AVO in Structured Areas

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ABSTRACT

Summary

Reservoir characterization using AVO and seismic rock properties in structured areas is of great interest but faces challenges. Some assumptions typically used in AVO processing, such as small dip and flat layer ray tracing, are no longer valid in structurally complex areas. This study explores some issues related to data processing in preserving offset dependent amplitudes in structured areas. In the study, ray tracing and elastic wave equation modeling are used to generate the data. Simple 2D structures and selected structural plays in the Arctic Basins and the East coast are studied to understand how offset dependent amplitudes in a structured area are influenced. To quantitatively determine the degree of the influence, the results of pre-stack time- and depth-migration are compared with zero-offset seismic attributes calculated directly form the geological models. The limitations and the methodologies using AVO analyses in structured areas are also explored.

Introduction

The analysis of Amplitude Variations with Offset in structured areas is important because the seismic image alone does not provide complete information to define a reservoir (Anna et al., 2002; Martin et al., 2002). As we know, amplitude preservation is one of important topics in seismic imaging (e.g., Dellinger et al., 2000; Duquet et al., 2000). Additional issues need to consider in AVO analysis in structured areas, including correctly positioning the signals, the amplitudes and determinng the angles of reflection at a common image or reflection point. It needs to be mentioned that small dip and flat layer ray tracing assumptions commonly used in typical AVO analyses break down as structures become complex. In this study, we attempt to examine these issues.

Our approach is to use the elastic rock properties and zero-offset P- and S-reflectivities calculated from the models as a benchmark for the seismically-derived elastic properties from pre-stack migrated gathers. The zero-offset attributes and elastic rock properties can be produced either directly from the models or from stratigraphic AVO modeling using Zoeppritz equation and ray tracing. The synthetic data to be processed by pre-stack migration is generated using full wave elastic finite difference method.

The fundamental aim of this study is to understand the influence of structure on offset dependent amplitudes. The ultimate goal is to explore the potential and limitations of data processing to correct for structure and honor pre-stack amplitudes in structured areas.

Geological models

A series of geological models are built to serve both theoretical and practical purposes. These models are designed with increasing geological complexity. Simple structure models are used first. The models are constructed with limited number of layers with single variable such as degree of dip. In the second type of models we incorporate well logs to take into account both geological and lithological influences. Structurally complex models are built based on typical plays in areas such as the Arctic Basins and the East coast of Canada.

Figure 1 shows an example of a geologic model constructed using well logs. For this model, two gas reservoirs are situated in the anticlines with a maximum thickness of 100 m and 50 m, respectively. This model has a lateral dimension of 9.5 km and a depth of 3.5 km. As this is a model with small dip, it is expected that the effect of structure on AVO is limited, and pre-stack migration will both preserve AVO and image the reflector.

