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FOOTNOTES
ON INTERPRETATION

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Pitfalls and Possibilities in Time-to-Depth Conversion

There are appreciable horizontal velocity gradients over short distances in simple clastic sediment environments, like those found offshore in the Gulf of Mexico. This Gulf of Mexico example contains significant velocity gradients that can cause simple (individual checkshot) time-to-depth conversions to be in error by as much as 100 meters (330 feet) within a distance of less than 3.2 kilometers (2 miles). It is possible to detect and, using high quality seismic velocity interpretation, to utilize these Velocity gradients.

Velocity measurements made from (~3 dimensional) seismic reflection data are, generally, faster than measurements made in (~2 dimensional) wells. The main reasons for this effect are: 1) sediment anisotropy; 2) simplifications to the methods for velocity estimation from seismic data; 3) geometry (ray path) considerations. Adjustments made to the seismic velocities in order to tie well velocities are bias corrections.

The method used, to find the velocity gradients in seismic data, is to construct a seismic velocity database. There are several methods available to build a database. The method used here required the repicking of the seismic velocity analyses, using a geologically constrained velocity model as a guide and statistical smoothing of the redundant seismic velocity data producing a highly reliable Seismic-Velocity-Volume. It is vital that the data be quality controlled and that questionable input data, due to complex geology and/or geometry problems, be avoided. Bias corrections are then applied to the volume to construct a Well-Calibrated-Velocity-Volume.

This example shows: 1) checkshot data may not be applicable for time-to-depth conversions away from the sampled location; 2) velocity fields, even in a simple geologic setting, can be complex; 3) it is possible to make velocity interpretations, from seismic data, that can be used for relatively accurate time-to-depth conversions; 4) proper velocity control can reduce drilling risk for those targets that are sensitive to errors in time-to-depth conversion.

