The effects of noise on AVO crossplots

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Summary

Random noise was added to pre-stack synthetic gathers to investigate the effects of noise on AVO crossplots. In agreement with previous studies we find that the noise rotates the trend of the data, as well as obscures the petrophysical properties and slightly anomalous events. With the application of a Radon filter to remove the noise, the trend is minimally rotated.

Class 1 and 2 sands are easily obscured by noise as they may lie along the background trend or be overlain by the rotation of the background due to the noise. However, noise causes Class 3 sands to trend parallel to the background trend. This is a reason for success in many of the Class 3 sands in exploration.

Introduction

Amplitude variation with offset analysis has been proven to be an effective tool for hydrocarbon detection. Using the Shuey (1985) approximation to the Zoeppritz (1919) equations lends users to insightful application and readily reveals the “AVO intercept” and “AVO gradient.”

AVO crossplots can simultaneously show many pairs of intercept and gradient points, thereby revealing information about lithology and fluid effects. Most commonly, the intercept is plotted on the x-axis while the gradient is plotted on the y-axis. When a relationship exists between the non-hydrocarbon bearing rocks in a time window, a well-developed background trend can be observed on the crossplot. Any deviation from the background trend is seen as anomalous and may be indicative of hydrocarbons.

The use and interpretation of AVO crossplots becomes increasingly difficult with decreasing signal to noise ratios. Slight deviations from the background trend may be masked owing to the effect of noise. Adding to this complication is the sensitivity of both the intercept and gradient terms, with the gradient being more sensitive than the intercept.

For our purposes, seismic noise may be defined as any amplitude variation with offset that is not offset-dependant reflectivity. Random noise can be a principle component of noise on AVO crossplots (Simm et al., 2000). As Hendrickson (1999) stated, the most effective way of removing random noise is to stack the data. However for AVO analysis, only limited stacking can be performed, and signal to noise ratios are poorer than for fully stacked sections.

Noise and crossplots

It is clear that noise can seriously degrade the interpretation of AVO crossplots. Therefore it is important to understand the effect that noise has on crossplots. Cambois (1998) stated the background trend observed on crossplots may not be indicative of rock properties, instead it may actually be a noise trend. Also stated is how the fluid-factor results in a far-offset stack in the presence of noise. Because it is a far-offset stack, this explains the success of AVO crossplots.

Hendrickson (1999) showed examples of seismic data from Auger Field and random noise on AVO crossplots. Strikingly the two plots looked very similar, and would indicate that the background trend observed can be just noise. Hendrickson also shows a rotation of the data as the signal to noise ratio decreases.

From these two articles it might be perceived that the background trend observed on AVO crossplots is indeed noise. The implication might then be to question whether any rock property information is being observed, or is hiding beneath the noise.

Modeling parameters

In order to ascertain the answer about whether rock property information is contained on crossplots, a series of synthetic examples encapsulating classes 1-3 were computed using Hampson-Russell. The models were constructed to ensure no tuning effects would be observed. After construction, the synthetic was imported into ProMax where random noise was added to a line composed of ten identical CDP’s. Analysis of the CDP’s was performed in Hampson-Russell’s analysis platform. Least squares regressions were applied to the background data above the gas sands to identify any rotation of trends as noise was introduced. The radon filter was applied in Hampson-Russell as well. Before application of the filter, an external mute was applied to the near surface reflections that were going critical. The Radon filter allowed 0 to 75 Hz frequencies to pass through, with a high and low Delta T of 10 and -10, respectively.

Modeling results

The addition of noise to any model revealed several things. The noise that was added has caused a scattering and stretching of the data points as compared to the noise free case. As seen in Figures 1 and 2, an elongated trend is observed for all data points. There is also a rotation of the background trend, a more negative slope, with decreasing S/N. However, the noise that has been added is on top of the original background trend.

With the addition of noise to each of the models, it became clear that a Class 1 and Class 2 sand behaved in a similar fashion. The Class 1 and 2 sands could be seen as anomalous events at higher S/N. However, as the S/N decreased the gas sand disappeared into the background trend as it became obscured by noise. Therefore, it is necessary to have a low signal to noise ratio, or a highly anomalous gas sand to be observed.

The effect of noise on a Class 3 sand has a very different response. At all increments of increasing noise, the Class 3 sand is clearly observed. Although the background trend rotates, the sand stays parallel to this rotation and is not encapsulated by the noise. Interestingly, the stretching of the data points caused by the noise has taken a Class 3 sand and moved it to a position which might be hard to determine if the sand is Class 3 or Class 4.

Least squares regression analysis was done to the background data above the gas sand. From this analysis it was discovered that a rotation of the trend was occurring as noise was added to the CDP's. Figure 3a shows the synthetic gather with no noise, and a low angle negative trend. Figure 3b diagrams 10 CDP's with a S/N = 1, the lowest S/N in the study, and a more steep negative rotated trend. A Radon filter, performed in Hampson-Russell, was then applied to the CDP's with additive noise. Figure 3c shows the result after Radon filtering. Clearly, the regression line has not been rotated as much as without the filtering.

