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Extract

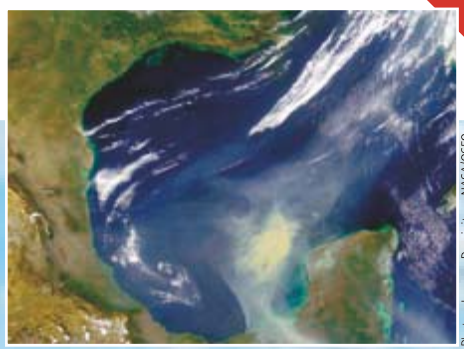


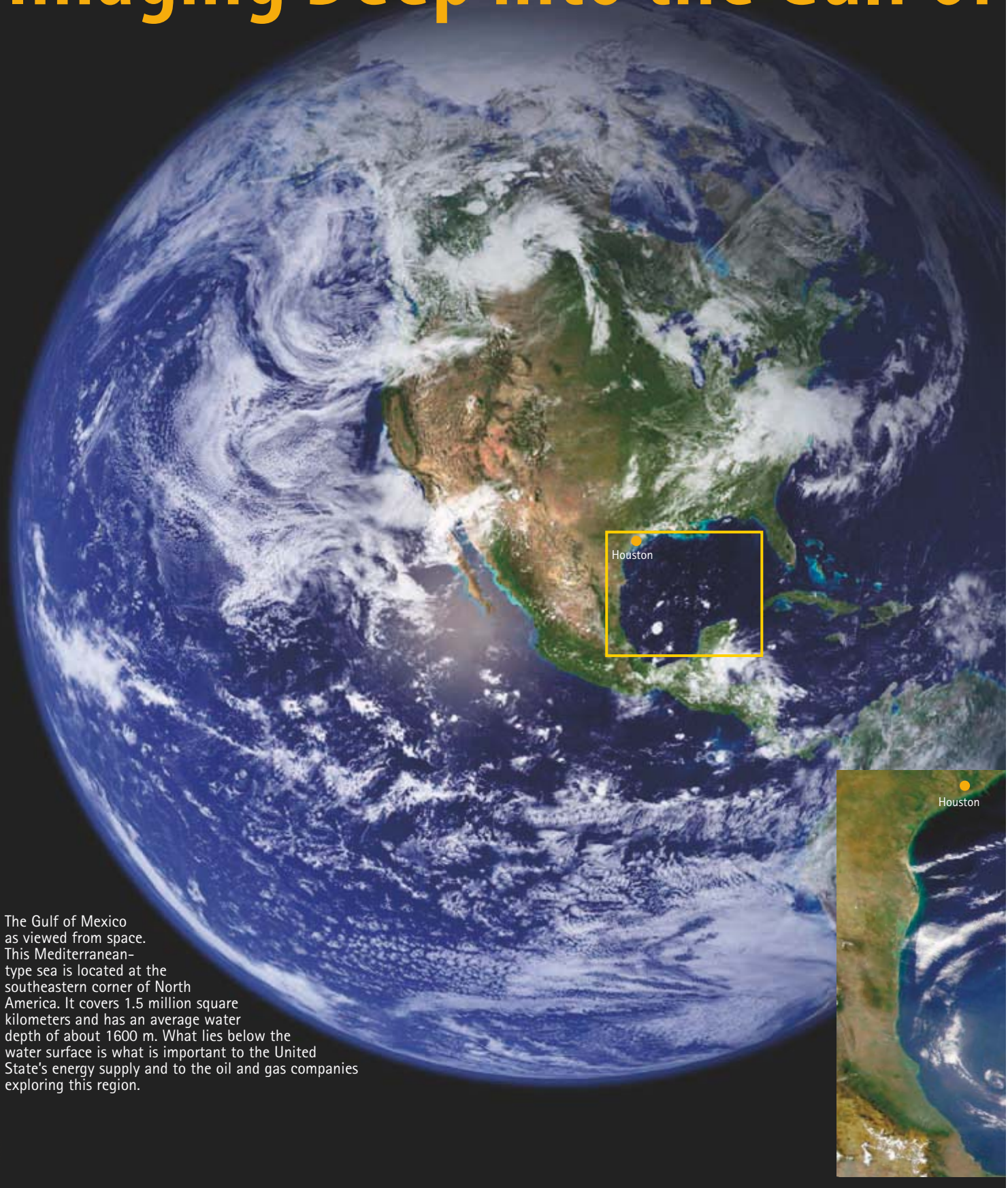
Photo: Jacques Descloitres, NASA/GSFC

www.geoexpro.com

Gulf of Mexico:
Deep Imaging

Kazakhstan:
A Sleeping Giant Awakes

Imaging Deep into the Gulf of

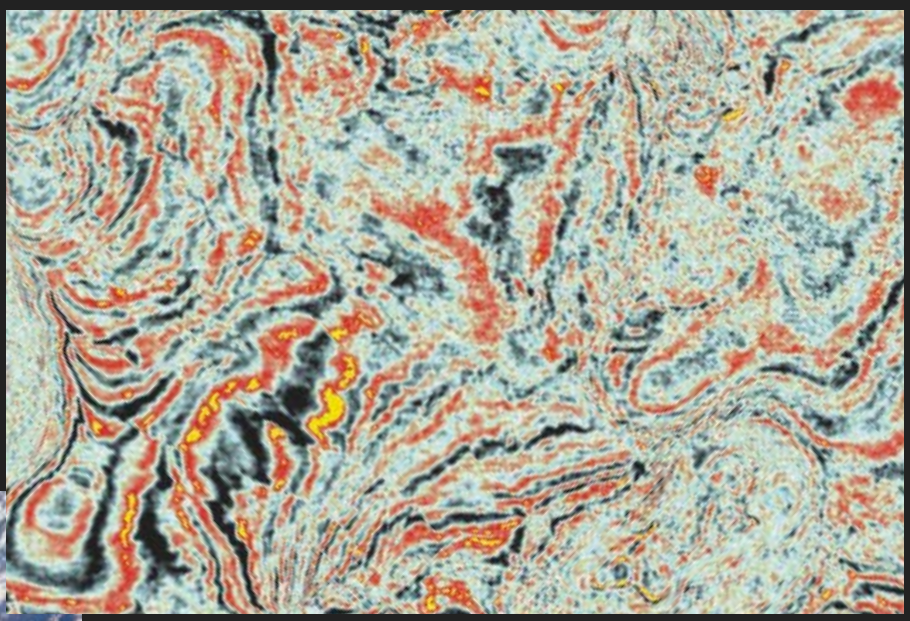


The Gulf of Mexico as viewed from space. This Mediterranean-type sea is located at the southeastern corner of North America. It covers 1.5 million square kilometers and has an average water depth of about 1600 m. What lies below the water