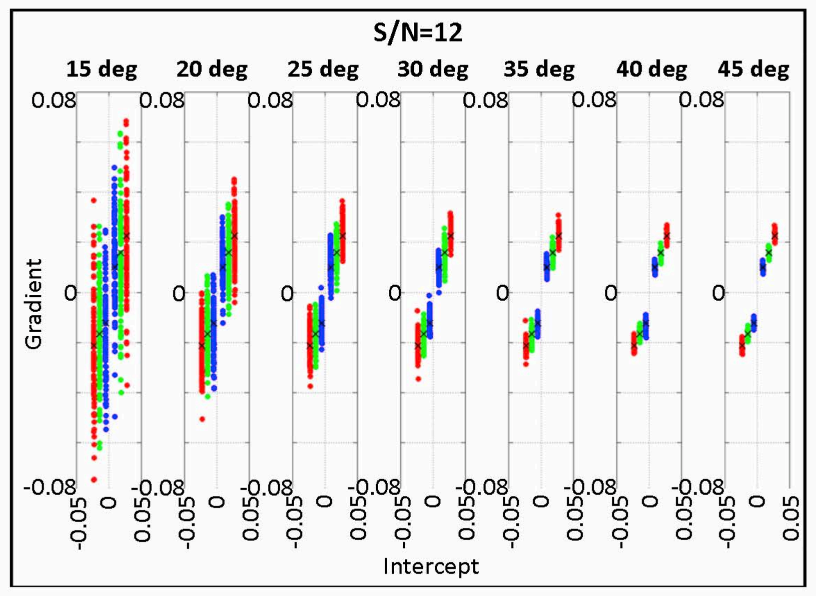

FIG. 7. Dispersion of the AVO-parameter estimation produced by the reduction of the maximum angle available.

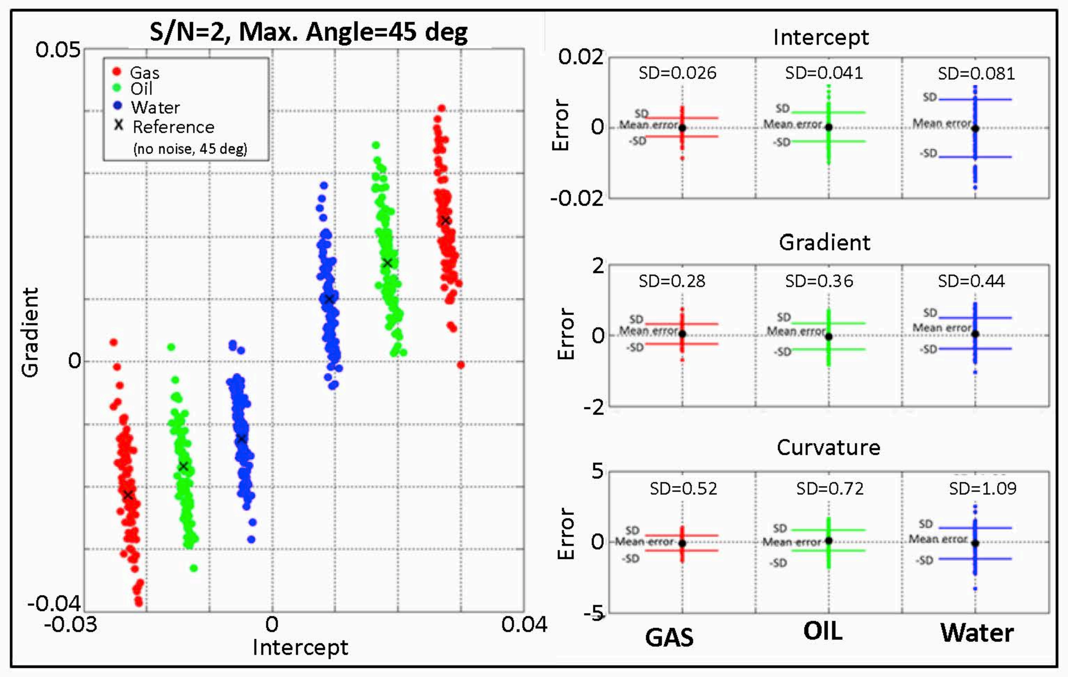

FIG. 8. Calculating the standard deviation (SD) of 100 estimations for S/N=2 and Max. Angle=45 deg. The SD represents the uncertainty of the AVO-parameter estimation.

