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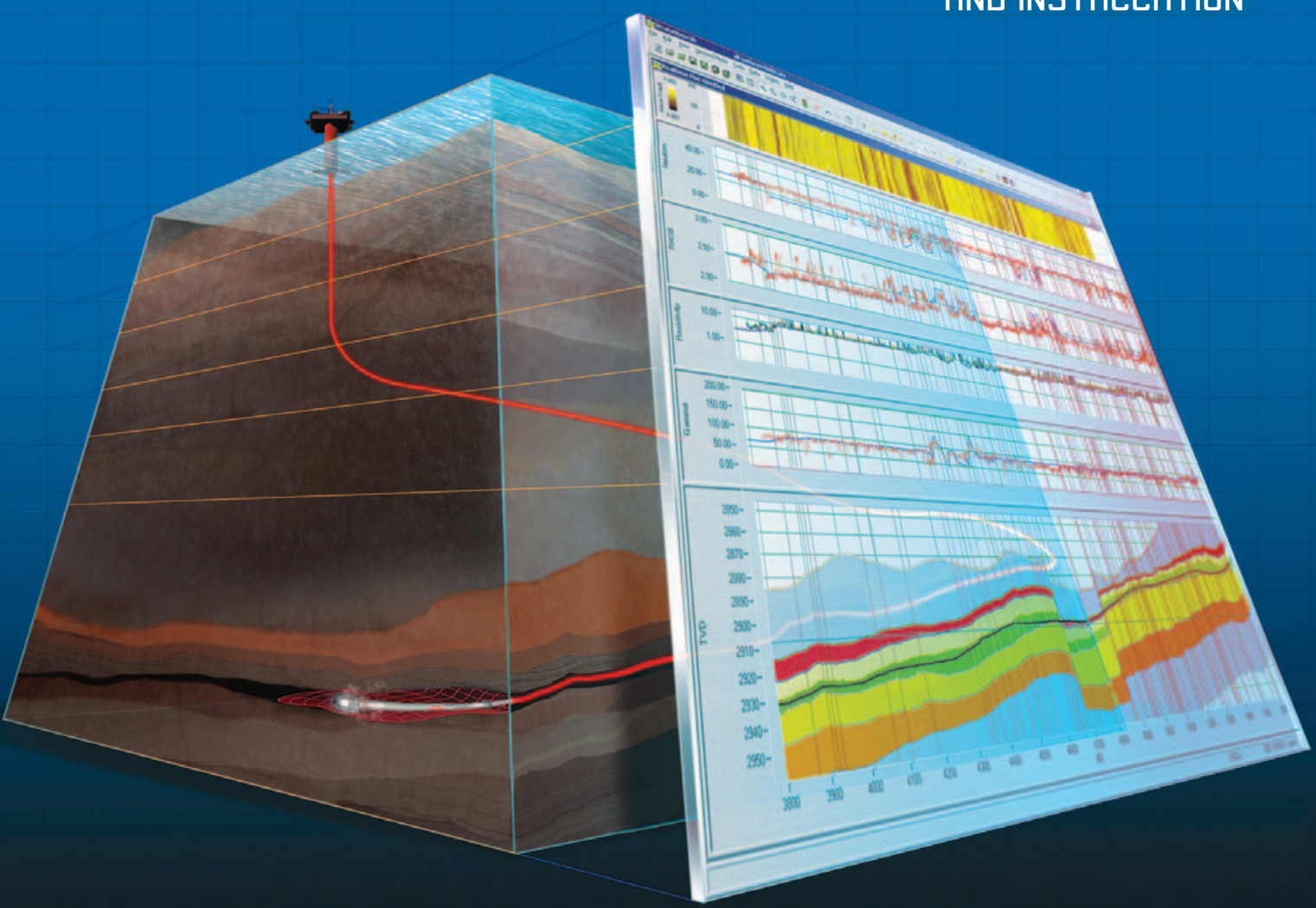

SPECIAL BONUS:
DIGITAL OIL FIELD

Pioneering a global play

Subsalt discoveries are exciting news. But they're not as risky as they used to be.

By RHONDA DUEY, Senior Editor

The buzz is everywhere — presalt, subsalt, Tupi, Jack, Tahiti, wide-azimuth seismic, reverse time migration imaging.

In other words, any target lying below a sheet of salt, whether in its original spot or having migrated over time, is a matter of great interest to oil and gas explorationists. The excitement is not new. But the success rate is. It's taken a confluence of new ideas and even newer technology to get us to 2009. And, according to Clint Moore, vice president of corporate development at ION Geophysical Corp., we are just now "in the dawn of the global subsalt play."

