

Exploration watch

Gulf of Mexico – stepping up to the challenges

The Gulf of Mexico has always been an attractive area for the oil industry, offering the ability to hold material positions and substantial running room in a region with large resources. The industry has successfully pushed the boundaries of deepwater technology to keep growing production in a technically demanding region. Having recovered from the post-Macondo slump, companies must now adapt to the lower oil price environment while continuing to develop new technology to tackle the high pressure, high temperature (HP/HT) challenges of the promising Lower Tertiary play. A focus on cost reduction has seen the continuing approval of projects, most recently Shell's Appomattox development. Meanwhile, although the deepwater rig count has so far remained resilient, activity is moving away from exploration and concentrating on appraisal and development.

Lower Tertiary: Promising play

The Gulf of Mexico has been responsible for developments in a number of key technologies that have allowed projects to be successfully brought onstream in ever deeper waters. Advances in seismic acquisition, processing and interpretation have also been instrumental in improving seismic investigation below the thick salt layers that are present above the Lower Tertiary play, an area that has recently been the focus of deepwater Gulf of Mexico investment and a number of discoveries and developments. Companies will need to continue to innovate to extend the HP/HT limits of equipment needed to operate here and improve the low recovery factors typically experienced in these reservoirs. Companies are increasingly working together on initiatives to meet these challenges, such as in BP's Project 20K, and we expect this trend of combining expertise to continue as companies look to cut costs.

Key events to watch in 2015

The current area of focus in the Lower Tertiary play is the Inboard Lower Tertiary, which is believed to contain the best quality reservoir in the play. Discoveries here include Shenandoah, North Platte and Anchor, all of which are being appraised with drilling currently ongoing. Meanwhile, the play extends into the Western Gulf of Mexico where the Mexican government is planning to open up its nationalised oil industry, with the auction of its deepwater blocks expected later in 2015.

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Cobalt Energy

Shell

EXPLORATION WATCH

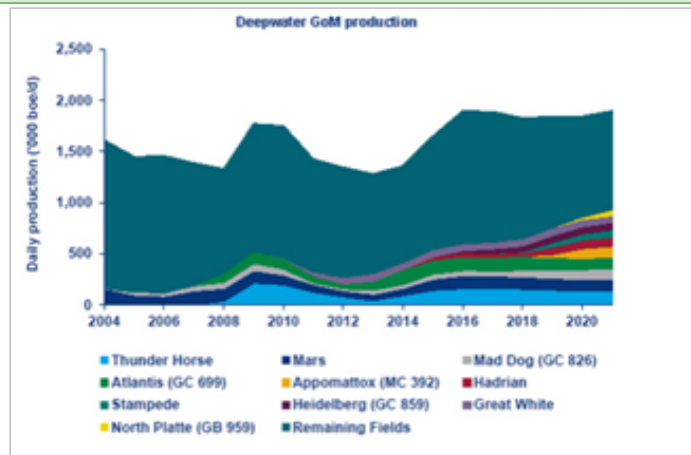
A periodic look ahead from our in-house petroleum engineer, Elaine Reynolds, looking at interesting exploration activities with significant potential impact on E&P equities.

Gulf of Mexico – still an attractive region

The Gulf of Mexico benefits from a unique combination of factors that make it a particularly attractive region for major operators, with Shell, BP and Chevron holding substantial acreage. Companies operating in the area have access to potentially large resources, together with the ability to hold large positions that gives them running room to grow, while the concentration of companies with interests in the region allows flexibility to farm in and out as necessary. The Gulf is close to a centre of excellence in a range of oil field applications from seismic to drilling technologies and benefits from a well-developed infrastructure. Together with the predictable fiscal regime and low tax rate of the US, this makes it a good place to replace reserves and grow production. The region is technically demanding, which plays to the majors' strengths, although US independents are also active in the region, with Cobalt and Anadarko holding key positions in the Inboard Lower Tertiary.

Production from the Gulf of Mexico is set to reach a new peak of 1.9mboe/d in 2016. Activity has returned to the region following the post-2010 Macondo slowdown and will result in an expected 18% production increase between 2014 and 2016 as new developments come online. Since late 2014 the Jack/St Malo, Tubular Bells, Lucius and Hadrian South developments have all commenced production, while Lower Tertiary exploration continues to throw up new discoveries, most recently in Chevron's Anchor discovery, announced in January 2015.

