

WAZ Survey Method Uses Single Vessel

By Nick Moldoveanu,
Jerry Kapoor
and Mark Egan

HOUSTON—Wide-azimuth (WAZ) towed-streamer acquisition has proven a successful method for exploration and development in the complex subsalt structures in the Gulf of Mexico. Wide-azimuth data have better illumination, higher signal-to-noise ratios and improved seismic resolution than conventional narrow-azimuth data. However, the WAZ surveys acquired so far in the Gulf have employed multiple vessels, which increases cost. A new WAZ method uses a "circular" geometry to acquire data with a single streamer vessel.

The WAZ towed-streamer surveys acquired to date in the Gulf have used three- or four-vessel configurations. A three-vessel configuration implements one streamer vessel and two source vessels, while a four-vessel configuration implements two streamer vessels and two source vessels or one streamer vessel and three source vessels. These WAZ towed-streamer surveys have used a "parallel" geometry, as any conventional marine streamer acquisition does, but a larger cross-line offset can be acquired because of the multiple vessels. Generally, the aspect ratio measured as cross-line versus inline offsets is smaller than 1.0, with 0.6 being the aspect ratio of a four-vessel configuration.

Acquisition efficiency of WAZ towed-streamer surveys increases when four-vessel configurations are used, which is an important factor when large exploration surveys are acquired. However, because of the parallel-type geometry, the efficiency is impacted by the line change (or turn), where significant production time is lost, especially for smaller, development-type

WAZ surveys. Acquiring data during line change now is possible with new marine technology, and has already been deployed on the Shenzi Field rich-azimuth (RAZ) survey.

The sail lines acquired during line change are typically semicircles, and this could be considered as a partial implementation of the circular geometry. The successful acquisition of data during line change for the Shenzi RAZ survey demonstrated the possibility of employing circular geometry for full-scale WAZ towed-streamer acquisition.

Circular geometry marine acquisition was first proposed in the 1980s. The idea was to sail in concentric circles around salt domes to improve structural (especially

fault) imaging. Although a few surveys were acquired in the Gulf of Mexico and North Sea using concentric circle acquisition, the marine technology at that time simply did not allow properly implementing circular geometry, and the method subsequently was abandoned. However, with today's technology, the potential of circular geometry for WAZ towed-streamer acquisition is quite attractive from both geophysical and efficiency point of views.

Circular Geometry

Circular geometry for towed-streamer acquisition can be implemented with a single vessel carrying multiple streamers, and one or two seismic sources by sailing along single or multiple circles to cover the survey area with overlapping circular

