HFVS Technology Applied to a 3D Multi-Component Seismic Project,

Alison Weir Small, Parallel Petroleum Corp., J.W. (Tom) Thomas, Seth Conway, Dawson Geophysical, Chuck Mosher, Robert Olson, Daniel Whitmore, ConocoPhillips

Summary: A multi-component seismic project was completed in May of 2006 in the northern portion of the Midland Basin of West Texas. The project consisted of a conventional multi-component acquisition program followed by an experimental multi-component acquisition program. During the conventional phase of the project each of the required component modes P, Sx, and Si were sourced independently over the 25 square mile project area. During the experimental portion of the project numerous source points were replicated using simultaneous acquisition of the required component modes to validate the application of High Fidelity Vibratory Seismic (HFVS) technology to multi-component seismic data acquisition. The HFVS scheme allows data from multiple vibratory sources to be simultaneously collected during the acquisition phase and separated in the processing stage. The test provided two data volumes acquired with the concurrent recording of the P, Sx and Si source modes and a third volume recorded with concurrent Sx and Si source components. The conventional P and S wave data provide a baseline for comparison with the experimental volumes acquired with the HFVS technology. The HFVS recording methodology has the potential to increase the production rate of a multi-component survey by a factor of three.

Introduction: The Diamond "M" field lies on the "Scurry Reef Trend" of West Texas in Scurry Co., Texas. The trend produces from carbonates which were deposited on the eastern side of the Pennsylvanian age Horseshoe Atoll, Figure 1. The Diamond "M" field acquisition project, which covers approximately 25 square miles, was first

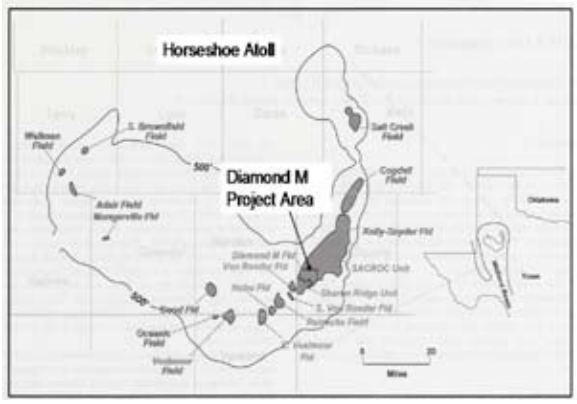

Figure 1: Location and Description of the Project Area

recorded as a conventional P-wave 3D survey, P-wave source into P-wave receivers (PP). Immediately following the completion of the PP survey the project area was re-recorded as a 4-Component S-wave survey (4C). Directly after the completion of the 4C survey the HFVS experiment commenced. By re-shooting selected source points, three distinct test data volumes were acquired, a hybrid, a swath, and a 2C by 2C as shown in Figure 2. The P-wave production source parameters employed sweep length of 12 seconds, bandwidth of 6-96 hertz and emphasis of plus 3 db/octave with a 3 second listen time. The S-wave 4C and HFVS test parameters incorporated sweep length of 18 seconds, bandwidth of 4-48 hertz and emphasis of plus

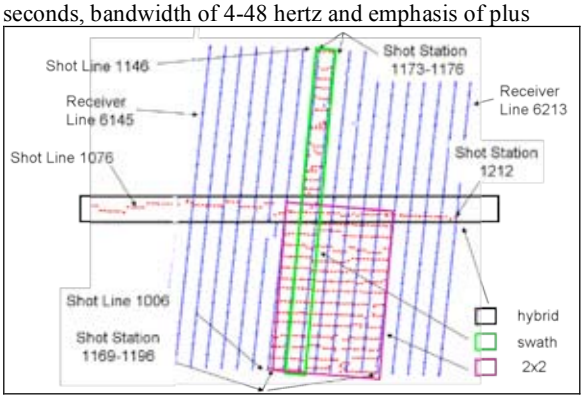

Figure 2: Experimental Source/Receiver Configuration

2 db /octave with a 6 second listen time. During the HFVS experimentation, the P-wave sweep length was increased to 18 seconds to equal the S-wave sweep time.