Exhibit 1: Deepwater Gulf of Mexico production forecast



Source: Wood Mackenzie

However, beyond 2016 production is currently expected to remain relatively flat as existing fields decline and the rate of start-ups falls from 15 in 2014-16 to eight between 2017 and 2020. Although the overall rig count in the Gulf of Mexico has dropped in the wake of lower oil prices, the deep water rig count has remained resilient, with jack-up rigs bearing the brunt of the cuts. However, activity does seem to be prioritising appraisal and development, with only five rigs drilling exploration wells compared to 14 a year ago.

Given the long lead times required to progress a project from prospect to development in the region, together with long production profiles, we expect activity to continue in the near term as operators focus on maintaining their long-term outlook while looking to reduce costs. For example, Shell's 175,000 boe/d Appomattox development was given the go ahead in June 2015, having achieved cost reductions of 20%, and is expected onstream in 2020. BP is aiming for a final investment decision on its Mad Dog 2 project by end 2015/early 2016 and is now working with a reworked project cost of \$10bn, significantly lower than its 2011 estimate of \$22bn. Moreover, it is not only the majors that are continuing to invest in the region. US Independent Cobalt recently

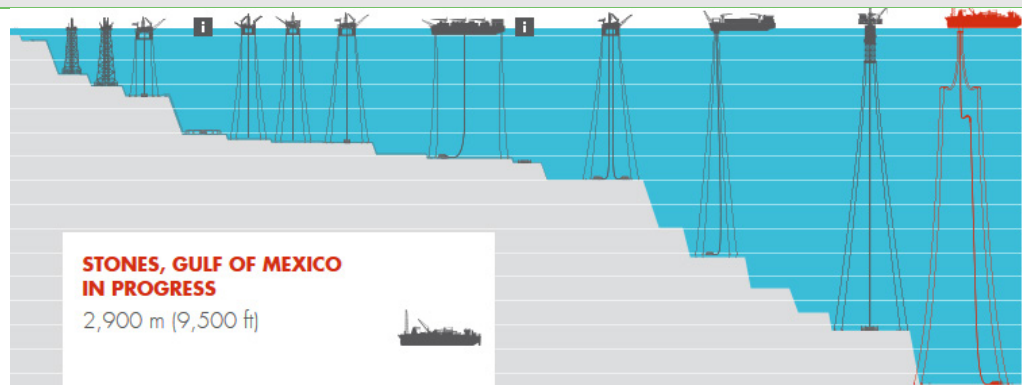
increased its stake in the Goodfellow prospect from 29.2% to 47%, where it is now the operator. The company believes that costs will come down in alignment with the price environment, maintaining the attractiveness of its discoveries in the Inboard Lower Tertiary.

Beyond cutting costs, companies will also need to keep innovating if they are to grow production into the next decade. To achieve this, we see a continuing focus on developing new technologies to improve the recovery factor in the Lower Tertiary and in extending the HP/HT operating limits beyond the 15,000psi and 250 degrees Fahrenheit that is currently feasible. Initiatives to tackle these issues include BP's Project 20K and Statoil's "unlocking the Paleogene", while new ownership structures such as the 2015 alliance between BP, Chevron and ConocoPhillips to develop the Gila and Tiber fields are designed to combine expertise and share costs to unlock further resources. Beyond these initiatives, the recent deepwater discoveries in the Mexican waters of the Perdido Fold Belt could point to the opening up of the next area of the Gulf for growing reserves.

Technology – pushing the boundaries

To develop the deepwater and ultra-deepwater resources in the Gulf of Mexico, operators have had to successfully overcome a number of key challenges while continuing to develop new technologies to extend deepwater capability further.

Exhibit 2: Shell deepwater projects



Source: Shell

Exhibit 2 is indicative of the advances made in deepwater developments in the Gulf of Mexico, with Shell being able to progress from the 1978 Auger development in 304m (1,000ft) of water to its currently in progress Stones development, which will operate in a water depth of 2,900m (8,000ft). The challenges involved were highlighted this year when Chevron had to postpone first oil from its Big Foot TLP development from 2015 to 2018 following the loss of nine of the TLP's mooring tendons due to strong water currents.