FIGURE 1

Circular Geometry Sail Paths

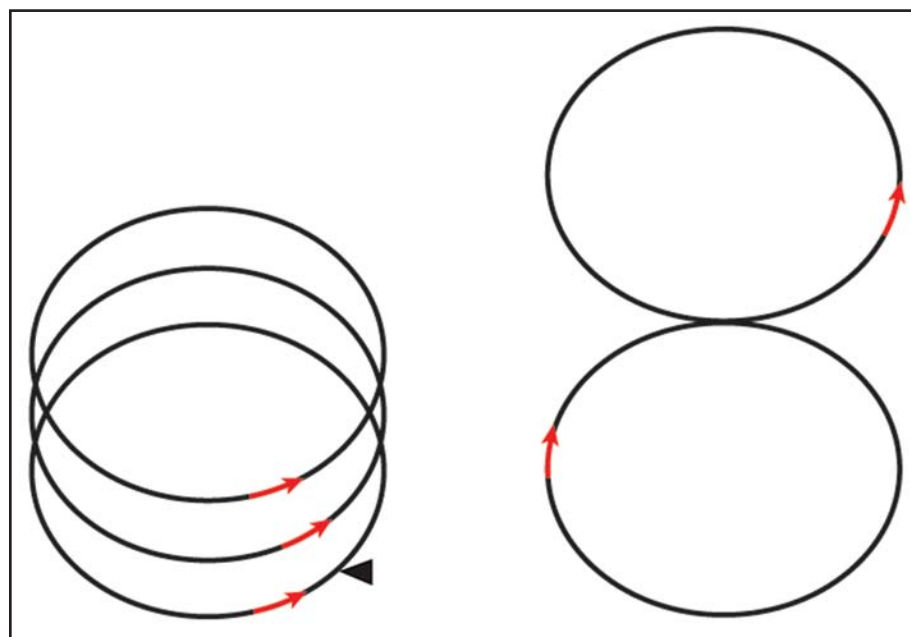
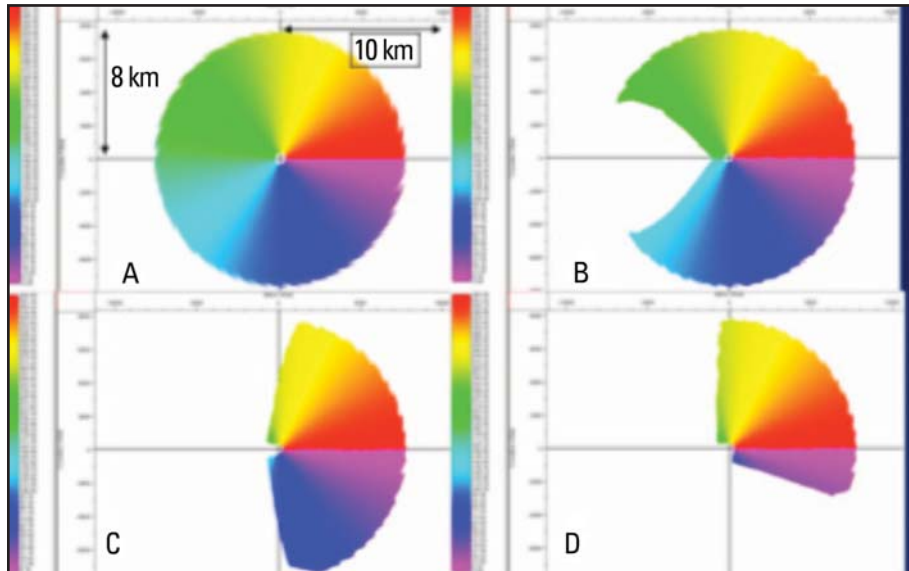




FIGURE 2
Vector Offset Component Diagram for Four Survey Areas



sail paths. Figure 1 shows circle-by-circle (left) and multiple circle (right) sail paths. Either sail path approach enables continuous acquisition because the line changes are virtually eliminated. The main design parameters for circular geometry are the number of streamers, streamer length, streamer separation, circle radius, and circle roll in X and Y directions.

To investigate the circular geometry concept, a survey area of 42X42 kilometers was modeled using a typical WAZ streamer configuration, except for the receiver interval, which was 50 meters instead of 12.5 meters to reduce the amount of simulated navigation data. Other survey parameters included ten 7,000-meter streamers at 120-meter separation, one source, a shot interval of 37.5 meters, a circle radius of 6,000 meters, and 1,200 meters of circle roll in both the X and Y directions.

A total of 610,720 shots were modeled. The fold coverage, azimuth and offset distributions were calculated after the data were binned with a 25X25-meter bin size. The fold coverage shows that maximum fold is placed in the middle of the survey, or target area, with the fold decreasing towards survey fringes. The average fold in the middle of the surveys is 1,560, decreasing to 290 at the edges. This compares to the nominal fold of 186 for a single pass and 372 for two passes with a parallel WAZ geometry survey acquired with two streamer vessels and two source vessels using the streamer configuration described in a 600-meter

sail line interval with 37.5-meter shot spacing.

Higher Fold

Higher fold is acquired with circular geometry as a result of the high-density shot distribution, which depending on the design could be 1.34-2.6 times larger. Since shots are distributed along several overlapping circles, shot distribution could be considered pseudorandom, a feature that could be beneficial for multiple at-

tenuation and imaging. Azimuth offset distribution, presented as vector offset component diagrams, was calculated in four different areas across the survey.

Figure 2 shows the vector offset component diagram calculated for the four areas (A, B, C and D), with the inline offset represented on the horizontal axis and the cross-line offset represented on the vertical axis. Azimuths are presented in color.