The orthogonal surface layout utilized by both the production and experimental acquisitions consists of nearly NS receiver lines distanced by 600 feet with perpendicular EW source lines spaced by 750 feet. Both source and receiver surface station intervals are 150 feet, creating subsurface bin dimension of 75 feet square. The shooting geometry for the PP production phase included 24 symmetrical single lines comprised of P-wave geophones with all 143 stations on a line live. The 4C production portion called for asymmetrical spread geometry of dual receiver lines, 14W-3E with odd numbered and 3W-14E with even numbered shot lines with all 143 stations on a line live. The experimental HFVS data was recorded into an 18 dual receiver line fixed spread, with the exception of 2 lines that also had P-wave receivers. The additional P-wave receivers were located on the first line numbered 6145 and the ninth line numbered 6177 from the west or the left side as referenced by Figure 2. The dual receiver lines utilized by the 4C and the HFVS portion of the project consisted of two- component analog geophones with one component oriented in the receiver line direction (Ri) and the other perpendicular or in the crossline direction (Rx). The source orientations were also labeled with respect to

the receiver lines. The (Si) source component was in the direction of Ri, the receiver line and the Sx motion is in the direction of Rx, perpendicular to the receiver line. Thus the nomenclatures for the pre-rotated components are defined as Sx, Si, Rx, and Ri. All four orientations are required at a source and receiver location for rotation into the transverse (TT) and radial (RR) components for processing.

Field Implementation: The first of the three experimental data volumes is named the "hybrid". The linear source points associated with the hybrid volume are outlined by the elongated EW black rectangle in Figure 2. During the "hybrid" acquisition, simultaneous sourcing of the three components Sx, Si and P was implemented through the HFVS technology. Six vibrators were involved in each HFVS "set-up", two vibrators for each component. Referenced back to Figure 2, the simultaneous shaking for the first HFVS set-up was performed with two Si-wave vibrators located on shot point 1212, while the two Sx-wave vibrators were on 1208, and the two P-wave vibrators were located on 1204, a 600 ft separation between vibrator sets. Six sweeps using the HFVS technology were performed by the 3 sets of two vibrators. The next set-up covered source locations 1211, 1207 and 1203. The last set-up was at shot point 1112, 1108, and 1104. Note the first source point eligible for rotation, recorded by both the Sx and Si components, is 1208 and the last is 1112. The resulting hybrid data volume consists of 96 rotate-able linear source points over 14,400 feet.

Experimental volume number two is labeled the "swath". The NS elongated green rectangle defines the source area. The source stations covered by the swath test are bounded by receiver lines eight and nine of the 18 lines. There are 4 source stations numbered 1173-1176 between the 600 feet spaced receiver lines and within the source area there are 29 source lines distanced by 750 feet and numbered from 1006 to 1146 by 5. As in the hybrid test, three component simultaneous sourcing is utilized. The initial HFVS set-up positioned the P-wave vibrators on the far north source line 1146 and station 1173, the Si-wave vibrator set was located 750 feet south on the corresponding source station 1173 of source line 1141 and the Sx-wave vibrator set another 750 feet south on source line 1136 and station 1173. Source stations 1174 through 1176 were covered in similar fashion with the P, Si and Sx vibrator sets remaining on source lines 1146, 1141 and 1136 respectively. After every 4th shot a line change was made with each vibrator moving south to the next shot line. The vibrators always moved from west to east on each shot line. The swath experimental volume generated 104 rotate-able source points from the 26 source lines, 1011-1136.

The largest rectangle in Figure 2 outlines the source area of the third test which is coined the "2x2". It differs from the hybrid and the swath tests to the degree that only the Sx and Si components were recorded. With two vibrator sets simultaneously shaking the minimum number of sweeps per HFVS set-up is two. Four sweeps were recorded at each set-up, with two vibrators in each set to match the energy of the baseline production data. On the initial set-up the Sx vibrator set was positioned on source line 1076 and station 1169. The Si vibrator set was distanced 750 feet south on line 1071, station 1169. The two source lines were acquired with the same relationship through source station 1196, a total of 28 HFVS set-ups. At this point the vibrator sets were interchanged, the Sx set on line 1071 and the Si set on 1076. The two lines were again recorded, satisfying the rotate-able condition of each shot point acquired with both the Sx and Si component. The 2x2 acquisition methodology was employed in a like manner on 7 pairs of shot lines from 1076 down to 1011. However the last shot line, number 1006 of the 2x2 experiment was acquired with the two sets, Sx and Si on the same shot point of the line. The initial setup had both sets of vibrators located on station 1169. The next HFVS setup was on shot point 1170 and so on, until the last shot point 1196 was covered. The 2x2 data volume covers 28 stations by 15 lines or 420 rotate-able source points.