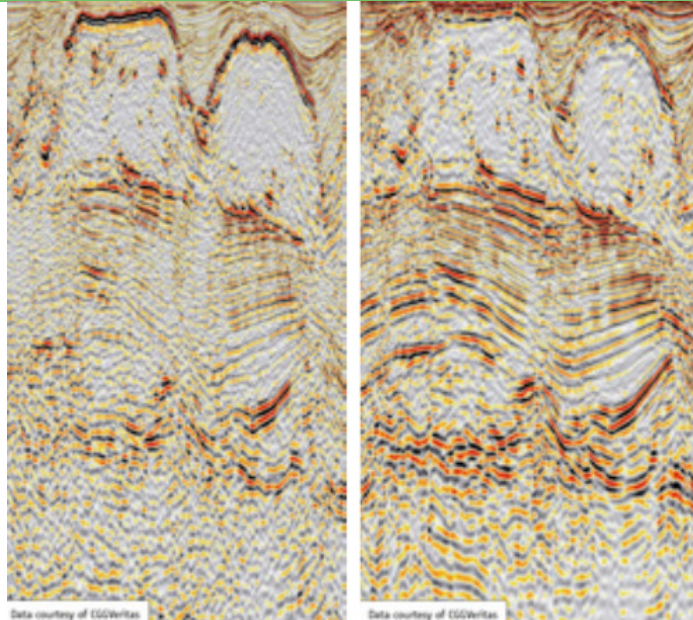
In addition to the deep water issues, there are a number of further challenges that continue to push the boundaries of technology. The most notable of these are detailed below.

Advances in seismic acquisition, processing and interpretation to enhance seismic imaging under salt layers

Most Lower Tertiary reservoirs lie beneath a thick layer of salt, which effectively masks the deeper horizons from seismic investigation. Trying to see through the salt has been compared to looking through the textured glass of a bathroom window, as it distorts the acoustic returns and makes it difficult to get an accurate picture of the geology below. In the last decade, technological advances such as wide-azimuth towed streaming (WATS) and reverse-time migration (RTM) have become

available and are now extensively used throughout the Gulf of Mexico. WATS was first used by BP in 2004 over what became the Mad Dog development and has since become the industry standard for complex subsalt imaging. WATS is a multi-vessel operation, in which the source and receivers are installed on separate boats, and this results in seismic data being gathered from many different azimuths, thereby providing a clearer picture of the salt and the underlying geology.

Exhibit 3: Seismic images showing improved results from WATS (right-hand side)



Source: GEO ExPro courtesy of CCGVeritas

RTM is a high-fidelity algorithm for imaging the most complex structures. Historically deemed impractical due to high computational costs, it has increasingly become the high-end final migration of choice in areas of the greatest structural and velocity complexity.

Improving understanding of the reservoirs to increase recovery

Lower Tertiary reservoirs typically have low permeability that can be distributed unevenly across the field, making reserves difficult to evaluate. The thick pay sections encountered mean that even a significant coring programme cannot recover enough core to fully describe the reservoir, while viscosity can vary within structures, suggesting complex filling histories. In addition, a number of fields have a low gas/oil ratio (GOR) so that hydrocarbons cannot flow naturally to surface and artificial lift is required. Due to these issues, the recovery factor is typically low at around 10%. Operators are looking at ways to improve this, with Statoil for example targeting recovery factors of 20% through the application of secondary recovery techniques, ie gas or water injection and the use of multi-lateral drilling.

Complex completions

Completions are usually required to be multi-zone across large intervals, while the combination of unconsolidated sands with low permeability requires wells to be frackpacked (ie fracking and gravel packing). This results in complex completions that are nevertheless expected to maintain reliable production with minimal completion failure.

Dealing with HP/HT

Current equipment has a technical limit of 15,000psi pressure and temperatures of 250 degrees Fahrenheit. Lower Tertiary wells can have bottom hole pressures in excess of 25,000psi and temperatures above 300 degrees Fahrenheit. In 2012, BP launched its Project 20K, an initiative to

develop the next generation of tools and systems to unlock these higher pressure and temperature resources, including its Kaskida and Tiber discoveries. The company expects this to be a multi-year initiative, which it hopes will unlock 10-20bnboe worldwide over the next two decades.

