GEO ExPro

GEOSCIENCE & TECHNOLOGY EXPLAINED

Vol. 4, No. 2 - 2007

www.geoexpro.com

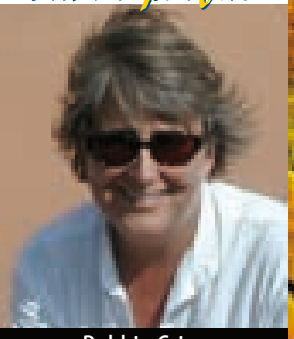
Photo: Berit Lokken

Geotourism:
Vesuvius and Pompeii

The Barnett Shale:
Producing Gas from Shales

Long Beach:
Oil Under Foot

ExPro profile



Robbie Gries

NEW 2006 MC-PROJECTS IN THE NORTHERN HEMISPHERE

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GREENLAND
- New AM survey, 37,000 km
- Updated Geo-Atlas

NORTH SEA
- New 2D survey, over 27,500 km

IRISH SEA
- 2 new 2D's, 2,850 km

NORWEGIAN SEA
- New 2D survey, over 9,100 km
- 5 new EM projects

BARENTS SEA
- New 2D survey, 4,700 km
- 2 new EM projects

SEA OF OKHOTSK
- New 2D, 8,500 km
- New Geo-Atlas

CHUKCHI SEA
- New 2D, 3,500 km (Available Q2-2007)

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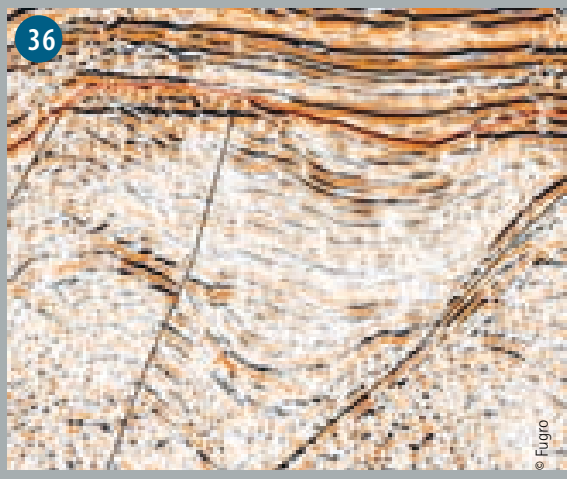
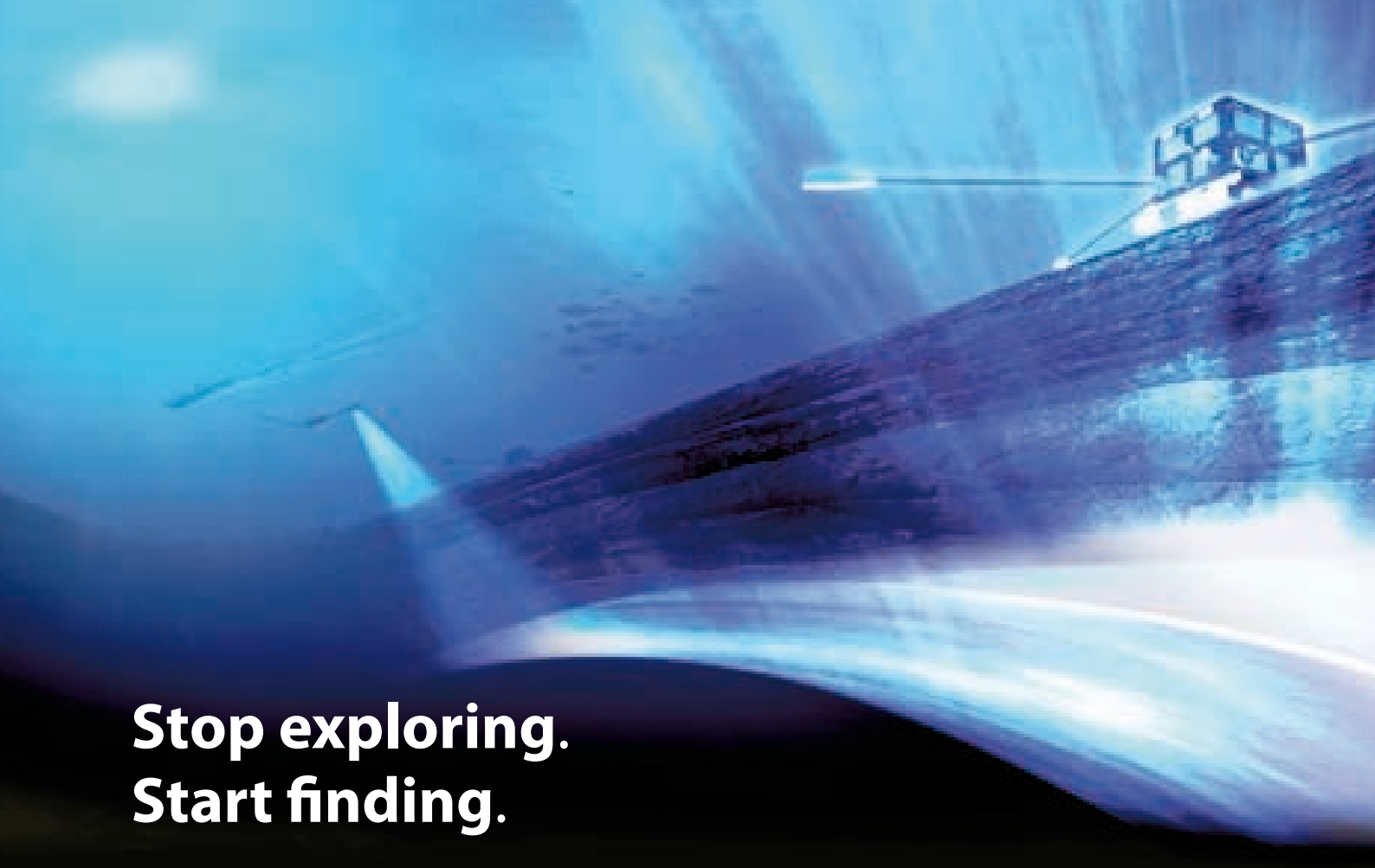
Columns

Features



Deep Imaging
Fugro Multi Client Services has acquired a 2D programme offshore Mid-Norway aiming at covering the Mid-Norway continental shelf with long cable (10 km) and long recording (10 seconds two-way time) seismic data. The regional extent and recording length of the lines provide a structural overview and deep imaging previously not seen offshore Mid-Norway.

Remote Exploration
One of the last intact wildernesses left on earth, Papua New Guinea is experiencing an unprecedented resurgence of interest from the hydrocarbon industry. Is it possible to encourage the advances of modernisation and the oil industry without jeopardising the ecology and culture of this amazing country?



Stop exploring. Start finding.

The last 20 years have seen huge advances in exploration technology. But success rates continue to decline.

It's been a hit-and-miss affair

In its pursuit of new hydrocarbons, the exploration industry has relied on indirect evidence.

Traditional exploration workflows, which evaluate petroleum systems, source rocks, seals and structures, are good at establishing the locations where hydrocarbons *can* exist.

But, emgs' award-winning seabed-logging technology is able to show whether hydrocarbons *do* exist.

Improving the workflow

Seabed logging remotely measures subsurface resistivity contrasts. Of course, as formation resistivity is the industry's most effective hydrocarbon indicator and has been for the past 75 years, it makes perfect sense to include seabed logging in the exploration workflow.

The new standard

Today, with more than 200 commercial surveys recorded, seabed logging is revolutionising how the industry finds hydrocarbons.

Seabed logging is enabling new exploration strategies such as scanning frontier and mature regions for new leads. These strategies are delivering prospects earlier than traditional methods. And operators continue to use seabed logging to rank prospects before they commit further resources.

It's hardly surprising then, that every day more and more exploration professionals are building seabed logging into their workflows. Indeed, right now over 35 leading operators worldwide are using seabed logging to evaluate existing prospects – and to find new ones.

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The Next Frontier

As we have now entered the International Polar Year (see also page 72), we should expect a strong focus on the development of fossil fuels in northern latitudes for the years to come. Environmentalists will (rightly) use this opportunity to remind us that we need to be very cautious when exploring and developing in these fragile regions. The oil industry will, on the other hand, be very keen on getting a better estimate of the Arctic oil and gas potential. Some of the major companies are thus likely to put pressure on governmental bodies to open up for geological and geophysical studies as well as exploratory drilling.

Photo: Halfdan Carstens

The Arctic is well known for its harsh climate and icy conditions and the resulting operational difficulties. By experience we know that these will all be overcome. Technological challenges will be solved in due time.

There are certain advantages with the Arctic frontier. Only five countries (USA, Canada, Denmark (Greenland), Norway and Russia) are bordering this huge area (six, if we include Iceland), and they are all blessed with democratic governments. They are also lacking dominating national oil companies that are nationalising the resources and making them unavailable to the international oil companies. The exception, you will argue, is Russia. May be so, but many international oil companies have a strong presence, and Russia has a need to take advantage of the technological developments in the western countries. Isolation is not an option if they want to exploit their resources.

For the patient oil company, with a strong capital base and a vision of being in business several decades from now, the Arctic may very well represent an exciting future.

Halfdan Carstens
Editor in Chief

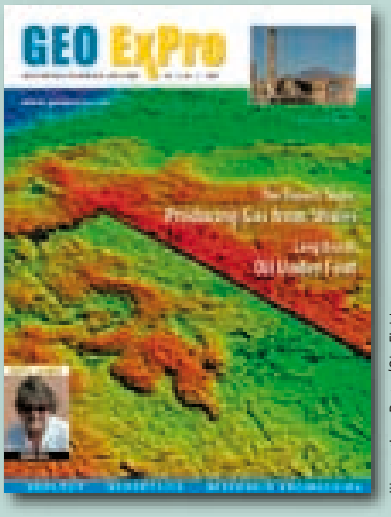

Illustration: Petra/Ola Field

Efficient 3D mapping

Vast amounts of 3D seismic data on the Norwegian continental shelf that belongs to the public domain have been merged in large supergrids. This opens up for detailed mapping and studies on a regional scale, and they are now widely applied in hydrocarbon exploration.

The front-page illustration elegantly demonstrates a submarine fan that was deposited on the basin floor in Paleocene times. The characteristic polygonal pattern outside the fan indicates that the basin floor consists of clayey sediments.

The 3D interpretation tool GigaViz has been applied. The tracker has followed the top of the clayey basin floor in the foreground of the picture. Given a seed point on top of the fans, the tracker has been guided to follow the top of the lobes whereupon nice lobes appeared. In the background the tracker has followed a slightly shallower horizon. No lobes can be seen at this level.

The seismic data set has been re-gridded to 12.5 by 12.5 metres. The tracker has used all inlines and x-lines with the same resolution and thus maintained the high resolution. Normally, triangulation is done on a 50 by 50 metres grid with loss of much of the detailed information. The image has a low light source in the north-east with some ambient light.

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APT expands to Wales

In the golden days of Hollywood the major studios' talent scouts, myth has it, were responsible for discovering budding 'stars' in the most unlikely places.

On that basis APT (Applied Petroleum Technology), the highly respected international Norwegian geochemistry and biostratigraphy consultancy service company, spotted outstanding talent in North Wales and immediately 'signed them up'.

A new associate member of the Llandudno based Geoscience Wales Ltd. (GWL) cluster group, leading North Wales based geochemists, Patrick Barn-ard and Dr. Steve Thompson, were invited to form APT UK Ltd. last September, by the Norwegian parent company.

"We have been able to play a major part in developing geochemical models for reservoir development and petroleum exploration applications over the last three decades, and have seen geochemistry change from more an art to a science. Companies exploring and developing resources in the North Sea in this latest stage in its development, need to exploit the more 'difficult' areas, which is where we feel we bring a unique skill set, based on our experience and technology," says Pat Barnard.

"We are delighted that APT recognises and appreciates our expertise in this area and that they approached us to form the UK company".

Based in Colwyn Bay, APT UK Ltd. now has the support of a world-class laboratory with state of the art equipment and facilities.

Last year APT were themselves purchased by ResLab (Reservoir Laboratories). This has allowed ResLab to continue its growth and diversification in the services offered through a strong industrial partnership, in which, now of course APT UK Ltd. can share.

"The opportunities offered to us by the support of the APT laboratories, infrastructure and the market penetration of ResLab, combined with the huge strength in depth of the GWL group of Associates, makes it possible for us to build a solid base of clients and business types. This includes the non-proprietary brands of studies, the so-called 'multi-client approach," Pat says.

"This may include cross border studies, such as the proposed Celtic Sea project covering the sea areas between Wales and Ireland, an under-explored area in which the presence of a working petroleum system has already been demonstrated by shows of oil and gas," he adds.

"As a director of GWL, I see this as a potentially fascinating area that would benefit from our expertise and the concept of the multi-client approach. This strategy could result in the creation of significant numbers of highly skilled jobs in the near future. It will also further pinpoint North Wales once more as a centre for Geoscience excellence, Patrick Barnard concludes."

Patrick Barnard, seen here studying mineralization in the Great Orme dolomites, is M. D. of newly formed APT UK Ltd.

ABBREVIATIONS

Numbers
(U.S. and scientific community)

M: thousand = 1×10^3
MM: million = 1×10^6
B: billion = 1×10^9
T: trillion = 1×10^{12}

Liquids

barrel = bbl = 159 litre
boe: barrels of oil equivalent
bopd: barrels (bbls) of oil per day
bcpd: bbls of condensate per day
bwpd: bbls of water per day

Gas

MMscfg: million ft^3 gas
MMscmg: million m^3 gas
Tcfg: trillion cubic feet of gas

Ma: Million years ago

LNG

Liquified Natural Gas (LNG) is natural gas (primarily methane) cooled to a temperature of approximately -260 °C.

NGL

Natural gas liquids (NGL) include propane, butane, pentane, hexane and heptane, but not methane and ethane.

Reserves and resources

P1 reserves:
Quantity of hydrocarbons believed recoverable with a 90% probability

P2 reserves:
Quantity of hydrocarbons believed recoverable with a 50% probability

P3 reserves:
Quantity of hydrocarbons believed recoverable with a 10% probability

Oilfield glossary:
www.glossary.oilfield.slb.com

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South Africa license round

South Africa's 2007 offshore license round is due to be announced in March. Blocks are on offer in the shallow water northern Orange Basin, the deep water southern Orange Basin, the proximal Bredasdorp Basin and the offshore Algoa Basin.

CGGVeritas is assisting the South African Agency for the Promotion of Petroleum Exploration and Exploitation (Petroleum Agency SA).

The western offshore comprises a broad passive margin basin related to the opening of the South Atlantic in the Early Cretaceous. This is known as the Orange Basin which is areally and volumetrically the largest of South Africa's offshore basins. It is under-explored with one well per 4000 sq km.

Several petroleum systems (oil and gas) are known to be operating in the basin, and two fields with multi-trillion cubic feet potential natural gas reserves have been discovered to-date: the Ibhubesi gas field off South Africa and the Kudu gas field off southern Namibia. Seismic coverage is extensive.

Area A lies in the shallow water area of the northern Orange Basin, on trend with the Kudu gas field in Namibia, 120km to the northwest and the Ibhubesi gas field, 95km to the southeast. There are only three wells in the area, one of which discovered gas in Middle Albian fluvial sandstones and tested 32.4MMscfgpd.

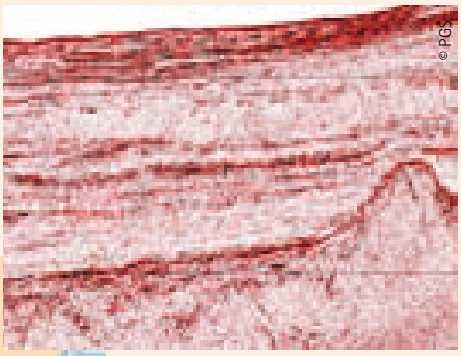
Area B lies in the the southern Orange Basin. Water depths range from 200m to 3400m. The area is highly under-explored with limited seismic coverage in the deeper water areas and only one well which was dry but encountered good quality source rocks. A wide range of play types are observed in the area ranging from syn-rift structural closures to deep water basin-floor fans.

The southern offshore region, known as the Outeniqua Basin, shows a history of strong strike slip movement during the Late Jurassic - Early Cretaceous breakup and separation of Gondwana. It consists of a series of en echelon, half-graben sub-basins: the Bredasdorp, Pletmos, Gamtoos and Algoa basins. Blocks are on offer in the Western Bredasdorp Basin (**Area C**) and the offshore part of the Algoa Basin and eastern margin of the Gamtoos Basin (**Area D**).

The Western Bredasdorp Basin has demonstrable potential with fair to good source rocks favouring oil to wet-gas expulsion, potential good reservoirs, and traps with effective seals in place. An active petroleum system can be demonstrated, and the area's close proximity to producing oil and condensate fields in the main Bredasdorp Basin, support the idea of similar hydrocarbon accumulations within untested structures.

The Algoa Basin can be subdivided into four en-echelon half graben which developed during Oxfordian to Valanginian rifting. Of the ten wells drilled in the basin, oil shows were encountered in the Barremian turbidite sandstones of the Algoa and within the syn-rift succession of the Port Elizabeth and Southern Uitenhage troughs.

Steve Toothill, CGG Veritas

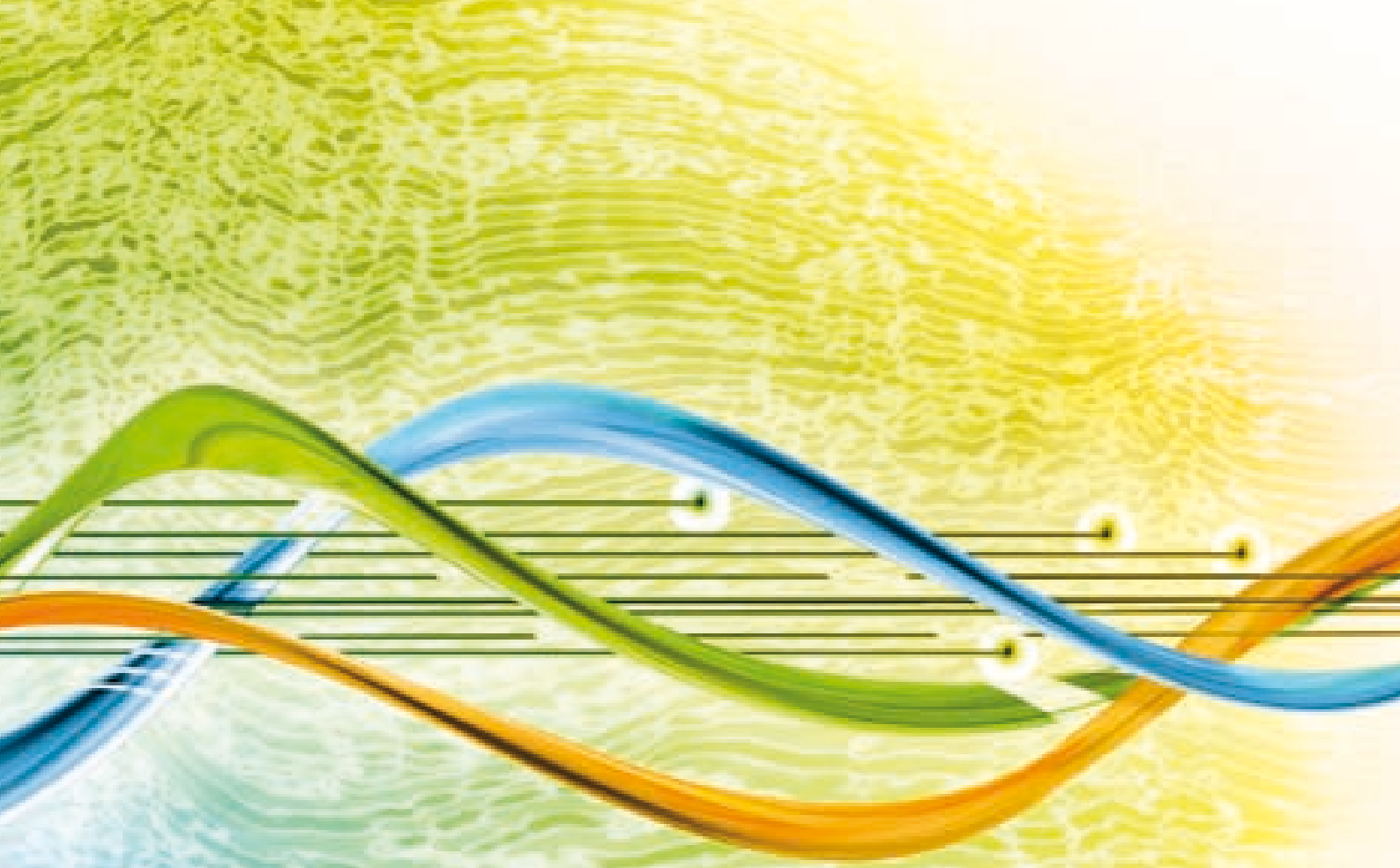


PGS acquired and processed 3660 line km of 2D data in the deepwater Orange Basin during 2002. The M/V Geo Explorer was used, towing a 6 km streamer. The survey ties into existing shallow water 2D and includes a number of well tie lines. Gravity and magnetic data were also acquired. PGS have interpreted the 2D and have produced a Prospectivity Report that is available together with any license of the seismic data.

OIL PRODUCTION 2005

	Mbopd
Middle East	25 118
North America	13 636
Russia	9 551
Australasia	7 991
South America	6 964
Northwest Europe	5 154
West Africa	4 722
North Africa	4 487
FSU	2 248
Other	1 205
Total	81 076

Source: BP Statistical Review of World Energy



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Continued Record Investment in UKCS

Jane Whaley, Associate Editor

The recent announcement of the 24th UKCS Licensing Round awards came at the end of another record year for the UK oil and gas industry. Over 700 million barrels of oil equivalent (MMboe) were discovered in 2006, the highest level since 2001, and a high percentage of wells found potentially commercial oil and gas accumulations.

A total of 104 companies, including 17 new entrants, were awarded 246 blocks in this latest round, bringing the number of companies in the UKCS altogether to 160. Of the 150 licences offered, 79 are traditional licences, compared to 70 in the 23rd round last year, 65 are Promote Licences, compared to 75, and, as in 2006, six are Frontier Licences.

According to Jim Hannon, of Hannon Westwood, the UKCS intelligence company, this all adds up to a very exciting period for the industry. "A high technical success rate, with the potential for bringing fields into production in as little as three years, makes the area very attractive to new entrants" he says.

The introduction of initiatives such as the Promote and Frontier Licences has proved both popular and successful (see Geoexpro Vol. 3, No. 6 for explanation of UK Licence types). A significant number of Promote Licences have continued into their third and fourth years and two discoveries, Sheryl and Oak, have already come out of this initiative. Jim Hannon also thinks that the fallow acreage initiative, whereby blocks or discoveries that have not been drilled for 3 years or more are either worked up or divested, is also proving to be a success. "This is the important contribution of the 'majors' to help the work going on in the North Sea," he explains. "Very few of them participated in the 24th round, but through this initiative they are now either working their acreage or giving it up. Our intelligence indicates that a few years ago the majors typically held 60% of the acreage in the North Sea as non-core and under-drilled, with little incentive to hand it back; this has now been reduced to 40% and declining."

"The entrance of fresh, new companies to the UKCS adds a lot of dynamism to the system, although it also leads to a certain amount of instability," Jim adds. "Many of these companies are young and small and have no income stream; their financial object may prove to be acquisition or takeover rather than production, a positive outcome for them, though not necessarily for the industry. We expect to see a certain amount of consolidation over the next few years, with large companies buying or merging with smaller 'Promote' concerns as a way of getting into the North Sea."

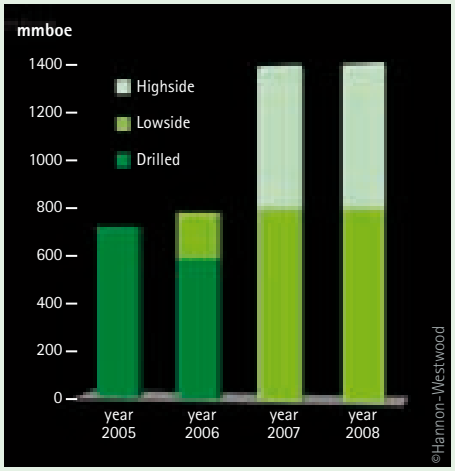
Jim Hannon believes that the biggest potential barrier to continuing success in the UKCS stems from the pace at which exploration is proceeding. "The 24th Round has commitments to 17 firm and 13 contingent wells," he explains, "bringing to over 200 the number of committed exploration and appraisal wells in the UKCS pipeline for the next two to three years. Because of rig constraints, we can only drill about 55 to 60 vertical exploration wells annually, so it will be two or three years before we can drill the wells in the queue. There is a danger that the backlog could result in the new entrants becoming frustrated and disappointed. If that happens, money will start to move elsewhere, as companies look for payback in less than three years. In addition, the smaller companies need rapid success, as they tend to work with borrowed money – too much delay and they could go under."

"The interest in the UKCS is still strong," Jim adds. "However, the UK authorities may need to think about the pace of activity and the time needed to absorb well results. Companies seem to be coping with annual rounds, but they may not be getting sufficient time to plan and think through results properly.

With a DTI inventory of 2,000 undrilled leads and prospects, a large stock of small discoveries waiting to be developed and an estimated yet-to-find total of 20 billion barrels or so, the UKCS should remain an exciting and vibrant arena for many years to come.

Jim Hannon has extensive experience in the industry, having worked for a number of companies in senior management roles throughout the world. Forming Hannon Westwood with Charles Westwood in 1993, Jim's expertise is in the area of portfolio rationalisation, strategic analysis and the use of market intelligence. (www.hannonwestwood.com)

Photo: Kat Hannon



The success rate for finding and appraising hydrocarbons in the UKCS has increased from over 50% in 2005 to around 75% in 2006. At the same time, the finding rate has also increased, from around 14 MMboe per well in 2005 to 23 MMboe per well last year.

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First Round Offshore Cyprus

On February 15th, the first license round offshore Cyprus was held in Nicosia.150 people from oil companies, investors and government relations were present at the opening.

The opening received a lot of attention from oil companies due to the large area of unexplored areas and the fact that huge oil and gas discoveries have been done in the regions surrounding Cyprus.The 2D lines PGS acquired in 2006 which is the basis for the license round support the expectation from the oil companies by showing a lot of interesting structures and possible traps.

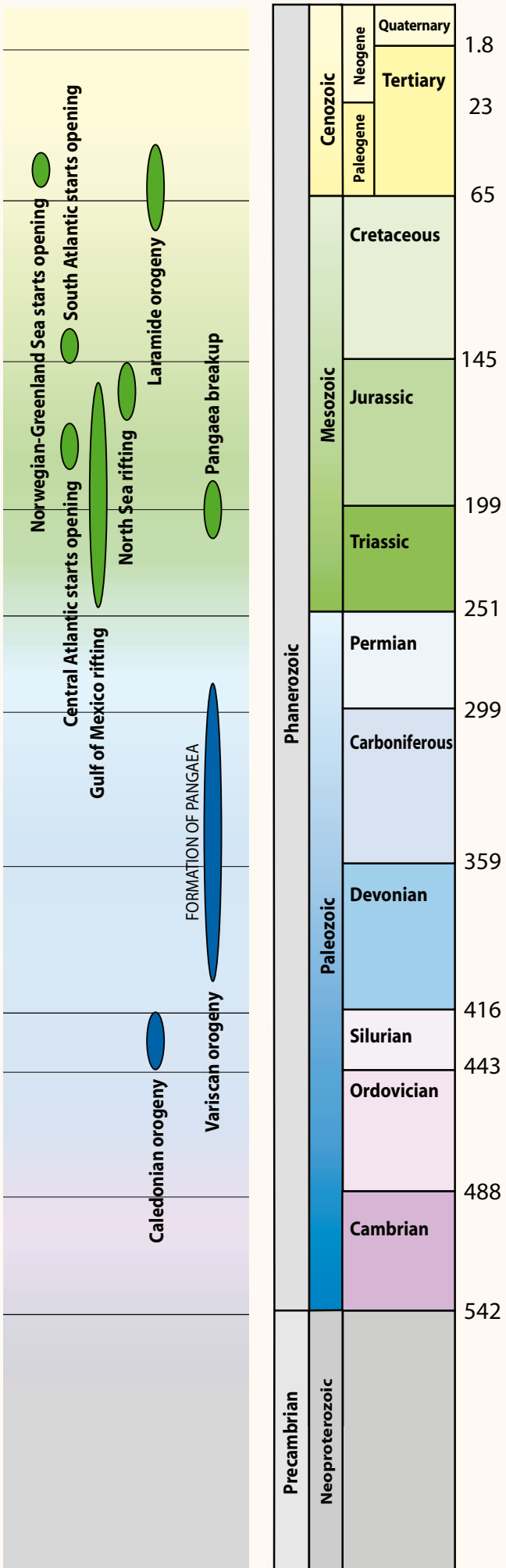
The sea mountain Eratosthenes in the south is especially promising. Eratosthenes was initially believed to be the basement but from the 2D seismic shows a sea mountain buildup from layered sediments. In the northeastern part of the region the attention has been given to structures showing flat spots which is an indicator of hydrocarbon- water contact.

