THE RAVEN FIELD: Planning For Success

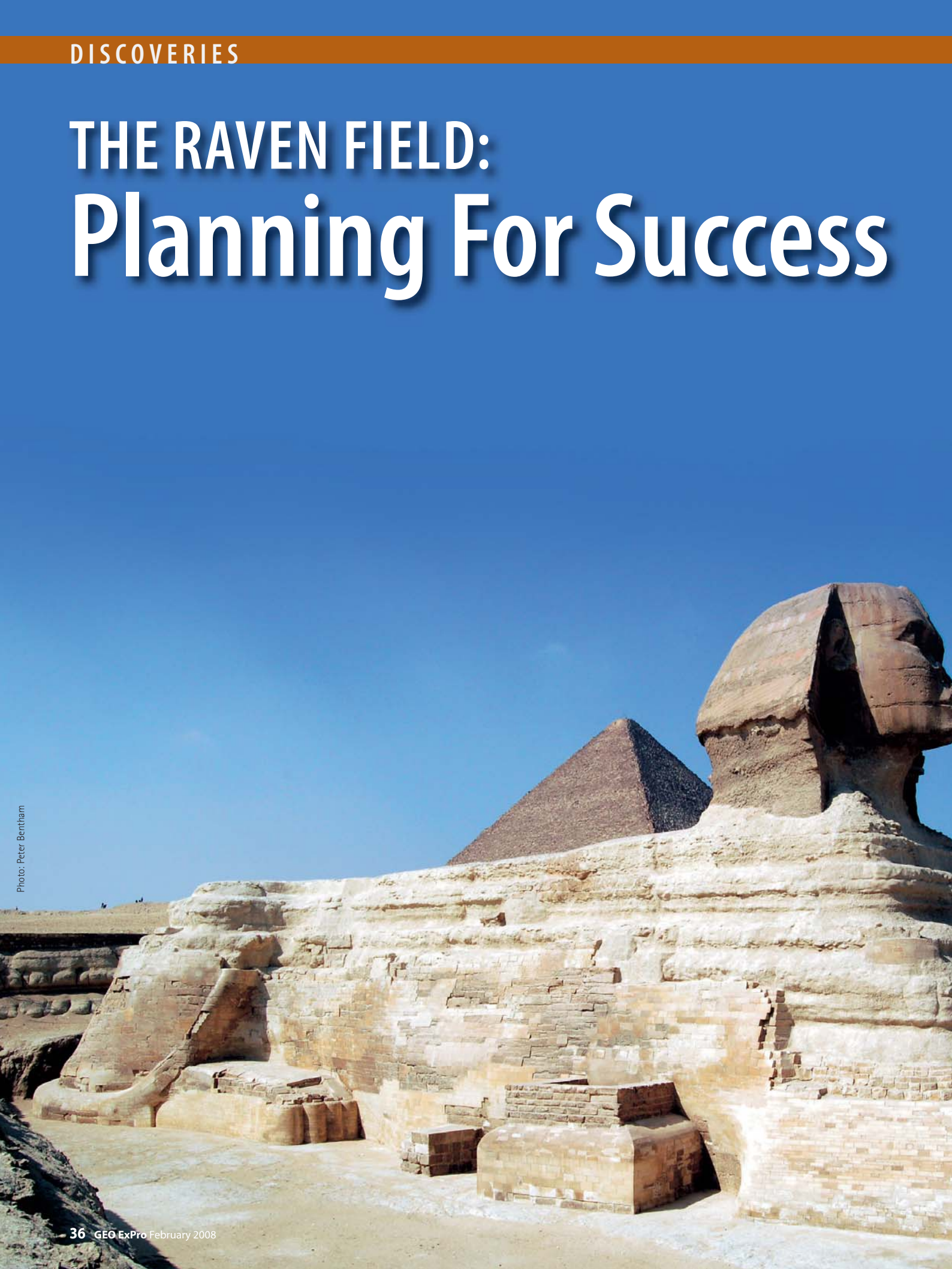


Photo: Peter Bentham

The Raven Field in the Nile Delta, discovered in 2004, has proved the window to a major new play in this prolific geological province and has de-risked a significant volume of Egypt's yet-to-find hydrocarbons.