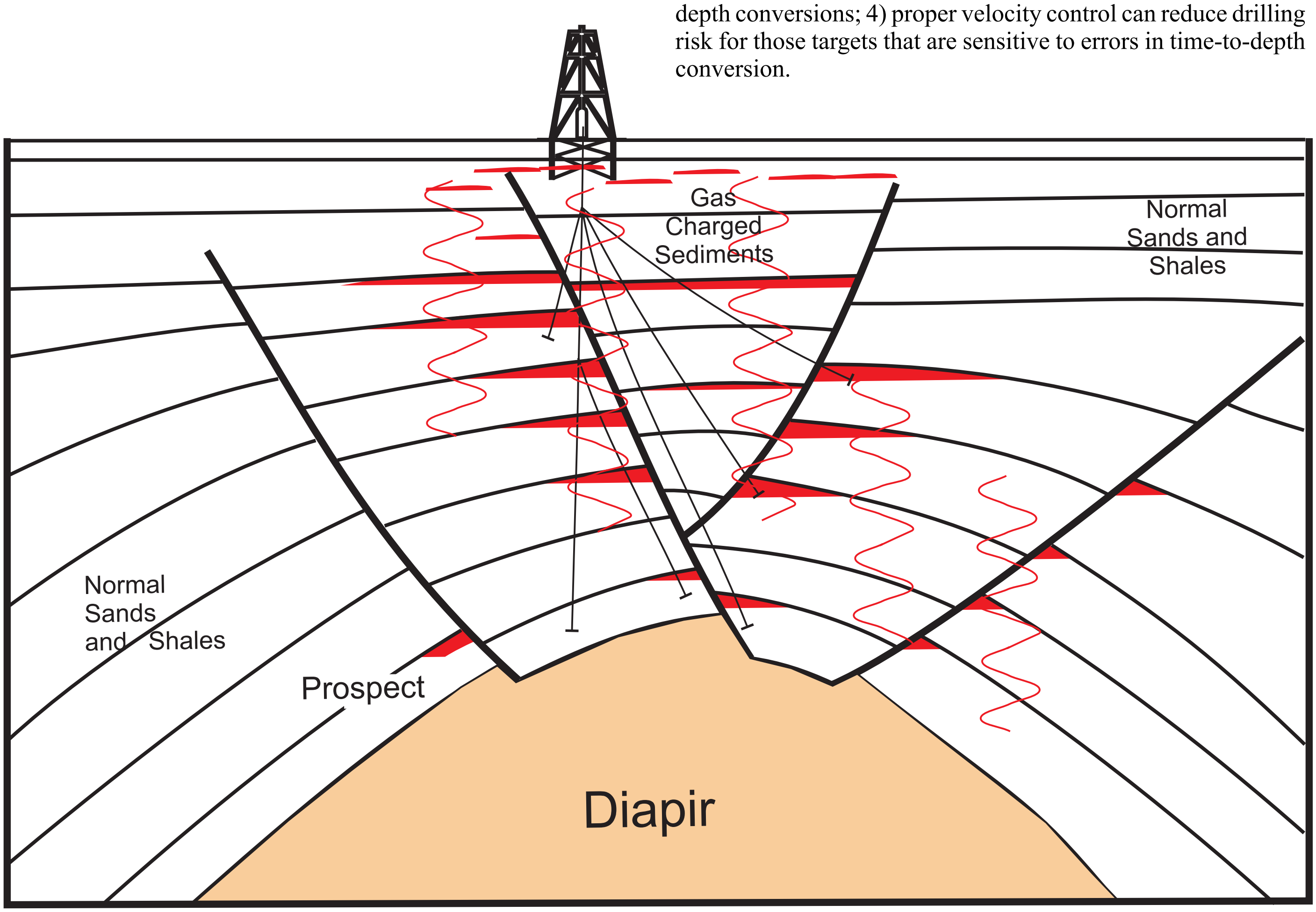

Figure 1. Diagrammatic representation of structural elements, gas migration paths and gas charged low velocity sediments that contribute to this velocity anomaly.

The data presented here covers an area over a shale diapir with structural closure. Here prospective sands that contain trapped gas were structurally high, truncated against faults that were caused by the relative uplift and bending of the sediments above the shale, and some stratigraphic pinchouts against the shale. The example structure is diagramed, schematically, in Figure 1. Numerous shallow sands were gas charged and gas production had been high from this field but is now nearing depletion.

There are several small seismic amplitude anomalies, probably gas, off the flanks of the main structure ("Bright spot" on seismic is diagrammed as "Prospect" on Figure 1). In an attempt to extend the life of the field and ensure depletion of all productive zones, a 3-D seismic survey was acquired over the area. The stated purpose of the 3-D was to delineate and properly locate any additional gas targets and to avoid missing those targets by ensuring correct well trajectories during additional drilling. If a target was missed, sidetracking or redrilling would be more costly than the benefit of the additional gas production. Comparisons of the time to depth conversions, using known well penetrations and bright events from the 3-D seismic time interpretation and interpolating the existing checkshot data, showed that horizontal positioning of the events was good but that the depths were much less accurate. The vertical checkshots were less and less appropriate for depth conversion as distance from the checkshot well to the comparison well bore increased. The checkshots in the vertical portions of all the wells were in fair agreement with the seismic, but, as deviated well bores extended away from the platform, discrepancies mounted. No "walk away" checkshots were acquired in any of the deviated well bores. One deviated well was checkshot, but, since the checkshot source was not vertical above the receiver in the well bore, the checkshot time/depth did not tie the seismic anomalies it was known to penetrate. Also, in order to reduce costs, sonic and density logs in the wells were generally only run over probable producing horizons and so only very localized interval velocities were available.

In this example area, checkshots were acquired in each OCS block's first well but not in any of the subsequently drilled wells, except one which was in a deviated hole. The checkshots in well locations numbered 1, 2 and 4 (Figure 2) were found to be acquired, either totally or partially, in anomalous low velocity sediments and checkshot location 2, being a deviated hole, did not tie to events along its trajectory as posted on the 3-D seismic sections. Well checkshot 2 was not, nor should it be, used for any time-to-depth conversion or bias calculation. Possible reasons for the low velocities around the production platforms are: gas saturated sediments, numerous gas accumulations, faulting, microfracturing and minor overpressure diagrammatically demonstrated in Figure 1. Table 1 lists the variation in time-to-depth conversion for common times and common depths, interpolated from the checkshot wells. Well 0 was drilled into a "Bright Spot" (Figure 2).