surface is what is important to the United State's energy supply and to the oil and gas companies exploring this region.

Photo: NASA/GSFC

Mexico

Recent deep gas and deep-water discoveries in the Gulf of Mexico are pushing exploration technology to the limit. In many ways, the future success will depend on the ability of the geophysical industry to address the technical challenges offered by deeper and more obscured geologic targets.



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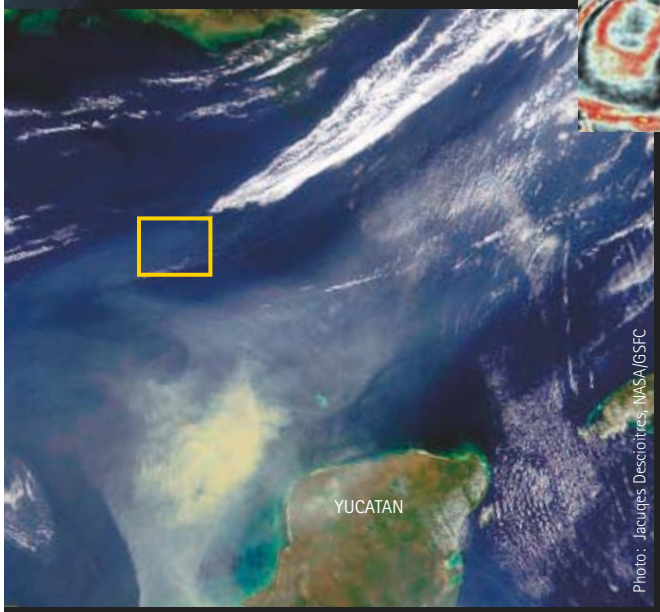
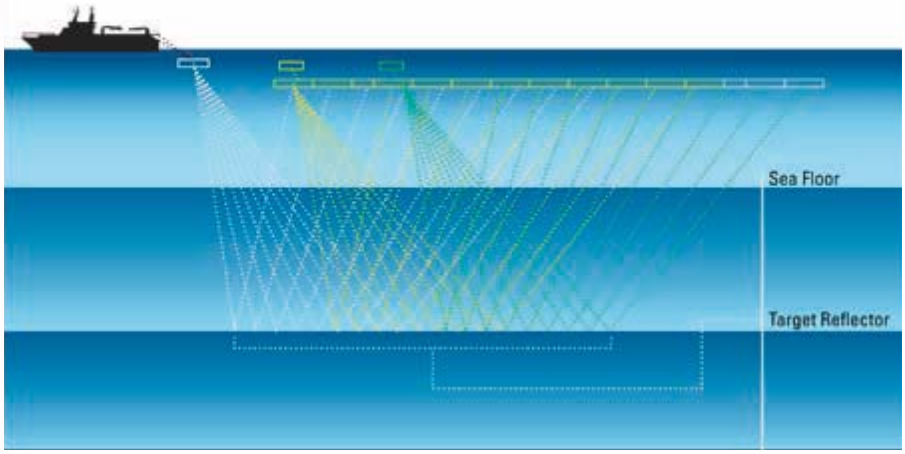


