Resolving shallow velocity anomalies through velocity model building and depth imaging–A case study from Kutch Saurashtra area, W.Off.Basin, India.

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Abstract

An accurate velocity model estimation is one of the most important factor in seismic imaging and subsequently interpretation. Non-removal of shallow velocity anomalies can reduce the quality of the post stack image, i.e., degrade deeper imaging and create time distortions in seismic horizons. Therefore, before building velocity model for deeper horizons we must ensure that all significant near surface effects have been removed. In order to incorporate near surface velocity anomalies into the model, a range of option can be used, depending on whether geobody geometry alone is discernible or whether its velocity distribution is also known. Here we describe, when we can only see the base of the geobody on a stack section, but due to low foldage, we were not able to measure its velocity error in CMP gathers. Although building complex near surface model is a time consuming, but very effective in proper imaging of events at deeper level.

Introduction

Compensating for near-surface small-scale velocity anomalies is a difficult and demanding task, and is usually dealt with very approximately (e.g., Armstrong et al., 2001; Jones, 2010). Here, I describe for shallow marine environments where we have limited fold and discernible geobody geometry. This analysis is in the context of building velocity-depth models for 3D pre-stack depth migration (PreSDM).

All raypaths that pass through a near-surface velocity anomaly will be affected by it, distorting the subsurface response over a distance of about half a cable length to either side of the anomaly. The distorted region actually extends beyond half a cable length due to the influence of the Fresnel zone, because we are really dealing with wavefronts rather than hypothetical rays. In addition, conventional velocity analysis and time processing deals with all traces in a common midpoint (CMP) gather using the same 1D velocity function; hence conventional time processing cannot compensate for these effects.

It should be noted that both NMO-corrected and prestack time migrated (PreSTM) data, even with the 'correct' velocity model, will exhibit the push-down distortion, as neither can correctly deal with the velocity anomaly of short spatial wavelength. In other words, both NMO and PreSTM make the assumption that all traces in a CMP gather should be processed with the same 1D velocity-time function pertaining to that CMP location. The actual velocity function may change laterally, but at any given CMP, traces from all offsets in the gather are treated as if they propagated in the same laterally invariant velocity-time field.

A steamer 3D data set was processed through PSTM and a reasonably good image volume was obtained. During interaction with interpreter, there was an apprehension about the structural low seen below 160 ms two-way time on the PreSTM image (figure 1). This observations underline the fact that there is no such thing as a 'correct' PreSTM velocity model, we can only compromise with ignoring lateral velocity change, whilst trying to flatten reflection events in a CMP gather. The consequence is that image distortion remains below velocity anomalies. Issues like this are not uncommon and can be solved by conventional PreSDM process with the appropriate velocity model.

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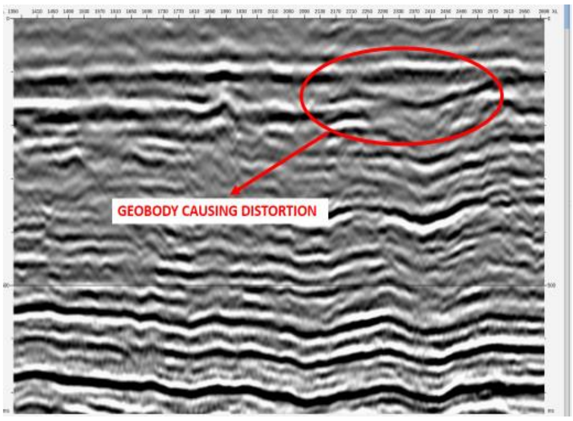

Figure 1: The Kirchhoff PSTM stack using correct velocity section shows that the push down image distortion is clear throughout the migrated section.

Ideally we would like to have the top and bottom of the body mapped and subjected to velocity analysis.Then a few tomography iteration would be sufficient to address the problem. However the acquisition geometry does not leave sufficient traces to perform conventional velocity analysis for the shallow body. A different approach was used to fix the problem. The shallow geobody was mapped. A series of velocities were assigned to it and the effects on image gathers at deeper level below it were studied. A final velocity was arrived at which gives a reasonably flat gathers. One way to validate the model could be deriving a shallow velocity model from the first arrivals (refraction part) of the data.

