Offshore oil prowess:
Eni’s expertise in deep offshore oil exploration

As the planet’s easy-to-find petroleum resources mature, deep offshore exploration and production lead the trend to the more difficult and challenging regions. Eni is one of a handful of leaders.

By Graham Chandler

Peak Oil theories aside, it’s no secret that the world’s easily-found petroleum reserves have mostly been discovered already. And as the planet continues to consume at the rate of nearly 1,000 barrels a second they are depleting. Exploration companies are pushing further into frontiers where environments are harsher, or were hitherto limited by technologies of the day.

The International Energy Agency predicts that oil will continue its dominance of the world energy scene well through 2035. By then, the organization projects, daily global consumption will have increased 18 percent to 99 million barrels per day. There will probably be enough to go around, but it’s ever-increasingly located in more expensive and complex frontier locations. So that’s where the exploration is trending.

New technology such as horizontal drilling and multistage fracturing is already unlocking vast new production levels from fields long abandoned as uneconomic—North America’s Bakken formation for example, which is expected to soon be producing a million barrels a day. These ‘tight’ and shale plays are skyrocketing in countries around the world and will help advance world production numbers. But it’s the frontiers where the big new elephant fields are being discovered.

Leading the new frontier exploration trend is the deep and ultra-deep offshore: the east coast of South America, the east and west coasts of Africa, and the Gulf of Mexico for example. Brazil is reported to have nearly 48 billion barrels of oil in water deeper than 600 meters. One field alone—the Lula—holds probably 6.5 billion barrels. Africa’s offshore west coast is where the world’s most active deepwater fields are found—primarily Angola and Nigeria.

The Gulf of Mexico, with more than 3,400 offshore production facilities, has been producing for decades. But further out, 300 or so kilometers from shore, the water is deeper and the geological formations are older. Esteemed energy research firm IHS CERA has suggested there’s nearly 13 billion barrels of...
recoverable deepwater oil out there yet. And already Shell’s Perdido production platform is on location producing from deposits 2,400 meters below the surface.

Knowledge of these deposits’ existence has been around for some time. Geological theory suggested the reservoirs were out there in sedimentary units past the offshore deltaics and into the turbidites. But the technology to explore and produce them wasn’t.

Holding back seismic exploration was largely the presence of massive salt layers which can be over two kilometers thick, laid down millions of years ago as ancient oceans evaporated. These high velocity media, with strong lateral velocity contrasts, induce such intense bending in the seismic waves that lots of the reflected energy can’t be recorded. This creates problems especially in the imaging of the salt flanks and in the formations below salt.

Leading the technological frontiers that have been unlocking the ‘salt barriers’ and making the discoveries possible is a handful of world companies. One who has developed the expertise is global player Eni.

Luca Mapelli, Potential Data Team Leader at Eni, explains how progress was made in seismic modeling that led to the breakthroughs. “First you search for easy targets, then when you need to increase the reserves you start looking for difficult targets,” he says. As these targets became the deep offshore, improved seismic processing capabilities were coming to the fore over the past decade, which opened up ways of looking beneath salt layers. “Explorers were able to better look beneath salt,” he says, “which still poses imaging difficulties, but less than before.” Those advances included better processing through PSDM, RTM and better data gathering using WAZ, MAZ, and coil shooting says Mapelli. PSDM, or Prestack Depth Migration, is a model-based seismic imaging methodology. Compared to conventional time migration image processing, which assumes that seismic waves are propagated in straight rays, PSDM is pricier and slower but the payoff is more precise determination of reservoir structures. RTM, or Reverse Time Migration, can boast simplicity and superior imaging quality by using a full solution 2-way wave equation—it makes no approximations limiting the direction in which

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seismic energy can travel. WAZ (wide-azimuth), MAZ (multi-azimuth) and Coil shooting are advanced acquisition techniques aimed at addressing the illumination problems inherent in traditional narrow-azimuth marine seismic.