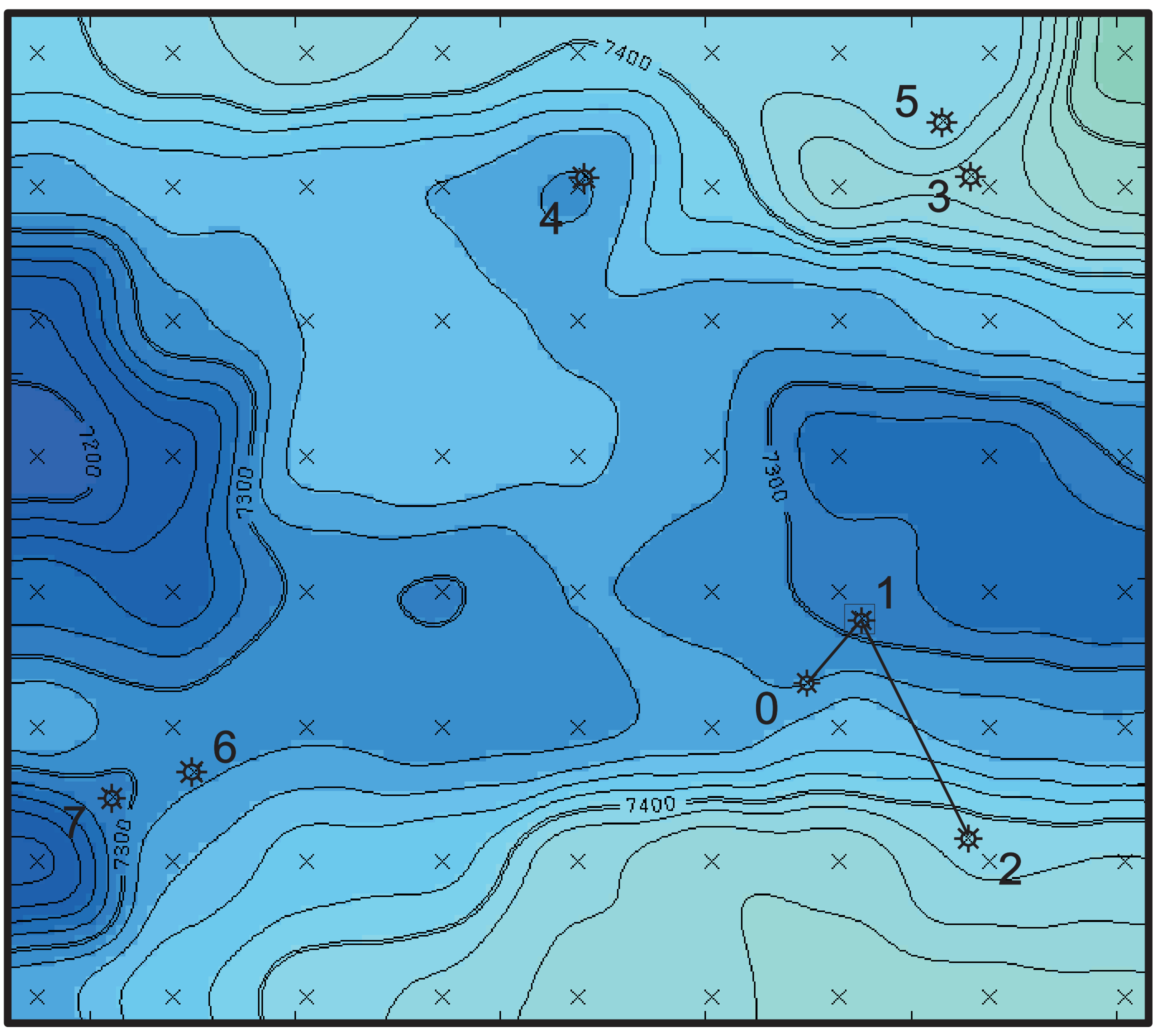

Figure 2. Well-Calibrated-Seismic Average Velocity. Contour interval 20 feet/second.