Comparing azimuth offset distribution for circular geometry to parallel WAZ geometry, the respective aspect ratios of circular geometry and parallel WAZ geometry are 1.0 and 0.6 with full-azimuth distribution acquired over the target area and wide-azimuth distribution acquired over the rest of the survey. In addition, near offsets are better recorded with circular geometry than with parallel WAZ geometry, and the maximum offset of circular geometry is smaller than the maximum offset of parallel WAZ geometry (the difference in the maximum offset is 800 meters for a 10-streamer cable configuration with 7,000-meter streamers at 120-meter separation.).

The wide-azimuth coverage and the high fold associated with the circular geometry allow splitting the data in different azimuth ranges for anisotropic velocity model building and fracture analysis.

Feasibility Test

A feasibility test for circular geometry

FIGURE 3
Estimated RMS Ambient Noise (Circular Geometry Test Data)

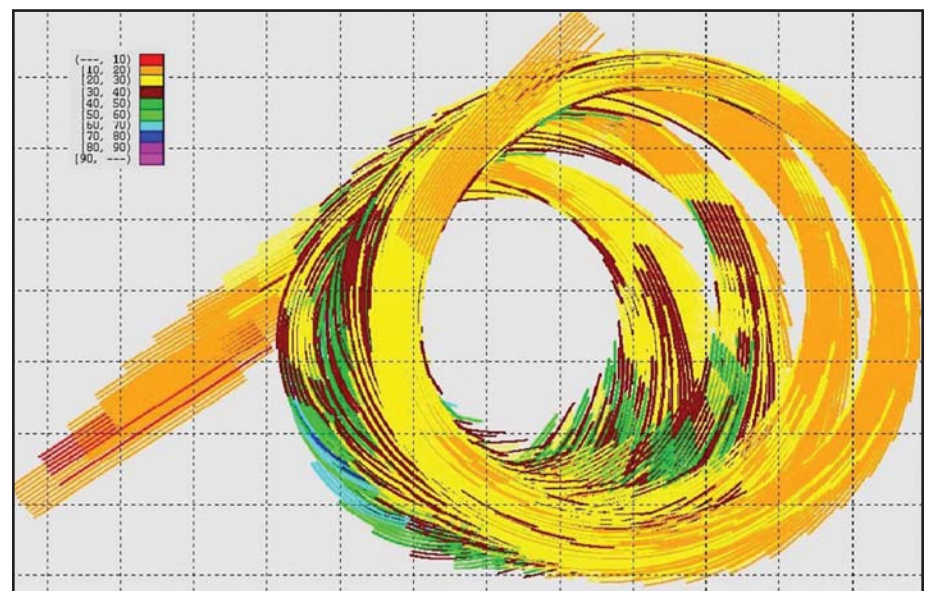
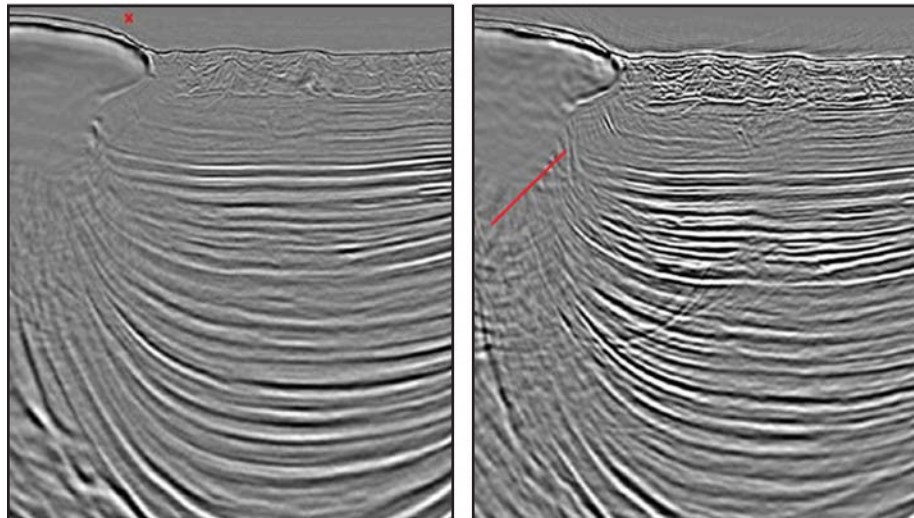