Cyprus is about to become a hydrocarbon producing country and in the future, Cyprus is planning to build an energy center to centralize the nation's energy administration.

The license round was opened by the Hon. Minster of Commerce, Industry and Tourism, Mr Antonis Michaelides. The opening was followed by a speech by the Hon. Minister for Petroleum of the Arab Republic of Egypt, Mr Sameh Fahmy, who claimed that Egypt supported Cyprus and will help Cyprus develop knowledge and technology for use in their offshore hydrocarbon industry. Mark Spencer Jones from PGS presented the seismic 2D data covering the region. The presentation of the seismic data was followed by a brief overview of the geology in the area supported by an interpretation of the seismic data.

The licensing round was opened 15th of February and will last until 16th of July. Until the closing date a company can apply for all blocks available but each block must have their own application. After the closing date the applications will be reviewed by the ministry which will offer the blocks to the companies with the highest ranking. When the block is awarded the licensee has three years to explore the area. The period can be extended by four years to a total of seven years.

A lot of attention from the local media was given this event since this it is an important milestone for the Cypriot people. Hon. Minster of Commerce, Industry and Tourism, Mr Antonis Michaelides to the left and Foreign Minister Mr. Yiorgos Lillikas to the right.



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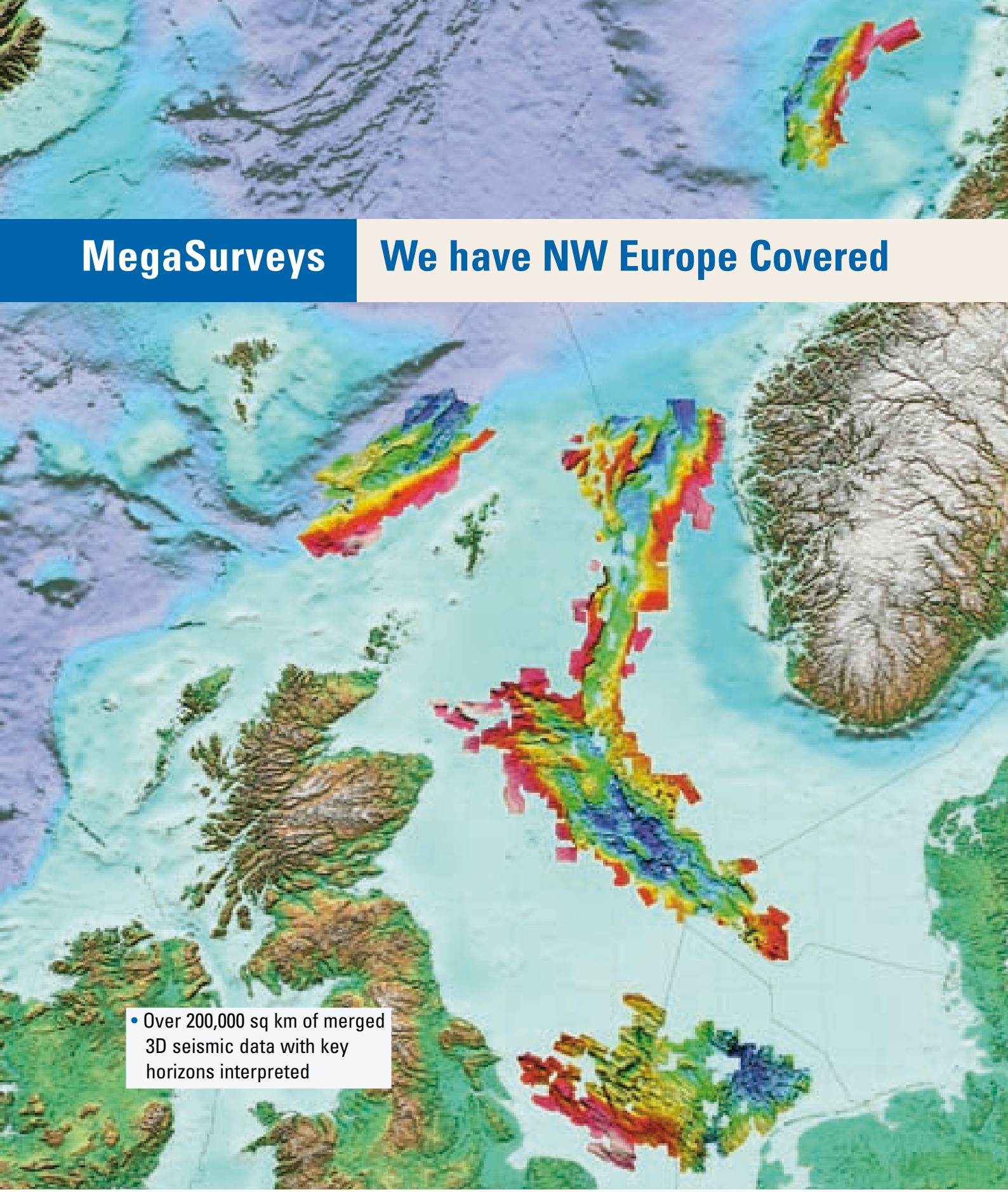

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West Africa acreage

CGGVeritas will participate in the launch of the Republic of Guinea-Bissau's 3rd Licence Round. Petroguin, the National Oil Company, is concessionaire for Guinea-Bissau and has retained CGGVeritas and First Exchange Corporation to manage data packages and distribute all technical and legal information related to the round. The round will run from now until April 30, 2007 and covers key acreage, both onshore and offshore Guinea-Bissau. Guinea-Bissau lies in western Africa and is one of the smallest countries (36,000 km^2) in continental Africa.

"Maastrichtian and Albian sands offer shelf-based opportunities in closures associated with salt diapirism. Modern salt imaging techniques could bring new life to this under-exploited play; the petroleum system is there, the reservoirs are there, the traps are yet to be found. On the shelf edge and slope, Cretaceous reefs offer further potential particularly where faulting, that defines the shelf margin, provides an additional trap-forming mechanism", says Richard Morgan, CGGVeritas Geological Services Manager.

First multiclient wide-azimuth

Total E&P is underwriting a major portion of the first exploration multiclient wide-azimuth towed-streamer survey in the Gulf of Mexico. The "E-Octopus" project covers 475 Outer Continental Shelf blocks in the central Gulf of Mexico, about 200km offshore Louisiana in water depths of approximately 1350m. The survey is acquired by WesternGeco.

To enhance the subsalt image, WesternGeco is employing the Q-Marine single-sensor marine seismic system with proprietary processing workflows and wavefield extrapolation migration (WEM).

"The acquisition of this extensive wide-azimuth survey will offer an enhanced ability to optimize well placement and reduce drilling risk, and will enable the comparison of geological analogues to assist in identifying potentially significant oil and gas reserves," says Joe Varisco, WesternGeco region manager, North America. "The combination of WesternGeco Q-Technology and industry-leading expertise in wide-azimuth design, acquisition and processing is creating a step change in subsalt imaging."

Seismic data acquisition commenced in mid-July 2006. Since then, over 200 blocks of wide-azimuth data have been acquired and are currently being processed. Completion of the survey is expected in April 2007. Fast-track WEM products will be available for interpretation in advance of the October 2007 Gulf of Mexico lease sale.

Improving consistency

Statoil is working with UK company Reservoir Imaging Ltd (RIL) on the development of a programme to improve the quality and consistency of its 4D seismic acquisition projects. The aim is to maximize the value of 4D seismic as a tool for monitoring the performance of oil and gas reservoirs, which in turn could potentially lead to the production of untapped reserves.

RIL, based in Edinburgh, Scotland has completed an initial project to QC and analyse all the 4D seismic surveys commissioned by Statoil in 2006. Data from 19 legacy 4D surveys carried out in previous years were also included in the analysis. The 10 projects from the 2006 4D campaign involved many different geological and environmental conditions and a variety of seismic acquisition methods.

One of the key goals was to provide consistent quality control across all the surveys so that outcomes of each project could be compared and highlight where adjustments were required. During the 2006 surveys, navigation data from the operating vessels was transmitted from the field to the shore at regular intervals so that RIL could process the data and generate a standard set of 4D attributes.

122 percent replacement

Exxon Mobil did in 2006 add 1.95 billion oil-equivalent barrels to its worldwide oil and gas reserves. Production totaled 1.6 billion oil-equivalent barrels, with 976 million barrels of liquids and 3.7 trillion cubic feet of gas produced. The corporation replaced 122 percent of production including property sales and 129 percent excluding property sales.

"With a 5-year average replacement ratio of 114 percent, ExxonMobil has continued to replace annual production with new quality opportunities," according to Rex Tillerson, Exxon Mobil Corporation's chairman and chief executive officer."

The reserve additions in 2006 came from all geographical regions. The most significant additions came from the Asia Pacific / Middle East region.

Proved reserve additions were also made in West Africa from developments in Angola and Nigeria, and from new developments and established operations in Norway, Malaysia, the Netherlands, Canada, Australia, and Russia.

With 22.7 billion barrels of proved oil and gas reserves at year-end 2006, split about evenly between liquids and gas, ExxonMobil's reserves life at current production rates is 14.2 years. The portion of proved reserves already developed is 64 percent.

Like Everywhere You've Never Been

One of the last intact wildernesses left on earth, Papua New Guinea is experiencing an unprecedented resurgence of interest from the hydrocarbon industry. Is it possible to encourage the advances of modernisation and the oil industry without jeopardising the ecology and culture of this amazing country?

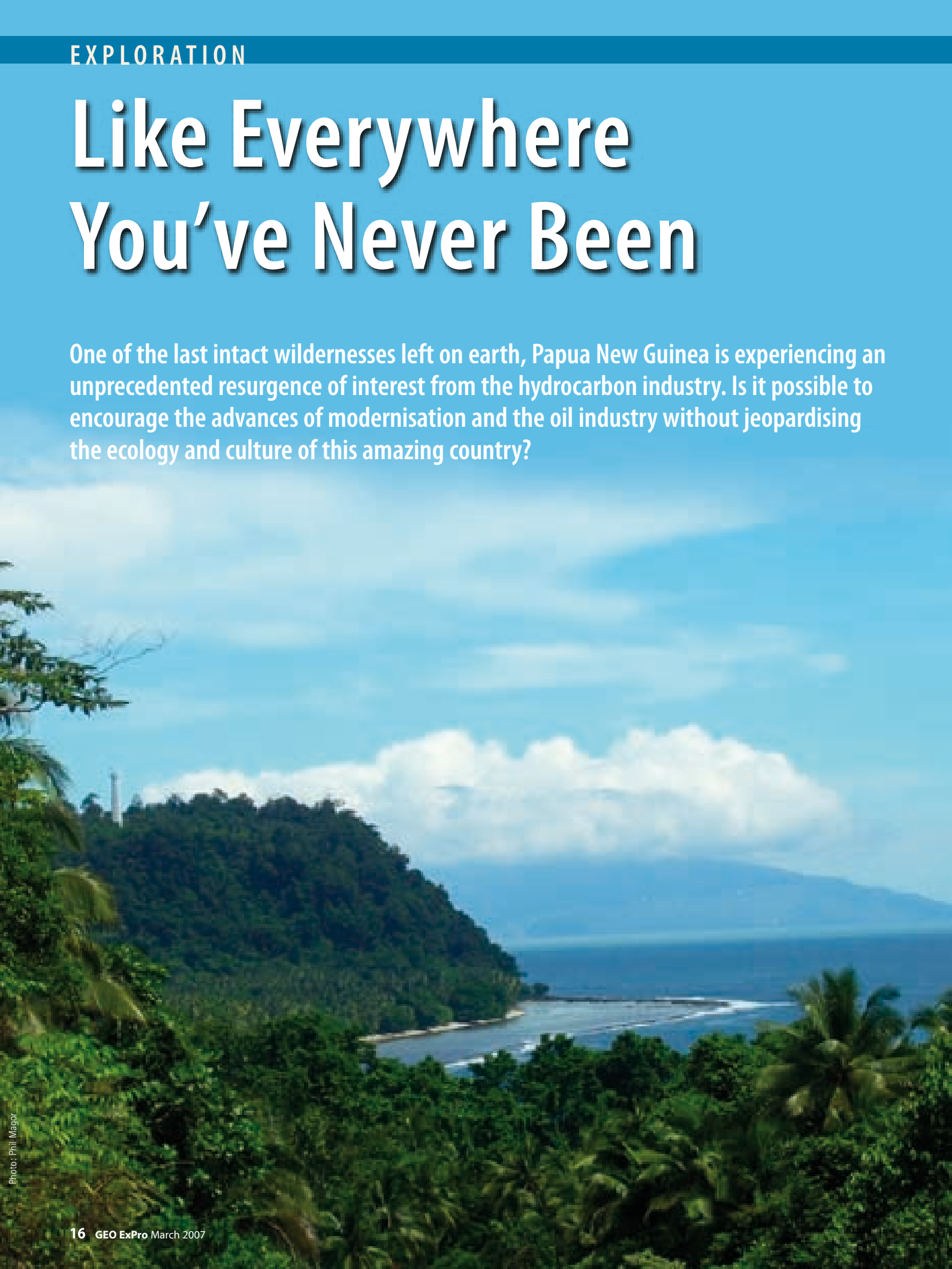
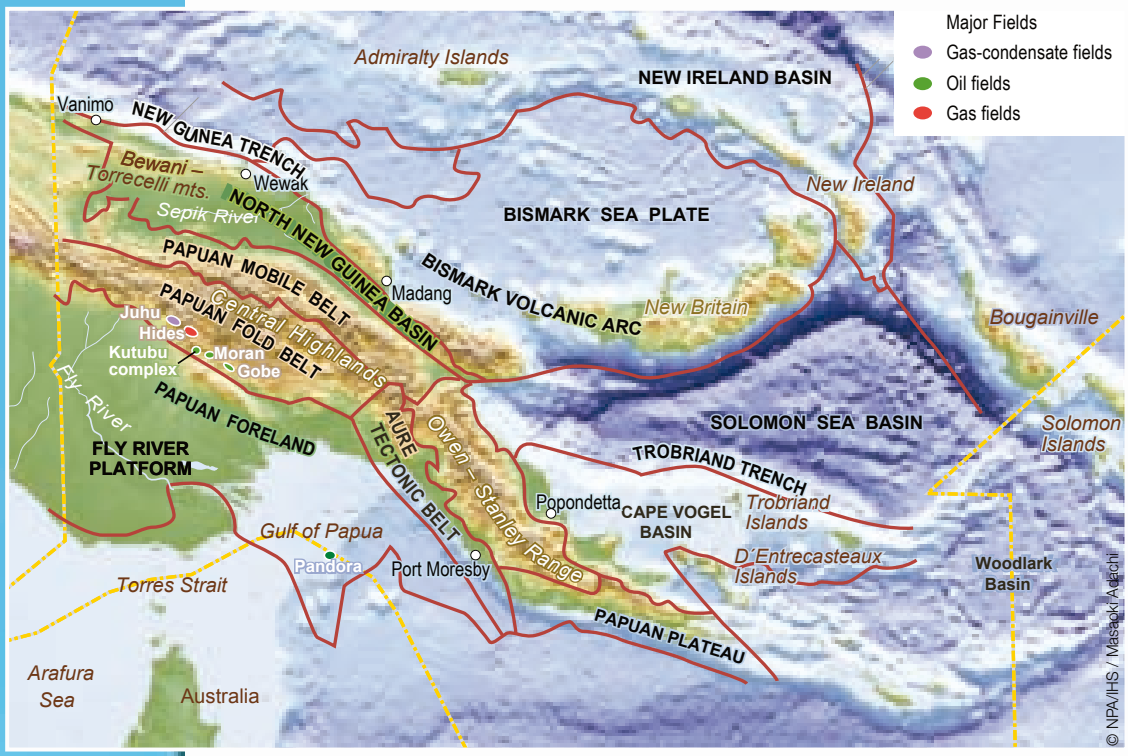


Photo : Phil Magor



Papua New Guinea lies in one of the most tectonically complex and active parts of the world. Over the past 65 million years, the region has seen the generation of seven separate active plate margins, three discrete island arc complexes and three small spreading ocean basins, two of which, the Bismarck Sea and Woodlark Basin, have continued opening to present times.

One of the great attractions of PNG is the stunning plant and animal life, particularly in the jungle. There are butterflies the size of dinner plates, spiders which spin webs like wire; sea eagles and ospreys hunting colourful parrotfish out at the reef edge; huge blue-headed cassowaries and wild boars; rivers and beaches with four metre long crocodiles; and myriads of chirping insects amongst the raucous blooms that set the forest canopy on fire.

The population of Papua New Guinea is as diverse as the terrain and there are several thousand separate communities, most with only a few hundred people. Many of these neighbouring tribes have been at war with each other for generations and outbreaks of fighting are still common.

Papua New Guinea is stunningly beautiful, with scenery varying from flat swamplands and dense rainforest to cloud covered mountain ranges reaching over 4,500m, separated by deep ravines and fast flowing rivers. Volcanoes, both extinct and active, are common features of the landscape.

Jane Whaley, Associate Editor

Sea shells are no longer the currency of Papua New Guinea, but it remains one of the last countries in the world to be relatively untouched by modern man. Lying at the eastern end of the Indonesian archipelago, it still has less than 700 km of paved roads, and much of the country is virtually inaccessible except on foot or by helicopter or small plane.

Spectacular landscape and wildlife

It is, however, a stunningly beautiful country, as Phil Magor, Papua New Guinea Asset Manager for Transeuro Energy, describes enthusiastically. "The combination of geology and climate means that the country has a unique and beautiful identity, ranging from white coral to black sandy beaches, clear azure seas to towering volcanic peaks, and from mist-enshrouded mountain ranges separated by deep ravines to the rolling rainforests of the deltas, all washed by two metres or more of rainfall each year."

As well as being blessed with spectacular scenery, Papua New Guinea (often called simply PNG) is richly endowed with natural resources, including gold, copper and, of course, hydrocarbons. Oil seeps were first recorded as early as 1910, and the first wells drilled a few years later, but it was only in 1991, after several unsuccessful waves of enthusiasm from oil companies, that hydrocarbons were produced in the country. A resurgence of interest, fuelled by high oil prices and more attractive petroleum terms, saw the first gas exports in the early 21st century. PNG now faces the difficult task of encouraging further exploration without endangering the fragile ecological and anthropological systems of this unique country.

Papua New Guinea is one of the most picturesque countries in the world, dominated by the Central Highland ridge, rarely seen without an ever-changing covering of cloud.

Papua New Guinea boasts one of the largest contiguous tracts of rainforest outside the Amazon

Complex and varied geology

Papua New Guinea lies in one of the most tectonically complex and active parts of the Pacific, on the converging margin of the Pacific and Australian Plates. As a result, the petroleum geologist is constantly presented with structurally difficult challenges and questions.

The country covers a number of sedimentary basins with tectonic settings ranging from passive margin continental shelf and thrust belts to rift basins. The central core is the Central Highlands, reaching over 4,500m, and up to 100km wide. It is tectonically part of the Papuan Fold Belt, which is composed of metamorphics and granite intrusions with younger material and volcanics. In places there are up to 12,000m of sediments, often with sections repeated due to recurring episodes of folding and thrusting.

South and southwest of the mountains lie the Papuan Foreland and Fly Platform, an area of flat rain forest, traversed by the meanders of the 800km long Fly River. The geology here is composed of flat Cretaceous to Quaternary sediments overlying block-faulted crystalline basement. This extends offshore into the Gulf of Papua, where Jurassic sediments onlapping basement ridges have been preserved, and there is evidence of Tertiary pinnacle reefs.

The area north of the Central Highlands, dominated by the valley of the Sepik River and the Bewani-Torrecelli Mountains, forms the North New Guinea Basin. Rapid subsidence led to the development of thick platform carbonates alongside deep water basins, filled with volcaniclastics. Sub-basins in this area could contain up to 10,000m of Late Tertiary sediments, and oil and gas seeps are common along fault zones, revising hydrocarbon interest in the region.

Southeast of the North New Guinea Basin lies the Cape Vogel Basin, which covers the northern side of the Papuan Peninsula and the offshore to the Trobriand and Woodlark Islands. It is filled with up to 7,500m of Tertiary sediments lying on ophiolitic oceanic crust. Widespread volcanism has been a feature here, with the formation of island arcs and the basinwide deposition of pyroclastics and volcanoclastics.

The eastern end of the Papuan peninsula is dominated by the metamorphic rocks of the Owen Stanley Range, formed as a result of arc-continent collision. To the south west of these lies the 400 km long Aure Tectonic Belt, thick folded and faulted Mesozoic and Cenozoic sediments with complex structures.

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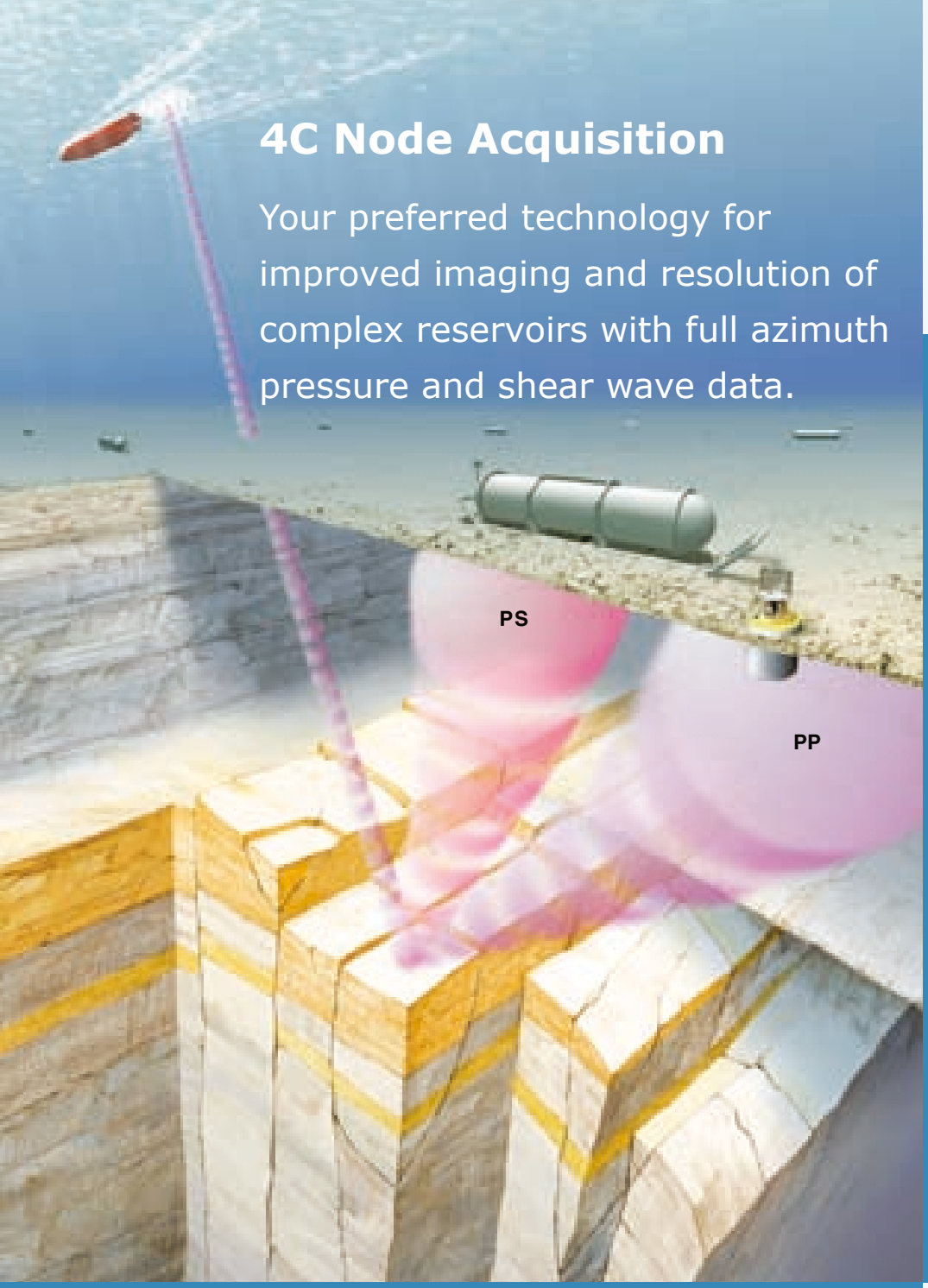

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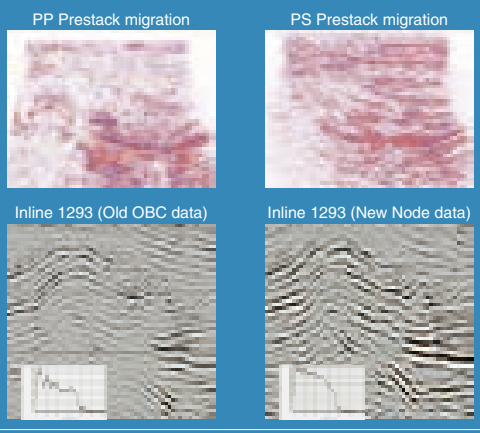

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The Trobriands, coral islands 130 km north of the eastern tip PNG, have been called 'the islands of love'. This stems from the beauty of the people and their islands, and is also a reference to their famous yam festival, when the local beauties are reputed to be very free with their favours. With regard to the hydrocarbon industry, the islands almost completely unexplored.

Undrilled anticlines and unexplored basins

Most of the petroleum exploration activity and discoveries have been concentrated in the Central Highlands. A total of 12 fields have been found here, in large northwest to southeast trending anticlinal structures, all reservoired in sandstones of the Late Jurassic or Early Cretaceous. A number of large undrilled anticlines remain in the main Foldbelt fairway, and improvements in seismic imaging, including methods of seeing through the ubiquitous dolomitised and karstified Darai Limestone, mean that subthrust structures in the foldbelt also offer potential.

Outside the Central Highlands and Papuan Foldbelt, PNG is virtually unexplored. The Papuan Foreland and Fly Platform, for example, with its simple, flat-lying geology, has 12 as yet undeveloped discoveries, found from very few discovery wells. In fact, all eight wells drilled in the Foreland Basin in the last ten years had shows or evidence of hydrocarbons.

The Aure Tectonic Belt is also underexplored, although there is evidence of a new petroleum system, while offshore in the Gulf of Papua stratigraphically trapped biogenic hydrocarbons have been proven in Miocene reefs. The North New Guinea Basin, where seeps were first noted back in 1910, has only nine exploration wells but no commercial discoveries. Potential here is also centred on Miocene reefs, although turbidites and basin floor fans may prove prospective.

The largely offshore basins in the eastern part of Papua New Guinea offer some of the most virgin territory available in the industry. The Cape Vogel Basin, for example, is virtually unexplored. It contains a number of thick depocentres, with potential for Tertiary anticlinal, fault and pinch-out plays and reef structures. TransEuro Energy recently proved its faith in this area by taking an undrilled coastal block near the town of Popondetta, hoping to drill in 2008.

Even more frontier level territory can be found in the remote New Ireland and Bougainville Basins, fore-arc basins centred on the island chains of the same names to the north of the Bismark Sea. Both these basins have experienced intense volcanism and the most likely reservoirs are porous and permeable volcanoclastics. Only a few thousand kilometres of seismic were shot and a single well has been drilled here, where water depths can exceed 2,000m.

Encouraging developments

Estimates of proven natural gas reserves in PNG range from 14 to 17 Tcf, but the government consider the potential to be over 40 Tcfg. Proved oil reserves are in the region of 200 million barrels, with estimated possible reserves up to 500 MMbo. Total production of oil to date is over 400 million barrels, with 1.6 million barrels of condensate and 66 billion cubic feet of gas having been produced for sale, significant quantities of gas having been reinjected.

