Accurate Depth Conversions Reduce Risk

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Abstract

That accurate depth conversions reduce risk is not a new concept. The challenge lies in the proper selection of velocity data and model types that will generate accurate depth maps for evaluation and drilling of prospective areas.

Velocity information is available from a number of different sources. Well velocity data are available from checkshots, vertical seismic profiles, sonic logs and geological tops. Seismic imaging velocities (stacking and migration) are interpreted from various seismic processes (2D/3D DMO, 2D/3D Prestack Time and Depth Migration) of the seismic data.

The type of model (imaging or depthing) and procedure selected is influenced by available data, lithology and the geophysical acquisition and processing parameters.

Our example illustrates the prospect resolution benefits using all available velocity data for an area of interest. We will also show the refinement gained by integrating other interpretations such as a seismic-derived fault interpretation and a salt configuration from a 3D-gravity model.

Introduction

The source of velocity data takes on importance when designing a time to depth conversion velocity model. The geologic problem and the types of data available determine the type of model. Various stages of seismic processing techniques generate various processed velocities. Some work for depthing others, do not. Pseudo and real velocity data derived from well information, such as check shot surveys, vertical seismic profiling (VSP), sonic logs, or time-depth pairs, maybe the most accurate for a particular location but unfortunately the least in number. The chart, Optimum Data for Velocity Models, (see Table A) is a guide for the interpreter in his selection of velocity data types to input into depth conversion velocity models. We will next discuss the advantages and disadvantages for each data type.

Well Velocities

The data the interpreter never has enough of are the velocity measurements taken at well locations; check shot and VSP. These data give the most accurate measurement of vertical velocity to the bottom of the well and are normally used as control data for velocity depthing models. Recalculation, editing and/or extrapolation processes of these data are required. Consistency and expertise are paramount.

Advantages to using Well Velocities

- Most accurate measurement.
- Data are available for purchase (inexpensive).

Disadvantages to using Well Velocities

- Data measurements are only as deep as the well.
- Extrapolation is required for extending control below total depth of well.
- Recalculation/editing is required of each check shot and VSP to insure data reliability.
- Limited number of control values and points.

Sonic Log Data

The use of sonic log data in velocity models is not a new concept. However, it is, the most underutilized available measurement of very accurate vertical velocity. Since a sonic log only measures the interval velocity and normally has very limited near surface velocity information, an accurate initial or starting velocity is required to generate valid average velocity data.

Advantages to using Sonic Log Data

- Accurate measurement of vertical velocity.
- Data are available for purchase (inexpensive).
- There are more wells with sonic logs than with check shots.
Table A. Optimum data for depth estimates.

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<th>Optimum Data for Depth Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>WELL VELOCITIES</td>
</tr>
<tr>
<td>Check Shot Data/Vertical Seismic Profiling</td>
</tr>
<tr>
<td>Sonic Log Data</td>
</tr>
<tr>
<td>Well Top Data</td>
</tr>
<tr>
<td>IMAGING VELOCITIES</td>
</tr>
<tr>
<td>3D Prestack Depth Migration</td>
</tr>
<tr>
<td>3D Prestack Time Migration</td>
</tr>
<tr>
<td>3D Post Stack Depth Migration</td>
</tr>
<tr>
<td>3D Post Stack Time Migration</td>
</tr>
<tr>
<td>3D Stacking Velocities (with DMO)</td>
</tr>
<tr>
<td>2D Prestack Depth Migration</td>
</tr>
<tr>
<td>2D Prestack Time Migration</td>
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<td>2D Post Stack Depth Migration</td>
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<tr>
<td>2D Post Stack Time Migration</td>
</tr>
<tr>
<td>2D Stacking Velocities (with DMO)</td>
</tr>
<tr>
<td>2D Stacking Velocities (no DMO)</td>
</tr>
<tr>
<td>GEOPHYSICAL INTERPRETATION</td>
</tr>
<tr>
<td>Time Interpretation</td>
</tr>
<tr>
<td>Fault Interpretation</td>
</tr>
<tr>
<td>Gravity Interpretation (salt/basalt models)</td>
</tr>
<tr>
<td>Magnetic Interpretations (basement model)</td>
</tr>
</tbody>
</table>

Disadvantages to using Sonic Log Data

- A valid initial velocity is required.
- Recalculation/editing is required of each sonic log to insure data reliability.
- Data measurements are only as deep as the well.
- Extrapolation is required for extending control below total depth of well.
- Limited number of control points.
- A digital “LAS” format tape/file is required.

