[GC]Imaging Deep Gas Targets Across Congested Marine Production Areas

By

Bob A. Hardage[1], Randy Remington[1], Michael Deangelo[1], and Khaled Fouad[1]

Search and Discovery Article #40190 (2006)

Posted May 2, 2006

*Adapted from the Geophysical Corner column, prepared by the authors and entitled, "Imaging Deep Gas in Crowded Areas," in AAPG Explorer, April, 2006. Editor of Geophysical Corner is Bob A. Hardage. Managing Editor of AAPG Explorer is Vern Stefanic; Larry Nation is Communications Director.

[1]Bureau of Economic Geology, The University of Texas, Austin, Texas (hardageb@beg.utexas.edu)

General Statement

Gas producers across the northern shelf of the Gulf of Mexico are now targeting super-deep gas plays--some targets at depths of 26,000 to 33,000 ft (eight to 10 km).
To image a target properly at a depth D, seismic data should be acquired with source-to-receiver offsets that extend to a distance equal to or exceeding target depth D. Thus, to create optimal images of these super-deep gas targets, seismic data need to be acquired with receiver offsets extending to eight to 10 km away from the source.

New Seismic Technologies

Two new marine seismic technologies now allow maximum source-receiver offsets of nine or 10 km:

- Super-long towed cables--If seismic data are acquired with a towed-cable option, both the hydrophone cable and the air gun source move across the target to be imaged.
- Stationary ocean-bottom-cable (OBC) or ocean-bottom-sensor (OBS) technology--If data are acquired with OBC or OBS technology, the sensors remain stationary on the seafloor as a source boat towing only an air gun array travels along the seismic line.

The distinction between stationary seafloor sensors and towed-cable sensors is important when considering the challenge of acquiring long-offset data for deep-target imaging across congested production areas. Both data-acquisition options are illustrated in Figure 1.

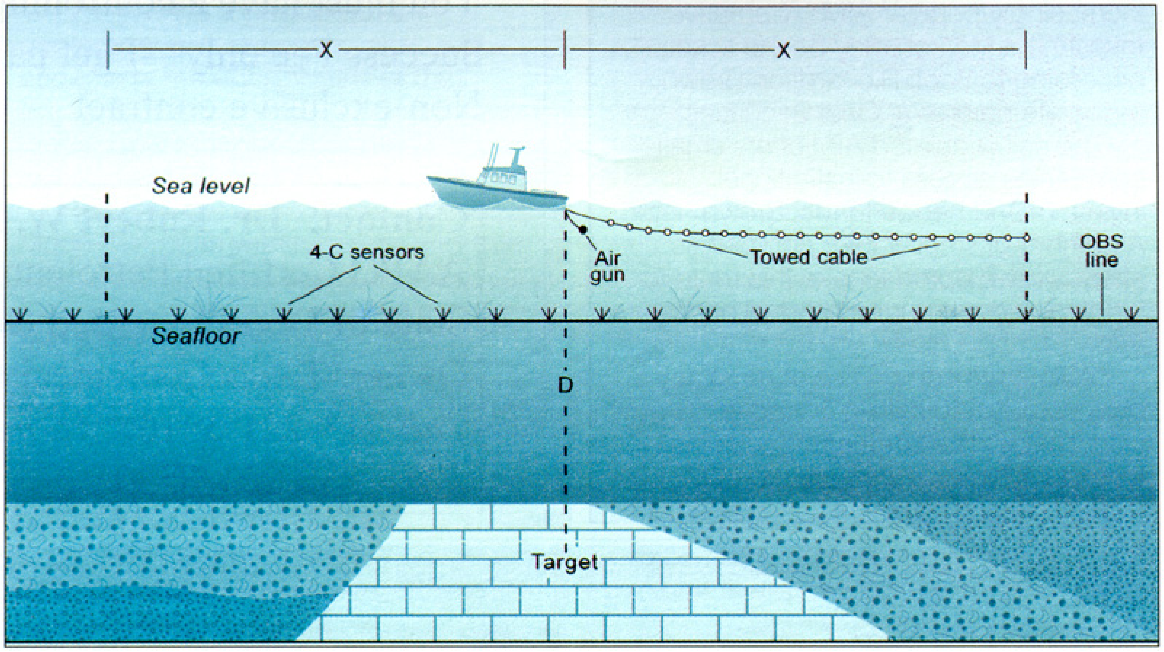

Figure 1. To image a target at depth D, the distance X from the source to the farthest receiver should equal or exceed D. Two options are shown for acquiring long-offset marine seismic data: super-long towed-cable technology and stationary ocean-bottom sensors (OBS) deployed on the seafloor. Seafloor sensors can be deployed as individual sensor packages with self-contained data storage or as long ocean-bottom-cable (OBC) linked to a recording boat.

