Continuous High Resolution Velocity as a 4D Attribute

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Abstract

4D (also known as time-lapse or repeat) seismic has in the past few years emerged as a significant technique for monitoring fluid movement within reservoirs.

Understanding the relationship between changes in petrophysical parameters and the corresponding change in seismic response has enabled geoscientists to monitor various changes in fluid content within the reservoir and surrounding rocks.

In this work, we assess the potential of another seismically derived attribute, namely velocity, as an indicator of reservoir change in the context of a 4D study.

Introduction

In recent years, an improved understanding of the petrophysics of the reservoir (eg. Wang, 2001) has enabled geoscientists to establish relationships between observed seismic attribute changes, and corresponding rock property changes.

Once it was established that such additional information could be extracted from surface seismic data (eg. Lumley, 1995, 2001), changes were made to seismic data processing sequences so as to better preserve relative amplitude changes, especially with regard to pre-stack differences between data vintage subsets (Harris & Henry, 1998).

Monitoring of changes as diverse as temperature (as in the case of steam injection: Lumley, 1995) and movement of fluid contacts have proved attainable and successful (Jack, 1997).

Here we present an application of a technique for estimating the velocity associated with pre-stack time migrated data to monitoring 4D change.

Previously, one of us (Jones & Baud, 2001) demonstrated the potential of a dense velocity estimate as a high-resolution tool for visualizing subtle changes not clearly discernable in the seismic amplitude response.

Success of such techniques depends to a large part on the data being correctly pre-stack migrated, so that all diffraction energy is correctly collapsed.

The Method

The technique employed here is slightly different than that described by Jones & Baud, but the objective is the same: estimation of an RMS velocity value for each pre-stack migrated CMP along a given horizon.

Perhaps the most restrictive assumption in these approaches is that of parabolicity in the residual move out (after NMO). Similar assumptions are common to most residual velocity analysis techniques, but from inspection of the data, the assumption is seen to be frequently violated to some degree. This can be an important drawback, as occasionally application of the residual moveout can degrade the stack for areas where the moveout was not parabolic.

Whereas previous techniques worked with scan-based RMO velocity analysis of CMP gathers (eg. de Bazelaire, 1988, Doicin et al, 1995, Jones, et al, 2000), in this work we employ a map manipulation approach.

Here we take the near and far trace stacks from the two data vintages (1984 & 1999) in conjunction to the interpreted time horizon for a key reservoir marker and the RMS stacking velocity field associated with this marker. The initial velocity field was determined from the superior 1999 survey, and applied to both data vintages during processing (for the purposes of NMO, DMO, and preSTM).

Using the interpretation as the center for a windowed operator, we perform a cross-correlation of the near and far stacks for a given data vintage. This yields an estimate of the residual time shift between the near and far traces. This is stored as an horizon based map of values.

Using an approximation for the parabolic residual moveout equation (Castle, 1994), we convert this time shift map to an associated RMS velocity map for the horizon of interest. This is done for each data vintage.

Differences between the resulting two continuous high-resolution velocity fields are inspected as an indicator of changes in fluid content for markers in the reservoir interval, and for other effects for markers outside the reservoir interval.

Norwegian North Sea Example

The example shown is from the Ula North Sea oil field, in the Vestland Arch in the Norwegian-Danish basin. The main reservoir is capped by the Top Ula event. Above this, we have the BCU horizon, which being outside the reservoir should not show production related effects. Analysis of the BCU event was used to check for non reservoir related acquisition related problems.

It was observed that we had consistent changes between the 1984 and 1999 vintages outside the reservoir (on the BCU event). This was interpreted as being related to the acquisition differences: the surveys were shot orthogonally. The small velocity changes measured at the BCU may be indicative of azimuthally anisotropic velocity variation in the overburden.

In figures 1 & 2 we see the seismic amplitudes extracted from the 1984 & 1999 preSTM volumes for the BCU horizon. A rough interpretation of the crestal fault is superimposed on the map in addition to the 3190ms contour of the BCU. Differences at the BCU are assumed to be related to the differing acquisitions, and not production related.

In Figures 3 & 4, we have the RMS high resolution velocity maps for the BCU, estimated with a trace sampling of 50m * 50m for the 1984 and 1999 data vintages. In figure 5, we see the difference map showing velocity variations of between +-25m/s in the crestal region.

It can be seen that we have distinct regions within the crestal zone. The area to the right of the fault, shows up in red-brown colours, corresponding to a velocity about 10-20m/s lower in the orthogonal 1999 data. To the left of the fault, we have a yellow-orange region showing little or negative change.

