Turning the world of prestack interpretation sideways
Larry Fink, Landmark Graphics.

Summary
This paper outlines an elegant approach to interpreting and analyzing prestack seismic data. With this technique, the average interpreter will be able to use prestack seismic to better distinguish between hydrocarbon-related amplitude anomalies and non-hydrocarbon-related amplitude anomalies.

Introduction
Ever since the CDP method was invented, interpreters have been looking at gathers for clues to help identify lithology and fluid changes. This is a case study in 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, they assume 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 non-physical 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.

Figure 1: The bottom image shows an auto-tracked, auto-interpreted, prestack horizon in green. The header plots, displayed above the gathers, are standard amplitude-versus-offset (AVO) displays of the horizons amplitude, which show significant changes in amplitude versus offset.

Figure 2: In the header, the green line is amplitude auto-tracked across a set of adjacent gathers. The red line is a standard limited offset intercept/gradient computation. The blue line is a more severely limited offset intercept/gradient computation.

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 has 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...
Turning the world of prestack interpretation sideways

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 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. John’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.

Figure 3: Steps 1 and 2 show how the prestack amplitudes are transformed so they can be viewed at their proper x/y location. Step 3 shows the amplitudes from 700 gathers flattened on an input poststack reservoir horizon.

The output of this rotation is called a "prestack offset cube".

AVO 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 shows a prestack offset cube hung on the associated structural 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.

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.

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. Figure 5 shows some prestack attributes in a header plot. Just as amplitudes can be rotated into prestack offset cubes, so can any other prestack attribute.
Turning the world of prestack interpretation sideways

**Figure 5:** Other attributes (such as prestack phase, frequency, pick deviation, and correlation) can be rotated into prestack offset cubes. In addition, these attributes can be useful in lithology/fluid analysis as simple header plots, as shown here.

**Gather QC and other prestack analysis methods**

The prestack offset cubes are also valuable tools for prestack data mining and QC. Figure 6, on page 4, shows how faults, multiples, noise, and mute issues can be observed as trends in the prestack offset cubes. In the gather QC workflow, interpreters observe anomalous regions in the prestack offset cube and compare those regions to the true full gathers within the anomaly. Be aware that there is no substitute for viewing/analyzing the native gathers! The prestack offset cubes are invaluable in the gather QC workflow in that they allow interpreters to map the lateral extent of the anomalous zones associated with the full gathers.

Beyond gather QC, the prestack offset cubes can be used to detect many subtle anomalies when differencing seismic data from different processing vintages or from 4D surveys. Figure 7 shows the differencing of two different vintages of prestack data. This is equivalent to differencing 31 different stack volumes, as the prestack fold in this case is 31 angle traces per gather.

**Figure 7:** There is much more detail in prestack difference cubes than in stack difference cubes, when looking for bypassed pay or just QC'ing the difference between seismic processing algorithms as shown above.

Another attribute of the prestack offset cube is the ability to simply view and interpret all the gathers within a standard interpretation system. Figure 8 shows how a survey of 700,000 gathers is easily viewed and analyzed in true 3D space.

**Figure 8:** Viewing hundreds of thousands of gathers all at once in their true spatial locations in a 3D view allows interpreters to easily map the three-dimensional extent of any prestack anomaly.
Conclusions

As shown, prestack offset cubes simplify the tie between the 3D geologic/reservoir environment and the 4D prestack seismic amplitude environment. Adding prestack 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.

Acknowledgements

I would like to thank John Kerr for coming up with and patenting this technique under US Patent No. 7,319,637, issued January 15, 2008. I would also like to thank Statoil for the use of some of their data from a 1986 survey. Lastly, I would like to thank Landmark for allowing me to present this new idea of turning prestack sideways.

Figure 6: On the left, offset cube gathers from five different geologic interfaces are observed. On the right, are some of the native gathers associated with the indicated prestack offset cube anomalies. This view shows how trends in prestack offset cube amplitudes can indicate faults, multiples, noise, AVO, et cetera. When a trend is observed in the offset cubes, then the associated full gathers need to be viewed and analyzed for proper due diligence of the amplitude analysis.