FIGURE 4**3-D Prestack Depth Migrations of Full-Aperture, Full-Fold Parallel WAZ versus Circular Geometry Feasibility Test Data**

Wide Azimuth–E-Octopus

Full Azimuth–Coil Shooting Test



was performed in the Gulf of Mexico over an area covered by a parallel WAZ survey. A single vessel equipped with one source array and 10 steerable, 7,000-meter streamers at 120-meter separation was used for the experiment. During the feasibility test, four circles were acquired with radii of 5.4, 6.0, 6.5 and 7.0 kilometers. The roll from circle to circle was 1,200 meters. The 5.4-kilometer radius corresponds to the turn radius typically used with the streamer configuration described above. The steering applied to the streamers was limited to maintain constant streamer separation. The objectives of the test included:

- Determining the feasibility of sailing along the circle with constant streamer separation while knowing, very accurately, receiver positions;
- Estimating the level of cross-flow current noise as a function of circle radius;
- Determining whether the data could be processed and imaged; and
- Comparing the results of four-circle processing with the results of full-aperture, full-fold WAZ data processing.

The test results proved that it is feasible to sail along circles maintaining constant streamer separation and positioning the receivers very accurately along the cable. Figure 3 shows the level of ambient noise estimated as a RMS value in a 500-millisecond window located at the end of the record. The maximum level of noise could reach 60 μ bars for a limited number of traces of the 5.4- and 6.0-kilometer radius circles. For the 6.5- and 7.0-kilometer radius circles, the level of noise was comparable or slightly higher than the noise recorded on straight lines.

The processing sequence applied on

parallel WAZ data also was applied on circular geometry data, including:

- Single-sensor coherent noise attenuation;
- Digital group forming at a 12.5-meter group interval;
- Navigation merge;
- Shot-by-shot bubble removal;
- Anomalous noise attenuation;
- Inverse Q-compensation (phase only);
- Residual wavelet shaping; and
- Geometric spreading correction.

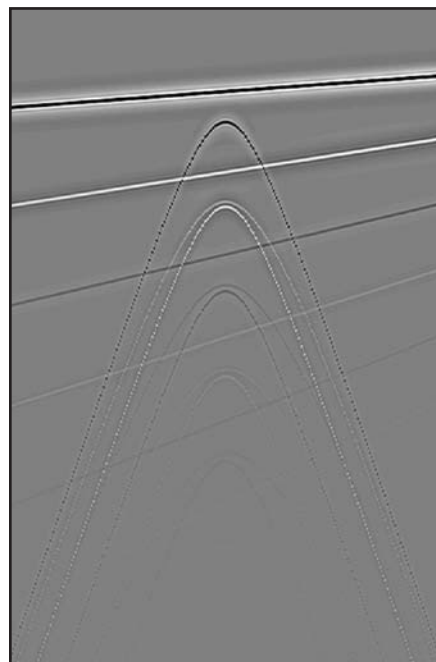
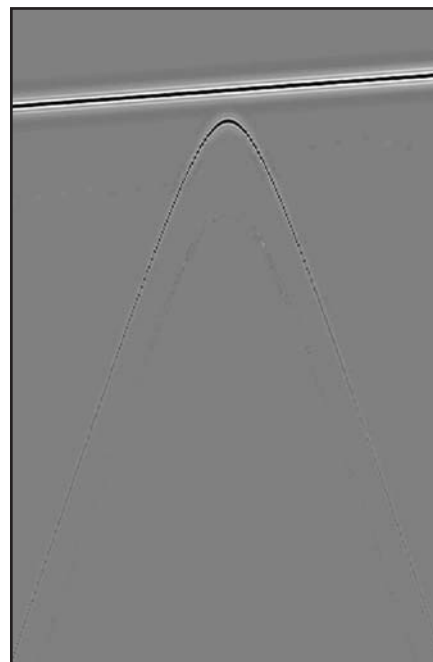
The 3-D prestack migration of circular geometry data was performed with the