Jane Whaley, Associate Editor

"Until 2004, the majority of discoveries in the Nile Delta were drilled on amplitude anomalies in the Pliocene. The Raven discovery was revolutionary for the West Nile Delta area, as not only was it found in an older, pre-Pliocene section but the reservoir rocks also exhibited potential Direct Hydrocarbon Indicators (DHIs) on seismic," explains Peter Cook, BP Senior Geophysicist for the Raven Project in Cairo.

"Out of about 100 discoveries in the Nile Delta, including 22 giant fields containing over 600 Bcgf, (17 Bm^3) 70% were well defined amplitude anomalies contained in Plio-Pleistocene deltaics or slope channel and channel/levee complexes".

Structurally, the Western Nile Delta is underlain by the outer part of a rifted Jurassic continental margin associated with the opening of the Mediterranean. It is characterised by a steep, fault-bounded margin that exerts a fundamental control on the overlying Eocene and younger slope channel deposits. The main source rocks in the Western Nile delta are thought to be Pliocene mudstones, which generate biogenic gas, with Eocene and Cretaceous sediments sourcing the recently discovered Pre-Pliocene reservoirs.

Risky business

"A large anticline, 20km long and 10km wide, part of the 160km long north-east plunging Raven anticlinorium, was the first thing that caught our attention," explains geophysicist Mai Afifi. "Using conventional 3D seismic data we mapped the structure as a large faulted 3-way closure, which has been growing throughout the Tertiary. There was clearly gas in the Pliocene sediments, but we also investigated the Middle Lower Miocene beneath the Pliocene. This lies beneath the Messinian lowstand system characterised by evaporates and mudstones deposited as a result of the dessication of the Mediterranean. In the exploration well area these evaporates are not very thick and so the seismic image beneath is not as severely affected on the Raven structure as it is in other parts of the Nile Delta."

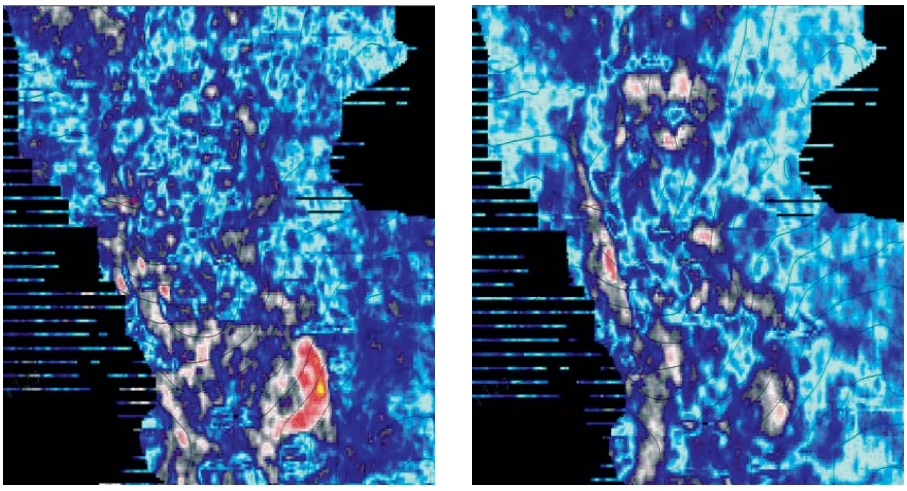
"The discovery was made in turbidite slope channels draped over the Raven ▶

The Sphinx, in Giza on the outskirts of Cairo, is carved from limestone of the Eocene Mokkatam formation. The Tertiary sea covering the area retreated 50 million years ago, leaving an embankment that became the north-north-west part of the Giza Plateau. As the sea receded, a shallow lagoon formed above a shoal and coral reef which petrified to become the layers from which ancient Egyptians cut the Sphinx. These rocks are all older than the main Nile Delta hydrocarbon reservoirs.

structural high," adds Hamish Matheson, geologist on the Raven project. "The channels are oriented north-west to south-east and were deposited in large scale erosional canyon systems up to five kilometres wide and 500m deep. Reservoir facies range from coarse-grained gravels at the base of the channel systems to fine-grained channel levees associated with the final stages of channel abandonment."