Photo: Jacques Descloitres, NASA/GSFC

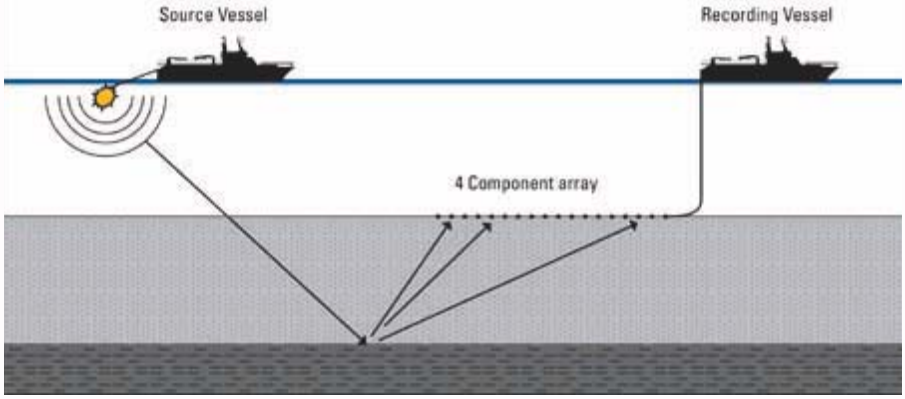
"Recently, we have seen wells drilled to more than 9000m, and in several cases wells were drilled 3000m or more after drilling through more than 3000m of salt. This is not your father's exploration program!" says Kim Abdallah, TGS VP NSA New Ventures.

Offset Acquisition



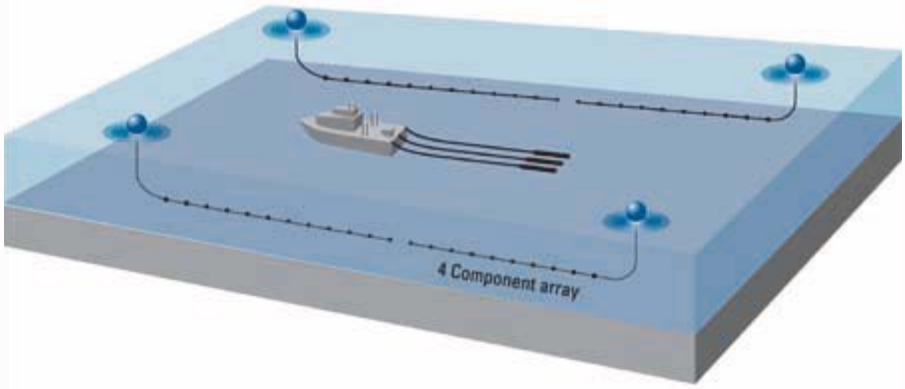
Seismic acquisition using a towed hydrophone array and towed energy source.

OBC-Type A



Seismic acquisition using a 4-component cable positioned on the sea bed and a towed energy source. The data is recorded on board the recording vessel.

OBC-Type B



Seismic Acquisition using a 4-component cable positioned on the sea bed and a towed energy source. The data is recorded in float buoys and retrieved periodically.

Thomas Smith, Associate Editor

It is no secret that it is becoming more and more of a challenge to meet the expected production increases in the Gulf of Mexico. With its incredible potential, the much touted deep gas shelf play seems to be just out of reach of today's drilling technology. For elephant hunting, the deep-water areas continue to receive the most attention. This has been aided by recent announcements of 12 deep-water discoveries and the emergence of the deep-water Lower Tertiary Wilcox trend.

Data Acquisition Challenges

The Gulf of Mexico has long been a proving ground for exploration technology. Few areas in the world offer the multiple geologic challenges of the Gulf of Mexico (GEO ExPro, No. 4/5, 2006; www.geoexpro.com). Potential hydrocarbon traps can be hidden by salt, gas clouds, multiples and water bottom issues (statics), to name a few. In addition to the geologic challenges, there are those man made challenges like thousands of surface obstructions, environmental concerns, political issues and basic supply and demand dynamics. On top of all of this, there is Mother Nature that must be dealt with in the form of destructive hurricanes and tropical storms.