Data Analysis of Source Gathers: The experimental data acquired with HFVS technology requires the pre-processing step of separation and inversion into the individual components. The 4C production data and the 4C portion of the experimental data require the additional step of vector rotation before entering the processing flow. After completion of these steps, data from each test and the equivalent production data may be compared. Figure 3 displays a comparison of equivalent HFVS and production shot gathers from a common source location taken from the

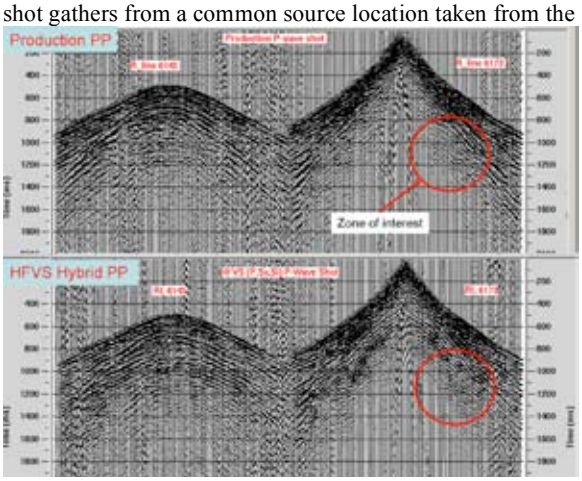

Figure 3: P-wave Shot Record Comparison Hybrid Test

PP production acquisition and the PP component from the hybrid test. A common rotated shot point from the 4C production and the hybrid TT data is displayed in Figure 4. The displayed receiver lines are separated by 4200 feet with some source-receiver offsets nearing 2 miles. The baseline for comparison of the HFVS shot gather data is supplied in the upper or production picture in the figures while the lower or HFVS picture is the particular mode separated from the simultaneously sourced data. The upper and lower pictures within a figure should be compared, as well as the lower pictures from the same test. For example, the hybrid HFVS shear wave data from Figure 4 should be scrutinized for P-wave cross feed with characteristics

apparent in Figure 3, and vice versa. The P and S-wave shot gather data from the hybrid test is displayed in Figures

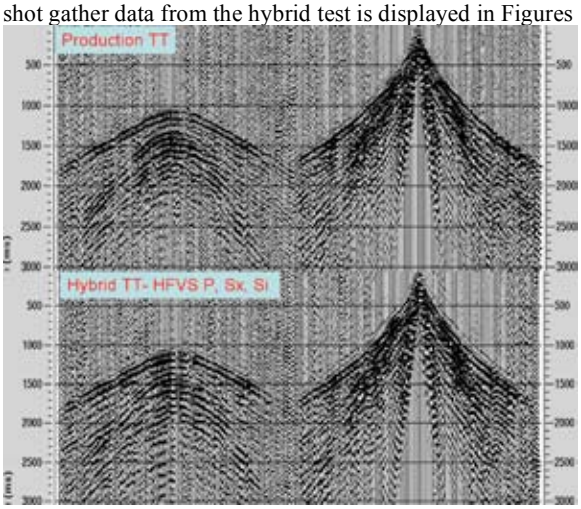

Figure 4: S-wave TT Shot Record Comparison Hybrid Test

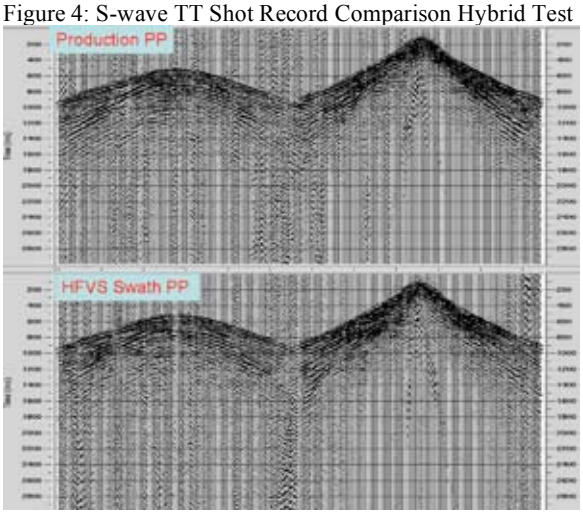

Figure 5: P-wave Shot Record Comparison Swath Test

5 and 6. The data from the 2x2 test with source separation of 750 feet is shown in Figure 7 and the data with no source separation is presented in Figure 8. Two component source data collected from the same source point at the same time is preferred for two reasons. The ground condition for the vibrator pad to earth coupling is assured to be identical for both the Sx and Si motion and the source location bookkeeping is much simplified. The data from Figure 7 and 8 should be compared with the caveat that the source locations were distanced by 750 feet.