Example of Production Congestion

An example of production congestion existing across some shallow-water areas of the Gulf of Mexico is shown in Figure 2. Here, a six-mile (10 km) diameter circle is positioned on the map to illustrate the difficulty of towing a six-mile cable across the area in any azimuth direction without snagging the cable on a platform, well head, or other surface-exposed facility. In contrast to the difficulty of executing towed-cable operations across this area, north-south OBC lines AA and BB and east-west OBC line CC (actual profiles used in one long-offset OBC data-acquisition program) pass within a few meters of several production platforms and other permanent facilities.

Once OBC sensors are deployed on the seafloor, a source boat towing only a short air gun array can maneuver through the congested area with minimal difficulty. Seafloor sensors are usually deployed along profiles extending 50 to 100 km. Thus source-to-receiver offsets of 10 km and greater are easily implemented with OBC/OBS technology for purposes of super-deep imaging in areas heavily congested with production facilities.

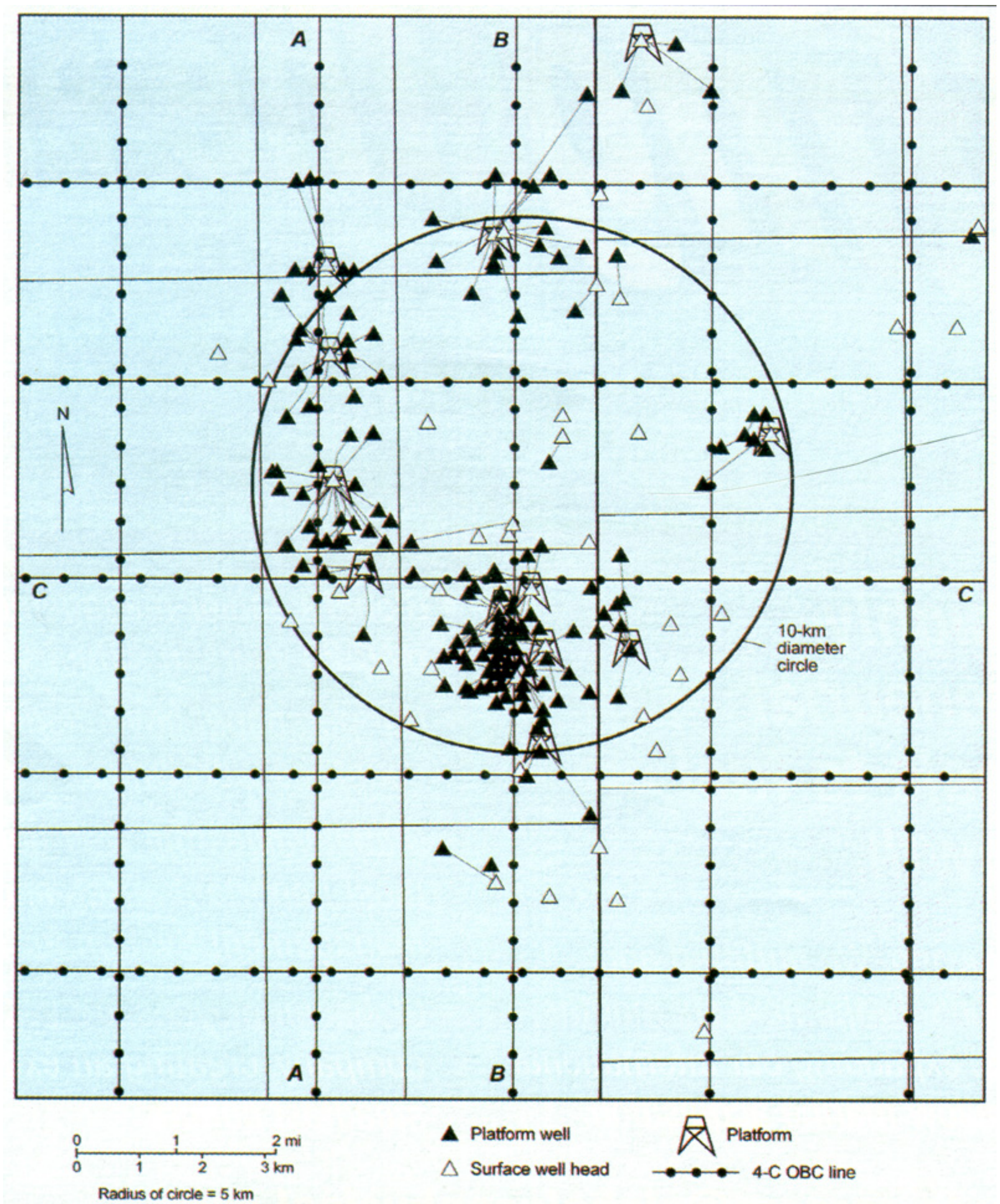

Figure 2. 4-C OBC data acquisition across one specific area of production congestion. Note how close OBC lines AA, BB, and CC are to many of the production facilities.

Example of P-P and P-SV Images

An additional appeal of OBC/OBS technology is that 4-C seismic data can be acquired, allowing targeted reservoirs to be imaged with P-SV (converted shear) wavefields as well as with conventional P-P wavefields. Towed-cable technology acquires only P-P seismic data.