More than ever, today's seismic data must meet the critical technical, financial, and timing requirements of the industry. Said factors over the last two to three years have caused the proprietary seismic acquisition and processing market to increase dramatically. Multi-client seismic data continues to comprise most of the data being acquired in the Gulf of Mexico, however, the increased costs and hampered capacity have reduced some enthusiasm for acquiring multi-client data. Now, only a handful of companies have continued to invest in multi-client surveys.

Deep Prospects

Motivated by the deep gas shelf play and aided by legislative relief, many of the older explored areas are coming back into the leasing mix. Most of the older geophysical and geological data available in these areas was not acquired or processed contemplating the drilling depths and complex targets that are now being explored. In some cases, imaging has been improved through more current reprocessing techniques but in other cases new data acquisition has been warranted. By utilizing existing data, areas in need of technical revival can be identi-

Large tropical storms like Hurricane Katrina (pictured above) can change the sea bottom, move structures (Pictured is the Diamond Offshore Drilling, Inc. Ocean Warwick where it washed up on the Alabama shore after Hurricane Katrina), and generally raise havoc with Gulf of Mexico operations. "In the middle of TGS' OBC acquisition program in 2005, Hurricanes Katrina and Rita passed through the Gulf. Upon our return to the project area, several of the surface obstructions were no longer visible" says El-Tawil.

fied and plans can be devised to optimize acquisition and processing.

"All of the easy projects have been done in the Gulf of Mexico. The level of complexity has risen dramatically. We must be prepared to create a good image of the subsurface all the way down to 14 kilometers simply by applying new imaging and acquisition techniques to seismic data." says Kim Abdallah, VP NSA New Ventures of TGS.

Across the Gulf of Mexico shelf, recent drilling targets have been as deep as 10 km. To create images of such deep targets, the data must be recorded with longer offsets and with longer listening times than the data historically acquired in these areas. Today's marine acquisition system typically tows six or more super-long cables extending 8 km or more across the exploration target. This equates to a vessel towing a swath of equipment 1 km or more wide by 8 to 9 km long. Complicated by the fact that the Gulf of Mexico shelf is highly obstructed with thousands of surface facilities and platforms, the ability to safely tow this amount of gear behind a vessel is very limited.

To overcome these difficulties, two methods of marine seismic acquisition are being employed by TGS to obtain the most complete coverage over these areas. A "multi-pass" acquisition technique is used to successfully achieve the longer offset required for today's shelf exploration. While effective, complete coverage with this technique is impossible due to water depths and obstructions.

A second method for acquiring this data uses stationary ocean bottom cables (OBC) on the ocean floor. Instead of towed streamers, the cables are affixed to the sea floor in pairs. A source boat makes several traverses between the cables before the cables are

Meeting Future Demand

The importance of the Gulf of Mexico to the U. S. energy supply cannot be over stated. The offshore area has produced 30 billion barrels of oil equivalent (4.8 Bm3) over the past 70 years. In 2004, oil production in the Federal portion of the Gulf of Mexico Outer Continental Shelf (OCS) was 1.48 MMbopd and 11 bcfgpd. These figures represent about 27% of the nation's oil production (94% of the Federal OCS oil production) and 20% of the nation's gas production (99% of the Federal OCS gas production).