Geology

Kutch Saurashtra basin is the earliest rift basin that initiated as a result of north and northeast drifting coupled with counterclockwise rotation of the Indian plate after its detachment from the Gondwana land during Late Triassic/or Early Jurassic. The structural style of the basin is unique. Nowhere in India is a similar style to be seen. On the land part the basin is distinguished by highlands that are the area of uplifts and plains that are the basins between the uplifts. In the offshore part of the basin, four major ridges with intervening depression, sub-parallel to the ridges identified in the on land part, are indicated by the geophysical and geological data. The southern-most of these offshore Ridges is popularly known as the Saurashtra arch. The Saurashtra arch, which is a prominent basement arch, forms the southern limit of the basin, whereas the Nagar Parkar – Tharad Ridge, exposed as Nagar Parkar hills and Maruda Hill of Precambrian age, forms the northern limit of the basin. These roughly east-west trending, tectonic elements are cross-cut by the Kori-Comorin depression and the Kori-Comorin Ridge, in the deeper shelfal part of the basin, and numerous margin-parallel horsts and graben of smaller dimension in the shallower shelfal part. The Radhanpur-Barner arch forms the eastern limit of the basin. The Laxmi-Laccadive depression and the Laxmi-Laccadive ridge are indicated by the gravity data to extend from the south to the southern deep-sea region of the basin.

Methodology

In the present scenario where we have poor data quality, perhaps due to low fold, where we are unable to pick moveout in gathers, so have no direct way to estimate velocity error, but are still able to pick the base and top of the geobody on a stack, we can proceed using a trial velocity within the geobody. The trial velocity might be estimated from assessing deeper pullup or push-down, or simply be a guess confirmed using a velocity scanning technique.

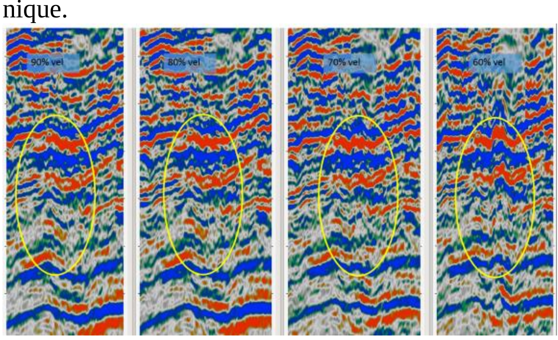

Figure 2: PSDM stack showing results of Velocity scanning

A geobody 160ms below the seabed was identified which is causing distortion of structure (push-down). The top and base of the geobody was picked to define the geometry of the geobody based on final PSTM stack volume. The geobody were picked on a dense localized grid of inlines and crosslines. A different velocity stating from 90 % to 60% of the initial velocity inserted into the geobody and PSDM was run each time using these velocity`(Figure 2).In figure 2 it shows that as velocity decreases distortion increases. Following this procedure further tomography was run to update the velocity model.

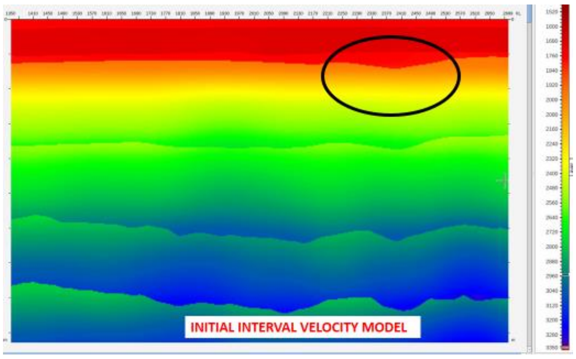

Figure 3: Initial interval velocity model showing the location of geobody (black coloured circle).