Keen to attract the oil industry, the PNG government introduced new fiscal terms in 2003. Measures included the reduction of corporate tax from 45% to 30%, leading

A true exploration geologist

Phil Magor is Asset Manager for Transeuro Energy in Papua New Guinea, where he has lived since 2004. He finds it an absolutely amazing place. "As well as the astonishing wildlife and the stunning landscape, with evocative place-names such as Landslide Mountain, Warp, Nomad and Blub Blub, there are the people, equally diverse and colourful in attitude and decoration," he explains. "Ethnic diversity in PNG is a striking testimony to the interaction of cultures and geography, at once keeping communities apart while driving others together. The tribal identities are preserved in distinct languages and dazzling local ceremonies, in headdresses of woven bark and feathers, with possum hats and grass skirts (and the women look quite nice as well!)."

Phil has more than 25 years experience as an Exploration Geologist in the oil and gas industry, working with major oil companies, smaller independents, and geological consultancies. A graduate of Bristol University, Phil has worked all over the world, including the UAE, North Sea, Malaysia, Libya and PNG.

Transeuro Energy, a small independent Canadian oil company with significant holdings in Canada, the Ukraine and Armenia, is a relative newcomer to Papua New Guinea. With 4 exploration licenses covering a range of basins and topography, it is one of the largest license holders in the country. Phil explains that they moved into PNG partly because "it had been overlooked for some time when oil prices were low and gas prices non-existent. It's expensive to explore, but we consider there is scope for a major discovery in at least two of our blocks."

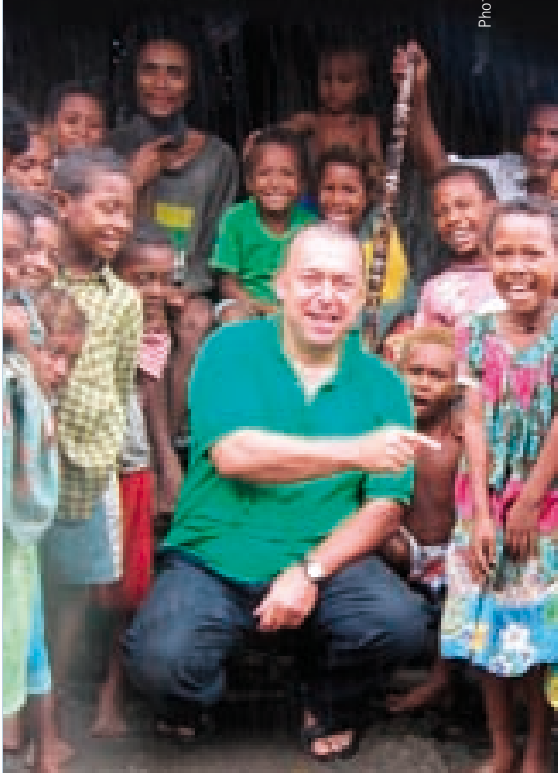

Photo: Keevin Doran

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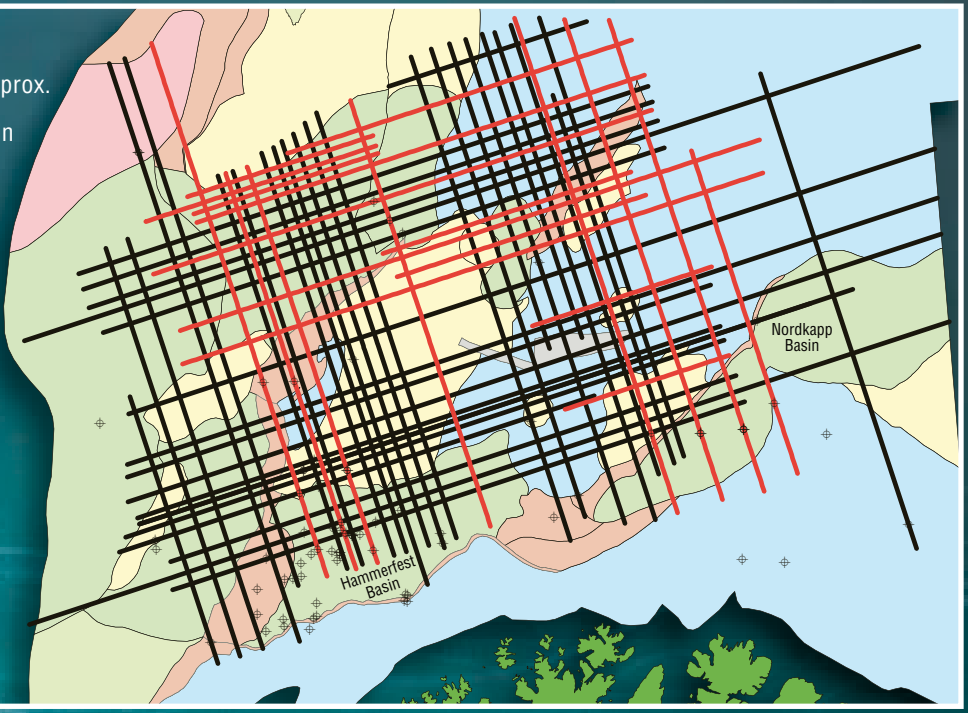

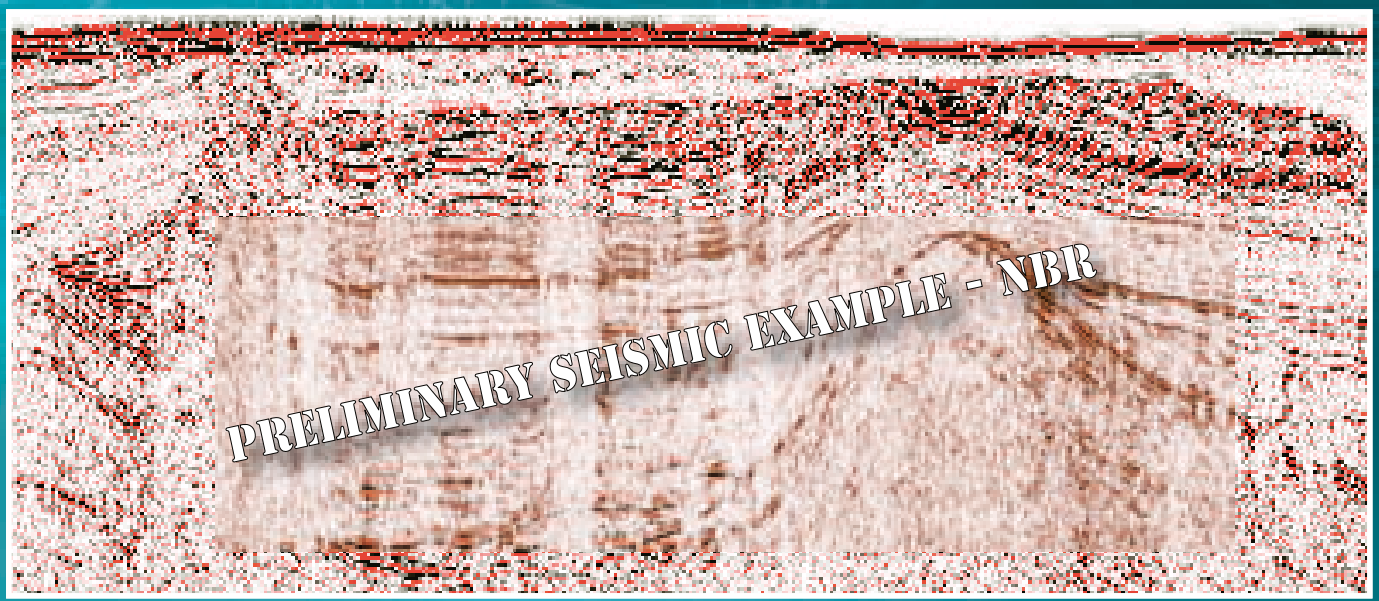

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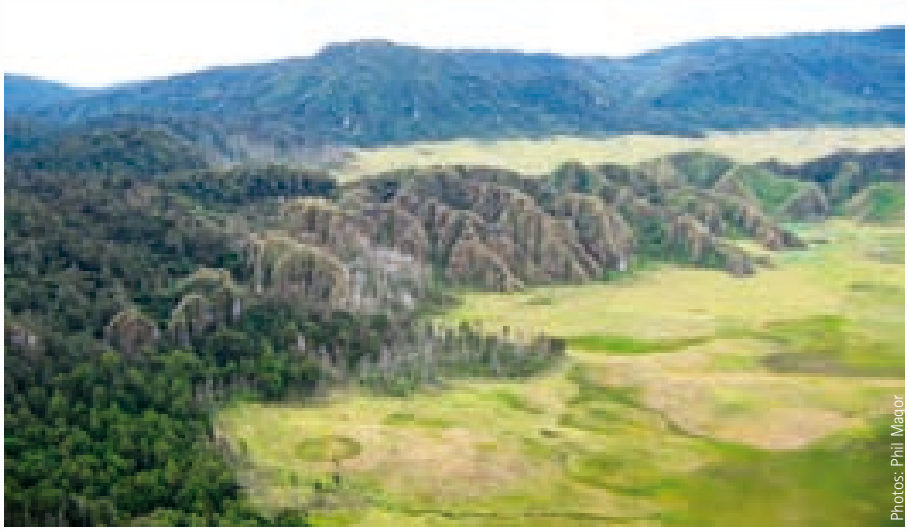

A dominant feature of the geology ,particularly in the west, is the Late Oligocene Darai Formation. This massive limestone, up to 1,750m thick, is a known reservoir in the south, in the Gulf of Papua. Further north, however, it outcrops at the surface, and erosion has produced an intensely karstified terrain which hinders the acquisition of conventional seismic data.

to an attractive marginal company take of 69%, especially favourable when compared to the fiscal regimes of other counties in the region. These incentives appear to have been very successful, as applications for new exploration licenses rose from five in 2002 to 45 by the end of 2004.

Since many of the discoveries in the country have tended to be gas-prone, there have been a number of initiatives to develop systems for both utilisation and export of gas. There are refineries in Port Moresby and processing plants at some of the Central Highland producing fields. Plans for a gas pipeline linking PNG with Australia were finally shelved earlier this year, but several countries and organisations have expressed interest in building LNG and other gas utilisation plants on the island.

Although starting from a low base level, infrastructure in the country is developing fast. There are access roads to the current producing fields. River transport is important for both freight and passengers, particularly on the Sepik River, and there are a number of deep water ports. The main method of trans-country transport, however, is flying, using small planes or helicopters, and PNG boasts nearly 600 airports, most with mud runways!

Land ownership is always a concern in negotiations over mineral rights in Papua New Guinea, as traditional communities own the land communally and do not recognise a permanent transfer of ownership when land is sold.

Grass huts and internet cafes

Phil Magor considers the people the greatest asset to living in PNG. "They have a disarming friendliness that has been their trademark for centuries. Their pride in their ethnic diversity can be seen not only in the villages, but in the cities, with the juxtaposition of the traditional and the ultramodern, with woven grass huts and internet cafes, street vendors and shiny hotels, open-air craft m and air-conditioned supermarkets."

It is this ability to relish their difference, their culture and their land that encourages the people of Papua New Guinea to embrace the promise of progress, while retaining their traditions and ensuring the protection of their natural world. With careful and sympathetic planning, the development of a hydrocarbon industry need not be incompatible with maintaining the ecology and landscape of this unique country: a country which, in the words of the Papua New Guineans themselves "is like everywhere you've never been." Long may it remain that way.

Diversity leads to 800 languages

Papua New Guinea, having been under the control of Great Britain, Germany, Japan and Australia, gained full independence in 1975 and is a democracy within the British Commonwealth. It has few major centres of population, except the capital, Port Moresby, and 85% of the people rely on subsistence farming. Mineral deposits, including copper, gold, silver and manganese, are the main exports.

PNG's geographical and cultural diversity has contributed it to being one of the most linguistically diverse regions in the world, with an estimated 820 different languages spoken in the country. The extent of the linguistic diversity is such that linguists cannot determined whether the languages all developed from the same proto-language or from several different ones. Most tribes, even those less than 100 strong, have their own language, and the majority of Papua New Guinean languages have no more than 7,000 speakers.

To make sense of this babel, three official languages, English, Tok Pisin and Hiri Motu, are spoken as a second language. English is used in official situations such as education and government although communities can choose the language for the first three years at school.

Tok Pisin and Hiri Motu are forms of pidgin language, developed where speakers of different languages need a common language and use the vocabulary of one language, often with a completely different grammatical structure. Tok Pisin is English-based and first developed in the 19th century, so the English vocabulary found in it is interesting. For example *Mipela*, meaning person, comes from the English 'my fellow', *bel hevi*, meaning 'sad', comes from 'belly heavy' and accident is translated as *buggarap*! .

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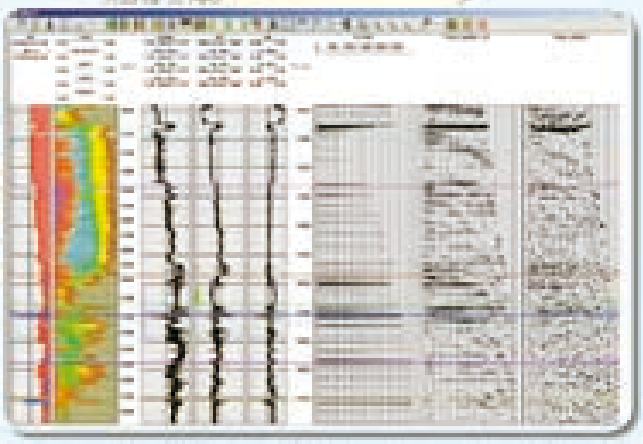

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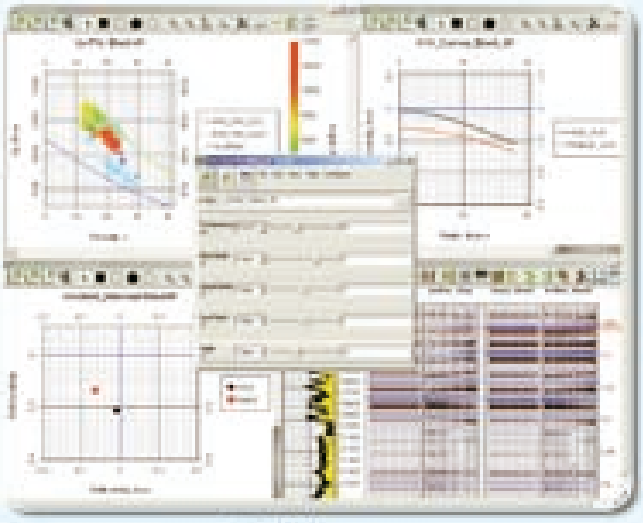

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Oil Under Foot

Some of the most productive oil and gas acreage ever discovered lie adjacent to the site of this year's AAPG National Convention in Long Beach. Separated by only 5 km, the "old, nearly depleted" Long Beach and Wilmington oil fields still offer exploitation opportunities despite the challenges of operating in an urban environment.

Photo: Long Beach Gas and Oil

Photo: Don Clarke

Thomas Smith, Associate Editor

Oil seeps have been utilized by Native Americans for thousands of years in the southern California area. It was not until 1892 that the first large oil strike was made by Edward Doheney and Charlie Canfield near the corner of Colton Street and Glendale Boulevard in downtown Los Angeles. Using the sharpened end of a eucalyptus tree to drill to a depth of 140m, the Los Angeles field was discovered. By 1897, the field was actively producing from 500 wells and is still producing today.

The Oil Rush

The discovery of three major fields in 1920-21, Long Beach, Santa Fe Springs and Huntington Beach, created a real oil boom in the Los Angeles basin. The Long Beach discovery well gushed oil 35m into the air and then was plugged by an ensuing cave in. After the well was cleaned out, it produced 1,000 bopd (160 m^3pd) and would eventually produce over 700,000 barrels (111 Mm^3) of oil.

At the time of the discovery, Signal Hill was being subdivided into residential lots, creating an onslaught of potential homeowners to become oil drillers. The parcels of land were quite small and soon Signal Hill would be so densely covered with derricks that the legs of many were actually intertwined. The field proved so prolific that most of the people that bought shares in wells actually made money. Even the relatives of persons buried in the Sunnyside Cemetery would receive royalty checks for oil drawn from beneath family plots.

The Long Beach field has produced nearly 1 Bbo and is the most productive field per acre ever discovered (about 1 MMb per acre). Over 3,000 wells have been drilled on this faulted anticline that has an area of only 2.4km by 6.4km. The maximum production was reached in December 1923, of 224,000 bopd (36 Mm^3pd) from 329 wells. Today's production is 3,850 bopd (612 m^3pd) from 285 producing wells.

Subsidence caused by an oilfield

One of the most dramatic cases of land subsidence caused by oil production occurred at the Wilmington field. Appreciable subsidence was observed in 1938, six years after the Wilmington discovery. Major subsidence was measured in the 1940's that was thought to be associated with the pumping of underground water at Terminal Island Naval Shipyard. However, the area continued to sink after groundwater pumping ceased. Subsidence exceeded 0.6m per year and, by 1958, affected 35 km^2. Total subsidence reached 9m.

Something had to be done as the effects of subsidence were destroying the area. Wharves were inundated by the sea; rail lines and pipelines were warped or sheared; buildings and roads were cracked and displaced. It was determined that oil, gas and water production caused pressure losses and the weight of the overburden compacted the oil sands, at the same time lowering the surface. Research indicated the only way to stop the subsidence was to repressurize the reservoirs through water injection and, at the same time, more oil could be recovered from the field.

Before water injection could be started, the area had to be unitized to ensure that all operators would comply. These mitigation measures took effect in 1960 and the area was stabilized 7 years later.

Once the subsidence was controlled, a vote by the citizens of Long Beach lifted a drilling ban that allowed for the development of the eastern portion of the field extending under the City and the harbor areas. In addition, restrictions were placed on development of the wells and oil facilities to ensure that subsidence would not occur and the natural beauty of the shoreline would be protected.

The area is monitored daily for subsidence and water injection volumes greater than the total fluids withdrawn are required. "Subsidence is still a big issue. If we ever stop injection and continue production, we would have immediate subsidence problems again. My job is to make sure we are putting the injection in the right locations," says John Jepson, geologist for the City of Long Beach.

Photo: Long Beach Gas and Oil

Subsidence from oil production had devastating consequences to the area, requiring mitigation.

Photo: Long Beach Public Library

Signal Hill about 1930, 10 years after the Long Beach field was discovered. The 110 m high hill located behind the City of Long Beach was used by local Native Americans to send smoke signals to surrounding locations, hence the name.

Oil is not always found in far away places nor does it have to be an ugly blight. These examples of how oil production can be accomplished in an urban environment lie next to the sight of this year's AAPG Annual Convention. Pictured are Grissom Island in Long Beach harbor, the City of Long Beach, and oil being pumped in a busy neighborhood.

The oil column is over 2,300m thick, starting at 800m from the surface to a depth of 3,100m. Production is from Miocene to Pliocene turbidite sandstones divided into 7 zones similar to the productive zones in the Wilmington field discussed below. The location is more proximal, resulting in a much thicker reservoir sand section than what is present at Wilmington, 5km to the south.

A recent second boom, the building of new homes, is now impacting Signal Hill. Since 2000, 10% of the city's single-family homes have been built and sold here and is the last remaining view property in the city. Many of the new homes are built over wells and while this building is going on, so is oil production.

The 86-year-old field is still being explored with a 3-D seismic survey planned for 2007 or 08. The owners have also ordered a specially designed drilling rig to reduce impacts to urban areas and hope to be drilling sometime in 2007. It has been nearly 30 years since the last well was drilled.

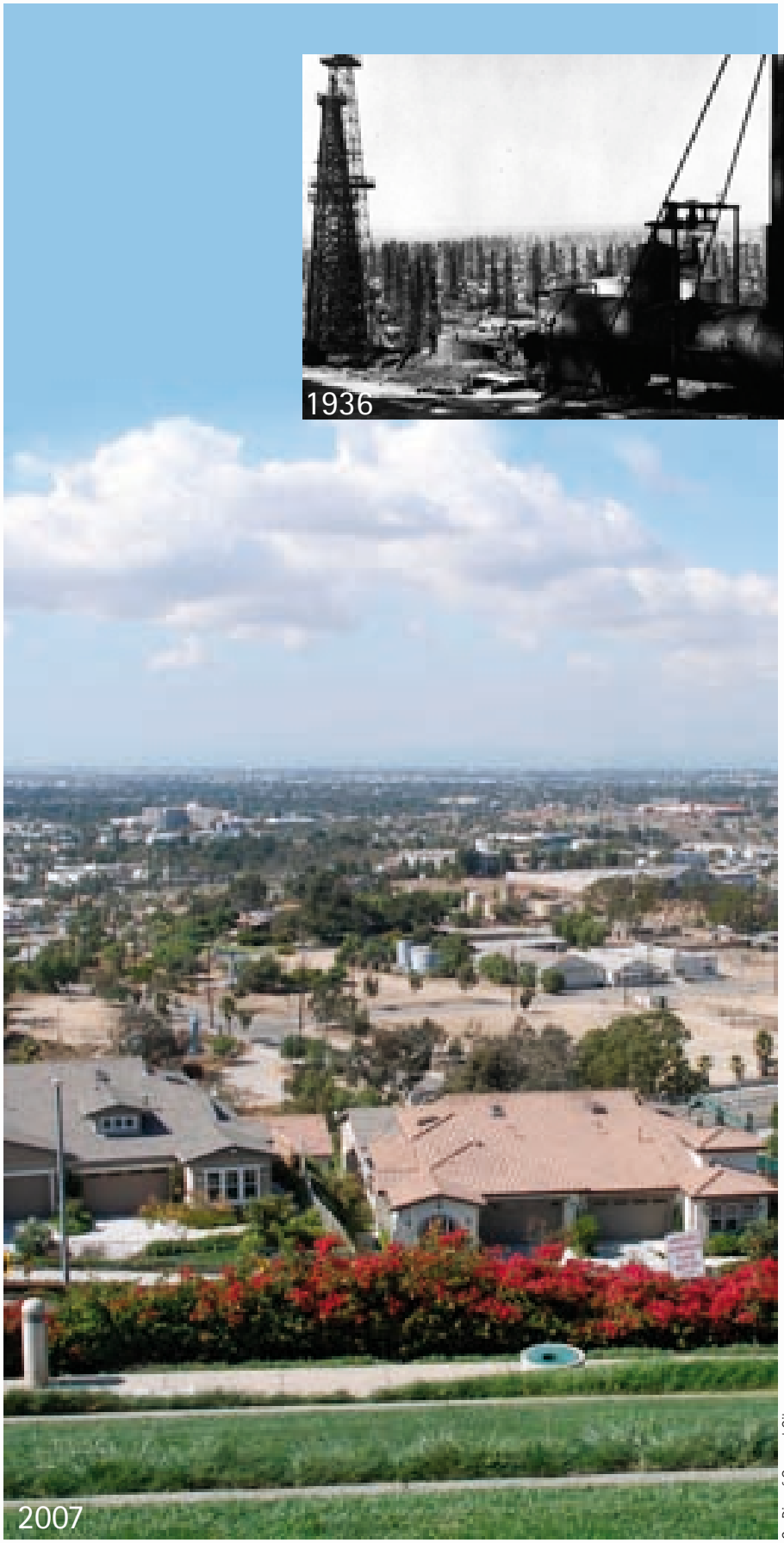
The Big Find

Discovered in 1932 with recoverable oil estimated to be 3 Bb (0.5 Bm^3), the Wilmington field is the largest in the Los Angeles basin and the third largest in the United States. It has already produced over 2.6 Bbo (0.4 Bm^3). Approximately 6,150 wells have been drilled within this field and about 3,400 of these are land-based, with the remainder drilled from offshore locations. The field is currently producing 46,000 bopd (7300 m^3pd) from 1,550 wells.

"I am amazed by the amount of oil left behind in these old fields," says Dr. Hilario Camacho of Signal Hill Petroleum, "and a lot of it can still be recovered."

The field is confined to a 5 km by 20 km northwest-southeast trending anticline that extends offshore beneath Long Beach harbor. A pier and 4 man-made islands were built in 1964 to extract oil from the offshore portion of the field.

The City of Long Beach was granted ownership to its tideland properties by the State of California in the early 1900's.



Ca. Div. of Gas and Oil

Pictured from near the same location, Signal Hill in 1936 and today. Homes are now being built over the old wells.

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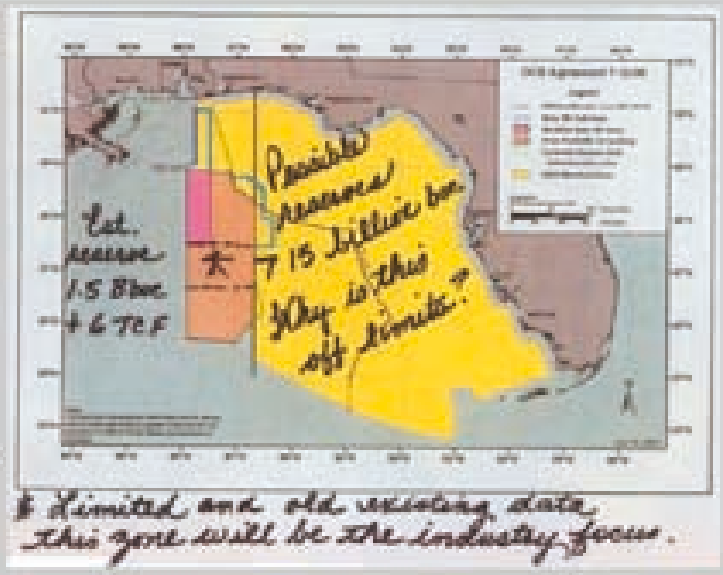

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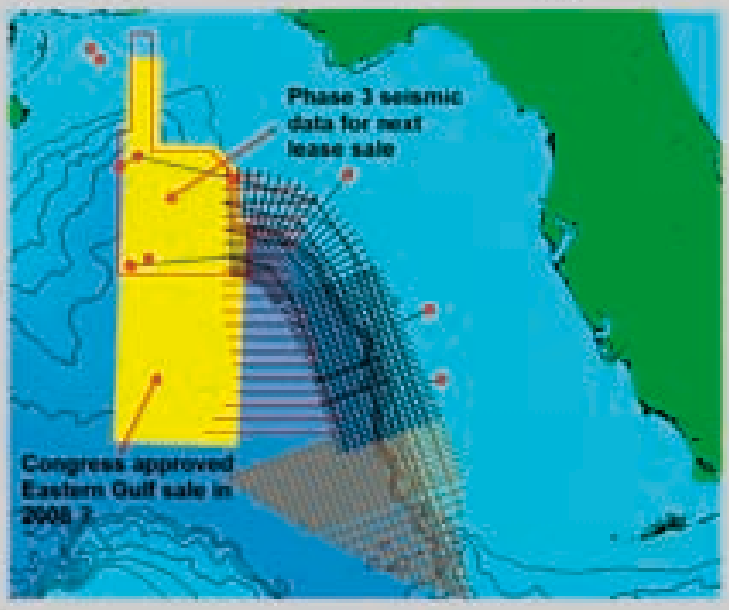

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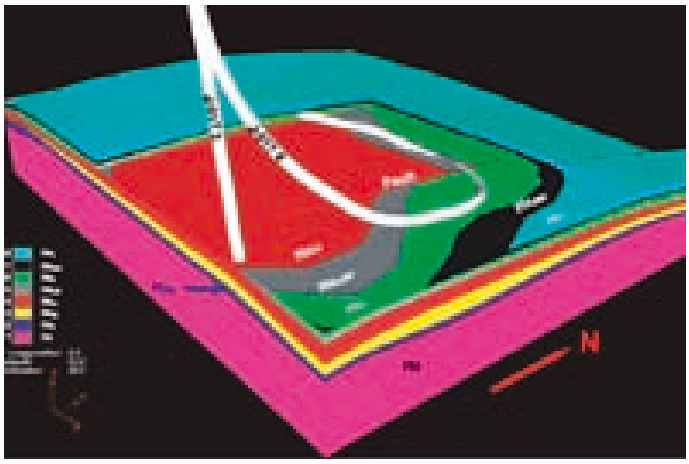
Location of Long Beach and Wilmington fields in the Los Angeles Basin.

Illustration: Ca. Div. of Oil, Gas, and Geothermal Resources



Map view of a tight-radius horizontal well penetrating a turbidite reservoir to recover bypassed oil.