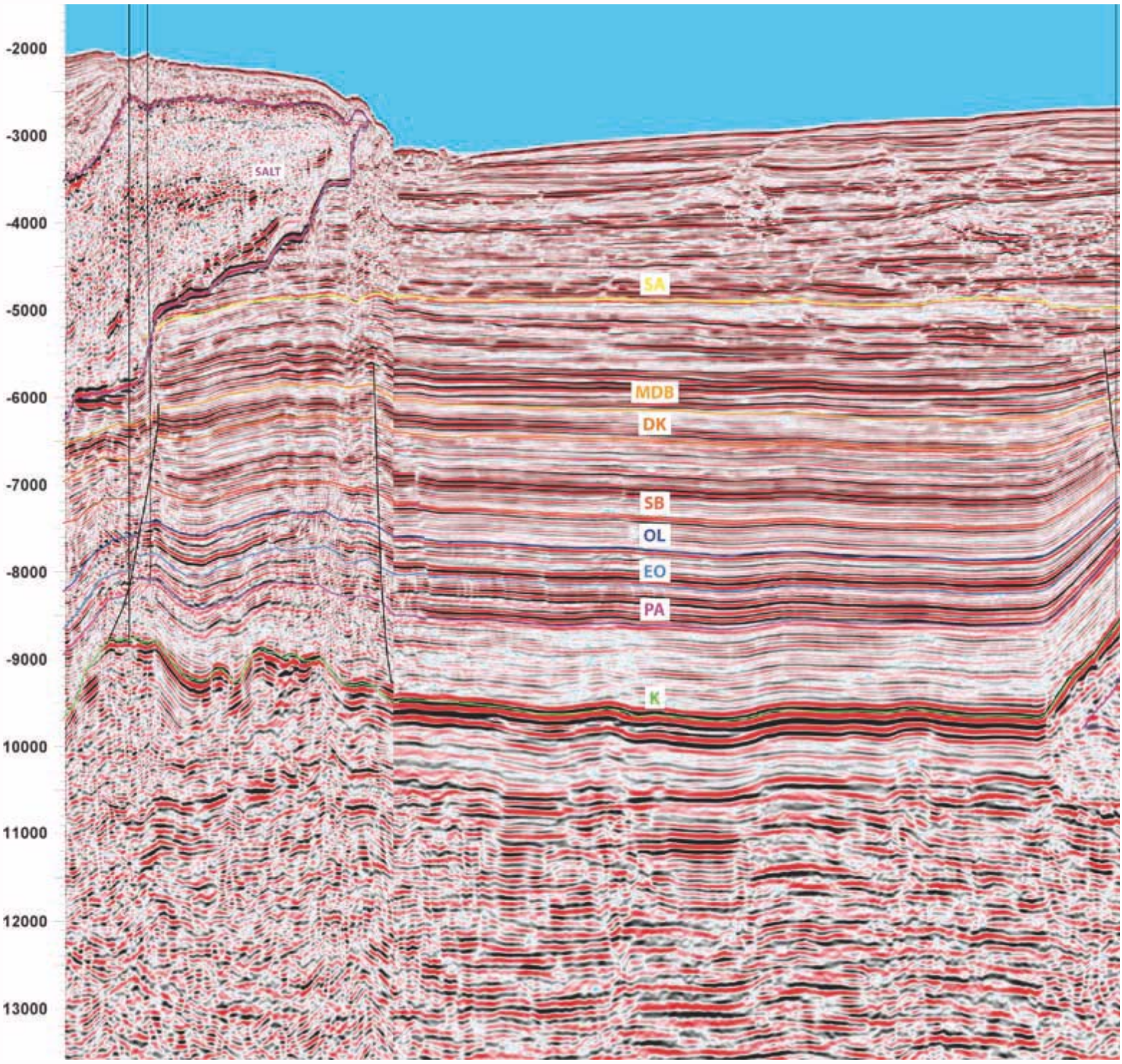
The Energy Information Administration (EIA) forecasts oil production to increase in the Gulf of Mexico to 2.41 MMbopd or over 41% of domestic production by the year 2015. Gas production over the same period is expected to reach 14 bcfgpd or nearly 25% of the nation's total production.

Since 1995, oil production in the Gulf of Mexico has increased 35% with deepwater production increasing 500% over the same period.

Availability of leases, new discoveries, and importance to the domestic energy supply will combine to keep the entire Gulf of Mexico a hot exploration target. Many 10-year leases are due to become available over the next several years and will be included in upcoming lease sales. The Minerals Management Service (MMS) has an aggressive five-year leasing program in the Western and Central Gulf of Mexico with 10 planned lease sales. No other lower 48 OCS lease sales are planned because most of the areas have been withdrawn from leasing until June 30, 2012.