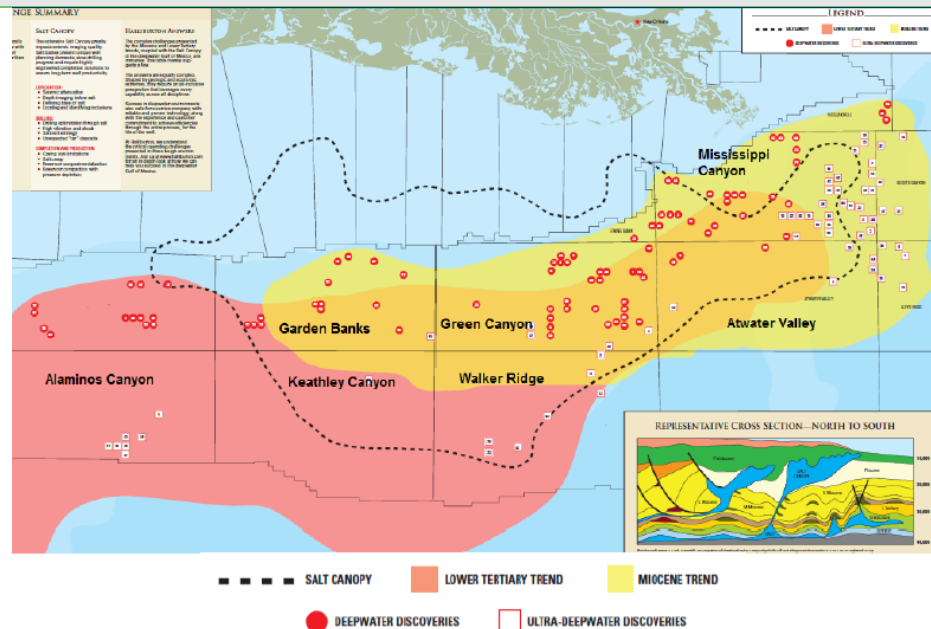
In 2013, BP set up a joint engineering team with Maersk Drilling to collaborate on concepts for the optimal design of the 20KTM drilling rigs, riser and blowout prevention equipment. Since 2012 it has also been involved in a joint industry agreement with Anadarko, ConocoPhillips and Shell to design and develop 20,000psi-rated subsea production equipment with FMC Technologies, including a subsea production tree and a subsea high-integrity pressure protection system. We expect to see further examples of similar collaborative initiatives to reduce costs and combine expertise as the industry responds to the lower oil price environment.

Key Gulf of Mexico plays

Development in the deepwater Gulf of Mexico is dominated by two key geological trends: the Miocene and the Lower Tertiary, or Paleogene. Both trends are masked by huge sheets of subsurface salt, which place extreme requirements on all aspects of well operations, and it was only with the advent of widespread 3D seismic in the 1990s that geoscientists could start to define structures on the basis of deep salt.

Production from the deepwater Gulf of Mexico was originally centred on Miocene turbidite sands and this remains the most important producing zone in the region. These complex depositional systems, combined with the presence of salt bodies, made it difficult to understand the reservoir geology, so that 3D seismic was essential. Located across the northern part of the Gulf, producing fields are predominantly located in Mississippi Canyon (Thunder Horse, Mars, Ursa, Na Kika, Tubular Bells), Green Canyon (Atlantis, Mad Dog, K2 and Heidelberg) and Garden Banks (Auger, Magnolia).

Exhibit 4: Gulf of Mexico deepwater map

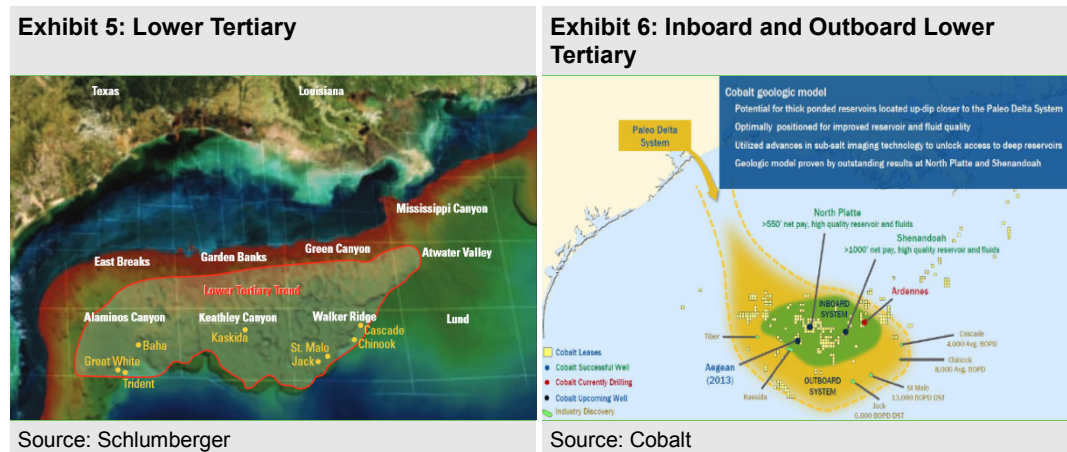


Source: Halliburton

Paleogene – still an emerging play

The Paleogene play sits to the south of the Miocene and is at an earlier stage of development. The play was initiated by the discovery of reservoir quality sands in the Baha-2 well drilled in Alaminos