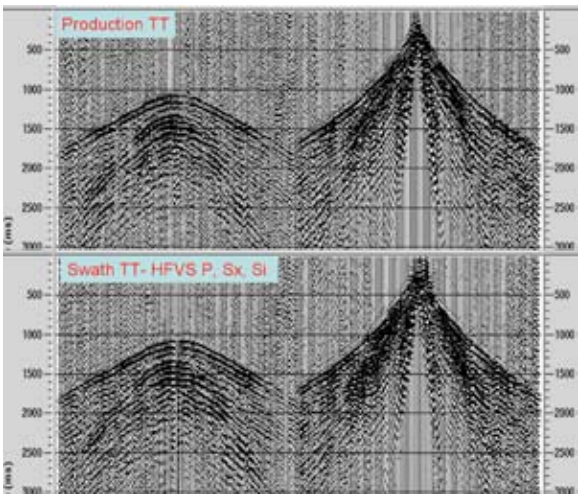

Figure 6: S-wave TT Shot Record Swath Test

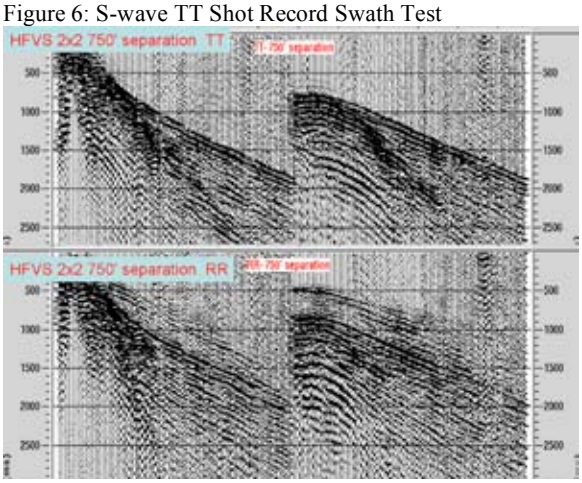

Figure 7: HFVS 2x2 Test Source Separation 750 feet

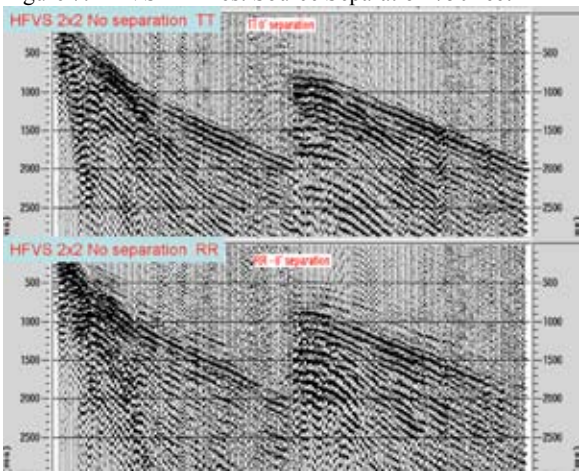

Figure 8: HFVS 2x2 Test "No" Source Separation

Data Analysis of Stacks: Due to the small amount of data available to be CDP stacked for the hybrid and swath tests the processing flow applied to both experiments is very

basic. The processing flow includes datum statics, true amp recovery, bandpass filtering, AGC, single NMO, auto-statics, CDP stacking and post stack FXY. However, even with the rudimentary processing and low fold the HFVS vector rotated TT shear wave data compares favorably to the production PP data. The 12 fold hybrid test stack comparison is displayed in Figure 9 and the 10 fold swath test stack comparison is displayed in Figure 10.