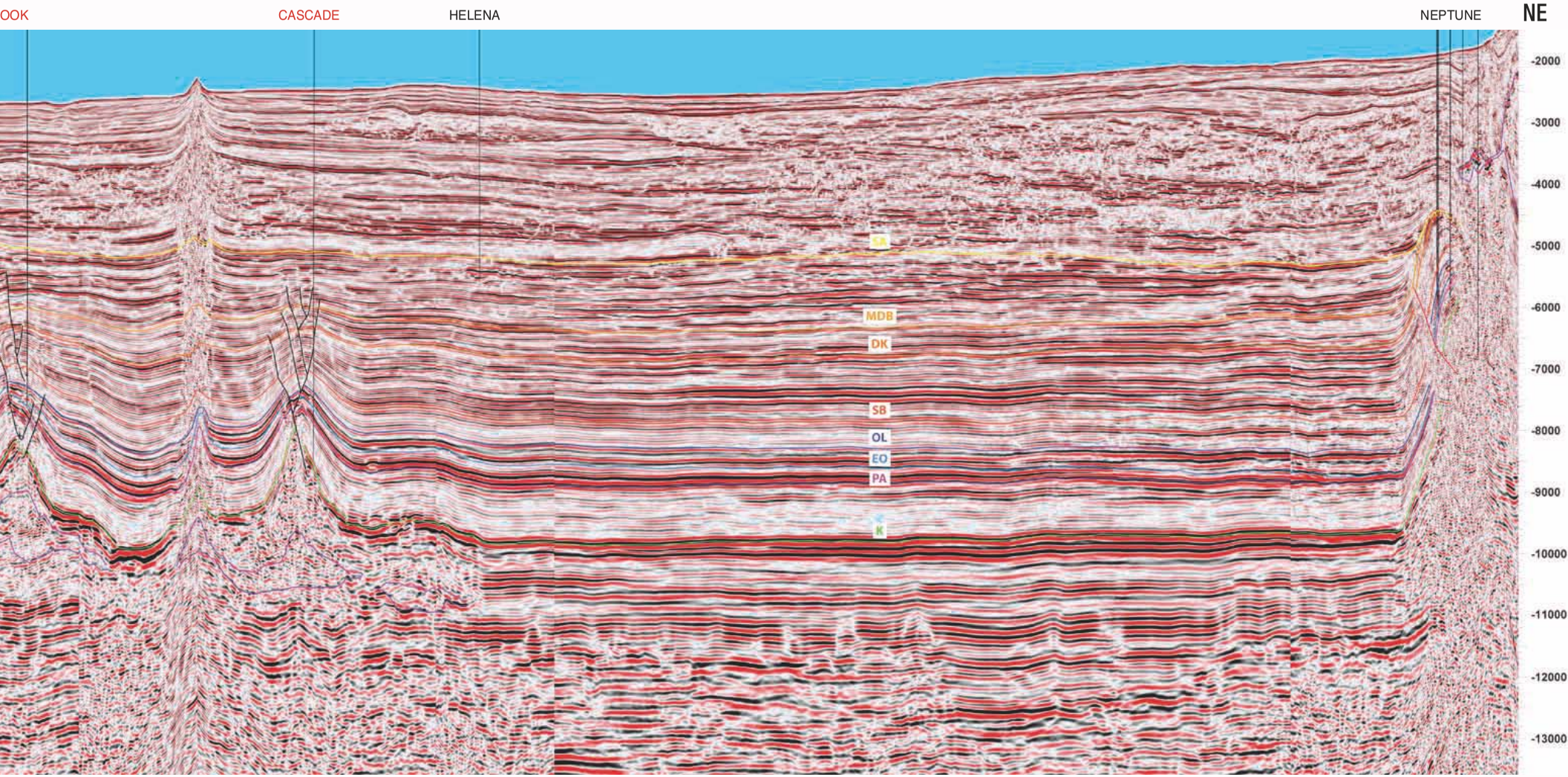
Deep-Water Gulf of Mexico

With 12 recently announced deep-water discoveries and an aggressive leasing schedule for the Western and Central Gulf of Mexico, exploration and production technology is being pushed to its limits. To meet industry needs to image deeper and more obscure targets, TGS-NOPEC Geophysical Company has over 2.5 million km of 2-D and 88,000 km^2 of 3-D seismic data available in the Gulf, of which this line is an example.



The Ocean Confidence semi-submersible rig is used to drill deep prospects in the deep-water Gulf of Mexico.

Sediments, similar to these off the current Mississippi delta, derived from the north, have been filling in the Gulf of Mexico since Jurassic time..



MMS and the Gulf of Mexico OCS Region

Before exploration and production can proceed in the Gulf of Mexico, law requires the MMS to approve every exploration well, every production proposal, the structural design of every platform as well as every pipeline, and must issue literally dozens of other approvals for the design and operation of facilities and measurement of product. It conducts extensive environmental reviews of proposed projects. MMS also conducts thousands of inspections every year to ensure operational safety and protection of the marine, coastal, and human environment.

MMS requires over 600 professionally trained employees in a host of disciplines to accomplish the immense tasks necessary to manage such an active exploration and production area. Petroleum engineers, geophysicists, geologists, marine biologists, oceanographers, other environmental scientists, offshore inspectors, and computer personnel are among other professionals that MMS employs. Along with oversight duties, MMS personnel provide numerous publications and information which can be found on their web site at www.gomr.mms.gov.

