Summary

This paper outlines an elegant approach to interpreting and analyzing 4D data. With this technique, the average interpreter will be able to use multidimensional data to better distinguish between hydrocarbon-related anomalies and nonhydrocarbon-related amplitude anomalies.

Introduction

Ever since the Common Depth Point (CDP) method was invented, seismic interpreters have been looking at gathers for clues to help identify lithology and fluid changes. This paper introduces an idea for analyzing CDP seismic gathers from a completely new perspective. Figure 1 shows a standard display for observing the changes in seismic gather amplitude versus offset or angle. Typically, when an interpreter sees a notable change in amplitude with offset, the assumption is the cause is some type of fluid or lithology effect.

The problem comes in the interpretation and analysis of these types of views, because offset/angle gathers do not live in physical x/y/z space. Gathers live in the nonphysical x/y/z/offset space. Since interpreters do not interpret in the offset or angle dimension, the standard practice has been to ignore the gathers and simply interpret on near/far stacked offset volumes or to interpret on intercept/gradient stacked volumes. In many cases, this shortcut to gather interpretation has proven quite successful. However, in many other cases, this method has failed miserably. As Albert Einstein stated so eloquently, “For every complex problem, there is a simple solution … that is wrong!” Figure 2 demonstrates how interpreting amplitude changes on the stack volumes will fail, depending on which offsets were chosen to be included in the analysis.

Clearly, the offset range has an enormous effect on the intercept/gradient computation, sometimes even flipping the polarity as shown on three of the last four adjacent gathers in Figure 2. The stacking process itself...
also smears the amplitude signature and masks the fluid/lithology fingerprint held within the gathers.

In recent years, computer memory and visualization technology have become powerful enough to enable workflows for gather viewing and analysis in a 3D viewer. Unfortunately, the viewers are still just three-dimensional and, by definition, the full gathers cannot be displayed or interpreted at their true x/y spatial location because of the 3D limitation, which excludes offset or angle. This paper unleashes a method that allows interpreters to view, analyze and interpret gathers and other 4D data at their true x/y location.

**Method**

Several years ago, a clever geoscientist named John Kerr came up with an idea for translating prestack data into physical space. Kerr’s idea was to simply rotate every prestack amplitude into the vertical dimension. In this way the vertical dimension is overloaded with both time and offset data (or with depth and offset or angle data), while the x/y dimensions remain pristine. Figure 3 shows how the prestack amplitudes are rotated into the vertical dimension.

**AVO and other 4D reconnaissance**

Once the prestack offset cubes have been created, they can be immediately used for AVO interpretation and analysis within any standard interpretation system.

![Figure 4: Comparing all the prestack amplitudes to the stack section along structure easily uncovers the lateral extent of the AVO anomalies highlighted in red and yellow in the middle of the image.](image)

**Figure 4** shows a prestack offset cube hung on the associated structural reservoir horizon. Hanging the prestack cube on the structural horizon provides insights beyond standard structural mapping, as it allows interpreters to observe whether the gather amplitudes are geologically reasonable within the assumed stratigraphic framework.

When analyzing a prestack offset cube (such as the one displayed in **Figure 4**), it is critical to understand that the first amplitude in the cube is at the true x/y/z location. The following amplitudes are at an increasing offset or angle from the original amplitude. Therefore, the arrow pointing to “oil AVO amps” in **Figure 4** is showing red-hot amplitudes only at the far offsets, while the arrow pointing to “gas AVO amps” is showing red-hot amplitudes at all offsets.

Prestack offset cubes are not limited to just amplitudes, they can be used to analyze any prestack attribute such as phase, frequency and correlation. In fact, any 4D or multi-D data can be displayed with this patented technology. **Figure 5** shows the same concept applied to temperature from Precambrian through present day of a 4D basin model.

The geologic history cube can be used to quickly identify areas within a basin that have spent extended geologic time in the “Golden Zone” between 80° and 120° C. Other basin model data, such as pressure, can also be converted into this novel type of interpretation cube. In general, these cubes can be used for data mining and QC.

When viewing these cubes in a 3D viewer, interpreters can analyze hundreds of thousands of gathers or simulation results all at once at...
their true spatial locations, which allows interpreters to easily map the lateral and 3D extent of any 4D anomaly. In the prestack world faults, multiples, noise and mute issues can be observed as trends in the prestack offset cubes. In the basin modeling workflow, interpreters observe anomalous regions throughout the basin’s history.

**Conclusions**

As shown, offset cubes simplify the tie between the 3D geologic/reservoir environment and the 4D prestack seismic amplitude or basin model environment. Adding offset cubes to the interpretation toolkit can lower the risk in well siting by helping resolve some of the ambiguity associated with lithologic and fluid identification versus noise and other processing artifacts.

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