An example of P-P and P-SV images constructed from 4-C OBC data acquired with nine km maximum source-receiver offsets across one congested area on the northern shelf of the Gulf of Mexico is shown as Figure 3. The P-SV image has been time warped to match

P-P image time coordinates. This time warping is a first-order depth registration of the two images based on an averaged VP/VS velocity ratio function for the area. This approximate image registration is sufficiently accurate to allow depth-equivalent geology to be identified in the two side-by-side images.

Encircled structural features A and B are interpreted to be depth-equivalent geology. The time warping technique positions reflections A and B in time-warped P-SV image space to within 100 ms of their positions in P-P image space.

A vertical salt structure blanks out the P-P and the P-SV images approximately midway between CDP coordinates 19,600 and 21,000. Using local seismic-measured rms velocities for depth conversion, the base of the data window in this display extends to approximately 7.5 km (~25,000 ft), the realm of super-deep gas targets.

Features 1 through 4 on the P-SV image indicate a cyclic depositional process, which is important geologic information that is not obvious in the P-P image. Feature 5 is an example of P-SV data showing strata that are not obvious in the P-P image. Feature 6 is an example of P-P data imaging high-dip strata better than P-SV data at this location. In our experience, we have found the opposite also to be true in some instances; that is, in some settings P-SV data image high-dip structure better than P-P data.

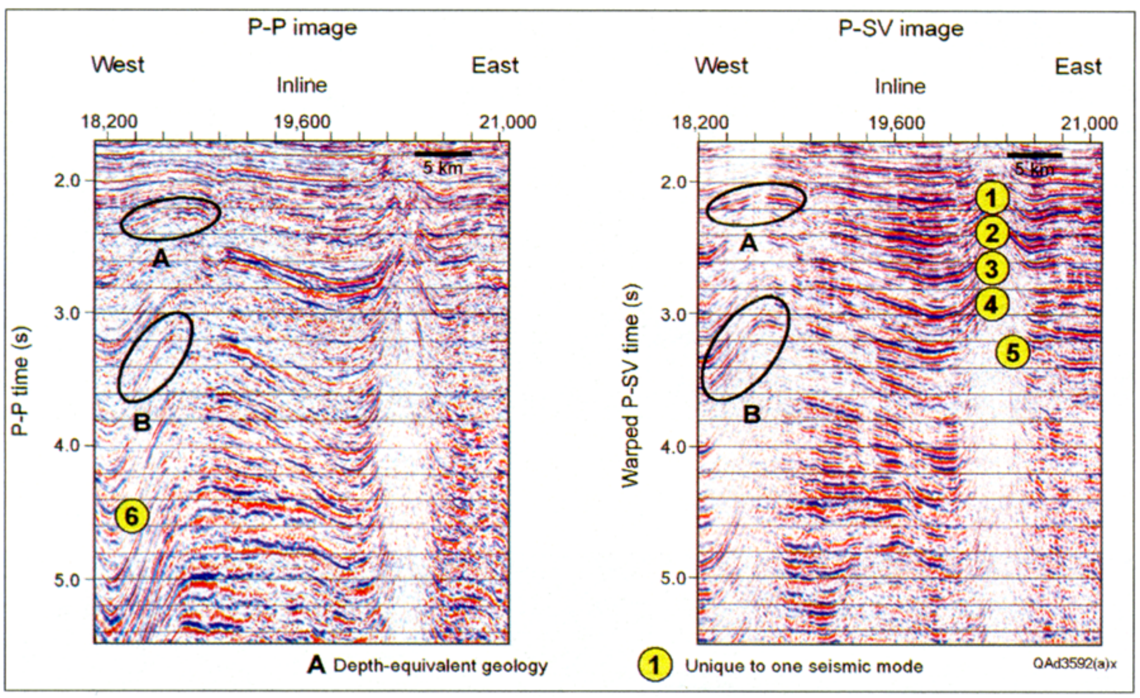

Figure 3. Comparison of deep, depth-equivalent P-P and P-SV data windows across an area of congested production facilities in the Gulf of Mexico.

Conclusions

Two important conclusions can be made from these data examples:

- First, the use of OBC/OBS seismic technology is an excellent way to acquire long-offset seismic data for imaging super-deep targets across areas where there are dense congestions of production and engineering structures. In some instances, OBC/OBS technology will be the only option for acquiring long-offset seismic data across such areas.
- Second, P-SV data image much deeper than many explorationists thought would be possible. It requires evidence such as shown in Figure 3 to establish the principle that P-SV data at depths exceeding seven km (~23,000 ft) have signal quality and spatial resolution equivalent to P-P data.

In addition to the data shown in Figure 3, our investigations have documented numerous other examples where P-SV images are equal in quality and resolution to P-P images at depths of 20,000 to 26,000 ft across the Gulf of Mexico.

Acknowledgment

The U.S. Department of Energy funded this research study; WesternGeco allowed the research team access to selected 4-C OBC multiclient seismic data.