"Pre-drill, few other wells in the vicinity had penetrated this stratigraphy, and the closest well is Habbar, 130 km to the east. Given the absence of well control, the development and effectiveness of the reservoir at these depths were regarded as high risk factors, and the lack of a well developed 4-way dip closure and definite evidence of charge were also issues of concern. The search for and recognition of a potential direct hydrocarbon indicator was instrumental in reducing these risks. In addition, the water depth over the acreage varies from 200 to 800m, and a deep marine channel, the Rosetta Canyon, dissects the slope. This is up to 1km wide and 200m deep and will have a significant impact on any infrastructure."

"The basal Pliocene appears to be a significant pressure seal, so the Pre-Pliocene rocks are over-pressured, and the high pressures and temperatures experienced at these reservoir depths are extremely challenging. This, coupled with the current level of development costs at a time when industry capacity is stretched, places additional complexity on the project logistics," Hamish continues.

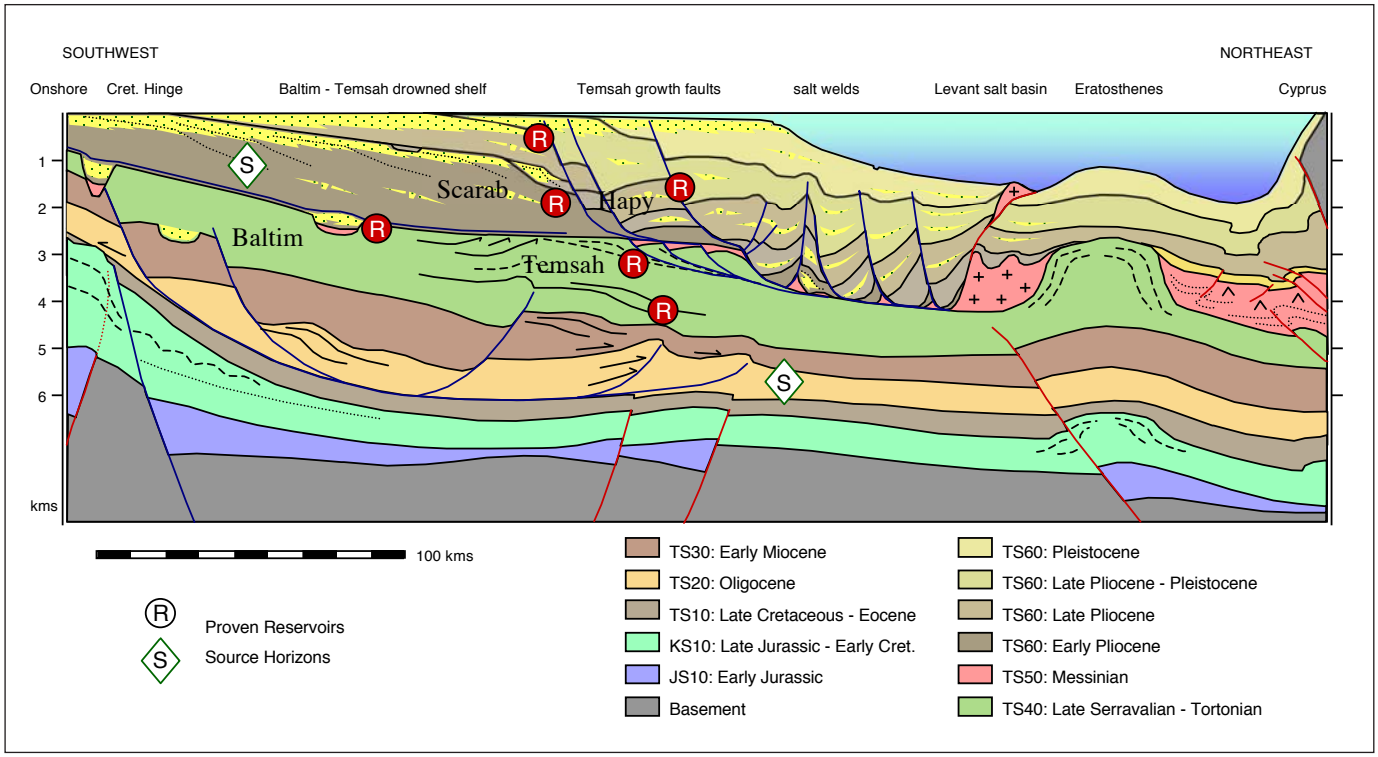


Acknowledgement: BP

Multiazimuth seismic was found to be very useful in delineating the Raven Field. The improvement in data quality found from using this technique resulted in the repositioning of the Raven 2 bottom hole location.

Planning for success

Raven 1 discovered gas at a rate of approximately 36.6 MMscfg/d (1.04 MMm3g/d) and 23 barrels condensate per million standard cubic feet with additional shows in the Upper Middle Miocene and Pliocene. "Within the discovery section there appears to have been a complex hydrocarbon fill and spill history, complicated by slope canyon ▶