Coil shooting, used in exploration for deep offshore fields, consists of streamers towed behind a ship on spiral routes rather than on the traditional regular geometric grids. It provides full azimuth coverage of the targets allowing more detailed imaging than conventional techniques, and the data acquisition rate is faster compared to other multi azimuth techniques such as MAZ or WAZ.

While these advanced techniques are now indispensable in the deep offshore arena, there’s much more to it. For consistent success, integration of techniques and methodologies has become paramount. “A new approach to exploration has to be developed with a higher integration, at all stages, of different disciplines,” says Mapelli, “such as seismic reflection and gravity modeling, both inverse and forward. Only such synthesis improves our ability to constrain non-unique results predicted by theory, allowing for solutions that are distinct and robust in practice.”

“I could never stress too much the necessity of close integration between seismic and gravity data interpretation,” he says. “It should not be intended as a simple sharing of results, but as a new working approach where each discipline drives the other.” This is possible because seismic velocity (the basic property measured by seismic methods) and gravity share a common factor: density.

He explains that, as seismic velocities depend on elastic parameters and density, gravity inverse modeling could help in the definition of a density volume that could drive the definition of the seismic velocity volume, which is an essential part of the migration process in PSDM. The link between velocity and density is based on empirical relations that are more reliable if statistically controlled by well logs, i.e. sonic and density logs.

“During the interpretation phase, both gravity/magnetic data and seismic data could be used together to derive a unique geological model,” continues Mapelli. “The contribution of gravity data is more important wherever seismic data encounter imaging problems such as the presence of thick salt, gas hydrates, basalt etc. The higher the initial uncertainty is, the greater the value of a gravity/magnetic and seismic integrated approach will be.”

Mapelli uses Geosoft software for data integration, as it allows processing of potential data in a unique environment, and the ability to load other data such as seismic and wells to better constrain the interpretation process. He says, “The drill plotting capabilities help with the integration of gravity data and well data. When available, well data can give a strong constraint on the interpretation.” Modeling capabilities, 2D as well as 3D, provide an easy way to check the consistency of a seismic interpretation, he adds.

These integrated techniques played an important role in the greatest discovery of Eni’s exploration history: the massive gas field in the Rovuma basin offshore Mozambique, which the company reported was “beyond expectation.” Exploration wells in the Mamba South showed up to 22.5 tcf, Mamba North 7.5 tcf, and Mamba North East 10 tcf; for a total of up to 40 tcf of gas in place. These are in waters 1,800 metres deep with overall well depths of 4,500 metres, “Exploration success was boosted by the application of proprietary technologies in the area of seismic mapping,” states the company’s 2011 Annual Report.

“Gravity data acquired together with seismic data played a key role in the processing and interpretation says Mapelli. “The gravity dataset helped in the definition of the main depocenters, especially the isostatic map which clearly shows the thickest part of the sedimentary section,” he explains. “Other elaborations helped in the enhancement of the anomalies thus providing a better view of the structures affecting the area. A 2D modeling along selected profiles allowed us to fine tune the geological model with a sequential adjustment of the initial model until the misfit error fell below a predefined threshold”

It has been an exciting proof of Eni’s expertise and technology. The company plans eight more wells over the next two years to monetize Mamba’s reservoir potential. For other companies, there are still thousands more square kilometres of offshore to explore. “Even the big salt provinces of west Africa, Gulf of Mexico and Brazil should be investigated in even greater detail and depth,” says Mapelli.

Development and enhancement continue, but so do new challenges. “While great improvements have been achieved in seismic imaging as well in potential data methodologies, the way forward is to improve the inversion methodologies for seismic data as well as gravity/magnetic data,” says Mapelli. “A real 3D joint inversion between gravity and seismic is the Holy Grail. Passing from a cooperative inversion to a joint inversion is the real step forward to get a unique geological model that satisfies the available data.”

The advances are paying off handsomely for many companies; one winner has been explorers’ reduced per barrel finding costs. Although exploration costs dwarf typical onshore per well figures, the sheer size of the deep offshore discoveries reduce the per barrel numbers. Brazil’s deep offshore Santos Basin for example yielded 30 billion barrels discovered with just 32 exploration wells.