Rewind to the 1980s, and the subsalt play in the Gulf of Mexico (GoM) was in the "predawn darkness." Moore was there as one of the pioneers, first as a senior GoM geologist for Diamond Shamrock and later at Anadarko. He recently gave E&P a tutorial on how we went from very risky prospects with a few fortunate discoveries to the kinds of successes the industry is enjoying today.

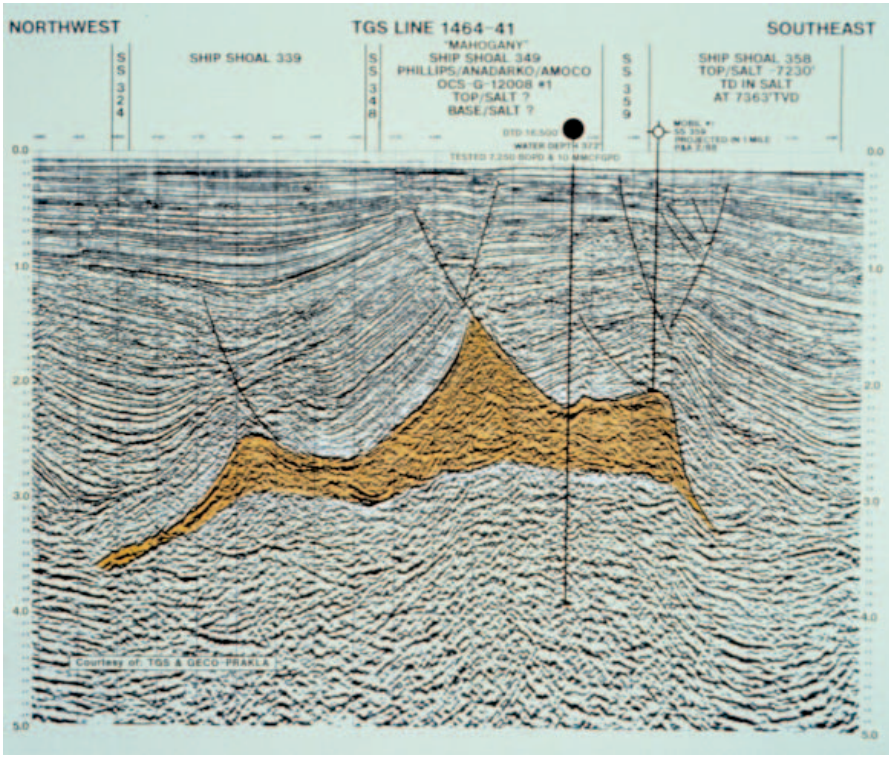

Figure 1. *Seismic profile from the Mahogany well, the first commercial discovery in the subsalt play. (Data courtesy of TGS and WesternGeco from AAPG Search and Discovery Web Site; images courtesy of Clint Moore)*

The 1980s

Moore said that presalt plays, plays in which the salt still lies where it was essentially deposited, have been explored and developed for decades. Usually these were fairly thin continuous salt beds that didn't present overly challenging imaging or drilling problems.

The Gulf was another matter. "The common thought at the time was that the salt was mostly vertical, and if you drilled into salt you were drilling into a vertical dome," Moore said. "What we learned in the 1980s, through a series of both intentional and unintentional subsalt wells, was that the salt could very much be a remobilized feature."

Early wells, intentional or otherwise, were not successful in finding much thickness of reservoir-quality rock below salt, and by the mid-1980s the general consensus was that subsalt plays in the Gulf were not very prospective, even though what looked like potential structures could sometimes be seen on seismic data. But during this time, what Moore called "concurrent exploration thinking among peers" was taking place, particularly within and among the majors (of which there were many more 20 years ago).

"That often generates momentum in furthering plays and play concepts," he said.

In 1985 Moore was a geologist at Diamond Shamrock, and the company purchased a lease in South Marsh Island Block 200. "This was a nice structural prospect with amplitude across the structure, and we drilled it with several partners," he said. "In early December of that year, we were drilling below 8,800 ft (2,680 m), and I received a midnight call from the mud loggers at the well site telling me that anhydrite crystals were coming across the shale shaker. That was certainly unexpected because we were many miles away from any known salt dome."

The partnership made the decision to stop and run a wireline log to check out the geology. Sure enough, the well had drilled into 250 ft (76 m) of salt

"that wasn't supposed to be there." They decided to drill ahead for another 72 hours and ultimately drilled through 1,000 ft (305 m) of salt, then 1,500 ft (395 m) of shale below its base, before they discovered "a very, very thick, highly porous and permeable sandstone interval" of almost 1,000 ft. While the sandstone did not contain oil or gas, it was proof that high-quality reservoir rock could, indeed, exist below salt in the Gulf.