Illustration: Tidelands Oil Production Co.

When it became certain that the Wilmington discovery extended under city owned land, the City's Harbor Department created a Petroleum Division. Now called the Department of Oil Properties, it is designed to protect city assets and act as primary operator in the oil field. Production here has generated over $450 million for the city and $4.25 billion for the state.

The average well in the Wilmington field produces 50 bopd (8 m^3opd) and many areas are nearing their economic limits with 96% water cuts, yet several new wells have come in at 800 bopd (127 m^3opd). Three-dimensional reservoir modeling, along with new completion technology, makes such successes possible.

The field produces from Miocene to Pliocene basin turbidite sandstones. The anticline is highly faulted. With new data, reservoir characterization has subdivided the 7 productive zones into 52 subzones and detailed mapping has identified areas to exploit bypassed oil. Tertiary and secondary recovery techniques utilizing steam are successful in the heavy oil reservoirs. Tight-radius horizontal wells deeper in the formation are also capturing bypassed oil, while three-dimensional models help isolate data inconsistencies. Once the final geologic model is created, 3-D visuals are used to accurately locate horizontal wells through improved drilling techniques and directional control.

Thanks to Don Clarke, Consultant and John Jepson, Long Beach Gas and Oil.

THUMS Long Beach Company is named for the original field contractors: Texaco, Humble, Union, Mobil, and Shell. To develop the eastern portion of the field, which lies offshore in Long Beach Harbor, 4 man-made islands were built. These islands were constructed to resemble resorts and blend into the surrounding coastal environment. They were named after the astronauts that lost their lives during the early years of the U.S. space exploration (Grissom, White, Chaffee, and Freeman). Pictured is Grissom Island.

Photo: John Jepson, Long Beach Gas and Oil

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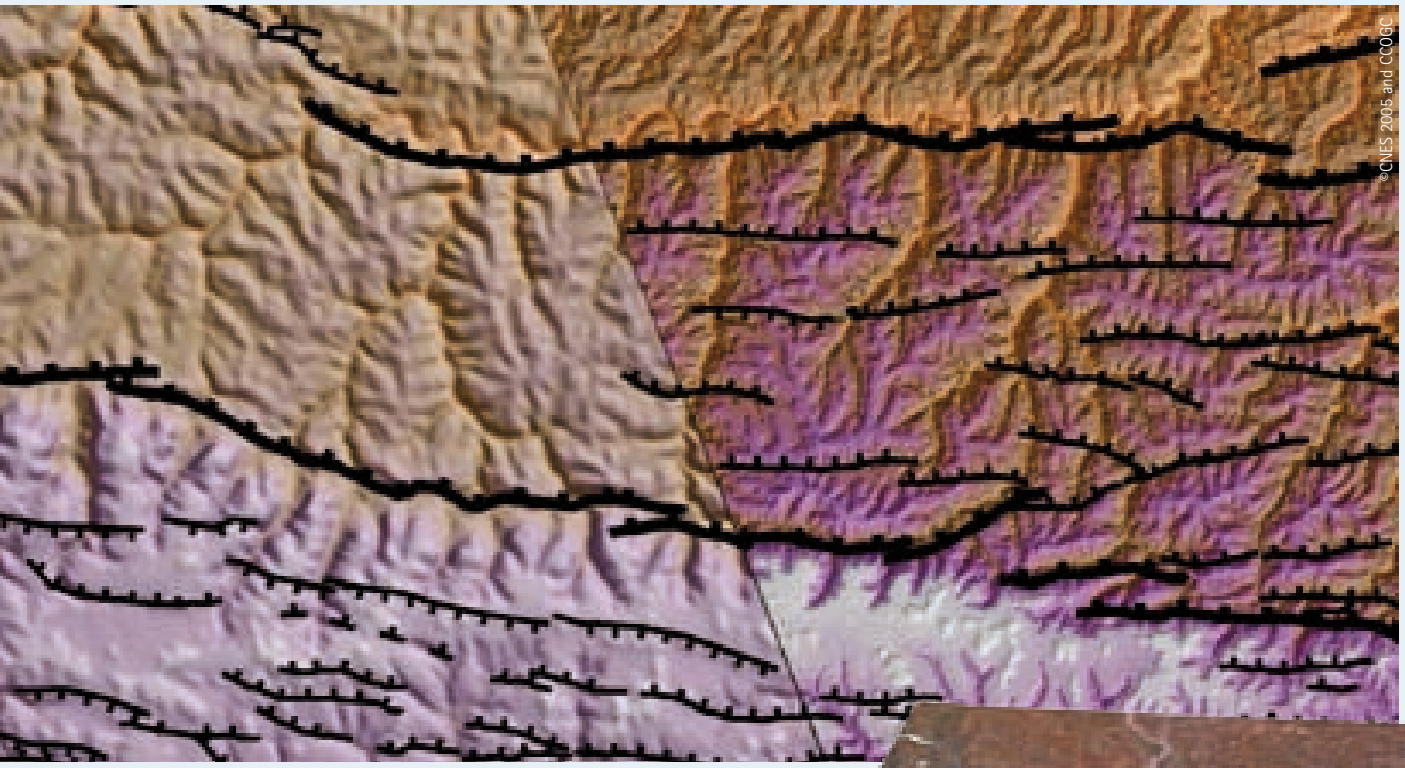
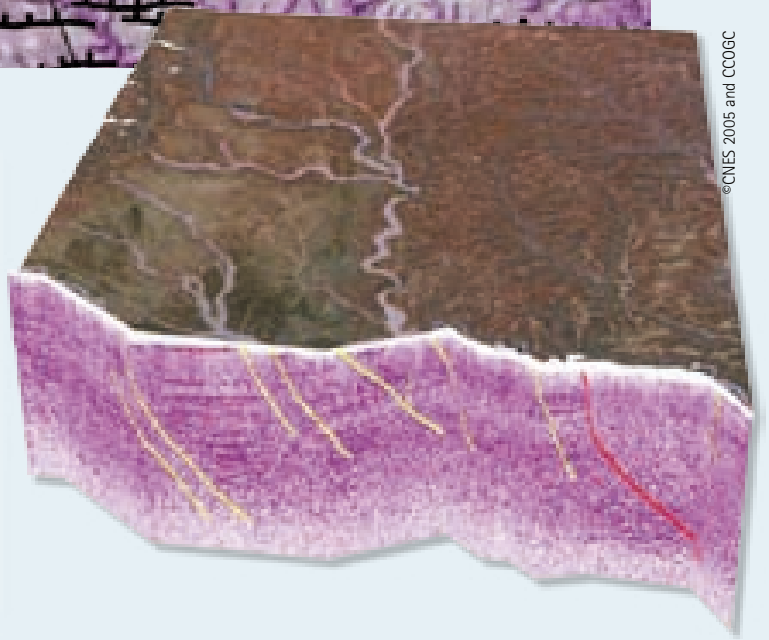
Visualising the subsurface: from 2D to 3D

"Improved resolution and clarity in remote sensing satellite imagery helps geoscientists to build models in hostile terranes, not only of the surface of the earth, but also the subsurface."



SPOT HRS data at a 20m resolution are used for block-specific studies. The amount of extra information provided by this level of resolution is illustrated by comparing the structural interpretation possible using SPOT data, on the right, with the coarser SRTM data (90m resolution) on the left. As can be seen, much more structural detail is revealed with the higher resolution data.



Satellite data is integrated with seismic information in the form of 'curtains' that hang from the geo-referenced surface thematic layers. This image shows that it is not always possible to drive nice straight seismic lines, in this case due to the challenging topography of Yemen. The line shows normal faults defining a half graben in the Masila region. Madbi Formation shales, the source rock of the petroleum system, exist in the Jurassic depocentres. River and Wadi systems flow parallel to and are controlled by the extensional structures. The relationships between surface processes and sub-surface geology are much easier to explain with this visualisation technique.

Jane Whaley, Associate Editor

Various applications of remote sensing imagery have been used by the oil industry for a number of years, as discussed in GeoExpro last year (vol. 3, no. 3). It is an area where the technology is continually advancing and, as remote sensing companies collaborate with experts in other fields, new ways of using this data are constantly presenting themselves.

"These developments now provide geoscientists exploring in hostile onshore terrains the ability to visualise the structure of prospective reservoirs from the comfort of their desk, well ahead of any expensive deployment of a seismic crew. Money well spent," says Alan Williams, Oil & Gas Manager with NPA Group, which specialises in deriving geo-information from Earth Observation satellites.

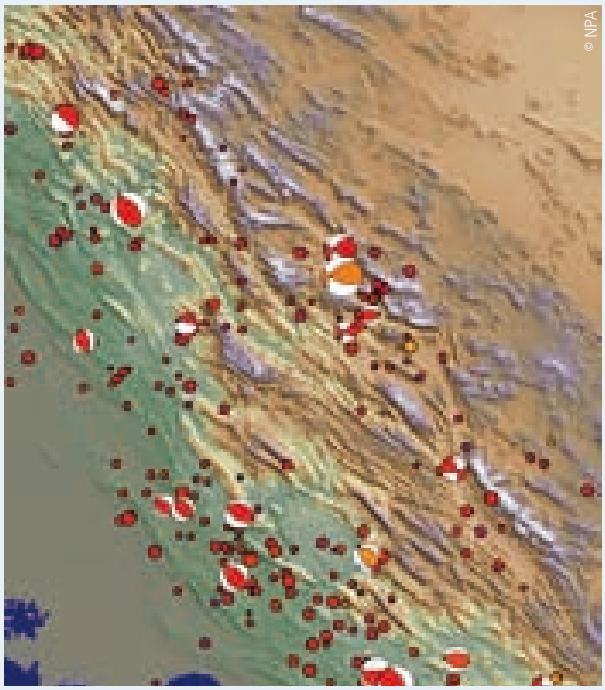
"Extracting information from complex foldbelts is the most exciting aspect of this kind of work."

Shuttle data covers the world

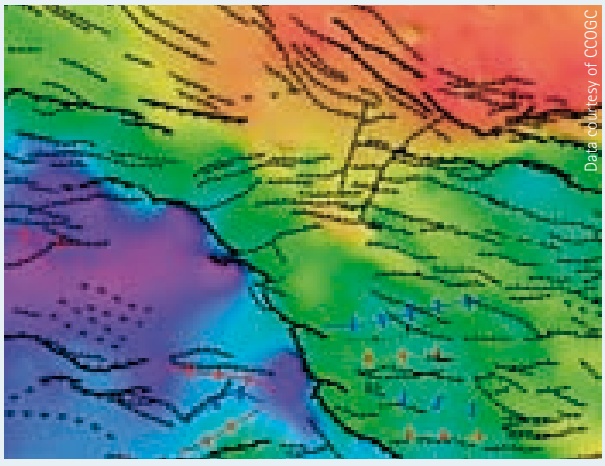
"Take, for example, Shuttle Radar Topography Mission (SRTM) data, obtained using a specially modified radar system on the Space Shuttle," explains Alan. "Data from this is free of the effects of clouds and has a resolution of 90m, creating the most complete, commercially available, high-resolution digital topographic database of the whole Earth."

"What I find so fascinating about using remote sensing imagery," Alan continues, "is the way we can go from a broad brush approach, to focus in on an area and look in detail at, for instance, faults patterns and dip angles. By working at all scales with companies which have expertise in seismic imaging and 3D modelling, it is possible to really visualise both the surface of the earth and what lies beneath."

NPA have recently been using satellite imagery to successfully assess areas in Yemen and Iran, as Mike Oehlers, NPA's Chief Geologist, explains. "Model building with satellite data can have a number of objectives, including detailed geological analysis such as horizon mapping, recording dip data and even 3D structural mapping. We can work at various scales, using, for example, 90m resolution for regional work, 20m sample size for mid range use, or even airborne at 1 metre or less for more detailed studies."



High resolution satellite imagery is used to interpret structural features such as faults and bedding. These interpretations are then integrated with alternative technology to augment the surface interpretation, before the exploration moves onto 3D visualisation. In this case the fault planes interpreted from satellite imagery of Iran were compared to the Harvard CMT database. In this view the size and angle of the ball indicates magnitude and direction of present day stresses, providing the remote sensing interpretator with some idea of the fault plane geometry at depth.



Structure contour map (rainbow colours) of Top Um Er Radhuma Limestone made entirely from remotely sensed data, including Landsat ETM, SPOT and SPOT HRS DEM.

Seeing the subsurface in Yemen

"Having identified the regional tectonic elements, we can combine remote sensing data with other technologies such as 3D modelling, as we have successfully been doing in a remote area in Yemen."

"The thick Um Er Radhuma Limestone, which covers much of the Hadhramaut-Masilah region in the centre of the country, creates enormous logistical and technical problems," explains Mike. "It is deeply incised and locally dolomitised, the latter creating a rubble-strewn surface that impedes geophone coupling and thereby reduces our ability to see what is going on at depth with seismic data."

"This limestone is, however, a blessing in disguise, as it forms an essentially flat surface at outcrop throughout the region, allowing us to map the geology of the area and develop a feel for the degree of structural and stratigraphic control on the plateau," Mike continues. "We can identify the effects of the separate Tertiary, Cretaceous and Jurassic rifting episodes in the Gulf of Aden by examining the interaction of different fault populations."

For the more detailed interpretation at block level NPA use SPOT data, which enables the creation of geological maps to a scale of 1:10,000. By tracing and digitising the stratigraphic boundaries and compiling the results in a geographic information system, it is possible to map

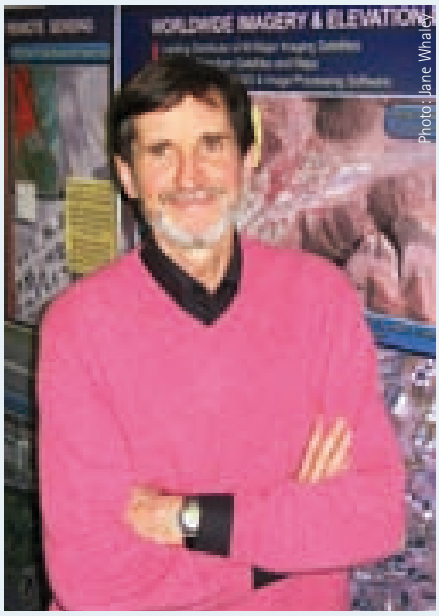


Photo: Jane Whaley

Alan Williams, NPA's Manager, Oil and Gas, worked in the field of remote sensing for a number of years before joining NPA 8 years ago. He is involved in the interpretation and marketing of offshore seep detection projects world-wide, developing NPA's flagship Global Offshore Seep Database.

the top of the Um Er Radhuma formation by digitally relating it to the elevation model. "Because the plateau is vast and extensively dissected, there is a huge volume of points to control the surface," says Mike. "We can follow the outcropping surface and, since we can see individual beds, we can follow the trace of the layer and accurately measure dip and estimate bed thickness. This allows us to extrapolate downwards from the horizon into the subsurface and predict the depth and structure of the reservoir."

"Areas where the Um Er Radhuma is covered by younger Tertiary sequences are dealt with in the same way, by mapping the higher boundaries and subtracting their thicknesses from the model to restore down to the limestone surface. When compared to well tops data in this area we discovered that we had an error of only 6m in our estimation of Um Er Radhuma elevation", added Mike.

Using seismic with remote sensing imagery

Having created high-quality elevation models, and through them accurate structure and contour maps, the explorationist can move a step further towards successfully imaging the sub-surface by combining these with seismic data. "Seismic is integrated with the results of the remote sensing analysis in the form of manifolds, which hang like curtains from the geo-referenced surface thematic layers," explains Mike. "As seismic data has good positioning control, we can closely link the 2D satellite imagery through interpreted features such as faults and show all these relationships in 3D. Whole 2D surveys can be visualized in this way to aid regional interpretation and, if there is a degree of risk due to poor line spacing, incorporating and integrating surface geology helps tie between the lines."

"The fact that Mars is covered by better resolution publicly available data than Earth is most frustrating."

This technique has been used to great effect in Yemen, which has a history of extension and rifting stretching back to the early Mesozoic. Although the most recent extensional phase can be seen in the Palaeocene Um Er Radhuma and


Photo: CCOGC

Typical Yemeni countryside in the Masila region. The wadi is gravelly and in the foreground some of the uppermost Cretaceous units can be seen covered with screes developing on and above the wadi walls, which are formed by the massive Um Er Radhuma Limestone Member in the background.

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younger sequences, it was the Jurassic and Cretaceous extensional events that defined earlier structure and palaeogeography. As a result, these are the structures that have had the most influence on hydrocarbon geology, including the source kitchens, reservoirs and seals, so it is important to attempt to image them accurately.

"It is also important to help identify superimposed, poly-phase deformation, as is often encountered in the Middle East", explains Mike. "Being able to view the 3D relationships between the surface and subsurface generates more confidence in the geological model. The relative position of these elements and timing of activation or re-activation is critical to exploration success. The ultimate aim, obviously, is to reduce risk."

Part of the toolbox

Using remote sensing imagery as an integral part of the explorationist's toolbox therefore has a number of benefits.

Firstly, it can be used to provide detailed surface, structural, dip and stratigraphic data. Secondly, the information can be further extended by using satellite data to map near-surface horizons, which are then projected into the subsurface with the help of modelling packages, in order to map deeper features, elements of petroleum systems and prospects.

Will this help you find oil? According to Alan, the answer is "not directly".

"The aim of any oil exploration project is to reduce the overall risk factor. 2D visualisation with remote sensing has traditionally been a successful tool to achieve this in well-exposed terrains where surface structures are assumed to mimic those at depth, such as fold and thrust belts. However, the ability of 2D combined with 3D to now accurately image structure at reservoir depth in areas of subtle dip and difficult surface access is impressive."

"This allows explorers to not only better plan their seismic grids but also gives them the confidence that valid traps will be present at depth at a very early, pre-seismic stage in the exploration cycle," concludes Alan Williams.

Acknowledgement:
Many thanks to Peter Bryant of CCOGC for permission to publish field photos and data from Yemen.

Another typical view of the rugged terrain near Wadi Masila. Here Qishn Carbonate beds in the hanging-wall rollover into a fault that runs along the wadi in the left of the photograph. Upper Qishn beds in the footwall are seen in the low hills to the left, mid-distance.

Imaging he

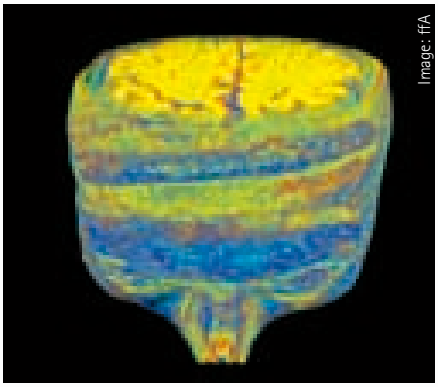
Jane Whaley, Associate Editor

It is probably unusual for a seismic imaging organisation to owe its origins to techniques developed to undertake head scans – but that was the root from which Foster Findlay Associates, known as ffA, grew. Founded in 1987, by the early 1990's ffA was a leading innovator in the field of image processing and analysis for medical imaging and other life science applications.

Close ties

In the current oil and gas climate, where most of the largest and accessible accumulations have been located, it is becoming more and more difficult to identify new potential reservoirs. To address this problem operators now have access to large amounts of 3D seismic data, but they face a major challenge to convert this data into useful information describing the subsurface. ffA drew on its experience in the life sciences to develop sophisticated image processing and analysis techniques that successfully deal with this issue.

"The parallels between the seismic industry and medical imaging are surprisingly close," explains Jon Henderson, Managing Director of ffA. "In both cases we need to visualise in 3D but cannot physically see 'under' the surface, and the most efficient and rapid way of doing this is by using



ffA evolved from a company specialising in medical imaging to one concentrating on the oil and gas industry, because the techniques used for 3D visualisation of what is going on inside the skull and under the surface of the earth are very similar. This image shows Jon Henderson's brain visualised in ffA's SVI Pro software.

ads and fault lines


Photo: Jane Whaley

Jon Henderson is Managing Director of Foster Finlay Associates (ffA), and first became involved with the company while doing research on cancer treatment for the National Health Service. He was looking for a high quality, flexible software platform from which to develop techniques for merging 3D information from CT & MRI scans. He is seen here with Claire Yule, Marketing Co-ordinator with ffA, which is based in Newcastle and Aberdeen.

sophisticated software algorithms to process and analyse complex images."

"ffA began developing 3D image processing and analysis techniques in 1993, when we entered into a leading edge collaboration with Shell's geoscience research group to develop image processing software that could be applied to seismic data," Jon continues. "The result of this partnership was a library of powerful 3D image processing algorithms and a toolkit for generating workflows to remove noise and extract geological information from 3D seismic datasets of any size."

The company subsequently commercialised the technology and has since continued to develop and provide the oil and gas industry with world-leading 3D image processing and analysis products and services. Based in Aberdeen, ffA's Services operation has processed over 150 operational datasets from E&P regions worldwide.

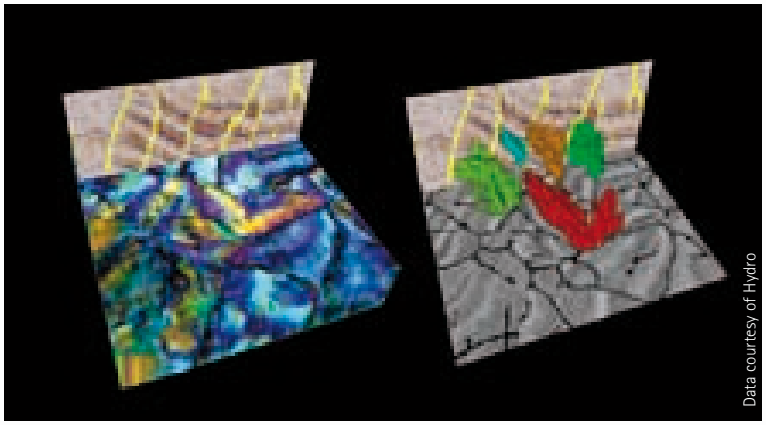
Quick, flexible image analysis

The technology developed by ffA facilitates the delineation of potentially important geological features, such as faults, within 3D seismic data rapidly, objectively and accurately, to provide geoscientists, well planners and reservoir engineers with subsurface images of unprecedented clarity. As Jon points out, "Good 3D image processing and analysis makes a big difference to seismic interpretation. For example, by using our technology interpreters can achieve a detailed reconnaissance of a North Sea block in a few days, rather than the several weeks or months this process would take using conventional techniques."

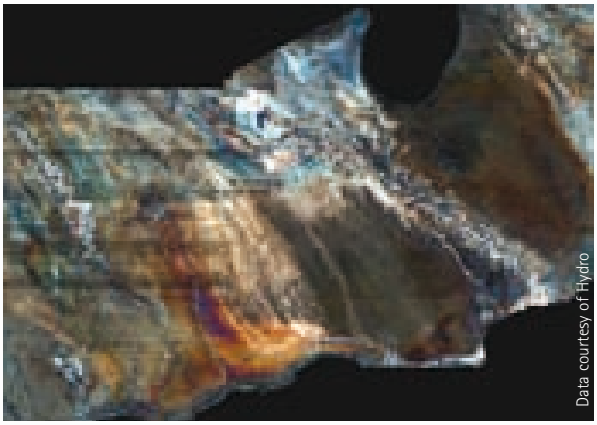
The technology pioneered by ffA is becoming a key part of the mainstream interpretation workflow for many majors, NOC's and senior independents. ffA's background technology was designed to facilitate fast track development and this is often done in partnership with major operators. "We have excellent software engineers, researchers, and geoscientists and we work closely with experienced operators to ensure that we are directly meeting the challenges faced by our clients" says Jon.

"A step change"

For example, a number of exciting new tools which were developed in collaboration with Hydro are now available in the latest release of SVI Pro, ffA's flagship software product. "The new release is an important development for the oil and gas industry. It provides a step change in both the quality of subsurface information that can be extracted from 3D seismic data and the speed with which such high quality information can be obtained," says Jon Henderson. "ffA Technology is contributing to the achievement of significant gains in drilling success and other key E&P performance indicators for operators worldwide. We have a tool which really can make a difference."


Data courtesy of Hydro

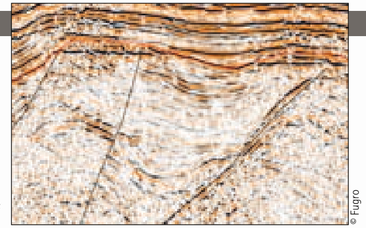
The left image shows volumetric RGB blending of the seismic response at different frequencies, shown with a vertical section through the original seismic data. The changes in colour clearly demonstrate the differences in seismic character associated with individual fault blocks. In the right hand image, the regions of similar seismic character have been isolated as 3D geobodies, allowing their size and connectivity to be calculated.


Data courtesy of Hydro

This RGB blended frequency decomposition map, taken from a stratigraphic imaging case study, offshore Angola, clearly shows depositional elements such as detail inside the channels, better edge delineation of the channel bodies, and information about wash over fans developed in the salt controlled mini-basins on the slope.

Offshore Mid-Norway

In 2004-2006 Fugro Multi Client Services acquired the first three phases (total 18,434 km) of a 2D programme, Mid-Norway Regional (MNR), aiming at covering the Mid-Norway continental shelf with long cable (10 km) and long recording (10 seconds two-way time) seismic data. The shelf contains mature, underexplored and frontier exploration areas. The regional extent and recording length of the lines provide a structural overview and deep imaging previously not seen offshore Mid-Norway. wThey will thus constitute an important tool for mapping the remaining exploration potential.



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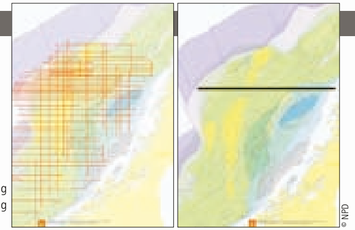
Flatspot within the Cretaceous on the Gjallar Ridge, (close-up of the rectangle on seismic).



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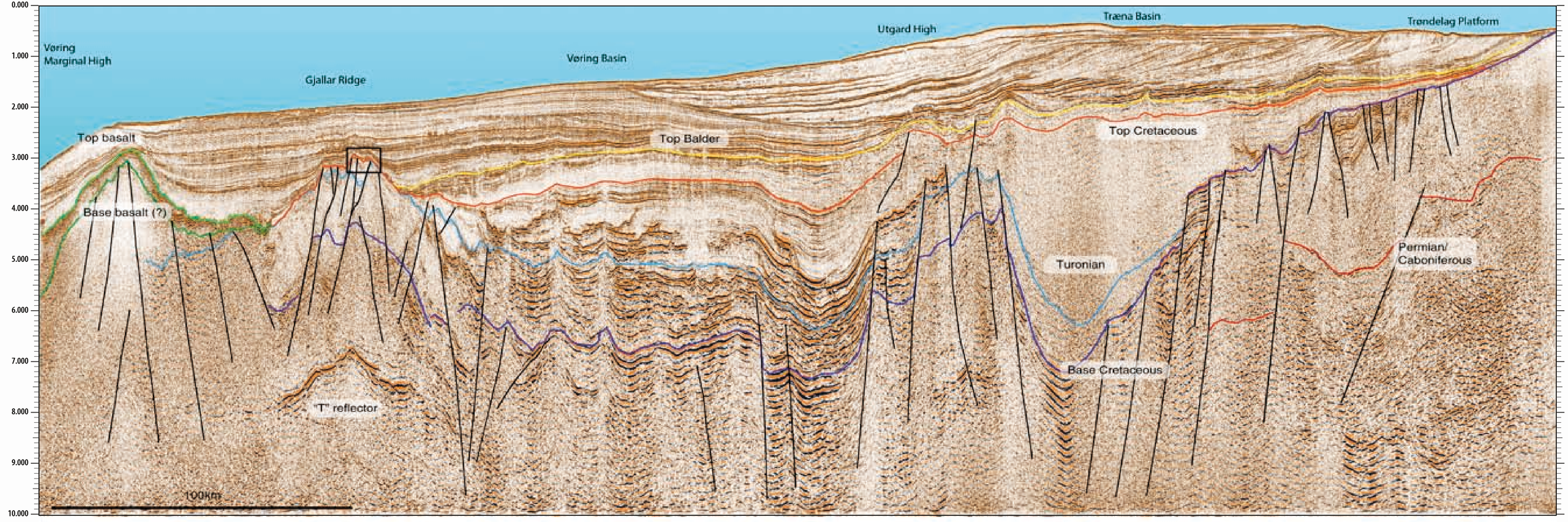
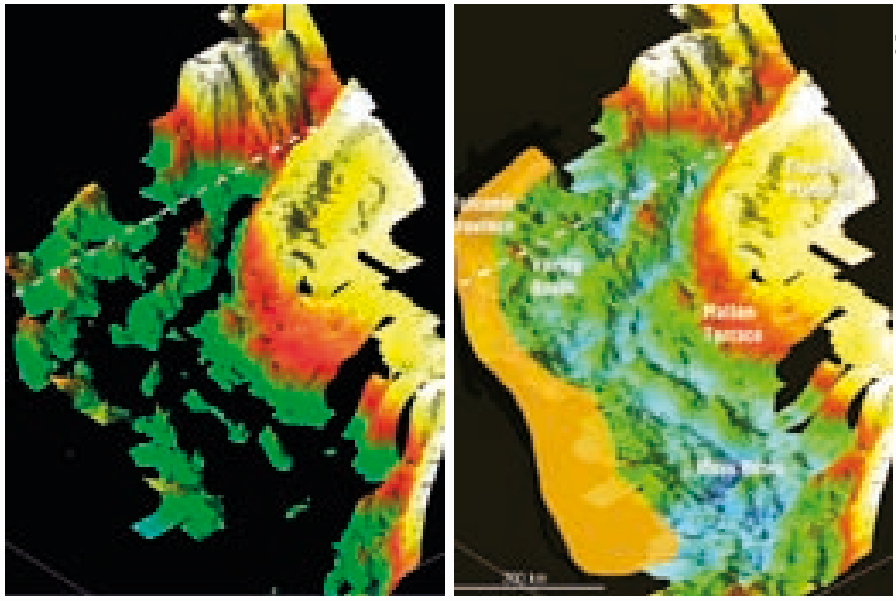
The seismic line is acquired in the northern part of the Norwegian Sea covering tectonic elements from the Trøndelag Platform in the east to the Vøring Marginal High in the west.