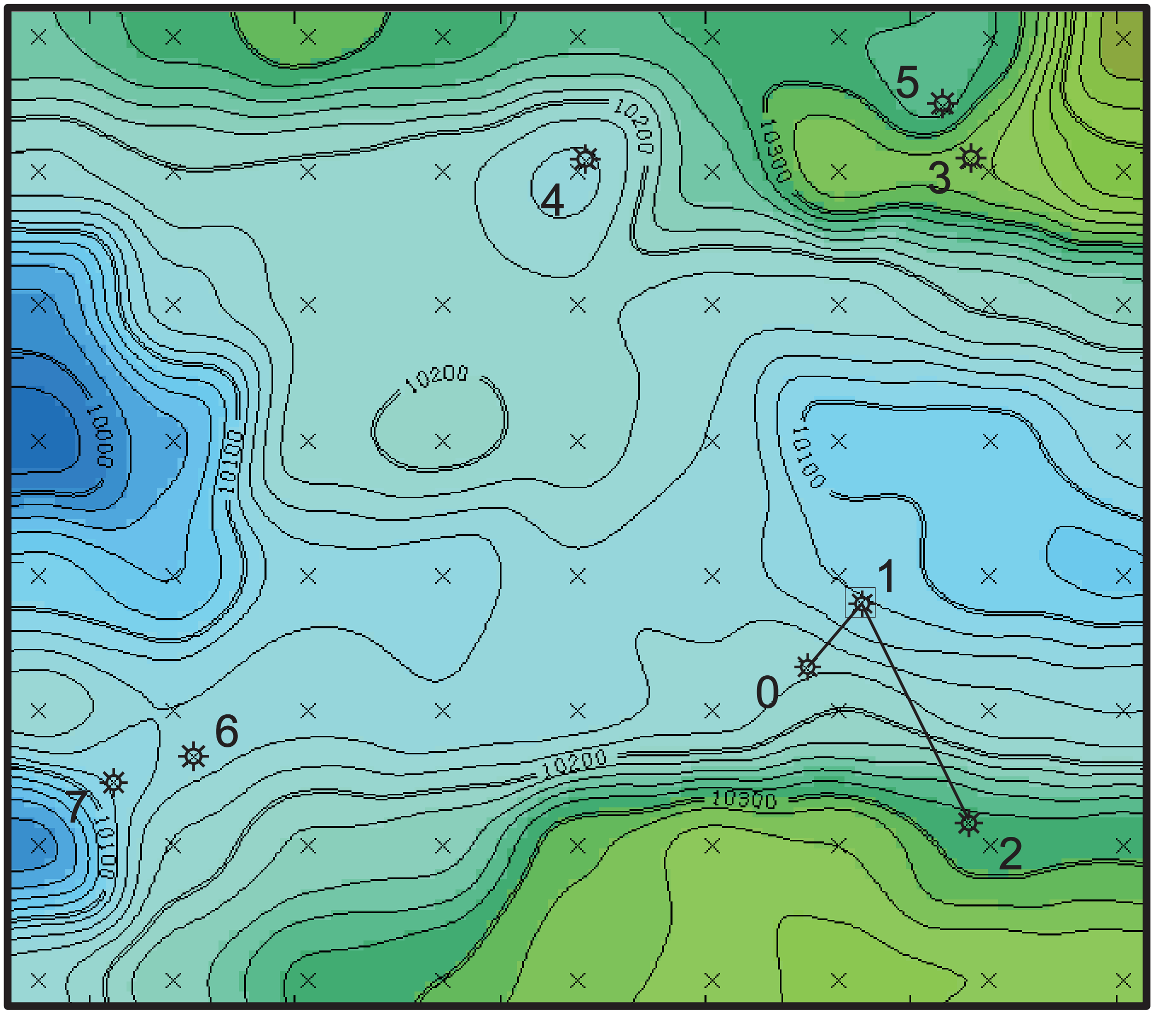

Figure 3. Well-Calibrated-Seismic-Depth at 2.775 seconds. Contour interval 20 feet.

Accurate velocity control away from checkshot control can be interpreted using high quality seismic velocity interpretation. The interpretation process builds local velocity gradients from the high sample density seismic. Once the seismic velocity field is interpreted, the bias between the seismic velocities and the more randomly located well velocities are calculated at the well locations. The contoured biases are used to calculate the Well-Calibrated-Velocities. It is assumed that the well-to-seismic .velocity bias has geologic significance and is similar in magnitude over extended areas or at least varies systematically within a local area. Figure 2 shows the map of the well calibrated average velocity at a constant time of 2.775 seconds, it demonstrates the magnitude of local velocity gradients and also shows the variability of velocity data over a relatively small area. Figure 3 is a map of the well-calibrated-seismic-depth, at a constant time slice, across a 3-D survey.

Well, data source type *(Horizontal distance from Well 0 horizon penetration)*	**time > depth** *(checkshots)*	**depth > time** *(velocity data base)*
"Bright spot", seismic time section: (Inline 0 feet, crossline 20 feet)	2.775	
Well 0, electric log: (deviated, sl offset 1650 feet, bhl offset 80 feet)		10175 feet
Well 1, checkshot: (straight, sl offset 1640 feet, bhl offset 1640 feet)	2.775 > 10119 feet	10175 feet > 2.789
Well 2, checkshot: (deviated, sl offset 1630 feet, bhl offset 4630 feet)	2.775 > 10235 feet	10175 feet > 2.758
"Bright spot", Calibrated Seismic Velocity database: (interpolated)	2.775 > 10170 feet	
Well 0, Calibrated Seismic Velocity database: (interpolated)		10175 feet > 2.776

Table 1. Comparisons of time/depth relationship of Well 0 with 3-D seismic using the nearest checkshots and the Calibrated-Seismic-Velocity database.