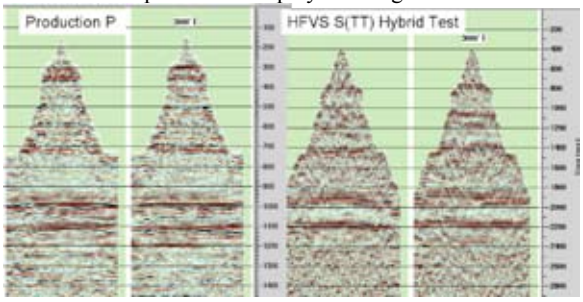

Figure 9: P and HFVS TT Stack Comparison Hybrid Test

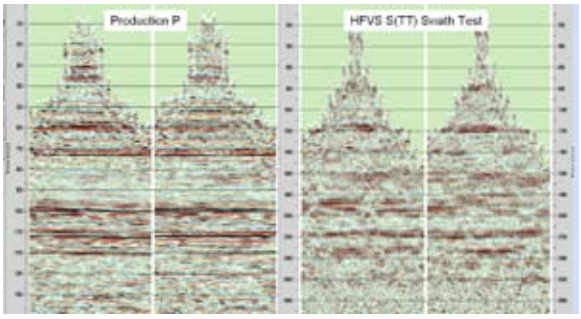

Figure 10: P and HFVS TT Stack Comparison Swath Test

The 2X2 test produced a larger data volume. The processing flow was expanded to include refraction statics and multiple velocity locations. The semblance and super gather data from one of the P-wave and S(TT)-wave analysis locations is displayed with Figure 11. Note that the bend in the semblance plot is near .7 seconds for the P-wave data and 1.4 seconds for the S-wave data, suggesting a VP/VS ratio of 2.0. FK spectrums and trace displays of the production PP, production TT and HFVS TT data are shown in Figures 12 and 13. Bandwidths of the stacks compare favorably between these datasets. The peak fold of the 2X2 test is near 100.

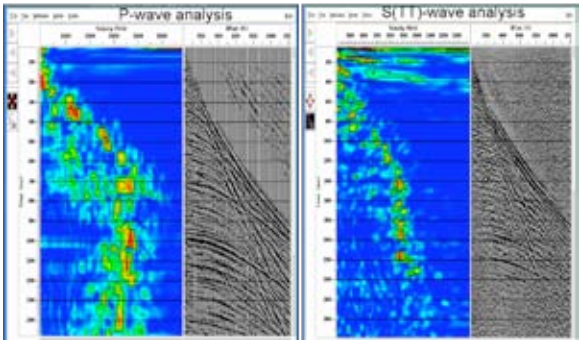

Figure 11: P and HFVS TT Velocity Analysis - 2x2 Test

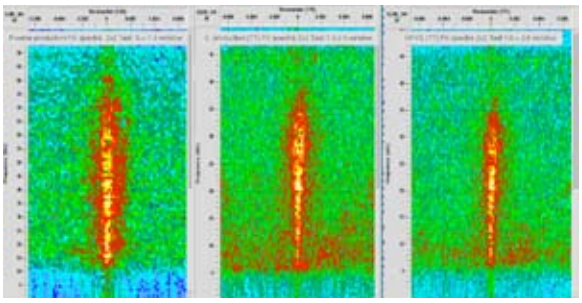

Figure 12: PP, Conventional and HFVS TT FK Analysis

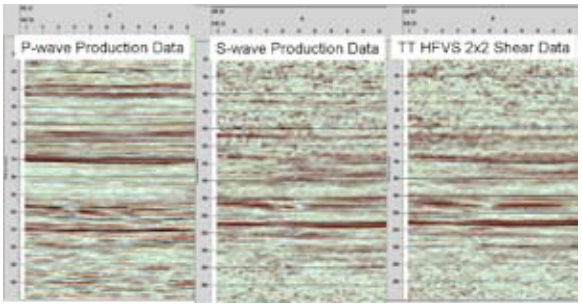

Figure 13: PP, Conventional and HFVS TT Stacks

Conclusions: In the Diamond M project area, comparisons of conventional and HFVS acquired multi-component seismic data demonstrate that HFVS acquisition methods produce data of comparable quality as conventional acquisition. The data acquired showed that it is possible to successfully extract and invert P, Sx, and Si components from simultaneously sourced data. Final stack of the HFVS 2x2 data showed that component "cross-talk" from the simultaneous sourcing did not significantly degrade the final stack. The FK plot comparisons of Production P and HFVS TT data showed that comparable bandwidth was achieved. In addition, the project has demonstrated the use of HFVS technology to improve the efficiency of acquiring full vector source data and shows the potential of reducing acquisition time up to a factor of 3. HFVS is shown here to be a viable technique for acquiring multi-component seismic data.