Conclusions

From the modeling performed in this study, the addition of noise affects the classes of sands differently. Class 1 and 2 sands are seen as anomalous events at high S/N, but are easily covered by the noise as a rotation of the background trend occurs. Class 3 sands are always semi-perpendicular to the background trend, and are stretched parallel to the background trend by noise even at low S/N. As the data points become stretched in the presence of noise, a Class 3 sand may become pulled into the range for Class 4 sands. This may lead to misinterpretation of a sand and missed hydrocarbon potential. There is a rotation of the background trend when noise is added, as other studies have showed. However, after Radon filtering the data has less rotation.

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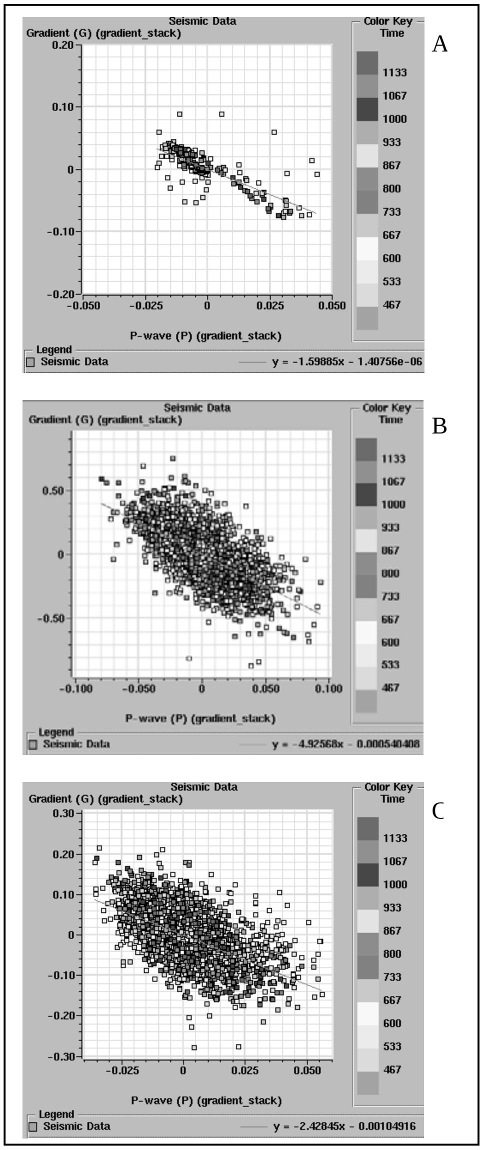

Figure 3. A) No noise. B) S/N=1. C) After Radon filter was applied to gathers with S/N=1.