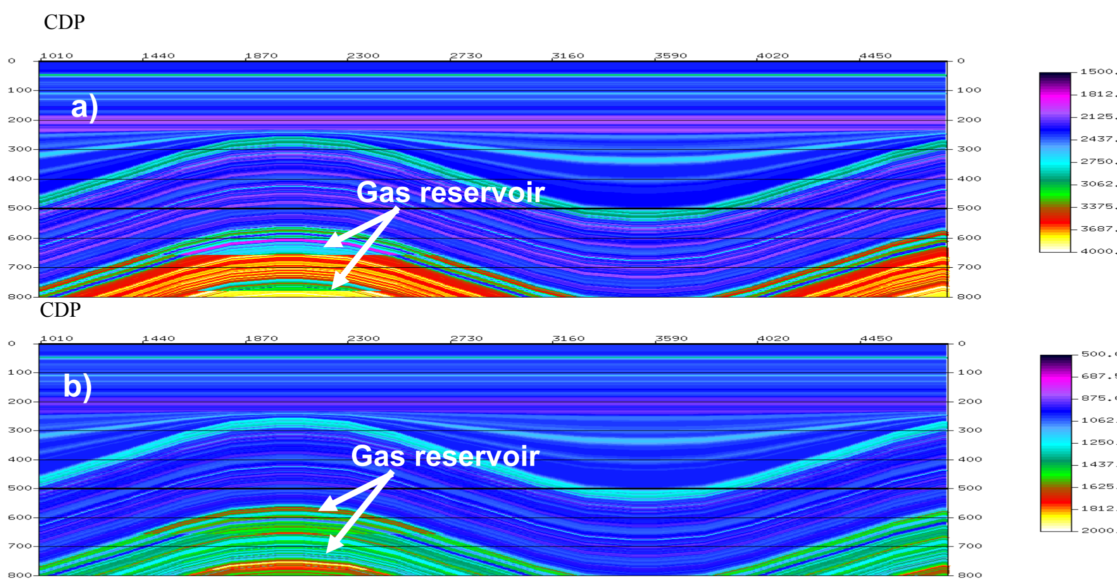

Fig. 1. P- and S-wave velocity for a model with small dip.

A relatively complex geological model is shown in *Fig. 2*. This model has the same lateral extension as the model shown in *Fig. 1* but with larger depth (6.5 km). The dips of the layers can be as high as 45 degrees. Together with the fault in the right wing of the anticline, it is expected the effect of structure on amplitudes can be significant. In this model, one gas-charged reservoir is embedded at the top of the anticline, and the other is located at the fault.

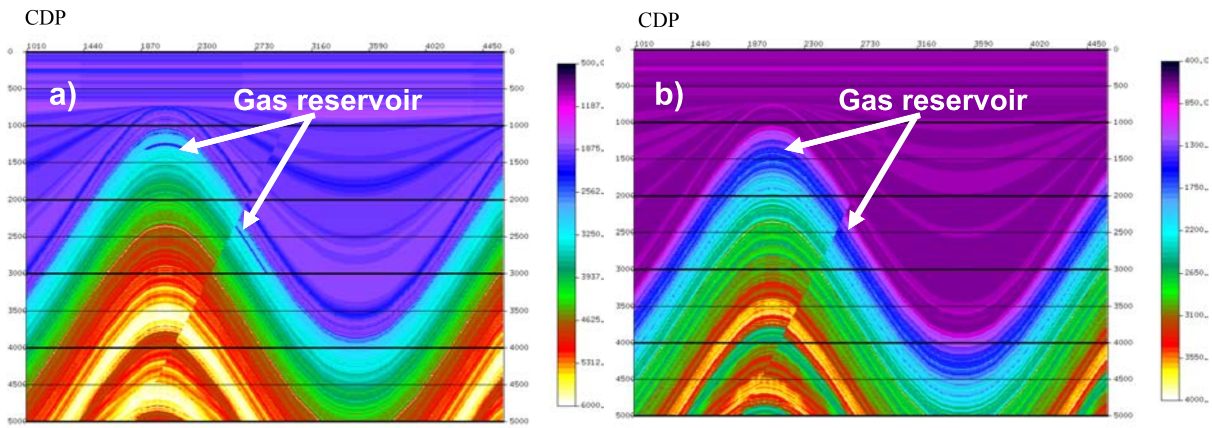

Fig. 2. P- and S-wave velocity for a model with large dip.

For each of the models shown in *Figs. 1 and 2*, one hundred and ninety-one synthetic shot gathers were generated using finite difference modeling. The source interval is 50 m, maximum offset is 2500 m for the first model and 6000 m for the second model. The receiver station interval is 25 m. The pressure source was used and it has a primary frequency of 40 Hz.

Pre-stack time- and depth-migration

The pre-stack migration methods used are Kirchhoff time migration, Kirchhoff depth migration, and wave equation shot gather migration. For the depth migration, ray tracing is used in generating the travel timetable.