Disadvantages to using Well Tops

- Limited number of control values (tops) per well location.
- Shallow and deep extrapolation is usually required.
- Limited number of control points.

Imaging Velocities (Stacking and/or Migration)

Imaging velocities are defined, as the velocity required to best image data in the stacking and/or migration processing sequence. A long acquisition streamer or cable length is necessary to obtain accurate deep velocity information. General rules concerning imaging velocity data are:

1. The streamer or cable length should be longer than or equal to the depth to the deepest structural objective.
2. Velocity measurements derived from data deeper than the streamer or cable length are very interpretative.
3. With the latest “state of the art” migration algorithms imaging velocity measurements are being calculated from seismic data that have been migrated to an accurate subsurface position. Prestack depth migration

Well Tops

Well top data is a correlation of seismic time to a measured well depth. These data can give a velocity model additional constraint where well check shots and sonic logs are not acquired. Errors occur when the correlated seismic times and well depths do not correlate with well check shot and sonic log times.

Advantages to using Well Tops

- Accurate vertical velocity measurement correlated to seismic times.
- The well top data is individually interpreted.
algorithms are the most accurate, followed by prestack time and DMO algorithms.

4. All imaging velocity data used in generating depth estimating velocity models should have at least a partial migration (DMO) applied.

5. All imaging velocity data used in generating depth estimating velocity models should have at least a partial migration (DMO) applied.

Advantages to using Imaging Velocities

- Seismic velocity data are abundant.
- Velocity data are densely spaced (500-meter grid).
- Velocity trends are good to a depth equal to the length of the streamer/cable.
- Velocities can be correlated to well data.

Disadvantages to using Imaging Velocities

- Velocity information is not acquired in a vertical direction only.
- Velocities are interpreted to image seismic events (stack/migration process).

Interpretation Data

Additional information from seismic and another geophysical interpretations can refine and improve depth estimating:

1. Fault interpretation - By adding fault control the velocity gradients are more accurately contoured and truncated in the velocity models.
2. Time interpretation - By adding the time interpretation one can calibrate the velocity model to the seismic time interpretation instead of the check shot times.
3. Gravity interpretation - Replacement techniques can be applied to the velocity model utilizing structural configurations determined from a 3D gravity model. This is especially useful in salt or basalt regimes.

Advantages to using velocity information derived from geophysical interpretation

- Velocity slices can be structural horizons instead of time slices (from sealevel or water bottom).
- Velocity model can be modified to tie seismic interpretation depth maps with well top data.
- Faults planes or other interpreted geological boundaries are optional.
- Sediment velocity models can be updated with interpreted Salt and/or Basalt models.

Disadvantages to using velocity information derived from geophysical interpretation

- Requires completed geophysical interpretation.
- Requires updating for any geophysical interpretation change.
- The important point is to use all available velocity information when building accurate depthing velocity models.

GOM Example: Depthing Velocity 3D Model

The area shown is in the deep water Gulf of Mexico. There is a large salt body with a very questionable base of salt reflector on the 3D seismic data. It is the intent of the example to illustrate the differences obtained in the depth results from depthing velocity models derived from the following:

1. Well velocity data.
2. Imaging (stacking) velocity data.
3. Editing and calibration of the well and imaging data to generate a clastic sediment velocity model.
4. Recalibration of the clastic sediment velocity model with the fault interpretation.
5. Replacing sediment with salt velocity using gravity interpreted salt model.

Techniques for velocity modeling vary due to different lithology and quality of available data. But by using all the information (well, seismic and interpretation) as described, one will generate accurate depth maps. These maps will provide improved economics in determining area and volume for potential and proven reservoirs.

As a closing thought, we would like to remind all explorationists that the intent of 3D prestack depth migration processing is to image the data. It is a prospect tool for placing the seismic reflections in an accurate lateral position, but normally not at a correct depth. The drill bit requires accurate depth estimates for cost effectiveness.
Notes