Mature, Underexplored and Frontier Exploration Provinces Offshore Mid-Norway

Idar Horstad and Kjell T. Thon,
Fugro Multi Client Services

The Norwegian Sea covers more than 200 000 km^2 of highly prospective acreage with many proven discoveries of Mezosoic and Cenozoic age. The large shelf area can be divided into three sub-regions: the partly mature eastern province (Trøndelag Platform, Halten and Dønna terraces and Nordland Ridge); the relatively unexplored deep Cretaceous basin province (Vøring and Møre basins) and the virgin western-most province with volcanic influences. Oil and gas discoveries have established proven petroleum systems in both the eastern province and Cretaceous basins. The volcanic province remains un-drilled but with new regional seismic lines it is possible to identify several structures with promising hydrocarbon potential.



The map to the left left is based on data acquired with a short cable, resulting in a recording time of 6 seconds two-way time, while the map to the right left is based on data acquired with a 10 km long cable, giving a recording time of 10 seconds two-way time. Note the difference in geological information between the two maps, a result of the thick Cretaceous sequence in the deep basin bringing the prominent seismic marker, Base Cretaceous Unconformity, to a depth of more than 10 km.

The terraces

The terrace areas within the eastern province (Halten and Dønna terraces) have been extensively explored for the last three decades and numerous commercial oil, condensate and gas discoveries have been made within rotated Jurassic fault blocks. On the Trøndelag Platform east of the terrace areas the Late Jurassic source rock is considered to be immature and although no commercial discoveries have been made the less explored Triassic/Permian play is believed to be more promising. The key to understanding this area is better imaging of the Paleozoic sequence and new, long offset data has significantly progressed the imaging of Paleozoic highs and basins within the platform area.

The deep water

Within the deepwater Vøring and Møre basins to the west there are many large structures, often covering up to several thousand square km each, which have only been explored by one or two wells, e.g. Gjallar Ridge, Vema Dome, Nyk High, Utgard High and Helland-Hansen Dome. A few oil and gas discoveries have been made but uncertainty remains regarding the reservoir and source potential within the different parts of the basins. Much of the uncertainty can be related to the difficulty in mapping the base Cretaceous unconformity which is often found at depths in excess of 6s twt, depths at which "conventional" seismic data often fail to provide a confident image.

New long offset (10 km) and long record length (10 s twt) data acquired offshore mid Norway has generated new and valuable information for the deepwater basins. A comparison of a 10 s twt map and a 6 s twt map illustrates the advantages of the long record length data. In addition to the structural improvements provided by the new data, gathers with far and ultra far offsets may also provide new information not previously available for analysis. Numerous undrilled and well defined DHI's (both flatspots and AVO effects) can be found throughout the basin area, (see seismic section for example). Due to the size of the structures and relatively few wells in the deepwater basins, this area can be characterized as underexplored.

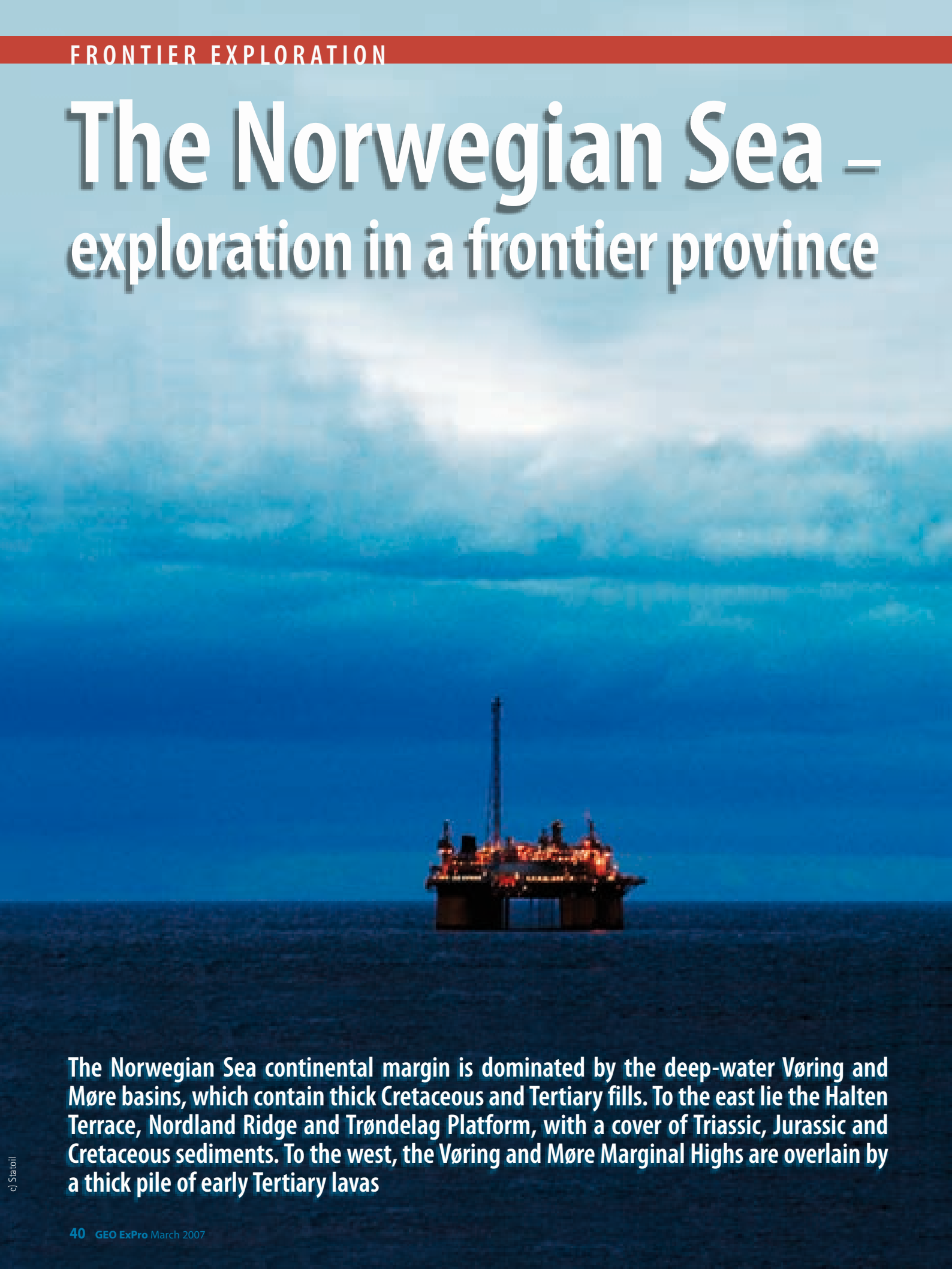
The volcanic province

The volcanic province, including the Vøring and Møre marginal highs, stretches along the entire mid Norway shelf and consists of both massive lava flows and large sill complexes. Much of the area is underlain by what is assumed to be a large northeast-southwest trending Mesozoic sedimentary high which is currently the focus of much of the industry interest offshore mid Norway. Although this area has not yet been explored by sub-basalt wells, drilling projects are currently being evaluated by the oil industry and academia. The volcanics vary in thickness from a few hundred meters up to several km and the seismic image underneath varies from good to poor (although not necessarily in proportion to the basalt thickness).

Promising sub-basalt observations such as well-defined fault blocks have been seen on several lines and oil companies and processing contractors are now focusing much of their efforts on improving the sub-basalt image, e.g. PSDM.

The sub-basalt region offshore mid Norway can be classed as a typical frontier area where the entrance fee may be high but where the potential rewards are well worth the effort.

The Norwegian Sea – exploration in a frontier province



The Norwegian Sea continental margin is dominated by the deep-water Vøring and Møre basins, which contain thick Cretaceous and Tertiary fills. To the east lie the Halten Terrace, Nordland Ridge and Trøndelag Platform, with a cover of Triassic, Jurassic and Cretaceous sediments. To the west, the Vøring and Møre Marginal Highs are overlain by a thick pile of early Tertiary lavas

David Mudge, Malcolm Gall and Katrine Holdoway, Ternan

Exploration in the Norwegian Sea in the 1980s and 1990s was concentrated on the Halten Terrace and along its faulted margins. This is the Haltenbank province, where more than 200 wells have been drilled, leading to some 50 discoveries, including the 15 Jurassic fields now in production.

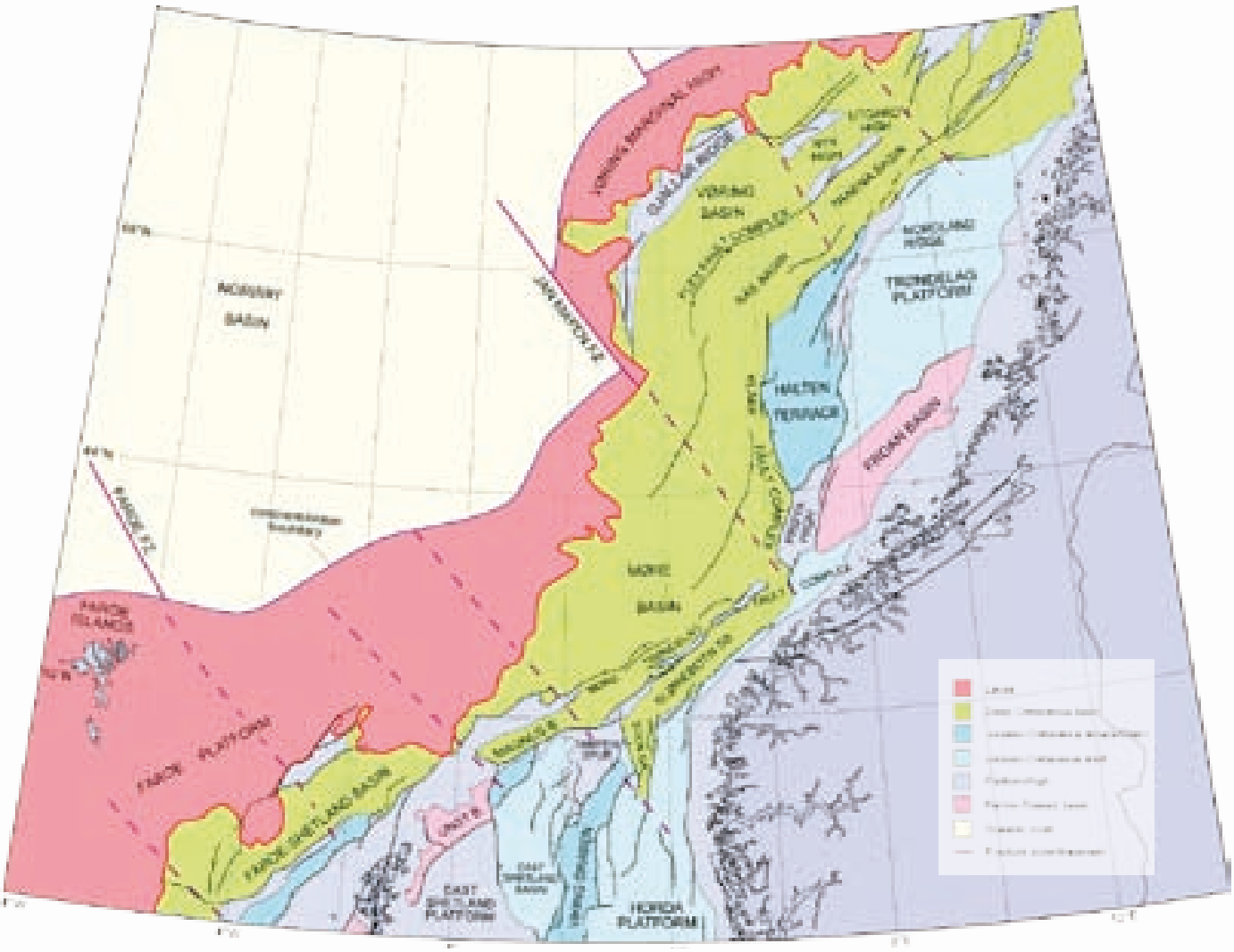
Drilling in the frontier Vøring and Møre basins did not start until 1997 and only 15 wells have been drilled so far. However, these have resulted in six discoveries, including Ellida, Stetind and the giant Ormen Lange gas field.

Haltenbanken is now an established hydrocarbon-producing province with continuing high levels of exploration and development activity following announcement of APA 2007. In contrast, the Norwegian Petroleum Directorate (NPD) has postponed the start of the 20th licensing round until 2008 to allow more time for companies to develop a better understanding of the geology and plays of the frontier province.

Strategy for exploration in a frontier province

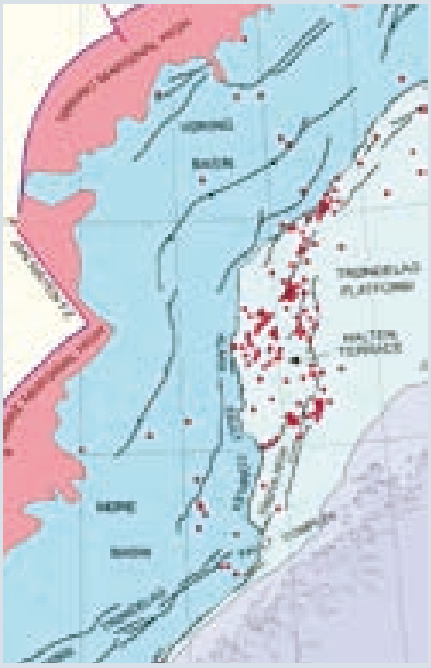
This article looks at how play prospectivity and exploration risk can be most effectively evaluated in the largely unexplored Vøring and Møre basins, where there is only limited well and seismic data. In these basins the main plays are slope and basin fan sandstones of the Cretaceous and Palaeocene. The Jurassic is deeply buried and not considered an exploration target at the present time. The key regional risk parameters are reservoir presence and hydrocarbon charge. Topseal is considered a secondary risk because of the likely presence of deep-water reservoirs encased in mudstones that will provide regional seal.

To persuade oil companies to spend money on frontier exploration, they need to be convinced that both reservoir and hydrocarbon charge are likely to be present, preferably at several stratigraphic horizons. Drilling in Haltenbanken has provided well data relevant to the Cretaceous and

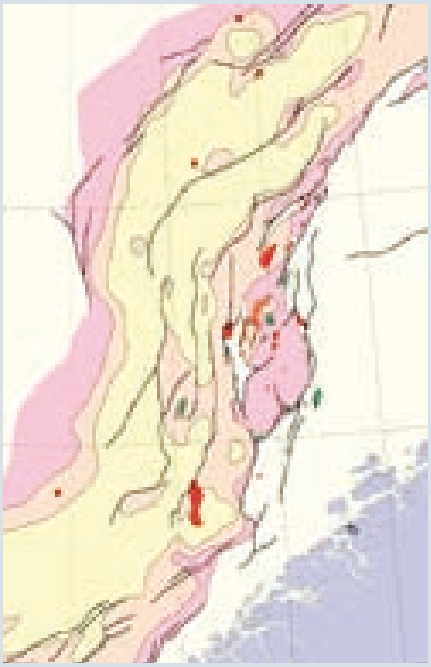


Tectonic Elements of the Norwegian Sea, Faroe-Shetlands and Northern North Sea

The Norwegian Sea, Faroe-Shetlands and northern North Sea are major hydrocarbon provinces located along the northeast Atlantic margin. Structural maps of the three areas have been integrated to help understand the geological history of this passive margin, which is bounded to the west by oceanic crust of post-Palaeocene age. The margin contains a series of linked NE-SW Cretaceous-Tertiary basins that overprint older Permo-Triassic and Jurassic rift systems with dominantly N-S and NNE-SSW trends. The basin trend is cut by a series of NW-SE lineaments that acted as transfer zones during extension. The most prominent of these is the Jan Mayen Lineament, which forms the boundary between the Vøring and Møre basins. The Norwegian Sea basins are separated from the Viking Graben rift system of the northern North Sea by the Møre-Trøndelag Fault Complex, which also forms the eastern margin of the Faroe-Shetland Basin. The western seaboard of the Cretaceous-Tertiary basin system is covered with a thick pile of lavas extruded prior to the start of sea-floor spreading in the northeast Atlantic during the Eocene.



Exploration Provinces and Well Database
The Norwegian Sea contains two exploration provinces. Most wells, shown in red, have been drilled in Haltenbanken, on the Halten Terrace and western part of the Trøndelag Platform (light blue). The western frontier province comprising the Vøring and Møre basins has only sparse well coverage (dark blue). To the west, these basins are separated from oceanic crust by a zone of thick Tertiary lavas.



Present-Day Upper Jurassic Maturity
The coloured area shows the present-day Upper Jurassic source rock kitchen. Yellow indicates overmature, areas of gas generation are shown in orange and oil generation in red. The oil, gas and condensate fields and discoveries are also shown.

Palaeocene plays, but for a more confident evaluation, the Norwegian Sea needs to be placed in its wider geological context as part of the northeast Atlantic margin. This region includes the northern North Sea and Faroe-Shetland basins, which are major hydrocarbon producers, together with the poorly explored Rockall and Porcupine basins, which also contain proven hydrocarbon systems.

The Northeast Atlantic depositional province

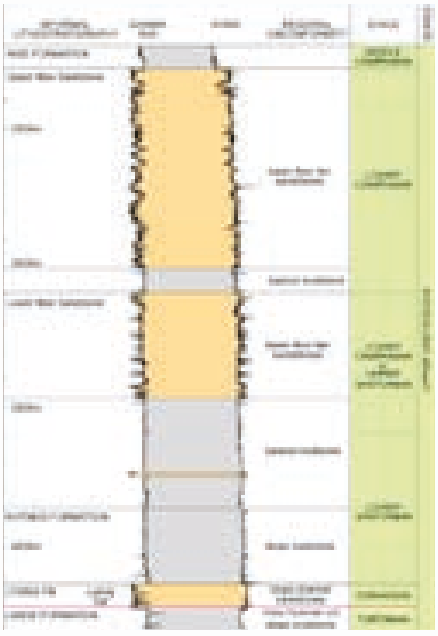
The Northeast Atlantic basins share a common plate tectonic history and were affected by the same extensional and thermal events. Basin development was associated with Jurassic rifting overprinted by deep Cretaceous subsidence and late Cretaceous/early Tertiary uplift and volcanism. As a result, the basins contain a similar suite of Mesozoic and Tertiary plays. So our knowledge of reservoir and source rock distribution is significantly enhanced by looking at the Norwegian Sea as part of a single geological province. Plate reconstruction has led to a better understanding of the tectonic and thermal controls on the evolution of basin architecture and depositional facies development. It has also provided evidence for the location and timing of clastic input into the Vøring and Møre basins from Greenland and the Norwegian margin during the Jurassic, Cretaceous and Tertiary.

The development of a common stratigraphic framework for the Norwegian Sea, Faroe-Shetland and northern North Sea basins has highlighted the similarities in age and depositional facies of the main reservoir and source rock horizons. For example, the late Triassic/early Jurassic transition from fluvial and coal-bearing sediments to transgressive marine sandstones and mudstones is seen in both the Åre-Tilje-Ror succession in Haltenbanken and the Statfjord-Nansen-Drake sequence in the Viking Graben. Similarities in facies are also seen in the Cretaceous and Lower Tertiary successions of the Faroe-Shetland, Vøring and Møre basins, e.g. the Sullom and Egga sandstones.

Finally, mapping across the artificial barrier of latitude 62°00'N gives a much clearer picture of the structure of the Møre-Trøndelag Fault Complex, its continuation as the West Shetland Spine Fault, and its relationship to the Slørebotn, Magnus and West Shetland basins.

A proven hydrocarbon system

The hydrocarbon system in Haltenbanken is now well understood. For the Jurassic plays in this province there is charge contribution from two source rock horizons: principally oil and gas from anoxic marine mudstones of the Upper Jurassic Spekk Formation, but also gas from coals of the Lower Jurassic Åre Formation. The presence of an active hydrocarbon system in the frontier province has also been demonstrated by a number of gas and oil discoveries in Cretaceous and Palaeocene sandstones. Depositional environment mapping suggests that Upper Jurassic source rocks are present throughout the Norwegian Sea region. The depth to the Base Cretaceous unconformity shows that although deeper parts of the Vøring and Møre basins are overmature, there is significant potential for mature Spekk Formation on the western flanks of both basins. Mature source rocks are also predicted to be present on Jurassic intra-basinal highs such as the Utgard High, Grip High and Vigra High, and along parts



Reference Well for Cretaceous Plays
Thick Upper Cretaceous sandstones have been drilled in wells in the Vøring Basin. Lysing sandstones were laid down in a slope channel setting, whilst the Nise sandstones represent basin-floor fan deposits. This well is located adjacent to the Nyk High and it is likely that the sands were sourced from this structural feature during episodes of late Cretaceous uplift and erosion. Hydrocarbons have been discovered in both sandstone intervals in the Vøring Basin, and the Lysing and Nise plays are predicted to have significant prospectivity in the frontier province.

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Ad material deadline	May 11th

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Publication date	September 3rd
Ad material deadline	August 17th

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Publication date	October 22nd
Ad material deadline	October 5th

GEO ExPro 06-2007

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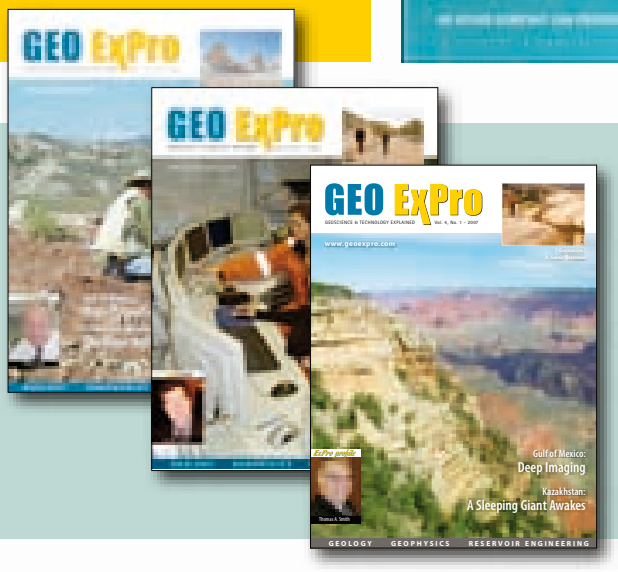

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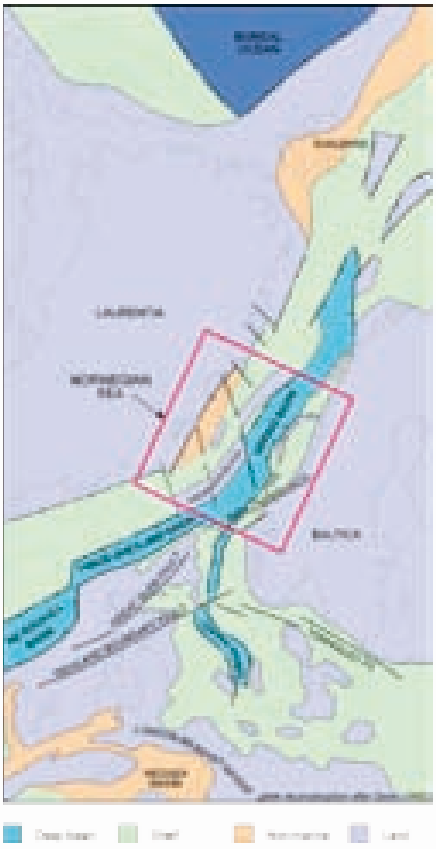


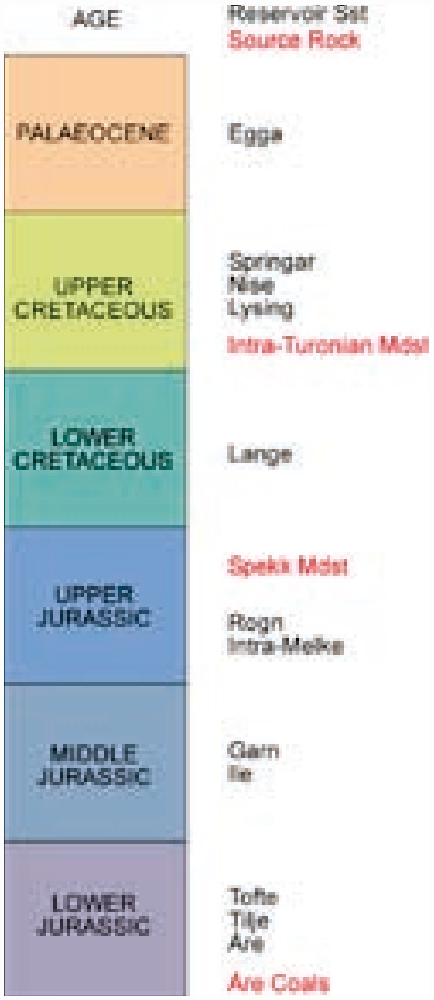
Cretaceous Palaeogeography, Northeast Atlantic
The Cretaceous depositional history of the northeast Atlantic was dominated by the presence of a seaway connecting the Atlantic and Arctic oceans. The area of the Norwegian Sea is outlined in red. The Vøring and Møre basins formed part of this seaway. Sands were shed into these basins during episodes of uplift and erosion along the Norwegian margin to the east, and from Greenland and smaller continental blocks, e.g. Jan Mayen, to the west. This seaway eventually became the locus of continental breakup and sea-floor spreading during the early Eocene.

of the footwall of the Fles Fault Complex. It is interesting to note the association of Cretaceous discoveries with some of these structural features. However, the origin of these hydrocarbons is still poorly understood and additional sources may be present, for example, shallower Cenomanian-Turonian 'hot shale' horizons in the Upper Cretaceous interval.

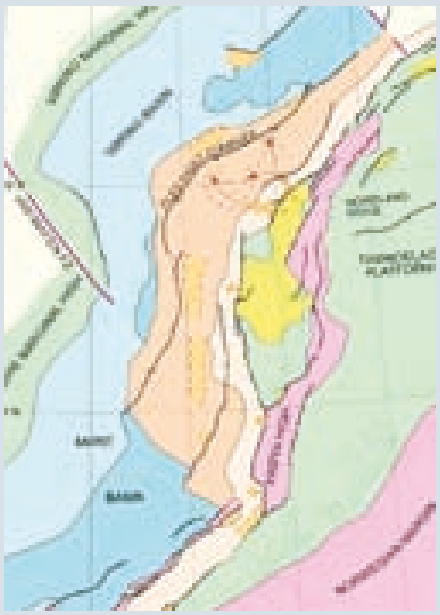
Reservoir distribution

Five reservoir intervals of Cretaceous to Palaeocene age can be correlated in wells drilled on the Halten Terrace, and in the Ormen Lange area and Slørebotn Subbasin. These are the Lange, Lysing, Nise, Springar and Egga sandstones. Sandstones of similar age also occur in wells in the Vøring and Møre basins; however away from well control, their presence remains unproven. In order to model the distribution of sandstones in the Norwegian Sea, gross depositional environment maps have been produced for each reservoir interval. These show the likely distribution of shelf, slope and basin environments and predict the location of sand-prone fairways.