Photo: MMS, Director

Pictured are MMS Director Johnnie Burton and Gulf of Mexico Regional Director, Chris Oynes. According to Oynes "The offshore oil and gas industry in the Federal part of the Gulf of Mexico is truly a large and multifaceted group. During December 2006, 86 exploration wells were being drilled in Gulf waters and 49 of these were in water depths of 1,000 (300 m) feet or greater. Ten exploration wells were in 5,000 feet (1500 m) of water or greater. Currently, there are approximately 3,911 production platforms, of which about 1,850 are major platforms (1,045 of these are manned by personnel) and some 182 designated operators are active in the Gulf."

retrieved and redeployed to increase the area of coverage. The OBC operation allows for better coverage in congested areas and often times is the only way to obtain data. It has additional appeal in that 4-C data can be acquired recording both P-SV (converted shear) and P-P wave fields. The OBC data does have limitations such as higher operational costs (than streamer operations) and water depth limitations.

"By using a combination of towed streamer configurations and OBC techniques, TGS has recorded long offset state-of-the-art surveys in some of the most difficult areas of the Gulf of Mexico shelf. This has been done while battling the havoc caused by recent weather disasters in the region when the Gulf was turned into a battlefield of floating debris such as trees, houses, appliances, stairwells, roofs, and runaway boats and rigs," says Abdallah.

Emerging Deep Water Technology

The recent discoveries and large potential in the deep water Gulf of Mexico have put added emphasis on this region. A significant portion of this play is covered in salt sheets ranging from hundreds of meters to thousands of meters. Drilling technology has advanced to allow the testing of reservoir targets to 10 km in water depths exceeding two km. To enable more accurate imaging below the salt bodies in the deep water, the seismic industry has made technological advances in data processing and data acquisition.

Looking beneath the salt layer is a major challenge throughout the world (see GEO ExPro, Vol. 3, No. 4/5, pp 26-28; www.geoexpro.com). Until recently, most of the improvements have come from data processing related advances such as advanced multiple suppression techniques, salt modeling exercises, Kirchhoff, Wave Equation and Beam Steer depth migration algorithms, and most recently, reverse time migration. Lately, advances related to acquisition methods have exploded with the emergence of multi-azimuth, wide azimuth, and rich azimuth techniques now being employed to address sub-salt imaging and multiple suppression issues. These emerging deep-water technologies are so new it could take years of analysis of the newly acquired data to determine if one method is superior to another.

Photo: TGS

"TGS-NOPEC Geophysical Company (TGS) has invested heavily in the Gulf of Mexico over the last quarter century. We are using our experience here to continue to design surveys in both the highly explored areas and some of the more frontier deep water areas," says Karen El-Tawil, VP NSA Sales.

Photo: Gary Fagot, MMS

This example of how obstructed some of the Gulf of Mexico can be is from the East Bay production facility. It was developed by Shell at South Pass in 1957.