Results and Discussion

If we were to use a smooth velocity model to perform imaging using PreSTM, we would be unable to resolve these small-scale features, which are typically 100–130 m in width. The 3D PreSDM image was created using a smooth background velocity field i.e. initial interval velocity (figure 3), the push-down is visible. The push down effect is seen clearly on PSDM stack section (figure 4).

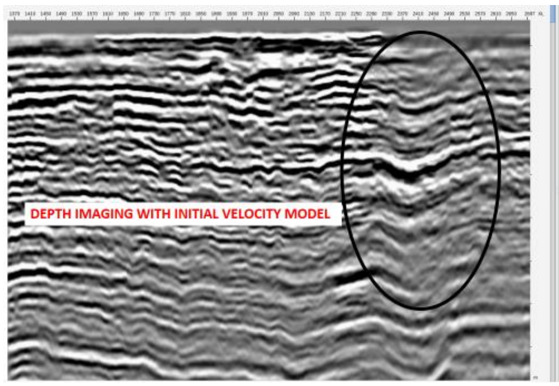

Figure 4: The Kirchhoff PSDM stack using initial velocity section show that the push down effect (black coloured circle) is present on the section.

Following a migration velocity scan to determine the best geobody-fill interval velocity, a PreSDM using the geobody-fill model was created (figure 5).

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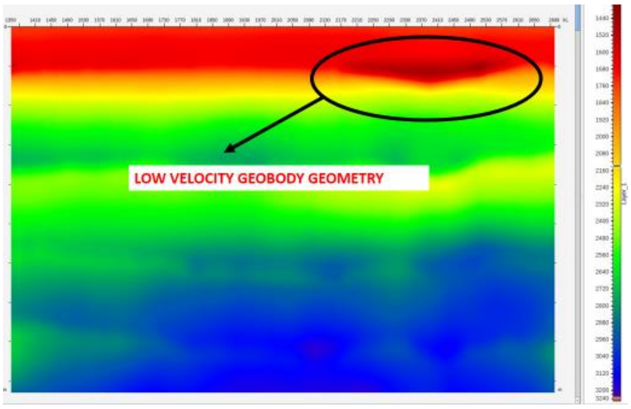

Figure 5: Final interval velocity using geobody fill model.

The PSDM section (figure 6), indicating the low velocity geobody and imaging improvement.

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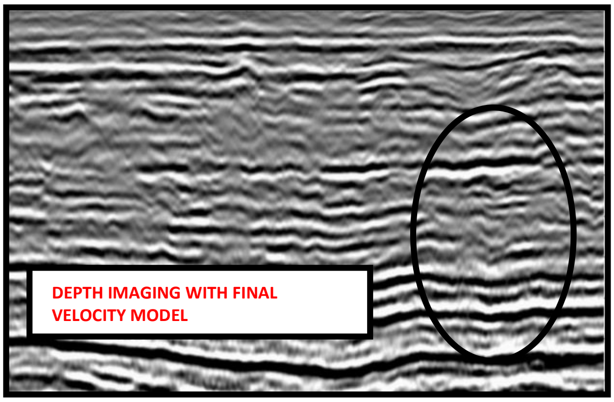

Figure 6: The Kirchhoff PSDM stack using above velocity section show that the improvement in migrated section is significant.

We resolved the shallow velocity anomaly problem by incorporating velocity scan of the geobody enables better resolution in the deeper section. Ignoring them is not a viable option.

Based on trial velocities run and corresponding PSDM, it was observed that 90% of the initial velocity giving lesser distortion on PSDM section, thus removing push down effect. After selecting the velocity of the causative body i.e. geobody a tomographic run was carried out where sufficient offsets are available for improvement of velocity. This updated velocity was used in final PSDM.

Conclusions

Resolving of near-surface velocity anomalies remains a challenging jobs. Failure to resolve such anomalies severely restricts our ability to adequately image deeper geological structure; hence some form of solution to the problem is imperative. The techniques described here commonly do offer the possibility of resolving many of the image distortion problems caused by near-surface velocity anomalies specially where tomographic updates does not gives good result due to lack of offsets.

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