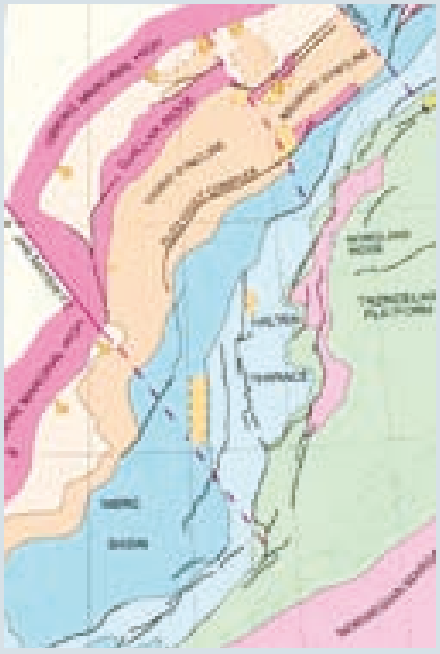
Construction of these maps is based on interpretation of northeast Atlantic palaeogeography for a series of time slices during the Mesozoic and Tertiary, and incorporates reservoir mapping from the northern North Sea and Faroe-Shetland basins. Regional seismic structure and isochron mapping of key Cretaceous and



Norwegian Sea Stratigraphy and Plays
Twelve hydrocarbon-bearing plays have been mapped in the Norwegian Sea. Most of the fields and discoveries are of Jurassic age and are located in Haltenbanken. However, the proven presence of reservoir and hydrocarbon charge in the frontier province together with the Ormen Lange gas discovery is very encouraging for future exploration, with the prospect of more giant fields being found.



Upper Cretaceous Lysing Gross Depositional Environments
This map shows gross depositional environments for the Upper Cretaceous Lysing play, based on a wider interpretation of northeast Atlantic palaeogeography and tectonic elements. Shelf, slope and basin environments are shown in shades of green and blue; areas of sand-prone deposition in yellow and orange. Zones of uplift and potential clastic sourcing are shown in pink. The asymmetrical nature of sand input into the Vøring and Møre basins during the Turonian and Coniacian is clearly seen.



Upper Cretaceous Nise Gross Depositional Environments
A major switch in clastic sourcing to the western margins of the Vøring and Møre basins took place during the Campanian. Large-scale block faulting accompanied uplift of the marginal highs with Nise sands being shed eastwards into the basin system and deposited in slope and basin channels and fans. Sand input from the east ceased and there was passive onlap of the Norwegian margin.

Tertiary horizons has been used for both source rock maturity modelling and to determine basin architecture, timing of uplift and the likely location of clastic source areas.

The way forward

Regional play analysis has been successfully used by Ternan to assess the remaining hydrocarbon potential of basins in various stages of exploration and development from mature to frontier. In the Norwegian Sea, the prospectivity of individual plays has been evaluated by combining the distributions of reservoir and hydrocarbon charge. This approach highlights extensive areas of play fairway at Jurassic, Cretaceous and Tertiary stratigraphic levels, where regional risk is predicted to be low. Blocks within these fairways can then be high-graded for detailed seismic interpretation, leading to the identification of potential leads and prospects.

Both the under-explored Haltenbanken province and the frontier basins hold substantial potential for significant discoveries in the future.

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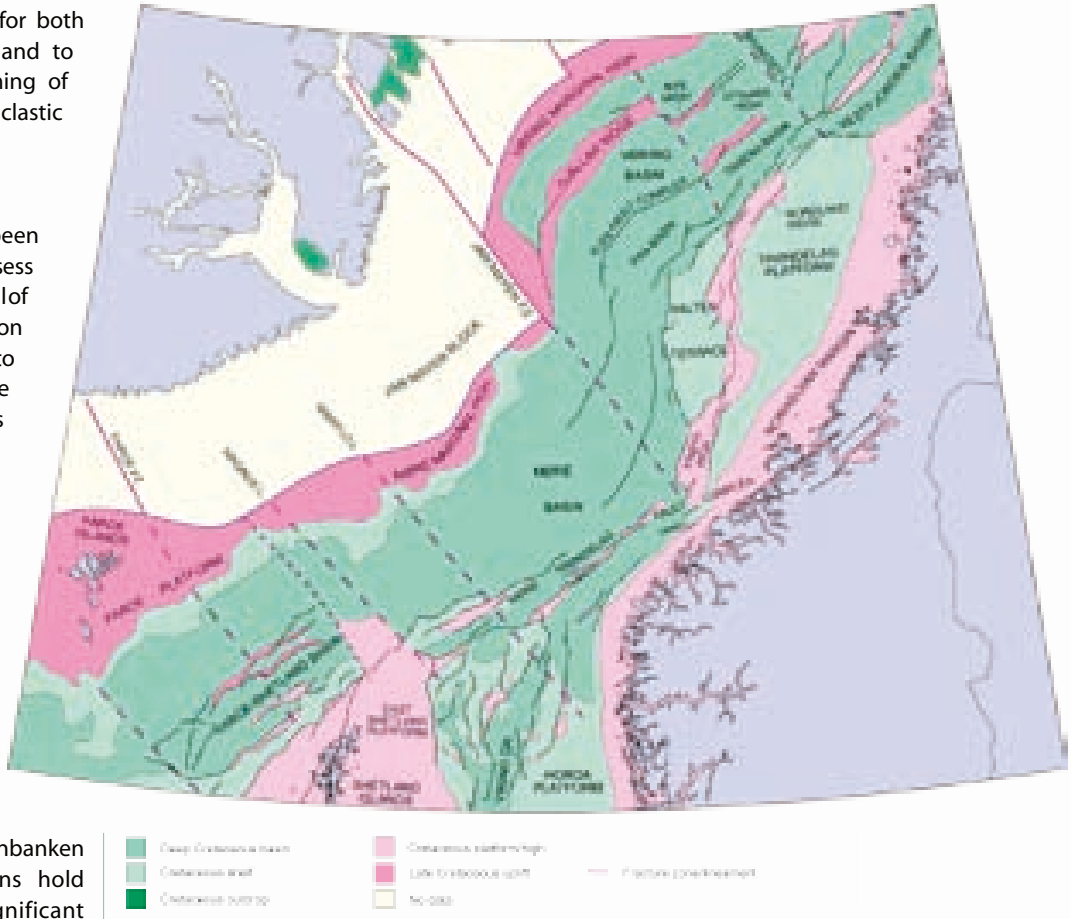

Cretaceous Structural Setting, Norwegian Sea-Faroe-Shetlands-Northern North Sea
Plate reconstruction shows the deep Cretaceous basin system in dark green extending through the Norwegian Sea, Faroe-Shetlands and northern North Sea. Understanding the regional uplift history of this province is the key to locating clastic source areas for the different reservoir intervals. The pink areas along the eastern margin of the basin system were sites of intermittent uplift and erosion for most of the Cretaceous. They include the Shetland Platform, Frøya High and Nordland Ridge. During the late Cretaceous there was a major palaeogeographic reorganisation with tectonic and thermal uplift of the western margin prior to extensive volcanism and plate separation during the Eocene. The Gjallar Ridge and other highs shown in red were formed at this time.

About the authors

David Mudge *(dmudge@ternan.com)* is Technical Director of Ternan. He has developed a consistent approach to regional play evaluation that uses stratigraphic and basin analysis to map and assess the hydrocarbon potential of basins of the North Atlantic and Arctic provinces, including offshore Norway, eastern Canada and Greenland.

Malcolm Gall *(mgall@ternan.com)* is a geoscientist with Ternan. He joined Ternan at the beginning of 2005 and his experience is focused on basin analysis and petroleum systems modelling.

Katrine Holdoway *(kholdoway@ternan.com)* is Managing Director of Ternan. She is an exploration geologist with extensive experience in regional studies, licensing round assessment and asset evaluation.

David Mudge (right), Malcolm Gall and Katrine Holdoway with Dan Mander (centre left), who joined Ternan at the end of 2006

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Producing Gas from Shales

Photo: Kevin Fischer, Pinnacle Tech

A rock as tight as a table top, the Barnett Shale has become the most prolific gas reservoir in Texas and the largest active natural gas play in the United States. Exploration in this play is truly cutting edge, pioneering stimulation technology that will undoubtedly lead to new shale gas production throughout the world.

Photo: Kevin Fischer, Pinnacle Tech

Thomas Smith, Associate Editor

The Barnett Shale play, in the Fort Worth Basin of north Texas, is currently producing about 1.65 Bcfpd gas (47 MMm³ per day) from over 5,600 wells. There are close to 150 rigs actively drilling at the current time to complete the nearly 3,000 permitted wells for this year. The play could eventually cover over 15,000 km² and has a potential mean volume of over 27 Tcfg (0.76 Tm³) (U. S. Geological Survey (USGS) estimates), making it the second largest gas play discovered in North America. Richard Pollastro of the USGS says "these estimates were determined from vertical well production. A reassessment using horizontal well data could raise these estimates considerably."

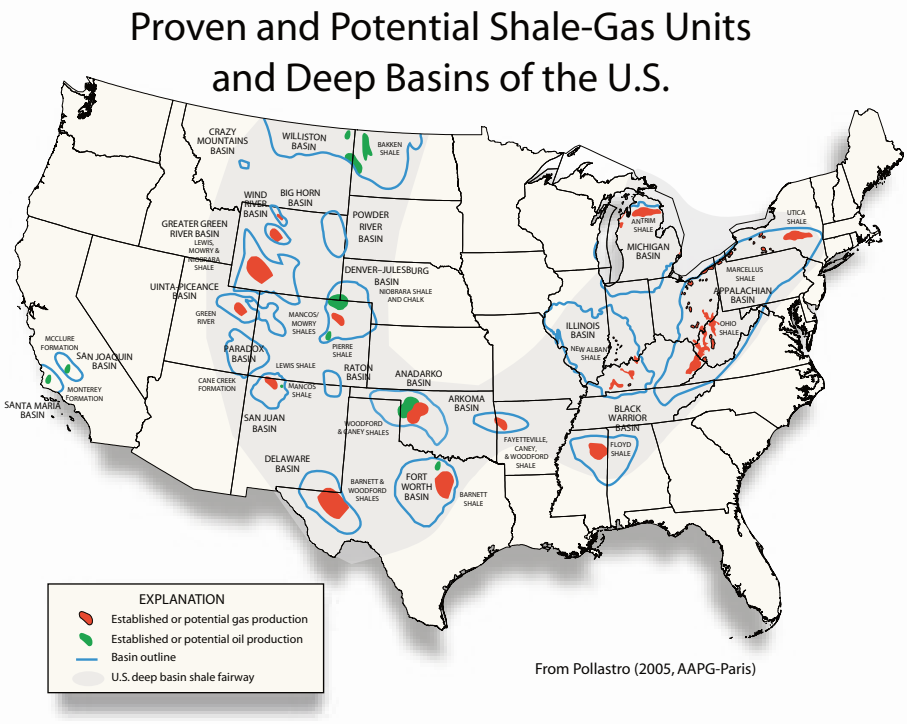
In the Beginning: Slay #1

The pioneering efforts of Mitchell Energy in the early 80's made this play possible. While drilling for conventional oil and gas resources, geologists and engineers began looking at the Barnett Shale and saw similarities to the productive Devonian shales in the Appalachian Basin. After several fracture attempts that resulted in minor gas flows, the interval was stimulated with 210,000 pounds of sand and Slay #1 was completed as the first Barnett gas well.

Mitchell Energy Corporation was first to test the interval in 1981, but it took many years and a stubborn persistence before its potential was realized.

Throughout the 50's and 60's, the Barnett Shale was thought of as spent source rock encountered when drilling to other objectives. USGS studies show this shale to be the primary source for nearly 2 Bbo (320 MMm³) and 8 Tcf (280 Bm³) of gas produced from conventional reservoirs in the Fort Worth Basin area.

Dan Steward, now with Republic Energy, was there from the first tests of the Barnett and through the learning stages of how to produce it. "The Slay well was drilled as a Viola Formation (directly underlies the Barnett) producer. It turned out tight. Mr. Mitchell had always wanted to test



The Barnett Shale and other potential shale gas plays in the US.

the Barnett which directly overlies the Viola," says Dan. "We started out with small fracs and poor results. It took 36 wells and increasingly larger fracs before we could say we had anything commercial. Most companies would have given up on the play, but Mitchell was well positioned in the area and looking to replace declining production with new prospects."

Growth of Completion Technology

Between 1981 and 1989, only 66 wells were drilled to evaluate the Barnett. Early stimulation used in these wells progressed from small CO_2 or N_2 fracture treatments to large gel fracs. consisting of 400,000 gallons of water and 1,250,000 pounds of sand. This system had a theoretical half-frac length of 450 m. The results were variable with wells producing up to 1 Bcf (28 MMm³) ultimate recovery. According to Bill Grieser of Halliburton: "At first we were concerned about using fresh water in a shale formation. Everything we had learned up to that time was that shales and water do not mix; we assumed all shales were alike. Now, we are finding out that every shale is unique".

Early in 1997, Mitchell Energy tried the first "slick-water frac" in the Barnett also called a light sand frac (LSF) that used 800,000 gallons of water along with 200,000 pounds of sand. This style of frac was borrowed from similar style jobs which were starting to be used in the Cotton Valley Sandstone of East Texas. "The light sand fracs were originally done out of a need to get the economics in line (gas prices were at historic lows) rather than research," says Bill Grieser. Microseismic mapping (explained later in this article) indicated that the LSF outperformed the conventional gel frac. system. Refracs of older producing wells also proved worthwhile in enhancing production and have become routine.

Horizontal drilling started in earnest in 2002 after Devon Energy acquired Mitchell. About 1500 horizontal wells will be drilled this year alone. These wells increased production twofold, slowed decline rates, and extended the play beyond the core producing area.

This core area has the Marble Falls Limestone as an upper frac barrier and the Viola Limestone for the lower frac barrier. Outside the core area, the Viola Limestone pinches out to the west and southwest. In the areas where the Viola is absent, vertical wells have had limited success because many have frac'd into the underlying Ellenburger, opening a conduit for water production. Horizontal drilling technology, combined with area specific frac treatments, have mitigated this problem and expanded the play into previously noncommercial areas.

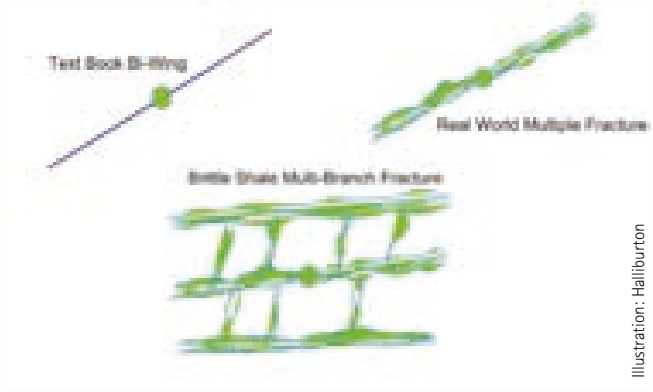


Illustration: Halliburton

Fractures like the complex example pictured here are the type that occur in the Barnett Shale.

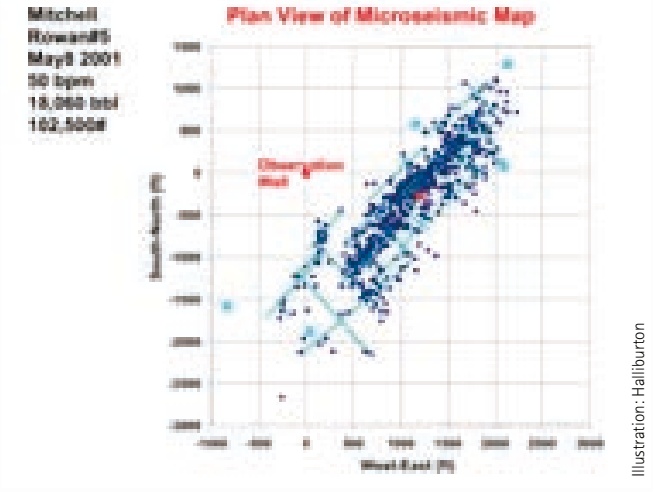


Illustration: Halliburton

Using a combination of surface tiltmeters and downhole geophones (see illustration on page 50), microseismic mapping has helped define the effectiveness of hydraulic-fracturing in the Barnett and refined the technology.

Complex Fracturing

The classical description of a hydraulic fracture is a single biwing planar crack with the well bore at the center. However, evidence gathered from microseismic mapping indicates that fractures in the real world are almost never that simple.

"The Barnett success has caused a new look at the Appalachian Basin and other shale gas plays. Areas that had previously been passed by are now being revaluated with larger Barnett type stimulation treatments and found to be productive."
Dan Steward, Republic Energy

Mapping has proven that a fracture treatment in the Barnett can be very complex. Fracture mapping technologies can provide insight into reservoir depletion dynamics and significantly help optimize reservoir management.

Studies using these mapping techniques illustrated that fractures in the Barnett grow in a complex network. The cumulative fracture network length, not the conventional fracture half-lengths, control gas recovery and reservoir patterns. Kevin Fisher, President of Pinnacle Technologies says "the Barnett permeability is so low that the drainage radius from any single fracture is likely only 10 or 20 feet (up to 6m). Because of this ultra-low permeability, a huge surface area is necessary to provide adequate

Geology

At first glance, the Barnett Shale may seem simple in terms of structural and stratigraphic complexity. However, geoscientists and engineers have gone to great lengths to understand the geology and geochemistry and their impact on successful production from the interval. Geological factors affecting ultimate reserves are the maturation pattern throughout the basin, regional faulting, underlying Ellenburger karsting and the thickness of the Barnett in the prospective area. Drilling, fracture stimulation techniques and completion strategy must be designed to match the needs of a given area.

The Barnett Shale is an organic-rich marine shelf deposit of Mississippian (Lower Carboniferous) age. It unconformably overlies the Ordovician Viola Limestone-Ellenburger Group and is conformably overlain by the Pennsylvanian Marble Falls Limestone. In the Fort Worth Basin, the Barnett ranges from 60 m thick in the southwest portion of the Fort Worth Basin to 300 m in the northeast portion. The core field area averages 150 m in thickness.

Composition is 2-8% organics, 20-30% clay minerals (illite), 45-55% silt (quartz and feldspar), and 15-19% carbonates (calcite and dolomite). It is also characterized by extremely low permeability, ranging from 0.000009 to 0.005 mD and 3.5% average porosity.

Wells drilled on or near faults tend to have high fracture gradients. Near major tectonic faults, water production is a problem when well stimulation fractures migrate toward the fault and into communication with Viola or Ellenburger water. Another problem that results in poor frac treatments is karsting in the Ellenburger creating faulted chimneys up through the Barnett. 3-D seismic surveys image those areas that should be avoided with current stimulation procedures and when that is not possible, cemented off.

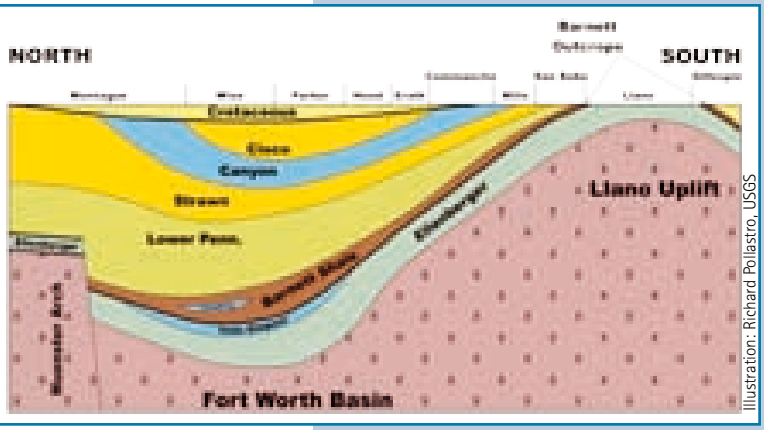
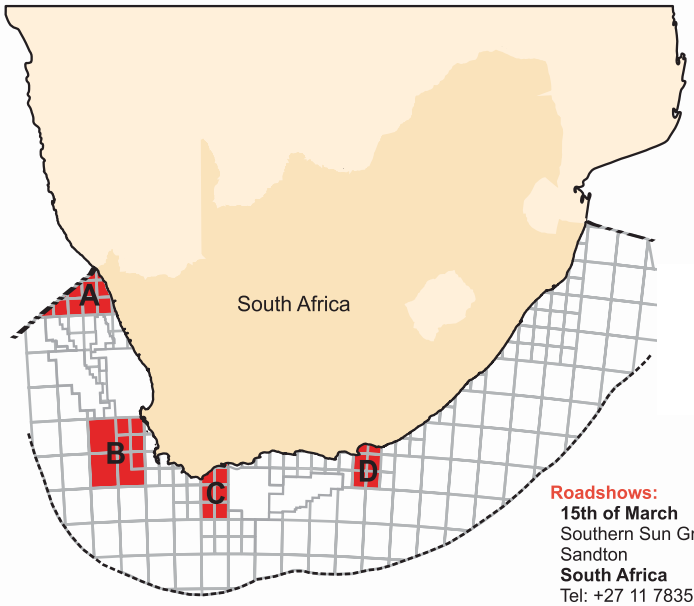


Illustration: Richard Pollastro, USGS

Generalized cross section for the Fort Worth Basin

Unlocking South Africa's Offshore Potential



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contact with the reservoir to profitably drain this resource. So while fracture complexity can be detrimental in some reservoirs due to restricting the ability to place proppant, in the Barnett this complexity is actually favorable to be able to increase production rates."

Fisher also says the Barnett wells can benefit from refracs, potentially even several refracs, because of the aforementioned small drainage radius. "A refrac can create a higher density fracture network (new cracks in between old cracks), thus increasing fracture surface area."

"Just about every oil company has a potential shale reservoir."

Looking to the Future

Organic rich shales have always been looked at as source rocks. Under the right conditions, oil and gas can be generated from these shales and migrates over time into reservoir rocks. Every petroleum system owes its existence to the presence of source rocks and now many of these source rocks are becoming productive reservoirs. Thanks to the successes in the Barnett, the production and inventory of shale gas is growing in leaps and bounds. "Just about every oil company has a potential shale reservoir. We are now seeing rapid expansion of shale gas production into Oklahoma, Arkansas, and Alabama," says Bill Grieser of Halliburton.

Dan Steward put it this way: "10 years ago, if you ask 100 geologists what makes a viable shale play possible it would be having an open, natural fracture system present. Now, after the Barnett experience, industry has found that fractures can be induced to produce economic gas. Simply put, it redefines our exploration model for shales. We are still learning and just about any area may be productive."

Special thanks to Bill Grieser and Katy Eichelberger of Halliburton, Kevin Fisher of Pinnacle Technology, Dan Steward of Republic Energy, and Richard Pollastro of the USGS.

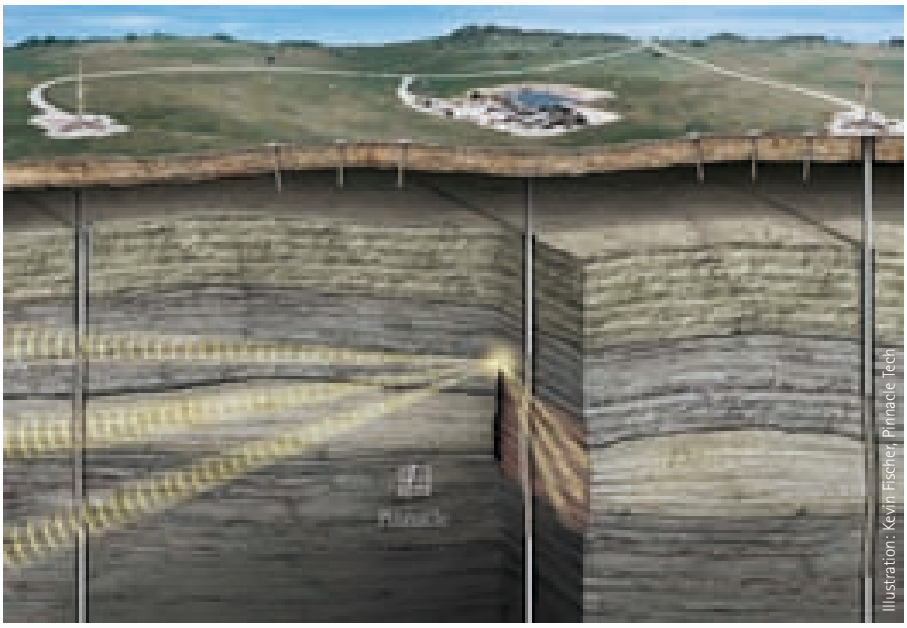

Illustration: Kevin Fischer, Pinnacle Tech

Surface tiltmeter arrays measure surface deformation. The downhole tiltmeters measure deformation patterns in adjacent well bores. Sensitive geophones measure micro-earthquakes caused by the fracture treatment.

Shale Gas

Shale gas production has been around for a long time, in fact, the first commercial well was drilled in New York in the late 1820's. By 1926, the Devonian shale gas fields in the Appalachian Basin were the world's largest known occurrence of natural gas. These shales extend from southwestern New York south to eastern Kentucky and central Tennessee with the largest fields found in Kentucky and West Virginia. Shale gas exploration and exploitation has continued to grow aided by tax incentives in the 1980's. These incentives have expired, but operators have continued to expand gas shale programs. This year, shale gas production in the US could approach 1 Tcf (28Bm^3), although exact numbers are difficult because the play is evolving at a rapid rate. Gas in place estimates total 581 Tcf (16 Tm^3) and the recoverable resource estimates range from 31 to 76 Tcf (0.88 to 2.1 Tm^3) and will probably go up as these plays develop.

Shale gas reservoirs store natural gas as free gas within the rock pores and natural fractures, and as absorbed gas on organic material. The speed and ultimate gas production is affected by these storage systems. The challenge in exploring shale gas plays is in obtaining economic production rates. Because shales are typically low to very low in permeability, fracture systems that exist naturally or are induced within the reservoir are necessary to sustain gas production. Some type of stimulation is required to get most wells to produce in commercial rates.

The real upside of shale gas plays are long-lived reserves and high success rates with attractive finding costs. New stimulation technologies will continue to expand the productive limits of historic play areas and add to the already impressive resource estimates.