Processing Challenges

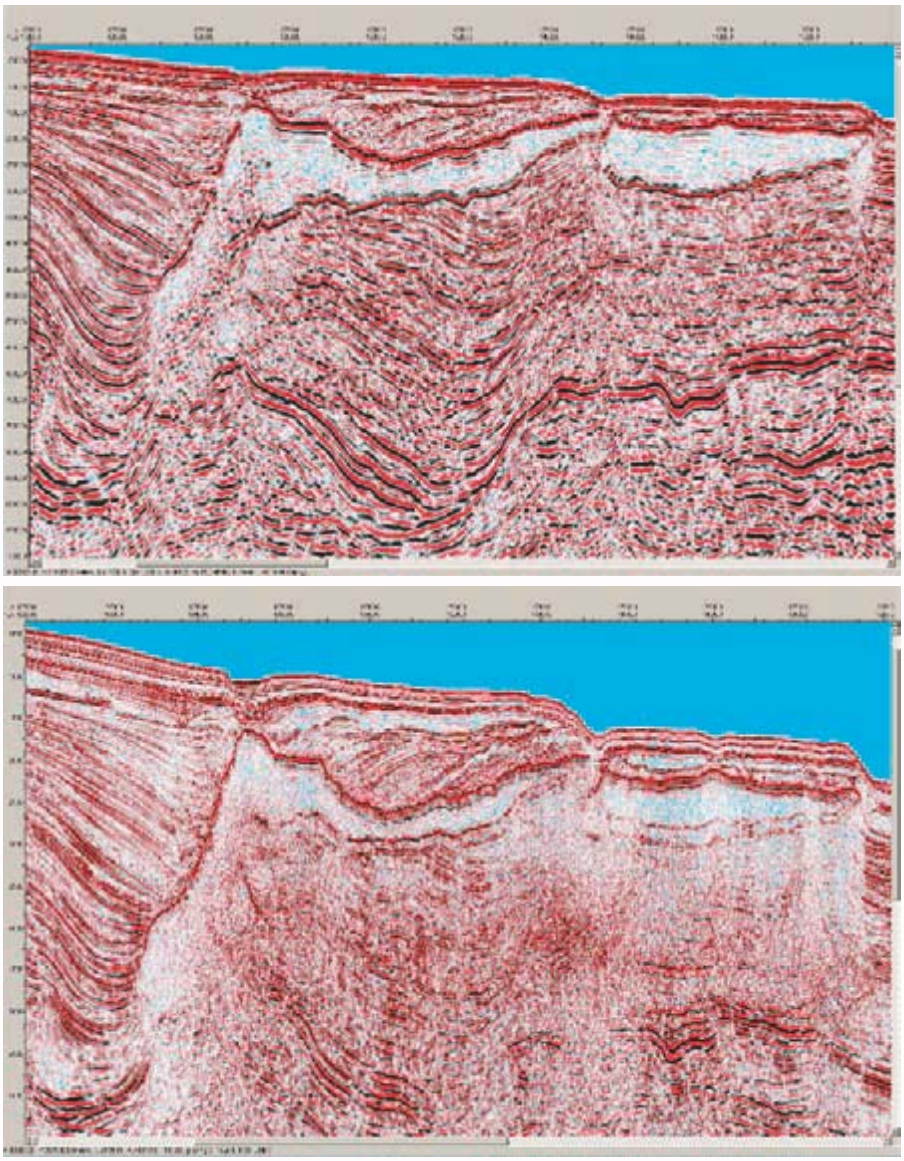
No matter what acquisition method is used in recording seismic data, a significant challenge remains in processing the data in order to optimize the subsurface image. The Gulf of Mexico is wrought with imaging problems due to the massive amount of salt in the basin. Although historically much more expensive and time consuming, pre-stack depth migration (PSDM) techniques have effectively helped improve the image previously unseen under salt. With more efficient hardware and software, PSDM is now considered a standard product for the Gulf of Mexico explorationist, but not the only tool.

Using all the data available through integrated software products that include purified and synthetic seismograms from digitized well logs allow for more accurate ties to the well bore. Sub-stack products are providing geophysicists additional tools for AVO evaluation and additional proprietary refinements of salt models. Multiple migration algorithms for its depth imaging are a must given that the complexity of sub-salt geology often requires that multiple PSDM volumes be produced. Some processing algorithms excel at imaging steeply dipping flanks of salt while others are better at illuminating the image below the salt. It is difficult to optimize both images with one migration algorithm.

Better sub-salt imaging is also aided through the study and analysis of energy propagation which help determine shadow zones that lead to poorly imaged zones. Interactive ray tracing helps determine the optimal parameters to properly image steeply dipping beds and sub-salt structures. Looking at pre-stack gathers in the time or depth domains allows for interpretation of both post-stack and pre-stack horizons. Determination of the best stacking angles can also be evaluated through the interaction with the gathers. Integrating processing with other geoscience applications fills the voids that exist in many interpretation systems.

Acknowledgements

Thanks to Jenny Salinas, Karen El-Tawil, and Kim Abdallah of TGS and Caryl Fagot of MMS for their help in putting this article and the seismic foldout together.



TGS MC Rivival 3-D survey: Top is the pre-stack depth migration and bottom is the pre-stack time migration.

TGS History

TGS-NOPEC Geophysical Company (TGS) was formed in 1998 when TGS CALIBRE and Nopec International merged. The company currently develops, manages, conducts, and markets seismic surveys, primarily serving the North Sea, Gulf of Mexico and emerging frontier regions such as Africa, Middle East, and Russia. Through gravity, magnetic, 2D, and 3D seismic data technologies, TGS provides comprehensive and regional image views to aid in the exploration of oil and gas. Their A2D Technologies unit is a provider of petroleum well log data with the largest database of digitized well logs available in the industry. They help companies acquire, interpret, and manage this data. To expand their seismic data processing technologies, TGS acquired the energy division assets of NuTec Sciences in 2004 to form TGS IMAGING. They also significantly expanded their geoscience knowledge-base through the 2006 acquisition of Aceca Geologica, an interpretive geoscience consultancy.

"Using the Gulf as our proving ground, the company has a world wide presence. We are an industry leader in data acquisition with one of the largest collections of 2D and 3D multi-client data and the most extensive online database of digital well logs ever compiled," says El-Tawil of TGS.