Results

Fig .9 shows the standard deviation (SD) as a function of S/N and maximum angle. The SD indicates the quality of the AVO-parameter estimation. Estimations with error higher than 20% are unstable. The error increases as the impedance contrast decreases. These results can be used for deciding the maximum offset when a new seismic survey is designed or for time-lapse seismic purposes.

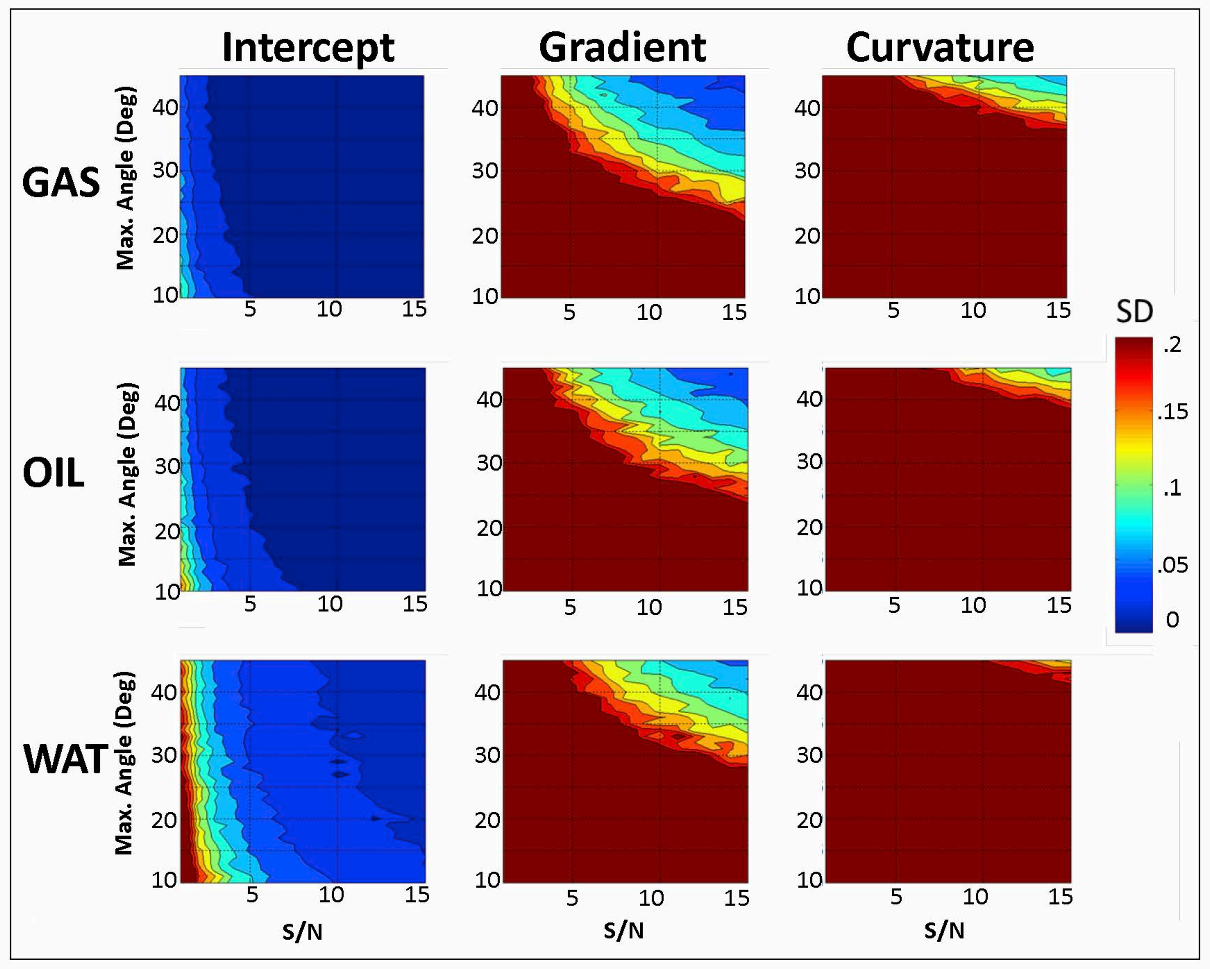

FIG. 9. Simultaneous effect of noise and maximum angle available on AVO-parameter estimation.

Conclusions

1) Random noise and available long offset are variables that affect the estimation of AVO-parameters. 2) The intercept is minimally affected by reducing offset and slightly affected by random noise. 3) The gradient and curvature are strongly impacted by both noise and maximum available offset. 4) The error tends to be higher if the target has low impedance contrast. 5) Long offsets provide stability when fitting the amplitude vs angle points in the presence of noise.

Acknowledgements

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