Pre-Stack Can Avoid Distortions

(Editor's note: The Geophysical Corner is a regular column in the EXPLORER and is produced by the AAPG Geophysical Committee.)

By RICHARD POSTMA

A problem that has always plagued geologists and interpreting geophysicists is the fact that seismic data resemble a cross-section of the earth, but are displayed in time rather than depth.

To tie well control to seismic, well logs must be scaled to time, using check shot surveys or velocity functions derived from other means. The vertical exaggeration changes with depth (because velocity usually increases with depth), thus distorting the perspective and changing the apparent dip of fault planes, etc.

These problems, however, are minor compared with the structural distortions that occur when velocity varies laterally as well as with depth.

A solution to these problems exists in the development of pre-stack depth migration.

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One of the principal motivators behind development of pre-stack depth migration was the desire to

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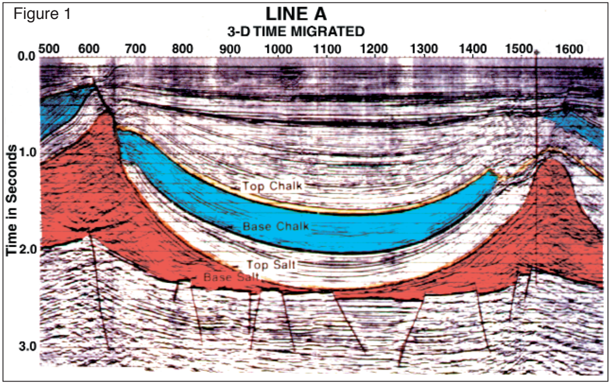
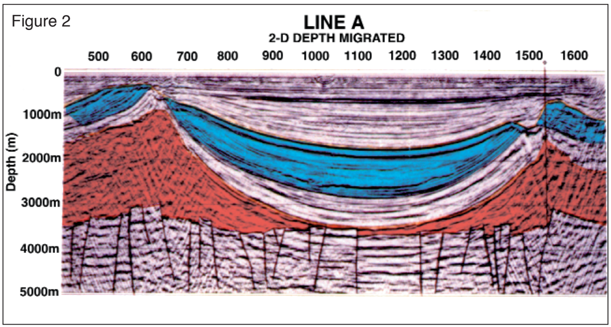
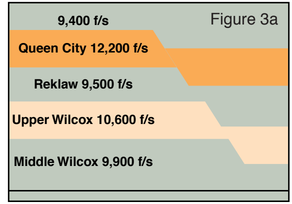






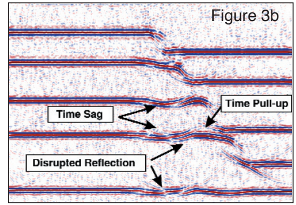


Figure 1 shows a 3-D time-migrated line across two salt domes. Note severe distortion of base salt between S.P. 500 and 700. A well was drilled near S.P. 1520. In Figure 2, a 2-D prestack migrated line of the same area provides improved imaging beneath the left salt dome, movement of fault image near the well, beneath the right salt dome. The well is now down thrown to the fault. Figures 3a and 3b show what can happen if faulting displaces beds with anomalous velocity; 3a is a fault shadow model, and figure 3b is an example of post-stack migration of synthetic data.