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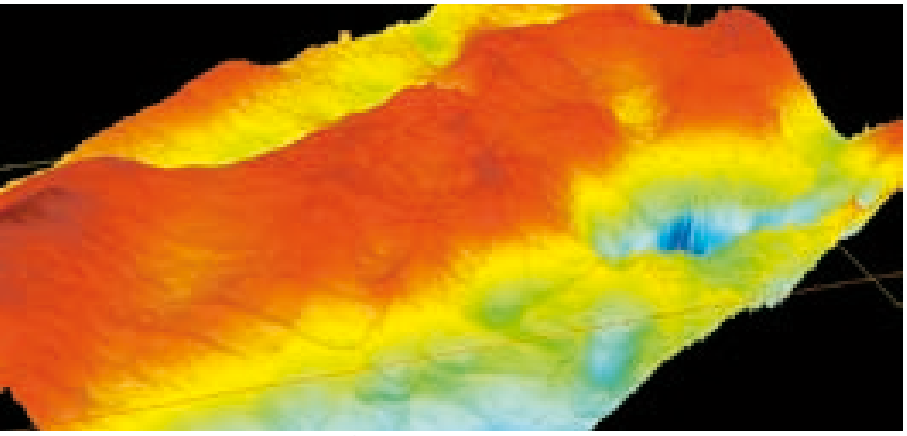

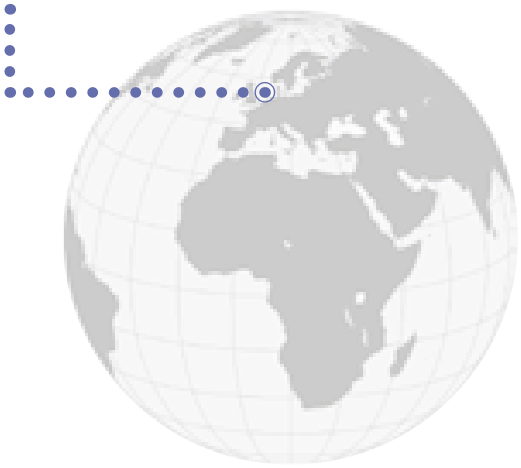

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AN I/O COMPANY

Combining R&D with Commerce

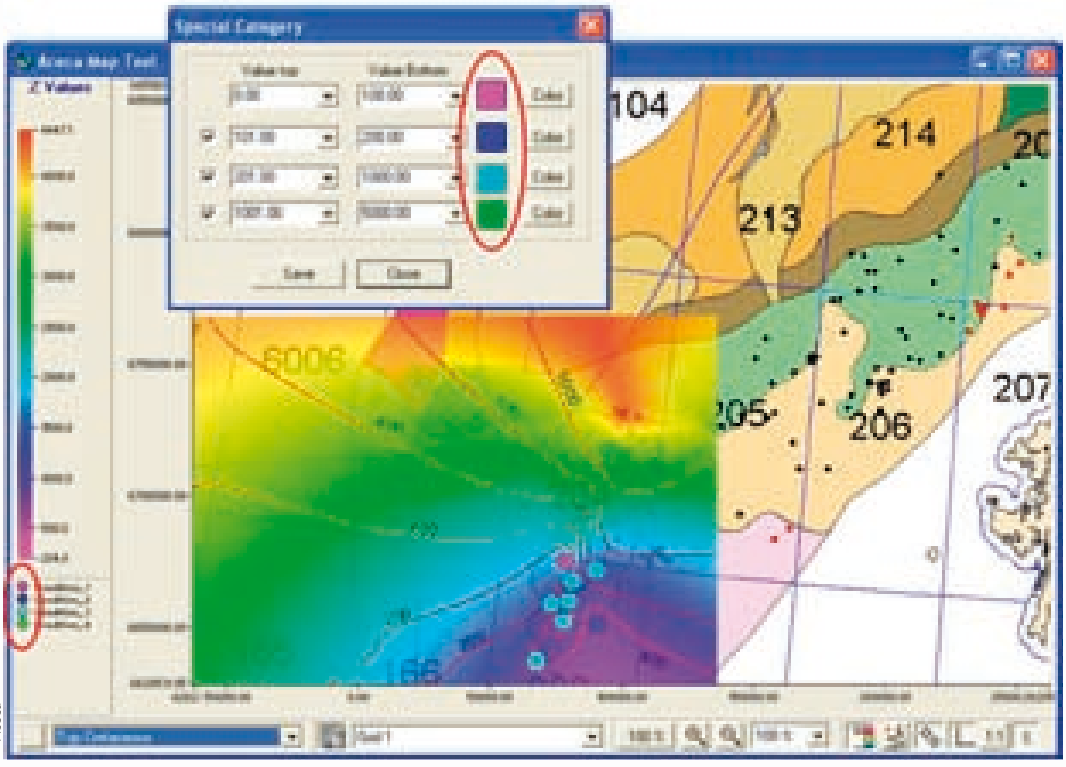
When Phil Slater, with colleagues Gavin Hudson and John Hanson, set up a small oil and gas consultancy in 1998 in south west London, he probably would not have imagined that just 8 years later he would be sitting in newly refurbished offices with more than 45 employees, part of the large TGS-NOPEC geophysics and service company.

Jane Whaley , Associate Editor

How did such impressive growth come about in such a relatively short length of time? "The successful amalgamation of quality science and research with effective commercialisation has been key," Phil explains. "In 2000 we merged with the Norwegian R and D company Geologica, meaning that in addition to our broad-based consultancy services we are also able to offer high competence scientific products and associated services."

Phil and Gavin had worked for Scott-Pickford, where they were involved with geodata products, creating multiclient studies and adding value to the extensive library of data and information which the company had built up over many years. In particular, Phil was involved with an innovative product known as the Facies Knowledgebase, a text-based series of basin-wide depositional facies interpretations put into a sequence stratigraphic framework.

Phil takes up the story: "As the era of $10 a barrel oil prices approached – hard to imagine that now! – downsizing became the name of the game. Realising this, we approached Scott-Pickford, by now part of the Core Laboratories Group, to undertake a management buy-out of the data products group, and when this was unsuccessful, we left and set up Aceca as an independent consultancy in 1998. As anticipated, Scott Pickford closed down the data products group, but sold us the intellectual property rights to the Facies Knowledgebase product. This meant that we could develop the project further, moving it from a text-based to a more visual product, which we call the Facies Map Browser, or FMB. With this visualisation system it is possible to review depositional systems across a basin through time. The FMB presents modelled details of the preserved section in the basin, with an audit trail to provide context and background detail for the conclusions presented. The map is essentially the driver, and the borehole and seismic information corroborate the map."



© Aceca

MapTool showing a mapped query result for a combination of data types.

PROMOTION

MTEM TAKES TECHNOLOGY INTO NORTH SEA

Significant step forward for Edinburgh based Oilfield Services Company

The revolutionary technology developed by Edinburgh-based MTEM to map offshore and onshore hydrocarbon deposits is to be deployed in the North Sea for the first time, in a tie-up between the fast-expanding company and operators Venture Production Plc.

The contract represents the biggest single deal for the company since it began commercial operation of its pioneering logging before drilling system.

MTEM (multi-transient electromagnetic) is to carry out work on a 24km stretch of a Venture-owned exploration block in the UKCS, having successfully completed offshore tests of its adapted R-Land system. The technology can determine, without the need for drilling, whether deep underground reservoirs contain oil and gas reserves.

MTEM has already successfully deployed the system onshore in projects in India.

Leon Walker, Chief Executive of MTEM, said: "This is a major step forward for the team at MTEM, one which we are looking forward to immensely and one which we believe will be keenly observed by the offshore oil and gas industry in its entirety. I am delighted to work with the team at Venture Production Plc and look forward to delivering our data to help them deliver their objectives."

Venture Production Plc's New Oil Asset Manager, Mike Travis, said: "Innovation is one of the keys to the future of the UKCS, and we are pleased to be associated with a company operating at the cutting edge of the industry as we look for new ways to develop our North Sea assets cost effectively.

"The technology is being applied to one of our most exciting potential field developments."

MTEM believes its technology will radically reduce drilling risk and potentially save the oil industry billions of dollars per year. Industry experts estimate the potential market for MTEM at around £500 million annually and the rapidly expanding Edinburgh-headquartered company established its first regional office in Houston in 2006 to meet the demand for its services in North and South America.

MTEM MULTI TRANSIENT

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High and broad science combined

"We had been working with Norwegian company Geologica and realised that there were real synergies between the two companies. Geologica had been established in 1996 as an industry and research council-funded R and D business in Stavanger, capitalising on the research work through the commercialisation of leading edge products and related services. It had a high science niche, concentrating on topics such as research into crustal heatflow and interstitial quartz growth, but the company found it difficult to expand within such limited areas. Aceca, meanwhile, had developed into a broadly based oil industry geoscience resource company, covering the whole range, from ideas and products to people. We bought Geologica in 2002 and since then the combined company has grown 4 or 5 fold, proving that the synergies we identified really existed."

A number of years on from this merger, the high science business is still a small but important part of the revenue stream, with the more general exploration services combined with multiclient work providing about 90% of the turnover. "The Facies Map Browser (known as the FMB) is still the flagship product of the company," explains Phil. "Having started on the UK Continental Shelf, followed by the Norwegian North Sea, we have now expanded the product to most of North-West Europe and are soon to complete a pilot study for the Nova Scotian Shelf, Canada. We are also looking at developing an FMB for Nigeria. In addition, the product does not remain static, as we are always developing new tools for use within it. In fact, with the recent addition of the ability to read georeferenced .tif files, the product is beginning a new life as a map management tool, allowing us to map trends and use legacy maps and seismic as well as new data."

Phil Slater is Managing Director of Aceca Ltd and was one of the founders of the company in 1998. A geology and geography graduate, with a Masters degree in Stratigraphy, he first started work with Clyde Petroleum, before moving into the consultancy field with GAPS and Scott Pickford.

"As the company has grown, however, we have attracted a higher calibre of staff, which means that we are now gaining access to premium commissioned work programmes requiring more experience coupled with advanced geoscience.

Under the TGS-NOPEC umbrella

The most exciting development in Aceca recently was the purchase of the company by TGS-NOPEC, the Norwegian seismic and services organisation. According to Phil, the senior management at TGS are very supportive and have ambitious plans for Aceca. "It has been very advantageous to us," Phil says. "We have been able to make staff compensation packages more in line with the rest of the oil and gas business, and we now have deeper pockets to do more exotic projects!"

"Moving away from the FMB, we have been developing some interesting new products which combine the high level of competence of our team with the wide range of data we can access through TGS and its associate companies. New ideas we are developing include deep shelf interpretation in the Gulf of Mexico, looking at older stratigraphic plays, and projects involving gas graph chromatography, which is a new and exciting field for us."

The progress of Aceca clearly shows that it is possible to support a continuing R and D profile while building a successful commercial company. "Product diversification is key," explains Phil. "We look forward to continuing with these developments and expanding our services still further under the TGS-NOPEC umbrella."

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Pioneering Geologist

Robbie Gries as the President of AAPG.

Photo: Robbie Gries

With her "dare to be different" philosophy and pioneering spirit, Robbie Gries was the first woman to graduate in geology from Colorado State University and the first woman to become AAPG President.

Thomas Smith, Associate Editor

Robbie Gries started and has built her own company, Priority Oil & Gas, by drilling close to proved production as well as buying reserves where infill development is possible. These are the economic realities of the business. However, her heart lies in frontier exploration as "one of the most exciting parts of being a petroleum geologist." Using resources from successful infill drilling projects, she is once again pioneering frontier plays in Colorado and Wyoming. She has also pioneered, and continues to play, a significant role in advancing women's position in the oil and gas industry.

Many Firsts

"Becoming the first woman President of the American Association of Petroleum Geologists in 2001 was truly a career highlight for me," says Robbie.

"Even greater than the honor of being AAPG President, was the opportunity to make a difference in the organization." Robbie traveled to 44 countries that year promoting geology, petroleum and AAPG. Her proudest accomplishments came in the education and involvement of young people around the world. She helped set up countless student chapters from Trinidad to Viet Nam, from Peru to Eastern Europe. Getting AAPG participation in the first multi-society electronic publication aggregate, GeoScience World, has lead to new and expanded education and research opportunities worldwide, especially in universities in developing countries that are literature impoverished.

Prior to becoming AAPG president, Robbie had many firsts "from getting rules changed so I could belong to Sigma Gamma Epsilon, the geology honor society at The University of Texas at Austin, to being one of the two first women to be made members of the Denver Petroleum Club (having experienced incidents of being "kicked out" of some male-only clubs)."

Robbie Gries in the Gebel Duwi desert of eastern Egypt.

Robbie with her vp of operations, Jessica Trevino and office manager Amy McLean during their 2005 drilling program.

Photo: Robbie Gries

Her early career, as well as the careers of her female colleagues, regularly involved such firsts as women became more accepted in the oil and gas world. "I found so much mentoring and support amongst the older male geologists. Their help and training was a positive while working in a primarily male environment, and they always outweighed the negative influences created by a few reluctant to accept change. Having a robust sense of humor helped a lot as well."

Hard Time Becoming a Geologist

Robbie Gries went to a very small high school in south Texas and never even heard of geology until her sophomore year in college. She drew a chemistry class with a reputed "battle-ax" as a professor, so decided to find another science. Other students mentioned, "geology has a really good instructor".

Robbie had always collected rocks and minerals when the family traveled and thought it would be "cool" to learn about that. "I fell in love with the science in the first lectures and switched majors soon thereafter." Transferring from Del Mar Junior College in Texas to Colorado State University, she became the first female to graduate from that school in geology (1966).

Robbie finished her Masters at the University of Texas at Austin in 1970, the same year she had a baby girl. At this time, she sensed that getting a job as a woman geologist may take some doing. "I never had any professor suggest I interview for a job, even when interviewers were on campus." She tried teaching for a while and loved it but had little patience for academic politics. It was not until three years later she did try to land a job in the oil patch. She freely admits "it was a wise decision on my part."

Early Training to Pioneer Thinking

This was 1973, and Robbie landed her first job as exploration geologist with Texaco in

Denver. Her timing was good as this company and all other large oil companies were under the mandate of the Johnson administration for Affirmative Action. They were hiring women to fill their "quotas".

At Texaco, Robbie had great managers, bosses, and mentors; all men, of course, and "they judged the women just like they did their male colleagues-performance, performance, performance??." Those were also the days when women were not allowed to go out on a rig, however, the women geologists managed to turn that around.

"My most exciting frontier play was to discover an unexplored basin beneath a pile of volcanics where some exceptional geologists had predicted we would find nothing but basement.

Her first wellsite experience was in Utah. "The geologist that trained me brought his wife along so she wouldn't be jealous." Robbie found it to be challenging to be a wellsite geologist ("don't we all?") and it was especially so during these years. "Someday I want to write a book! But growing up as a shrimper's daughter, the roughnecks and crews found me fairly unfazed by antics and language. I, in fact, just LOVE being out on the wellsite to this day."

While with Texaco in Denver, Robbie began to look at sediments beneath thrusted Precambrian mountain fronts as potential targets. The thinking at the time was that these ranges were vertical uplifts. She developed structural sub-thrust prospects for Texaco. It was not until years later and by other operators, that any of the prospects were successfully developed.

These were boom times for companies, and independents were attracting all the male geoscientists from the majors. Her boss at Texaco quipped "that pretty soon the majors will have only women working as independent companies do not have minority quotas to fill". It did not take too much time after that before an independent contacted Robbie, offering her a fat raise, car, override, and petroleum club membership.

That company was Reserve Oil Inc. in Denver where Robbie had the liberty to expand on her unconventional exploration ideas. She did field work and acquired acreage on frontier plays in the Idaho portion of the Basin and Range, the Colorado San Luis Valley, the Wyoming Hoback Basin, and many others.

Unfinished Business

There are journeys that can take a geologist back to the origin of life, to the deepest ocean depths, or flying down the side of an active volcano. These are the experiences unique to the discipline. Robbie Gries knows this journey is not always an easy one. In a career that included raising a child, being accepted as a woman in a man's world, enduring business setbacks and highs, she knows all too well what women geoscientists face in the oil and gas world.

"It is very disappointing to see how few women remain in geology and particularly petroleum geology. Twenty-five to thirty years ago women were only 10% of the workforce in petroleum geology (even less in engineering). But then women made up only about 10-15% of the graduate school degrees. Even 10 years ago, women were 30-50% of the graduates, yet the number in our industry did not rise." Women are hired and are amongst the best recruits, but not retained. Robbie feels this creates "a critical workforce problem, as we are dangerously short of young, well educated geologists to meet the resource needs of this planet's population. To lose these excellent young geologists is to waste an enormous human resource and to waste very valuable educations."

It is Robbie's desire to do more to help women geoscientists. "We need to emphasize to companies how important it is for them to create a working environment that promotes retention of women; one that allows women to continue their careers while going through their child-rearing years." AAPG has developed the Professional Women in Earth Sciences (PROWESS) committee to promote solutions to this issue. This committee is sponsoring a session at this year's AAPG annual meeting in Long Beach entitled "Women in the Energy Industry: Developing Negotiation Skills".

Back to the Frontier

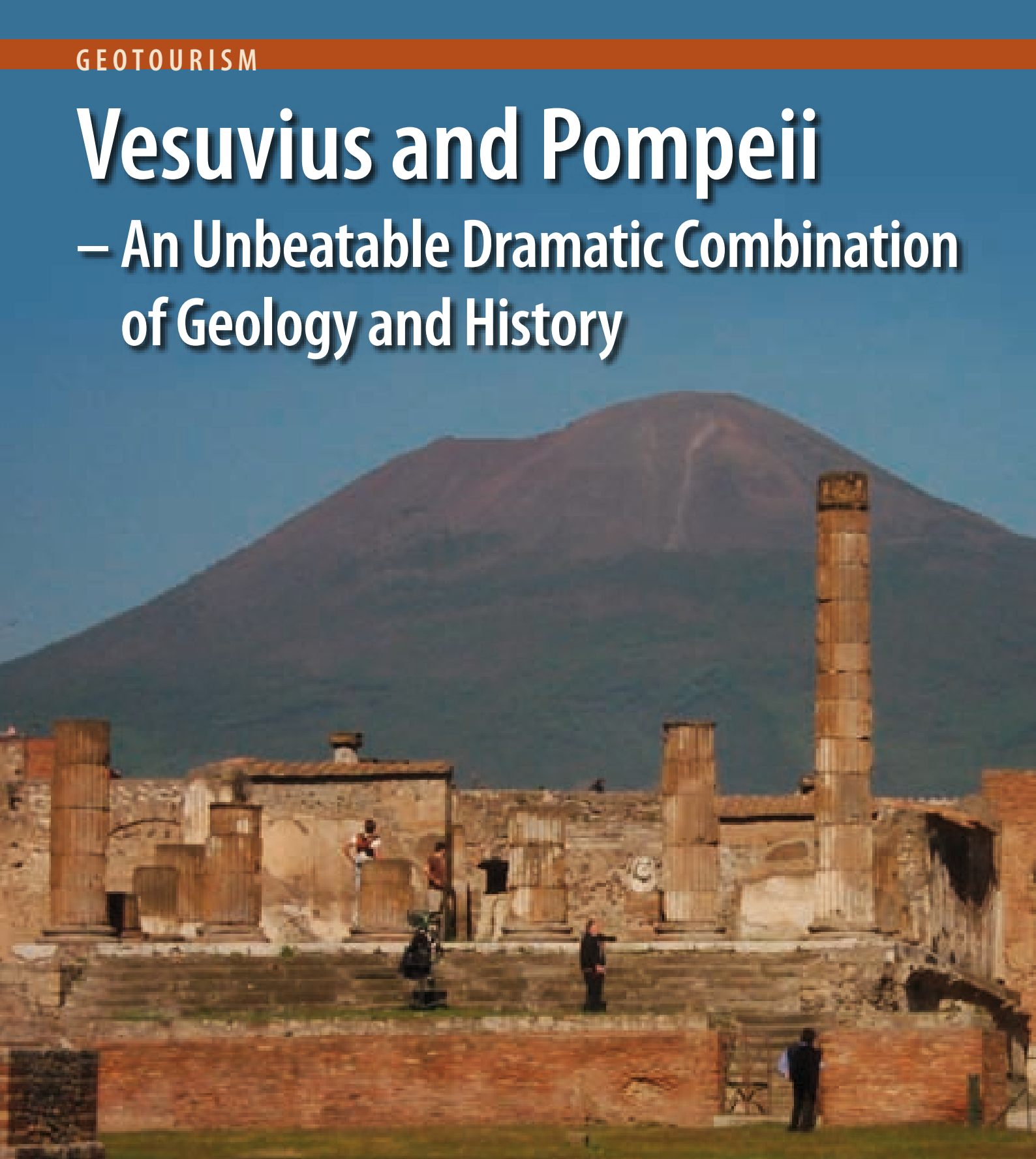
Robbie worked as a consultant and developed prospects on her own after leaving Reserve Oil. During the oil slump of the early 90's, she had prospects turned back and deals go sour. She was forced to learn acquisition and started to buy price-depressed properties. After putting together a company merger but leaving after only a year, she formed Priority Oil & Gas and started buying properties in Kansas in 1995. They drilled 40 wells on these properties in 1999, all but one were successes. The next drilling project had 36 wells and, again, only one dry hole.

The success of her small company (consisting of Robbie, the office manager and numerous contract consultants) has led Robbie back to what she loves to do. "I have recently put together two exciting frontier plays. The first is in the Powder River Basin where I now have partners in a 3-D seismic survey and an upcoming well. The second is another frontier play in southwest Colorado." Like Robbie's life, these are sure to be challenges and opportunities.

Photo: Robbie Gries

Robbie with female students at the Nigerian Association of Petroleum Explorationists in Port Harcourt, Nigeria.

Vesuvius and Pompeii – An Unbeatable Dramatic Combination of Geology and History



In AD 79, the cataclysmic eruption of the volcano Vesuvius completely buried the towns of Pompeii and Herculanaeum with up to 30 m of ash. The volcanic debris gently preserved the city from decay for almost 1,700 years, so today tourists can wander around the streets of this ancient Roman town, imagining what life must have been like almost 2,000 years ago. Perhaps it is the combination of a devastating natural disaster with the mystery of ancient times that brings more than 2 million tourists to Pompeii every year.

Photo: Morten Smelror

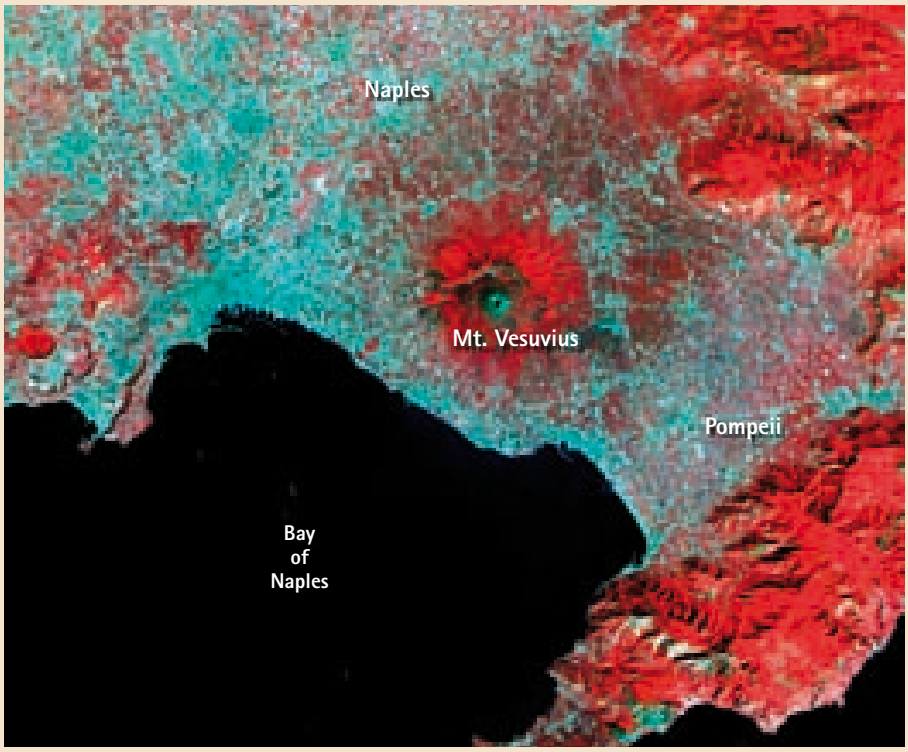


Photo: NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team

This image of Mt. Vesuvius Italy was acquired September 26, 2000, and covers an area of 36 by 45 km. Vesuvius overlooks the city of Naples and the Bay of Naples in central Italy. Vesuvius is intensively monitored for potential signs of unrest that could signal the beginning of another eruption.

Photo: Berit Lokken

The towns of Pompeii and Herculaneum were rediscovered in the 18th century, and following excavation in the 20th century they now witness Roman life from 2000 years ago. Hundreds of victims are preserved together with wooden objects and food items.

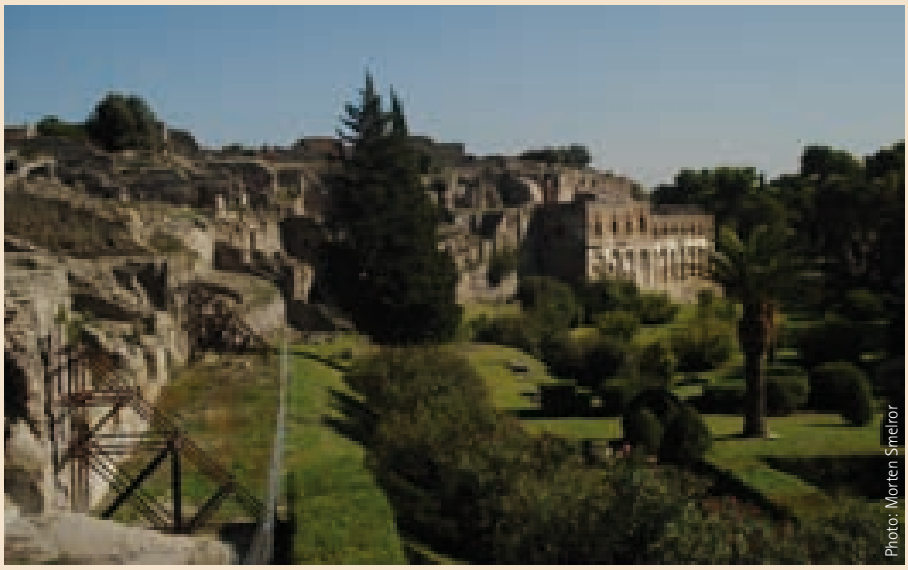
Berit Løkken and Morten Smelror

The bay of Naples is considered one of the most beautiful parts of Italy. The landscape is peaceful and friendly, with omnipresent Mount Vesuvius as a scenic gentle giant, surrounded by slopes of vineyards and woods. The sun is warm and radiant, and a pleasant breeze drifts in from the Mediterranean. But there is a dark side to all this beauty. Below, deep in the ground, rages an active volcano. In fact, the Vesuvian volcanic complex, which originates from twelve thousand years back in time, was responsible for one of the most disastrous eruptions in the history of man.

At about 1pm on 24th August, a warm summer day in the year AD 79, Mount Vesuvius erupted violently. Terrified people witnessed the volcano spitting out enormous amounts of lava, burning stones, boiling mud, poisonous gases and ashes into the sky as the subterranean channel opened with devastating power. One side of the mountain was torn away for a length of two kilometres. By the end of the following day, thousands of people were dead and the flourishing Roman cities of Pompeii and Herculaneum had disappeared beneath tons of ash, pumice and solidified mud.

Most of what we know about the eruption comes from the Roman writer Plinus the Younger. In his famous two letters to the historian Tacitus, written 16 years after the disaster, Plinus gives the story which is regarded as the oldest written account of vulcanology. While he witnessed what happened from a safe distance at Capo Miseno, his uncle, the naturalist, writer and Roman officer Pliny the Elder, with his insatiable investigative curiosity, set sail across the Bay of Naples to face the disaster and his own death.

Doric columns at the Pompeii Forum. As early as the end of the second century, the Roman government had men digging at Pompeii to retrieve large public statues from the forum and to remove building materials for other towns. The salvage work had to be curtailed while Vesuvius violently erupted for seven days in 203 A.D.



There is much information to be gleaned about Roman living arrangements in Pompeii, from the modest dwellings of the simple workmen to the large and magnificent villas with sumptuous decorations of the noble class.

In addition to his observations, Plinus the Younger describes the details of the eruption based on notes taken from those who had accompanied his uncle. These unique documents not only help us to scientifically reconstruct what has become known by specialists as a *Plinian eruption*, they also tells us how terrifying and shocking it was for the witnesses and victims of the disaster: "You could hear women lamenting, children crying, men shouting. There were some so afraid that they prayed for death. Many raised their hands to the gods, and even more believed that there were no gods any longer and that this was one unending night for the world."

Most of the citizens managed to escape, but more than 2,000 were killed. First, pumice 'rain' slowly started to fall, prompting most inhabitants to flee the city. This was followed by a flood of warm ash and gas streaming rapidly down from the mountain. Those who stayed behind were killed. The ash and pumice that covered Pompeii and its inhabitants came to provide a 4 m thick cover, which protected the city for almost 1,700 years.

At the time Mount Vesuvius erupted, Pompeii was a wealthy Roman trading town, famous for its fish sauce and its grand villas. It was international and cosmopolitan, with a population which included Greeks, Etruscans, and residents from Africa, in addition to Romans. Of Pompeii's 20,000 inhabitants, half were children.

A Pompeiian Home

The houses of Pompeii generally had an entrance from the street that led through a narrow passageway into an inner courtyard known as an *atrium*, used as a gathering place to welcome guests and entertain children. Usually it contained a pool called an *impluvium* to collect rainwater for various uses. On either side of the atrium, there might be bedrooms, storage rooms or a library of scrolls. If the Roman home had an upstairs, these rooms often had doors or balconies overlooking the atrium.

Most homes included a garden (*viridarium*) with plantings, statues and fountains, with water fed through lead pipes. The wealthy Pompeiians enriched their homes with elegant gardens decorated with frescoes of plants and flowers and an abundance of modern conveniences.