"Sand of that magnitude had not been seen below salt before in the Gulf until that moment," Moore said. "The South Marsh Island 200 well is a discovery of petroleum geological significance, but it was a dry hole. Still, it was, for me, and eventually my fellow geological colleagues, a huge 'discovery moment' because it demonstrated that the Gulf had another major play concept that could have far-reaching commercial potential."

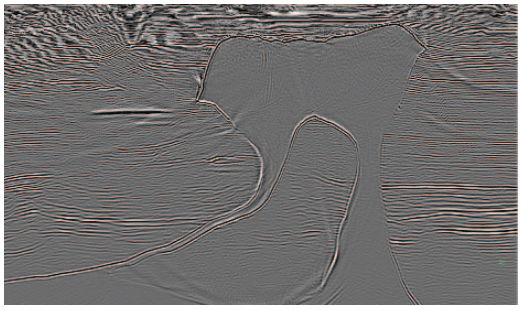

Figure 2. RTM images more clearly reveal deep salt-sediment geology than other forms of processing.

Mahogany

Despite this promising news, Moore's superiors at Diamond Shamrock were very concerned about the imaging issues beneath subsalt, with good reason. Sound waves travel through salt at a velocity much higher than surrounding sediments, meaning that anything below the salt is imaged poorly by conventional processing, if at all. His company didn't think the imaging issues could be solved any time soon.

He soon moved over to Anadarko, where GoM subsalt exploration was of great interest. As a result, Anadarko leased several subsalt prospects in the 1990 lease sale, partnering with Phillips Petroleum to test the concept further. Ironically, Anadarko stood out of Phillips's bid on the two leases that became the Mahogany discovery but bought back into the prospect before the wildcat well was spudded. Amoco bought into the prospect as well and, with Phillips as operator, the three partners discovered the Mahogany field in 1993, which ultimately became the first subsalt producing field in the GoM.

This is not to imply that these companies had somehow overcome the imaging issues — Phillips bid on Mahogany based on 2-D data and then applied its newly developed prestack depth imaging algorithm to a subsequent 3-D survey over the leases, which helped to improve the image quality of the subsalt section "enough to position the proposed location of the wildcat well," Moore said.

The discovery well penetrated 3,825 ft (1,160 m) of salt and logged more than half a dozen individual sandstone zones between depths of 12,300 and 16,300 ft (3,750 and 5,000 m), with the main oil zone roughly 180 ft (55 m) thick. Later development drilling found additional oil sands as well. The field was brought online in 1996 and soon was producing almost 20,000 b/d of oil.

The Mahogany discovery was quickly followed by both commercial and noncommercial discoveries at Teak (1994); Enchilada (1995); and Gemini, Agate, and Monazite, all in 1996.

(Interestingly, Mahogany was not actually the first successful GoM subsalt discovery — Exxon discovered oil sands below salt at Mickey, later renamed Mica, in 1990 at Mississippi Canyon Block 211. But it didn't develop the field for 10 years, whereas Mahogany came online about 3 years after discovery).

This century

While the subsalt play in the GoM took off during the 1990s, it was still a rather hit-or-miss process because of the lack of compute power to run the types of algorithms needed to more accurately image below salt. Moore said that the ultra-deepwater lease sales in 1995-97 saw companies step up leasing past the subsalt play into ultra-deep water (more than 2,625 ft or 800 m), encouraged by easier-to-image prospects near the edges of those salt structures.

But technological advancements, led primarily by rapid increases in computation speed, have caused prestack depth migration to give way to reverse time migration (RTM), thus providing much clearer images of subsalt structures. In fact, Moore joined ION-GX Technology in early 2008 when that company announced a much faster and clearer RTM algorithm. Today's RTM results more clearly image the salt and the subsalt structuring for optimal pinpointing of well locations, while early efforts such as at Mahogany only inferred possible structures beneath salt.

Additionally, new acquisition configurations such as wide-, multi-, and rich-azimuth technologies have provided better raw data to be available for the advanced RTM processing.

With recent developments offshore Brazil as well as other places around the world, presalt and subsalt plays are increasingly becoming part of many oil companies' portfolios. But Moore said that geological concepts must continue to evolve. "Ultimately, there are few limits on future global oil and gas potential below salt. Whether its subsalt or presalt, we just need to accurately image below it.

"It's still morning on the planet in terms of the play. We've got decades to go, yet we've come a tremendous distance since the 1980s in terms of technology and success. I expect those future decades to be even more significant." FNP

Editor's note: *Don't miss Hart Energy Publishing's Subsalt Solutions Conference Sept. 22, 2009, at the Omni Woodway in Houston. Clint Moore will be the luncheon keynote speaker. For more information, visit www.hartenergyconferences.com/subsalt.*