Graphics courtesy of Richard Postma

Figure 4

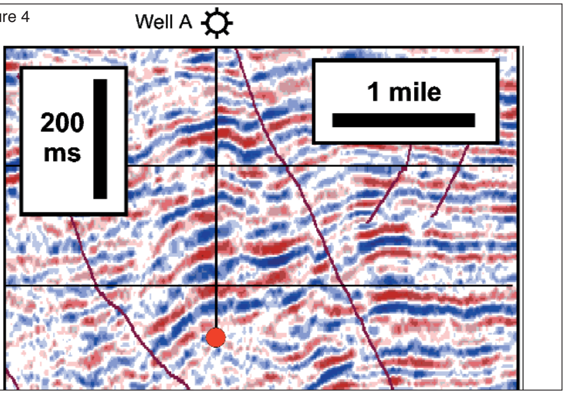
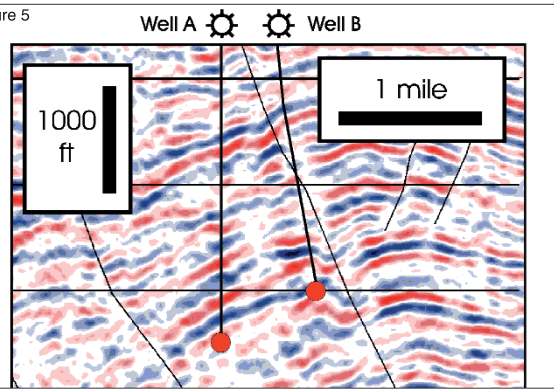


Figure 5



These figures show a comparison of a seismic line in South Texas, with time migration poststack time migration (left) and prestack depth migration (right).

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image seismic reflectors beneath salt structures. The abrupt velocity contrasts between the salt and adjacent sediment – coupled with the sometimes radical structural features associated with salt tectonics – produced severe distortions in the seismic travel times.

The result is frequently a very poor stack and time pull-ups in the events that do stack.

Time migration incorrectly migrates the distorted events because of the rapidly varying lateral velocities. An example of this from the Southern North Sea gas basin is shown in figures 1 and 2.

Figure 1 is the 3-D time migrated line from a survey across two salt structures. The objective is the Rotliegendes sand beneath the Zechstein salt. The greatest velocity contrast is actually between the Cretaceous Chalk that has been forced upward by the salt movement, and the overlying Tertiary clastics.

It is this Tertiary-Cretaceous boundary and the structure on it that produces the greatest distortion.

Severe distortions can be seen in the Base Salt/Top Rotliegendes reflector beneath each of the structures. The event actually criss-crosses in a reverse “bow-tie” beneath the left-hand structure. An apparent fault is seen beneath the right-hand structure.

Prestack depth migration, shown in figure 2, reveals a very different picture. The “bow-tie” under the left structure has been unraveled, revealing a much more clearly imaged and have moved somewhat.

Note the well that was drilled with the intention of reaching the upthrown side of the fault (figure 1). It, in fact, went to the down-thrown side, as seen in the depth image (figure 2), and reached the base of salt at exactly the depth indicated in the depth section (about 300 meters low to prognosis, as interpreted from the time section).

Another more subtle example of the value of prestack depth migration is the “fault shadow” problem. Figure 3 illustrates, with model data, what can happen if faulting displaces beds with anomalous velocity, thus causing abrupt lateral changes.

The raypaths of various offsets passing through the faulted zone are disrupted such that:

❒ They stack poorly.

❒ The stacked traces have severe time distortion.

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Such distortion can easily be interpreted as structure and/or secondary faulting.

Figures 4 and 5 show a comparison of a seismic line in South Texas, with time migration and prestack depth migration. The effect is most clearly seen in the two circled areas, where the time section indicates folded beds that are much more planar in the depth section. False structures could very easily be interpreted on the time data.

Other problem areas where depth migration can help include overthrust faults, channel fills, reefs and karsted or eroded carbonate in the section above the zone of interest.

In short, any time the objective lies beneath disrupted geology, dipping geology or geology that has significant lateral variations in the overburden velocity, depth migration can be useful.

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There are two reasons for performing depth migration prestack, rather than after stack:

❐ The velocity model can be derived directly from the data, usually with more accuracy than from stacking velocity or extrapolated well control.

❐ The stack itself is disrupted and degraded beneath velocity anomalies. Prestack depth migration, with a correct model, can improve the stacked image.

Deriving and refining the velocity model is an iterative process, requiring numerous preliminary migrations and analysis cycles. Because of this, depth migration is expensive compared to other data processing procedures.

But it is cheap compared to the cost of drilling dry holes (see figures 1 and 2)!

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