Each room was heated by hot air running through cavity walls and spaces under the floors, while sophisticated hydraulic pumps provided running water. In fact the entire city had an excellent system for the control and distribution of water. From a great reservoir, water flowed through underground pipelines into drainage systems and aqueducts supported by arches. The urban structure of the town was the classic Roman style, with rectilinear and right-angled roads (the *cardines* and *decumani*), paved with Vesuvian stone.

Everyday life

When visiting Pompeii today, the paved streets even now bear the marks of Roman cartwheels, and you still find the public fountains on many street corners, where the inhabitants used to meet and mingle. High footpaths were built on either side of the cobblestone streets, which were crossed by means of large, raised stones because the streets had little drainage. Along the main roads there were taverns and cafes, similar in some ways to our fast food restaurants today. The citizens could leave the public baths and grab a quick something to eat at one of the many early franchises.

The Forum was the administrative and corporate heart of Pompeii. Situated at the end of the main street of Pompeii, this was the centre for politics, religious activities and trade, with huge temples, public buildings, basilicas and all kinds of shops. Although only the ruins can be seen today, one can almost feel the presence of previous life here, with merchants offering their goods, legal proceedings taking place and people meeting and gossiping. Like all Roman citizens, the Pompeiians enjoyed violent entertainment. The remains of a huge amphitheatre, with room for several thousand spectators, is situated in a corner of the city. Here gladiators amused the audience by fighting for their lives.

The public baths were an important part of everyday life for a Pompeiian. Beautifully decorated, you can see the remains of these baths today, with the *tepidariums* which were filled with lukewarm water and the *caldarium*, filled with hot water. Slaves would rinse and clean their client's bodies with metal scrapes and give massages with aromatic oils.

Many of the houses contain the remains of well-preserved frescoes.

In Pompeii there are reminders of death everywhere. In 1863, Guiseppe Fiorelli developed the ingenious technique of making plaster casts of the voids in the ash layer left as the remains of people and animals decomposed, often reproduced in astonishing detail.

Plinian eruption

A *Plinian eruption* is the ejection of large volumes of ash and pumice in a well-defined eruption column, where the resulting dispersal of pumice covers an area of over 500 km². Coarse pumice pyroclasts from *Plinian* eruptions usually fall within tens of kilometers of the vent area, although the ash particles produced by very energetic eruptions or those carried along with the pyroclastic flows can be found hundreds of kilometres from their source.

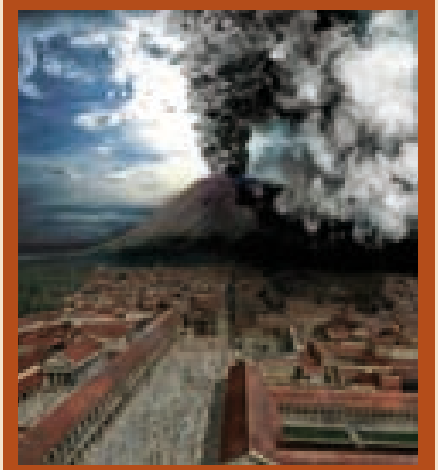

The last day of Pompeii, as seen by an artist.


Photo: Morten Smelror

The typical streets in Pompeii and other ancient Italian cities were built of paving stones of basalt, a rugged igneous rock. The centre of the road is raised to allow water to run off into the gutters.

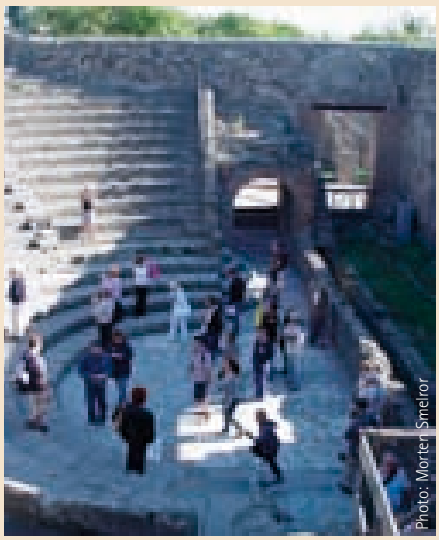


Photo: Morten Smelror

The small theatre, or *Odeon*, had a seating capacity of 1,000 and is among the best preserved of ancient theatres. It originally had a permanent roof to improve the sound quality for musical performances and prose readings.

On your own

The excavations of Pompeii started in 1748, but sloppily and without proper planning at first. Treasure hunters escaped with valuable amphoras, statues and coins. In 1860 the archaeologist Giuseppe Fiorelli became the leader of the excavations, at which point scientific planning and methods were introduced to the excavations. Mapping, cataloguing and restoration of the buildings started. Today Pompeii is one of the oldest and most thoroughly examined archeological sites in the world. A lot of the artifacts found in Pompeii can be viewed in the Museum of Napoli. (*http://www.marketplace.it/museo.nazionale/*).

Going to Pompeii as a tourist today can be a real test of patience. First you queue up to get a ticket, and when finally inside, you follow a stream of tourists along the streets and into the many houses, at each of which you have to wait your turn before entering. Taking pictures without other tourists appearing in them is almost impossible. Nevertheless, a visit to Pompeii is worth the effort. Because of the tourist invasion and also the heat of the warmest summer months, it is recommended to avoid the high season.

For your first visit to Pompeii it is a good idea to join a guided tour through the city. This way you get the best and easiest introduction to the historical facts of this fascinating town. Several tourist agencies offer trips combining a tour around Pompeii with a trip to the top of Mount Vesuvius. For all tourists, Vesuvius, the mountain of Bacchus, and Pompeii, the seat of Venus, comprise a unique site, providing an unbeatable combination of scenic and thrilling nature with the extraordinary, well-preserved remains of an ancient Roman city.

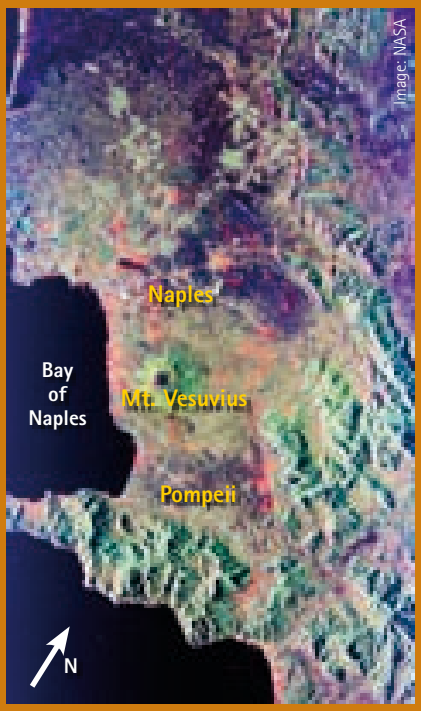
Active Vesuvius

Vesuvius is the only active volcano on the European mainland. The last eruptions were in January to April 1944, during the days of the allied occupation, when the cone of the volcano collapsed some 200m into the crater, creating the large concave summit characterising Vesuvius today.

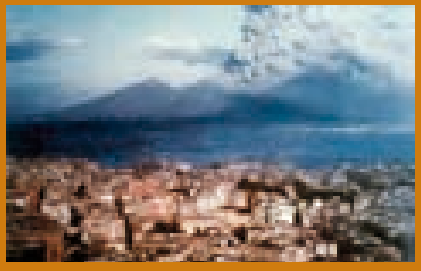
Prior to this, there had been an almost uninterrupted alternation of eruptive phases and more quiet and stable periods since 1913. During this time, never more than a complete year passed without lava emission, and the volume of material poured out by Vesuvius from 1913-1944 has been calculated at some 250 million cubic meters (equivalent to 1.6 billion barrels, i.e. a giant oil field).

In addition to the famous eruption in the year 79, the historic documents tell us about eruptions in 203, 472, 512, 993, 1036, 1038, 1039 and in 1500. In December 1631 a violent eruption occurred, causing the death of around 4,000 people. Further eruptions followed in 1660, 1737, 1779, 1794, 1822, 1850, 1855, 1858, 1861 and in 1872. This last eruption completely surrounded the Vesuvian Observatory which had been commissioned between 1840 and 1845. The director at that time was the famous Luigi Palmieri, who did not want to abandon the building surrounded by flowing lava, but remained "on duty" to observe what happened.

After this event Vesuvius stayed calm until April 1906, when a new violent eruption took place that significantly changed the shape of the volcano, creating a crater with an internal size of 84 million cubic meters at the top of the majestic mountain.



The central cone of Vesuvius is the dark purple feature in the center of the volcano. This cone is surrounded on the northern and eastern sides by the old crater rim, called Mt. Somma. Recent lava flows are the pale yellow areas on the southern and western sides of the cone. Dense urban settlement can be seen around the volcano. The city of Naples is above and to the left of Vesuvius. Pompeii is located just below the volcano.



THE ARCTIC CONFERENCE DAYS 2007

TROMSØ, NORWAY 3 – 7 SEPTEMBER 2007

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ICAM V **3 – 5 September**	The Fifth International Conference on Arctic Margins
AGREE II **6 - 7 September**	The Second Conference on Arctic Geology, Resources and Environment
SEST **3 – 5 September**	The Conference on "Shelf Edge and Shore-line Trajectories, A Dynamic Approach to Stratigraphic Analysis"

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Resource Assessments

Having done resource assessments since 1975 when he joined the United States Geological Survey, Kenneth Bird has a superior knowledge of the process and realities presented in these reports. We ask him about the methodology and what the numbers actually mean.

What prompted you to do your first resource assessment?

When I joined the USGS in 1975, it was just a couple of years after the first shock of the Arab Oil Embargo, and there was growing concern that the U.S. was running out of oil. The basic question of how much oil remained to be found in the U.S. was critical to national security, public policy and land management decisions – the same reasons that exist today for doing assessments. At that time there were conflicting estimates by prominent USGS scientists: A rather pessimistic estimate by M.K. Hubbert indicating U.S. oil production had already peaked (in 1970) and an optimistic estimate 3-times larger than Hubbert's by V.E. McKelvey, director of the USGS. I was hired to work on the petroleum potential of carbonate rocks of northern Alaska, not to do assessments. But shortly after joining the Survey, it became clear that assessment work was an increasingly important part of my job and that of many other Survey geologists. All totaled, I've been involved in 20 to 30 assessments.

Over the years, you have developed a "tried and true" methodology. How was your methodology developed?

The origins of the play-analysis method we currently use can be traced to a resource-appraisal method developed by Roy and others of the Geological Survey of Canada in 1975. Their method was modified and incorporated as one component of a more comprehensive analysis of the National Petroleum Reserve in Alaska (NPRA). This 1980 assessment involved exploration, development, production, transportation, and the distribution of petroleum resources.

What is the assessment process?

The initial step of the assessment is to define the basic unit of assessment or play. The play is defined as a volume of rock with common geologic attributes, such as source rock, reservoir rock, trapping mechanism, and timing. Then, for each play, distributions of prospect size and number, reservoir thickness and porosity and trap fill are combined

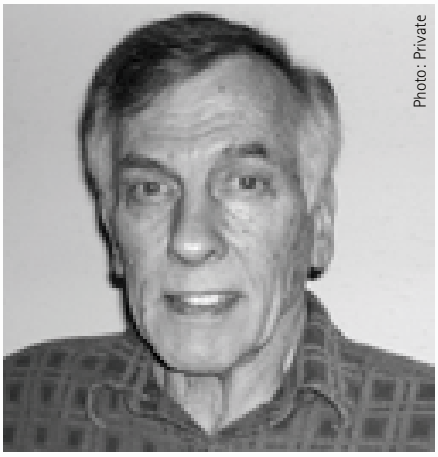

Photo: Private

Kenneth J. Bird is a geologist with the U.S. Geological Survey specializing in the petroleum geology of northern Alaska, where his experience spans more than 40 years. He is a co-leader of the Alaska Petroleum Studies Project, one of the larger projects funded by the Geological Survey Energy Program. He has a doctorate degree in geology. His work experience includes seven years with an oil company and 30 years with the USGS. With interests primarily in stratigraphy and sedimentology, he has been extensively involved in petroleum resource assessment activities in Alaska and elsewhere in the U.S. He has authored more than 100 papers and abstracts, most related to Alaska petroleum.

to produce an estimate of the number and size of potential petroleum accumulations. The resulting distributions are then risked to weigh the likelihood that geologic conditions are favorable to generate a certain sized accumulation and an estimate of in-place petroleum resources for each play is generated. A recovery factor is then applied to calculate recoverable resources.

Who comes up with the parameters used in the assessment?

Typically for each play there is a lead geologist who is responsible for the parameters. This geologist draws on the efforts of a team consisting of geochemists, log analysts, paleontologists, stratigraphers, engineers, seismic interpreters, structural geologists, and basin modelers.

The results include 95th and 5th percentiles and the mean. What do the figures actually indicate?

The assessment methodology yields results that express a range of uncertainty. To stress the importance of this uncertainty, results reported include 95th and 5th percentiles, which are considered reasonable minimum and maximum values. The mean expresses the average or expected value.

There was a lot of speculation about the Arctic National Wildlife Refuge (ANWR) in Alaska. Was there any political pressure to "inflate the numbers"?

No, none whatsoever.

You have seen some of the areas drilled after doing a resource assessment. How do the results of the assessments stack up with reality?

The pace of exploration in northern Alaska is such that only a few wildcat wells are drilled each year and those may test prospects in different plays. So it takes a good number of years of exploration to get a sense of how our assessment results compare with reality. One of the plays assessed in 1994 as part of the 1995 National Oil and Gas Assessment was the Barrow Arch Beaufortian play in which we estimated a mean value of about 1.5 billion barrels of technically recoverable oil remained to be discovered. This has been one of the more actively explored plays, and since 1994 numerous oil discoveries have been announced (Alpine, Fiord, Oooguruk, Placer, Midnight Sun, Spark, Rendezvous, Lookout) that together represent a volume of oil approaching about 50% of our mean value estimate, or about 700 million barrels of oil.

What is your view of the future of Arctic Alaska as a petroleum province?

Arctic Alaska has a long way to go before it can be written off. Outside of the State lands coastal strip, the area is still very lightly explored and the gas potential has hardly been tested. It is safe to say the future depends on economics; the price of oil and gas, the construction of a gas pipeline, and the economic limit of the oil pipeline.

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Moving Beyond Prudhoe Bay

Historically, exploration and development have been concentrated in the central North Slope primarily on state and native lands. Having produced over 15 Bbo (2.4 Bm³), Alaska's North Slope is one of the most prolific areas in North America.

Many of the key geological elements that contributed to the large accumulations already discovered extend into adjacent frontier areas. The National Petroleum Reserve in Alaska (NPRA), lying west of the Prudhoe Bay area discoveries, is an area being actively explored and for good reason. The United States Geological Survey estimates (see Q & A, this issue, page 64) have 10.6 Bbo (1.7 Bm³) and 61.4 Tcfg (1.7 Tm³) as the expected recoverable resources. Estimates range from 6.7 to 15 Bbo (1.0 to 2.4 Bm³) and 40.4 to 85.3 Tcfg (1.1 to 2.4 Tm³). Higher oil prices and new technological advances have also made this area more economically desirable. A proposed gas pipeline to take North Slope gas to lower 48 markets makes development in NPRA even more attractive.

"The energy resources of the National Petroleum Reserve in Alaska are essential in meeting our nation's energy demands and are a major part of the President's National Energy Plan. This is a long-term strategy to keep the oil flowing in the Trans-Alaska Pipeline, and decrease America's dependency on foreign oil sources," says acting BLM Alaska State Director Julia Dougan.

© USGS

Oil companies are looking west, into the National Petroleum Reserve in Alaska, to help offset the production decline at the Prudhoe Bay field and keep the Trans-Alaska Pipeline flowing for many more years.

Early Exploration

NPRA (formerly Naval Petroleum Reserve No. 4) is 23.5 million acres (95 Mkm²) (about the size of the state of Indiana) and was set aside by President Harding in 1923. Two rounds of exploration by the government followed. Early drilling, from 1944-1953, had a stated aim of determining whether or not commercial quantities of petroleum were present within the NPRA. The second drilling program was conducted between 1975 and 1982. The primary objective of this program was the acquisition of geological knowledge.

The federal government held four competitive lease sales in the NPRA from January 1982 through July 1984. Over 8.8 million acres (36 Mkm²) were offered and the industry acquired approximately 1.4 million acres (57 Mkm²). Little actual exploration work was conducted on this acreage and only one exploration well was ever drilled; all leases have reverted back to the federal government. These sales came at a time when oil companies were busy exploring holdings nearer to Prudhoe Bay, along with a 1985 oil price collapse, all of which impacted North Slope activities. As a result, NPRA remained largely unexplored at a prospect level.

New Look - New Plays

New leasing activity commenced in 1999, with the Bureau of Land Management (BLM) conducting four lease sales through 2006. These sales have made over 18 million acres (73 Mkm²) available for oil and gas exploration. Eight different companies currently own 384 leases containing about 3.7 million acres (15 Mkm²). Through 2006, 21 exploration wells have been drilled by five different operators. ConocoPhillips is by far the most active, drilling 16 of those wells. The other companies are British Petroleum, Anadarko, Total and FEX. Conoco Phillips have tested significant flows of oil and gas in four exploratory wells. The largest flows were encountered at Lookout #2 that flowed 4,000 bopd (630 m³pd). Four exploratory wells are permitted for 2007.

Even with all the recent and past oil and gas activity, NPRA remains sparsely explored.

Being the largest oil and gas producer in Alaska, and currently the most active in exploration, ConocoPhillips is positioned to take advantage of the enormous opportunities in the NPRA. They are the first company to file an environmental assessment for a 5-year winter exploration drilling program to evaluate their extensive acreage holdings. The program includes up to 11 drilling pads and 44 wells and sidetracks to be drilled through 2011.

Erec Isaacson, Vice President Exploration and Land for ConocoPhillips Alaska sums it up this way, "Technology and Alpine-style developments* will be the key to our future on the North Slope. Through the extensive application of long-reach horizontal wells, we have successfully decreased the surface occupancy to 0.25% of the field area and been able to reach smaller, onshore pads."

*Note: Discovered in 1994, the Alpine field is now considered a giant field having over 500 million barrels (80 MMm³) recoverable. Development there is from satellite drilling pads similar to how offshore fields are developed.


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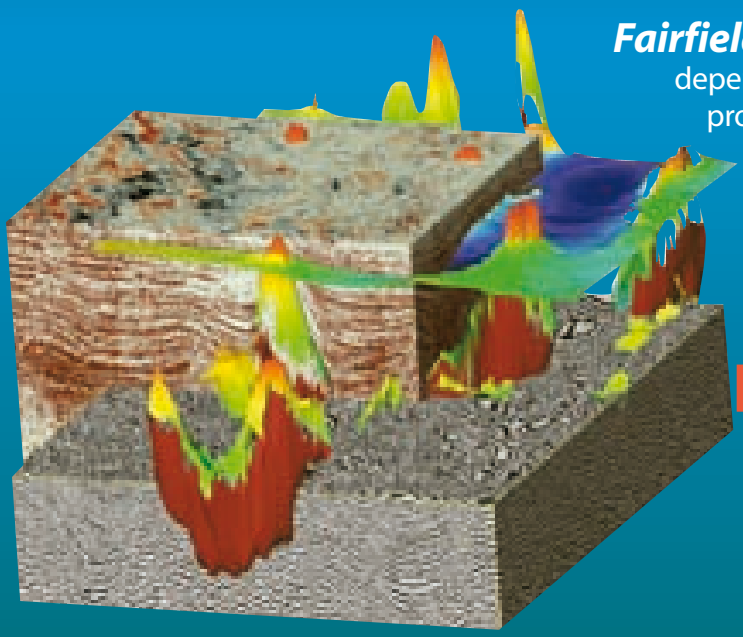
Just who *is* Fairfield?



Fairfield is the resource explorationists can depend on for the acquisition and processing of proprietary and multi-client data. For 30 years Fairfield's seismic knowledge and understanding has brought major advances to the seismic industry.

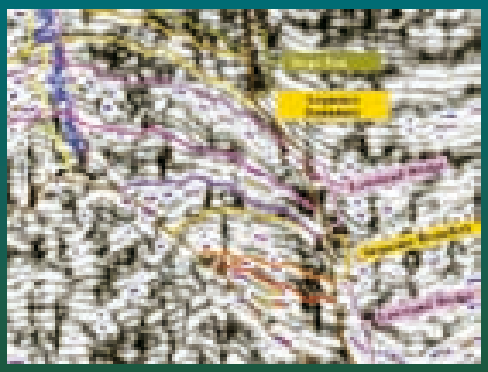
Multi-client Seismic Data

Fairfield's multi-client seismic library includes over 22,000 square kilometers of 3D GOM data, imaged to 12,200 and 15,250 meters using Fairfield's Tomographic Depth MVA.

Processing

SPICE

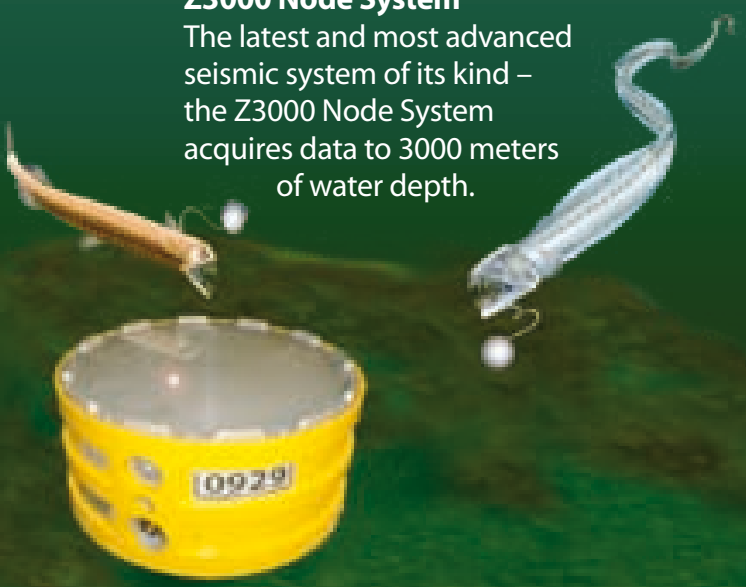
Fairfield's ongoing research and development efforts bring new technologies to the marketplace. For example, Fairfield's new SPICE technology shows critical structural and stratigraphic detail extracted from the seismic wavelet.



Acquisition

Z3000 Node System

The latest and most advanced seismic system of its kind – the Z3000 Node System acquires data to 3000 meters of water depth.



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The International Polar Year

The Arctic sedimentary basins found onshore and offshore only five countries (USA, Canada, Denmark (Greenland), Norway and Russia) may prove to contain significant oil and gas reserves.

We have already entered the International Polar Year (www.ipy.org). It happened March 1st with a grand opening in Paris.

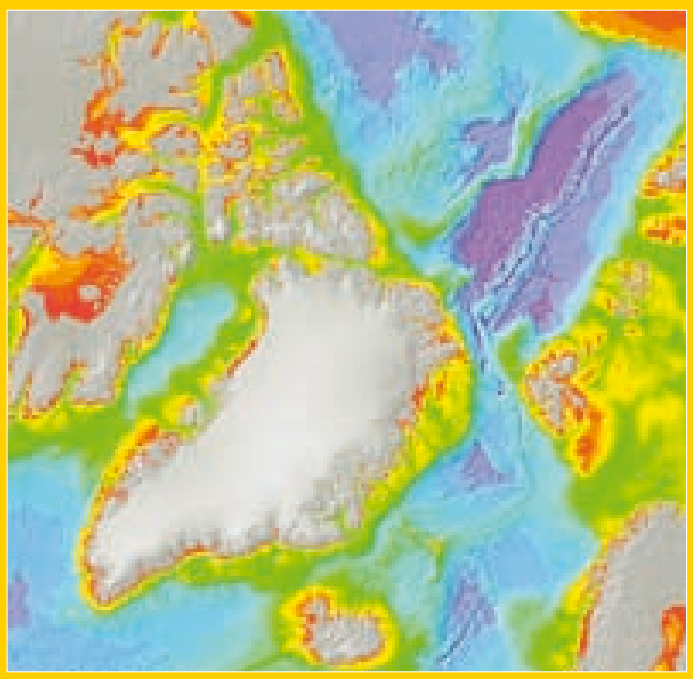
The International Polar Year (IPY) is an intense scientific campaign focusing on the Arctic and the Antarctic from March 2007 to March 2009. In order to have full and equal coverage of both the Arctic and the Antarctic, IPY covers two full annual cycles from March 2007 to March 2009 and will involve over 200 projects, with thousands of scientists from over 60 (!) nations examining a wide range of physical, geological, biological and social research topics.

While exploration for oil and gas in the *Antarctic* is a long shot, the deliberate search for hydrocarbons in the *Arctic* is well under way and continually expanding, always further north and to ever more remote regions.

"If the U.S. Geological Survey (USGS) is right, 25 percent of the world's undiscovered petroleum reserves could be found in the Arctic. Thus, the Arctic region could be part of the solution to the growing energy needs of the world", Odd Roger Enoksen, the Norwegian Minister of Oil and Energy said when opening the Arctic Frontiers Conference in Tromsø, Norway, lately. It focused on the development potential in the Arctic region and the corresponding environmental challenges

Vast petroleum reserves in the Arctic *may* be the key source of world energy in the future, but it remains to be seen. So far, we are largely relying on the estimates made by USGS in their worldwide petroleum resource assessment that was published in 2000 (GEO ExPro No. 1, 2004).

Norway alone could host 6 billion barrels of oil equivalents (recoverable), and NPRA (see this editions ***Hot Spot***) could eventually prove between 7 and 15 billion barrels of recoverable oil. In addition we have to rely on sedimentary basins offshore Greenland, Canada, Alaska and – not the least – Russia. While some of these basins have already proven to be quite prolific (e.g. the Barents and Kara seas), others (e.g. offshore Northeast Greenland) are virtually unexplored and may eventually turn up completely dry. Some caution is therefore strongly recommended when making predictions of the Arctic fossil fuel potential.



CONVERSION FACTORS

Crude oil
1 m^3 = 6.29 barrels
1 barrel = 0.159 m^3
1 tonne = 7,49 barrels

Natural gas
1 m^3 = 35.3 ft^3
1 ft^3 = 0.028 m^3

Energy
1000 m^3 gas = 1 m^3 o.e
1 tonne NGL = 1.9 m^3 o.e.

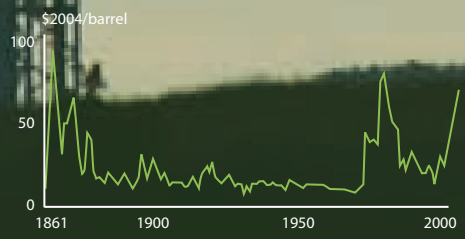
Numbers
Million = 1 x 10^6
Billion = 1 x 10^9
Trillion = 1 x 10^{12}

Supergiant field
Recoverable reserves > 5 billion barrels (800 million Sm^3) of oil equivalents

Giant field
Recoverable reserves > 500 million barrels (80 million Sm^3) of oil equivalents

Major field
Recoverable reserves > 100 million barrels (16 million Sm^3) of oil equivalents

Historic oil price



2007 PROSPECT INVENTORY

MISSION : to establish a prospect inventory across open acreage on the UK and Norwegian continental shelves.

Approach

We are to undertake a prospect delineation, volumetric and risking exercise across open acreage in preparation for the on sale of each prospect three months prior to the UK 25th and Norway APA 2007 licence rounds. Adopting a high science approach we shall de-risk each prospect with respect to reservoir, seal, charge and trap in order to shorten the project cycle time for client's own licence round subsurface review work. It is anticipated that each prospect will be scrutinized directly by client peer review and risking committees prior to featuring in their licence applications.

In addition to defining and risking the subsurface expression of each prospect, we shall also address the reservoir engineering issues of recovery factor and reservoir deliverability.

Timing

This new initiative has commenced with anticipated delivery dates of

ITEM	TITLE	DELIVERY MONTH
1	UK 25th Licence Round	To be announced
2	Norway APA 2007	June

Contact

For further details of this new initiative please contact Philip Slater – philip@acreca.co.uk - at our London office.

Please note: Whilst we are engaged by a number of clients in exploration work programs in both the UK and Norwegian sectors, we wish to reassure them that we shall treat this Prospect Inventory initiative to regional outside of those we are commissioned to otherwise generate prospects in order to avoid any possible conflicts of interest.

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