Canyon in 2001. This well was targeting Mesozoic fractured carbonates, but established good-quality sands in a turbidite section of the Wilcox Formation. This early well was drilled in an area to avoid salt, but once the viability of the deepwater Wilcox trend was established, operators began chasing prospects updip and under the salt, resulting in discoveries such as St Malo and Jack. The Paleogene is currently the focus of the majority of deepwater Gulf of Mexico investment and home to some of the largest discoveries. However, to date only three developments are producing from the Paleogene. Shell's Perdido development, covering Great White, Silvertip and Tobago in Alaminos Canyon, was the first commercial Paleogene development and came onstream in 2010. This has been followed by Petrobras's Cascade/Chinook in 2012 and by Chevron's Jack/St Malo in December 2014. Shell's 250mboe Stones project was sanctioned in 2013 and is currently under development with a target for first oil in 2016.



The Paleogene is characterised by older sediments with low permeabilities, lateral heterogeneity and dead oil, which all contribute to low recovery factors in the order of 10%. In addition to the complex reservoirs, the prospects have high bottom hole pressures and ultra-deepwater depths, making the wells technically challenging. Ultra-deepwater is defined as greater than 5000ft (1,500m), while the reservoirs can be over 30,000ft (10km) deep and have reservoir pressures in excess of 25,000psi.

In recent years a geological model has been proposed that separates the Lower Tertiary into inboard and outboard systems. It has become a successful area for independents, with Anadarko the operator on Shenandoah, while Cobalt is the operator of North Platte and Goodfellow and a partner on Shenandoah and Anchor. The Inboard Lower Tertiary is believed to have better permeability and fluid quality and thicker reservoirs. The North Platte and Shenandoah discovery wells, drilled in 2012 and 2013, appeared to support this. North Platte has a gross resource range of 400-850mboe, while the Shenandoah-2 appraisal well encountered over 1,000ft of high-quality net oil pay. Although the 2013 Inboard Tertiary Ardennes well did not encounter commercial hydrocarbons, Chevron's recent Anchor discovery in January 2015 to the north of Ardennes found hydrocarbons in multiple zones. Indeed, in March 2015 a consortium including Anchor operator Chevron bid \$41.1m for a Green Canyon block in the vicinity of Anchor. Appraisal drilling in the Inboard Tertiary is currently ongoing at Shenandoah, North Platte and Anchor.

Perdido Fold Belt – into Mexico

The Paleogene extends to the Western Gulf of Mexico where the Perdido spar is located approximately 200 miles south of Galveston. The development sits on the Perdido Fold Belt (PFB), part of the Cenozoic compressional fold system in the Gulf of Mexico that consists of a series of south-west/north-east trending kink bands with flanks cut by reverse faults. In addition to Wilcox turbidite sands, the PFB also contains Cretaceous carbonate and chalk. Within 50 miles of Perdido and in Mexican waters, state oil company Pemex has made a cluster of discoveries on the PFB

since commencing exploration here in 2012 and the Mexican government hopes to farm out its Exploratus, Trion, Supremas and Maximino discoveries. The results of the government's initial auction of shallow water exploration blocks announced in July 2015 were disappointing, with only two out of 14 blocks on offer being awarded. Details of the most anticipated deepwater part of the Mexican auction round have been delayed to end September as the government looks to improve its terms following the lack of interest in the first phase.

In US waters, there are currently no plans to drill in Alaminos Canyon outside the Perdido development area. However, there has been interest in recent lease sales, where for example ConocoPhillips bid \$30.6m for AC475.

Conclusions

The Gulf of Mexico remains an attractive place for E&P companies and the region has recovered from its post-Macondo slowdown to achieve peak production in 2016. However, current forecasts indicate that the production rate will remain flat for the remainder of the decade. To achieve growth into the next decade, companies will need to innovate to drive down costs and unlock resources in ultra HP/HT reservoirs and to improve recovery factors in the emerging Paleogene trend. We expect to see an increase in collaboration between companies to achieve this. Key events to watch in 2015 will be the appraisal results of Inboard Lower Tertiary discoveries Shenandoah, North Platte and Anchor, while the results of the Mexican deepwater blocks bid process will give a first indication of interest from international companies in an extension of the Paleogene into Mexican waters.

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