same velocity model used for parallel WAZ data. Figure 4 shows a comparison of prestack depth migrations of the two data sets: a full-aperture, full-fold parallel WAZ survey (top) and circular geometry feasibility test data (bottom). Although the fold and migration aperture of circular geometry data were inferior to full-aperture and full-fold parallel WAZ data, the two images compare very well. The feasibility test confirmed that circular geometry data could be successfully acquired and processed.

Synthetic Modeling

A simple velocity model consisting of a dipping reflector and a diffractor was used to generate primary events followed by five bounces of multiple reflections using a single-vessel, single-source circular geometry acquisition parameters. The goal of this synthetic modeling exercise was to determine how the 3-D multiple attenuation process performs for circular geometry.

A general surface multiple prediction (GSMP) method was applied on this synthetic data set. Figure 5 presents a constant near offset section extracted from circular geometry data before multiple attenuation was applied. The result after GSMP is shown in Figure 6. Multiple attenuation performed very well on circular acquisition data, with the main benefits of this geometry for multiple attenuation being the high density of sources/receivers and the acquisition of near offsets for every shot

FIGURE 5**Constant Near Offset Section Extracted from Circular Data Before Multiple Attenuation****FIGURE 6****Constant Near Offset Section After GSMP Multiple Attenuation**



point.

Circular geometry is very efficient for WAZ towed-streamer surveying, with its ability to provide continuous acquisition using a single streamer vessel with a single source array. In a simulated acquisition of parallel WAZ geometry with four passes over a 900 square-kilometer area using a four-vessel configuration (one streamer vessel and three source vessels) versus and circular geometry acquisition over the same area, the total time for parallel WAZ geometry was 62 days to acquire 160,000 shots, compared with 61 days to acquire 321,706 shots for circular geometry (with 100-percent vessel utilization in both cases).

In fact, modeling results show that single-vessel circular geometry acquisition for larger exploration projects is cost efficient and could deliver better geophysical attributes that parallel WAZ methods.

The processing of circular geometry data is not different from the processing of parallel geometry data if the processing sequence is performed in the depth domain. Noise attenuation for circular geometry is conducted mostly in the shot domain, as with WAZ parallel geometry data. The imaging of circular geometry data is based on common shot wave extrapolation

migration (WEM), but other migration methods could be used. The full-azimuth distribution of circular geometry data could make it possible to derive an accurate anisotropic velocity model, and consequently, more accurate imaging.

Modeling results, feasibility tests and the first commercial survey acquired with

circular geometry prove that the technique can be used for WAZ towed-streamer acquisition. Proper implementation requires streamer steering, accurate receiver positioning and advanced noise attenuation capability. □

NICK MOLDOVEANU is geophysical adviser in WesternGeco's Center of Excellence for Subsalt Imaging in Houston. He has been with Schlumberger Geco-Prakla and WesternGeco since 1989, holding technical positions in data processing, seismic programming, marine acquisition and reservoir seismic services. Moldoveanu is involved in developing new acquisition and processing techniques for seismic imaging in complex environments. He holds M.S. degrees in geophysics and mathematics from the University of Bucharest.

JERRY KAPOOR manages the WesternGeco Center of Excellence for Subsalt Imaging in Houston. He began his career with Geophysical Service Inc. in England, and has managed seismic

data processing centers in Stavanger, Houston and Bedford, England. In 1990, Kapoor began developing and applying technology to image steep dips and subsalt sediments. Since 1994, he has managed the evolution of WesternGeco's depth-imaging business from prestack depth migration to wide azimuth surveys. Kapoor has been involved in a number of successful complex imaging projects in the deepwater Gulf.

MARK EGAN is the North America geophysics manager and integrated solutions group manager at WesternGeco. He has experience working for WesternGeco in data processing, modeling, marine survey design and land survey design. Egan holds a Ph.D. in geophysics from the University of Houston.