Acknowledgement: BP

The structural framework shows a series of faulted basement and pre-rift fault blocks with a Cretaceous hinge line over which the current delta and Palaeo-Nile delta has prograded, resulting in a stacked pay system of slope channel deposits from Eocene to Recent. The pink Messinian horizon represents the salinity crisis, a time of extreme lowstand when the delta was exposed and deposition was dominated by anhydrites and halites. In the Raven area this is not as thick as in the salt provinces to the north-west and in the Eastern Nile Delta, where it forms a significant decollement surface with associated fault block rotation and minor salt diapirism, setting up much of the trapping mechanisms.

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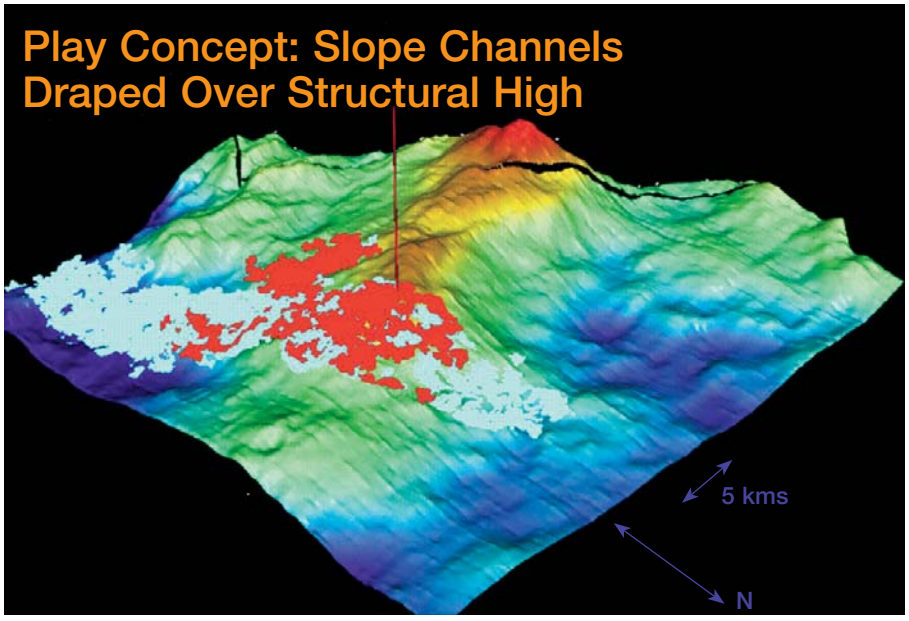

The play concept is fairly simple: a slope channel system draped over a structural high. The channel systems in this display are coloured blue for response on the near offset sensors closest to the boat and red for a high amplitude response on the sensors at the end of the seismic cable, up to 6kms away. The effect of distance and angle on the seismic response of the reservoirs can be a strong indicator of porosity and therefore possible hydrocarbons.

sedimentological processes creating significant reservoir heterogeneity," Peter says. "We expected rapid lateral facies changes, which was confirmed by drilling sidetrack wells and the acquisition of core and pressure data. We soon realised that we would have to take great care over our seismic and geologic interpretation in order to delineate the field as accurately as possible. We were planning for success!"