The map of the difference in stack amplitude for the BCU (figure 6) shows a more patchy appearance. Again, this is probably related to acquisition differences, as we would not expect to see production differences for this horizon.

Conclusions

We have shown that high-resolution continuous horizon consistent velocity estimation can be used to deliver a 4D attribute. In conjunction with petrophysical data, we will assess the significance of this information, and contrast it with other ‘conventional’ 4D difference attributes.

Interestingly, the figures shown here deal with an acquisition artifact. The imprint of this artifact on the reservoir attribute maps must be taken into account during interpretation.

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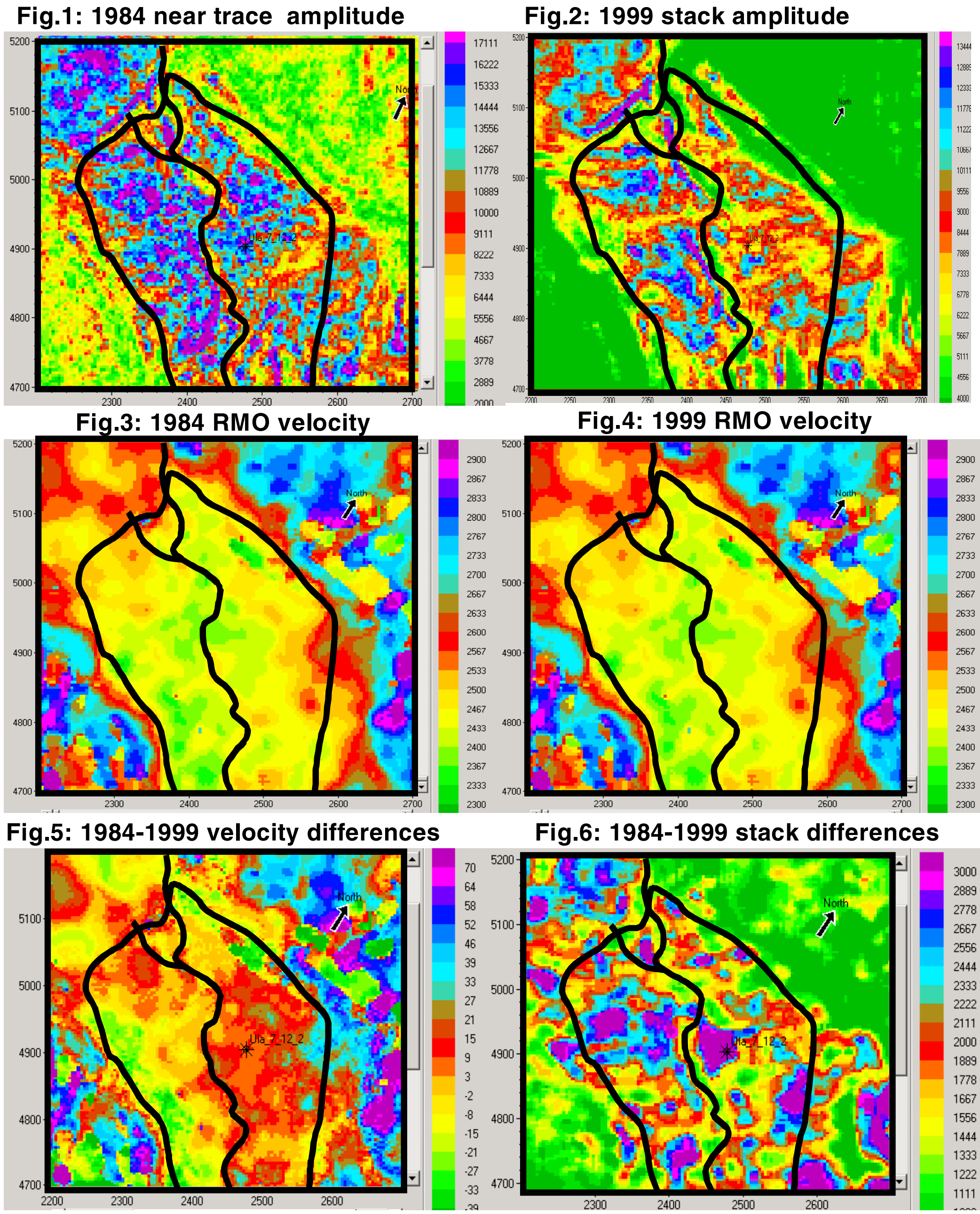

Maps for the BCU with the 3190ms BCU contour & fault superimposed