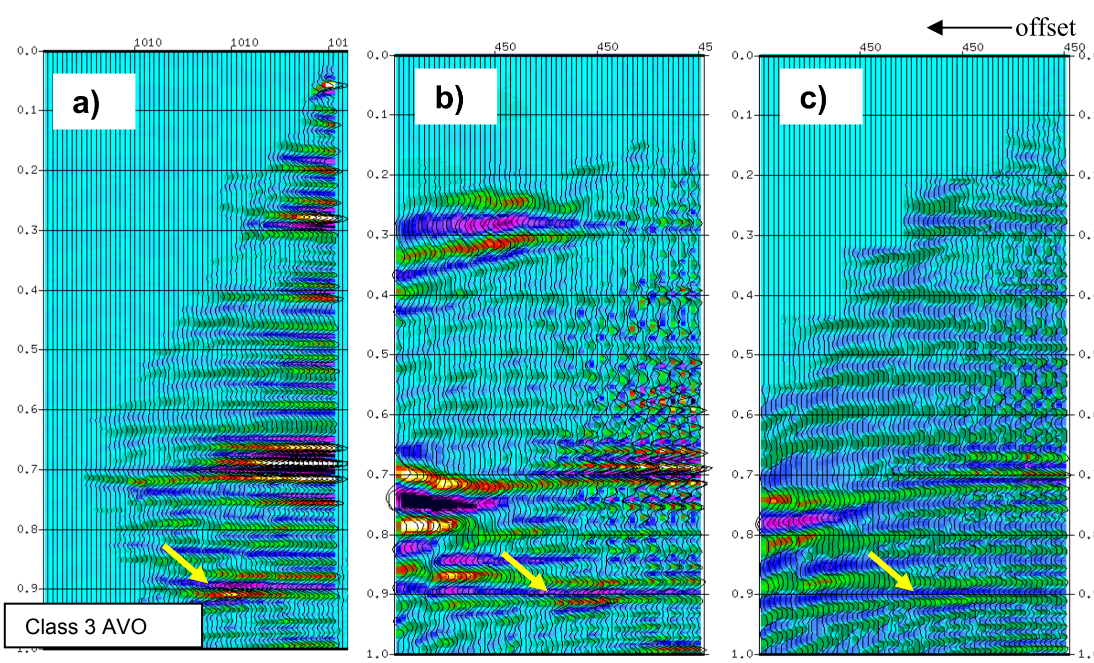

Fig. 3 a) input gather; b) after PSTM; c) after PSDM.

The preliminary test results using Kirchhoff time and depth migration for the (low dip) model in *Fig. 1* are shown in *Fig. 3*. For the depth migration, the velocity model has the grid size of 25 m. The ray is shot every 25 m. The depth increments are 5 m to a depth of 1000m, 10 m from 1000m to 2000m, and 15 m greater than 2000 m. The data at the location corresponding to the top of the anticline and the thickest part of the reservoirs is analyzed in detail. Figures 3a, b and c show the input CDP gather, the CDP gather after pre-stack Kirchhoff time and after pre-stack depth migration (converted back to time for comparison). For this specific location, time migration gives a better result: PSTM has preserved the offset dependent amplitudes. For example, we can see that the Class III AVO anomaly at 0.9 s corresponding to the deepest reservoir (Class III is a trough which brightens with offset) has only a small change after the migration. This is expected as the model has relatively small dip. The depth migration gives similar offset dependent amplitudes but it has relatively larger difference in comparison with the CDP gather before migration.

Conclusions

Angle-dependent reflectivities may be affected by both geologic structure and by data processing. This study investigates how structure affects AVO, and how the data processing, particularly pre-stack migration, is to properly image and preserve AVO behavior. AVO analysis in structured areas is studied using data generated by elastic finite difference modeling for various geological models, ranging from structurally simple to complex. Preliminary study using pre-stack migration yields results that show consistency with the prediction. Additional work is underway for generating more data and performing more quantitative analysis.

Acknowledgements

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