"Given the complexity of the reservoir, we embarked on a program of technically advanced seismic acquisition to provide a high quality dataset suitable for both appraisal and development," adds Mai. "Immediately after drilling we collected a Multi-Azimuth (MAZ) streamer dataset (see GeoExPro Vol. 3, no 4/5), with a total of 6 azimuths. This was needed because the Messinian section, with its rapid lateral velocity variations, creates large scale image ray distortions, absorption and scattering of rays especially in the central and western parts of the structure. A single pass towed streamer creates uneven illumination, but by using many azimuths this effect is much reduced. We are still improving the data, collaborating with partners like PGS, Western and BP's Exploration Production Technology Unit, to look at parameters such as adaptive summation, azimuthal velocity and depth migration."

"Acquiring the MAZ as early as possible after the discovery has allowed us to optimize the appraisal and development planning. As an example, the improvement in data quality resulted in the repositioning of the first appraisal well 200m west of its original location."

"The MAZ seismic we acquired and the way in which we use it is one instance of this forward planning early in the field life," Hamish continues.

Geohazards

Another example of the way in which the Raven team in BP were planning for success early in the project is the attitude they took to geohazards. Possible risks on and close to the sea floor include shallow gas accumulations and changes in sea bottom topography which could impact the positioning and layout of wells and subsea infrastructure.

"The location of the Rosetta Channel through the field was an obvious risk. In addition, the Nile Delta in this area has a number of palaeo-landslides at different scales, from the few metre thick debris flows seen on the current sea floor to the mega landslides which occurred some 250,000 years ago. In order to understand the risk from geohazards, we acquired extensive engineering quality geotechnical data early in the project," explains Peter. "We initiated a detailed hazard study, with a number of phases of data collection, including 5,750 km of Ultra High Resolution seismic, and the world's largest Autonomous Underwater Vehicle (AUV) program, covering 7,000 line kilometres. We also undertook current metering and obtained and analysed sea bottom and shallow sediment cores."

"With the help of these data we are beginning to have a much more detailed understanding of seafloor and shallow seabed conditions through the delivery of engineering quality datasets. We can create a quantitative risk assessment of these hazards, understand their areal distribution and assess their effect on each part of the potential seafloor development layout. We will know well in advance if we need to re-route a pipeline or to strengthen certain pieces of equipment to withstand particular events. This is the cornerstone of the geohazard assessment and is being worked by a group of specialists and BP personnel in liaison with the extended geohazard team in Cairo, and is ongoing through the project as more data becomes available."

Significant volumes derisked

With 3 wells drilled on Raven to date and another currently in progress, the forward planning put into the development of the field is paying off. "The appraisal well Raven 3 also tested deeper prospectivity on the anticline beneath the current discovery levels and this information will influence our development options – another example of planning for the future," Peter says. "Moving into higher temperature and pressures will require specialised drilling and development equipment, in which forward thinking and well planning is critical."

With reserves figures quoted in the press to be in the region of 4 Tcfg (17 Bm^3), the success at Raven has derisked a significant volume of the Nile Delta's yet-to-find volumes. It has also opened up a new play fairway in Lower Miocene slope channels in what was considered a mature basin. The use of new seismic technologies, in particular multiazimuth surveys, has proven critical in delivering the highest quality data to the subsurface staff in order to evaluate the geology and its influence on development facilities.

As Mai says "taking Raven from a high risk prospect to a producing major field, in an extremely challenging environment and at a time when industry capacity is stretched, has shown that forward thinking and meticulous planning for success can bring rapid and extensive rewards."