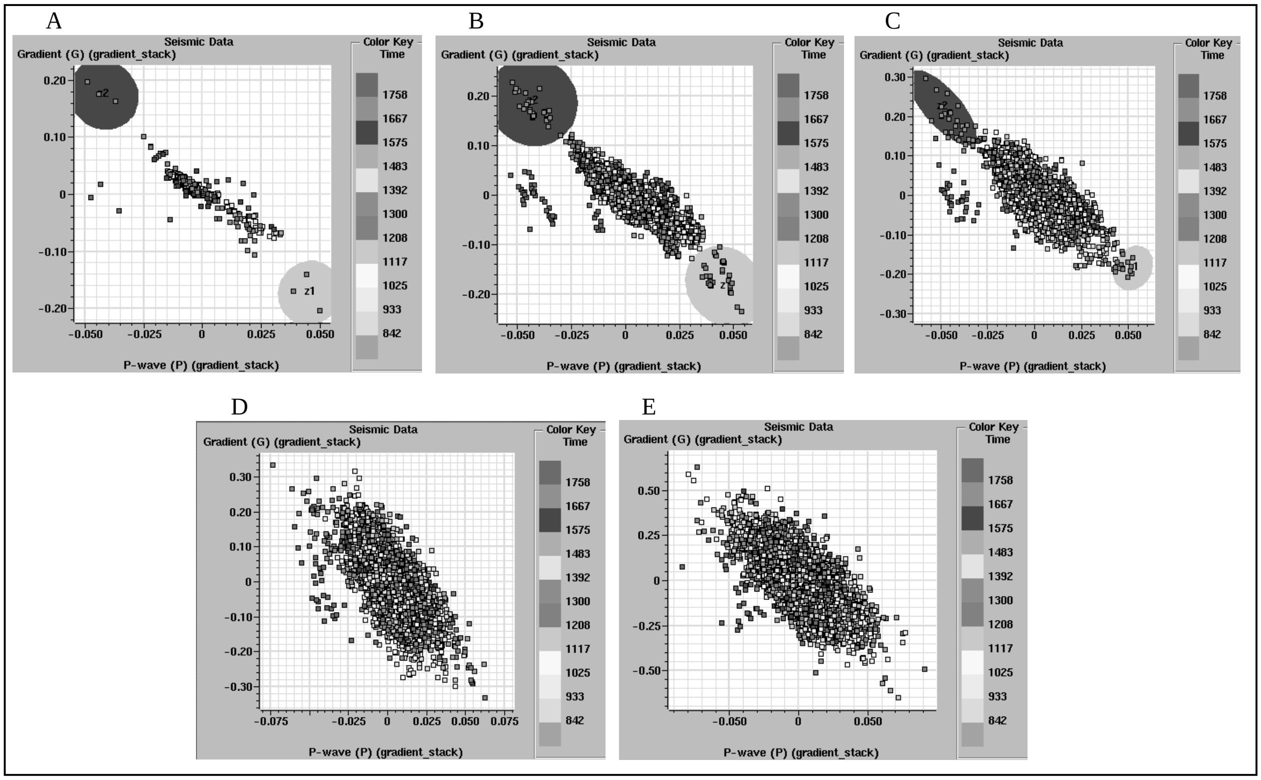

Figure 1. Class 1 sand with increasing amounts of noise. A) No noise. B) S/N=10. C) S/N=5. D) S/N=2. E) S/N=1. Yellow ellipse is the top of the sand, while the blue ellipse is the base of the sand. Window is 1100 ms and centered at 1300 ms.

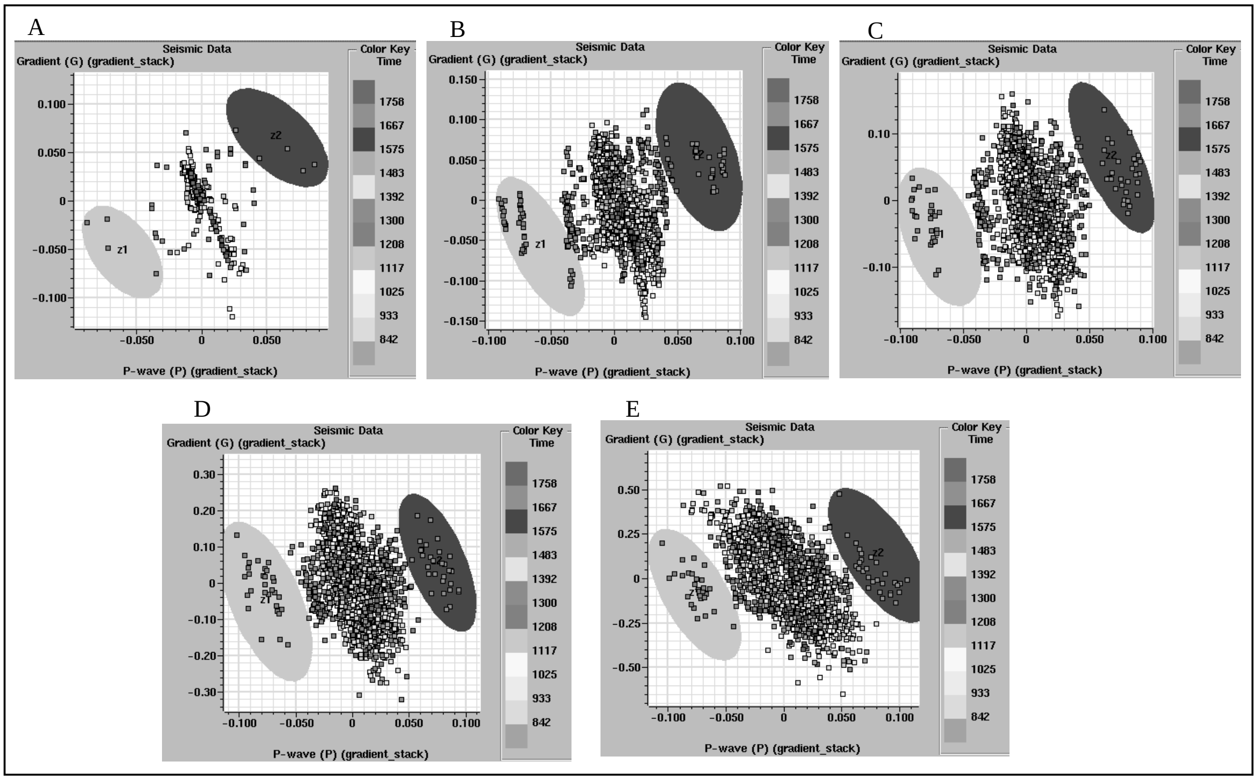

Figure 2. Class 3 sand with increasing noise. A) No noise. B) S/N=10. C) S/N=5. D) S/N=2. E) S/N=1. Yellow ellipse is the top of the sand, while the blue ellipse is the base of the sand. Window is 1100 ms and centered at 1300 ms.