Figure 4 is a map of the well depths derived from utilizing only the checkshot velocities. A comparison of Figure 3 and 4 demonstrates the possible error in time-to-depth conversion should a single checkshot, or linear interpolations between checkshots, be used for depth estimates. In an area of layered clastic deposition, even quality checkshot data may not be applicable for time-to-depth conversion away from the points of measurement. In summary, checkshot extrapolation or interpolation for depth conversion is, at best, a risky proposition.

This case study demonstrated a common exploration problem and suggests caution in the acceptance of less than rigorous treatment of valid velocity data. Points for the interpreter to remember:

- ➤ Velocity fields, even in a simple geologic setting, can be complex.
- ♦ Checkshot data may not be applicable for time-to-depth conversions away from the sampled location.
- ★ It is possible to make velocity interpretations, from seismic data, that can be used for accurate time-to-depth conversions.
- ● Proper velocity control can reduce drilling risk for targets that are sensitive to time-to-depth conversion errors.

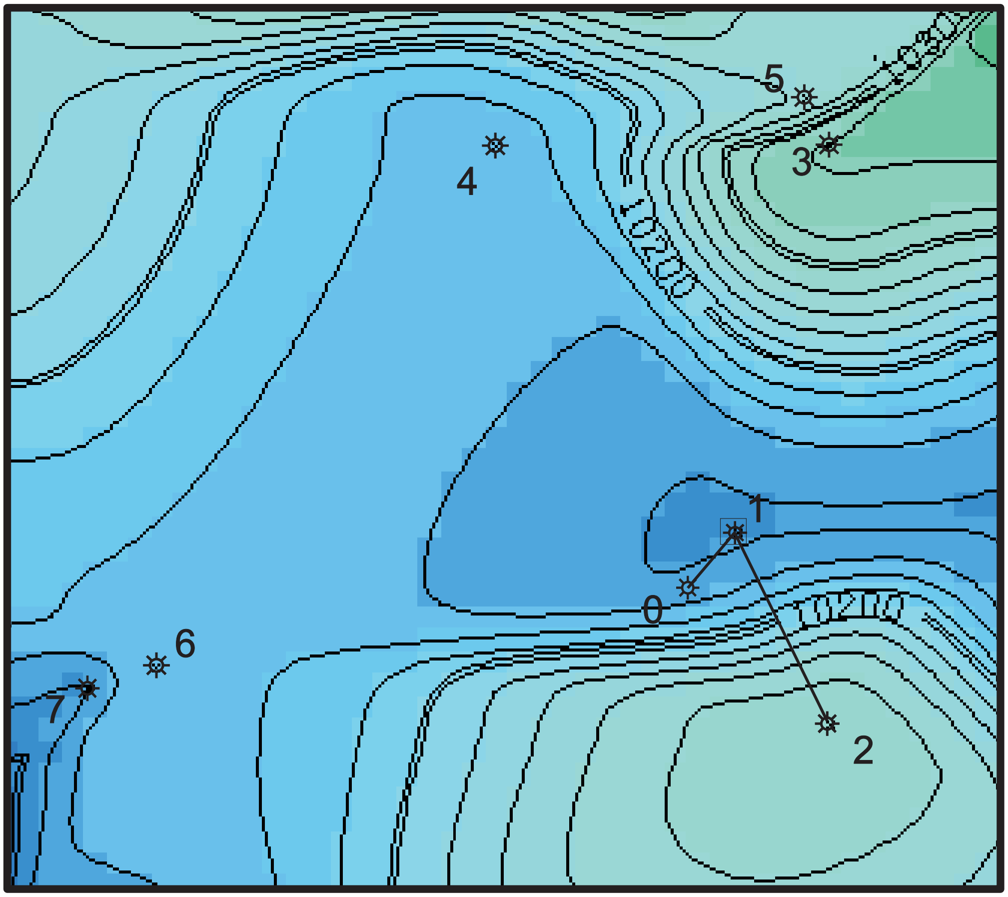

Figure 4. Checkshot well depths at 2.775 seconds. Contour interval 20 feet.

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