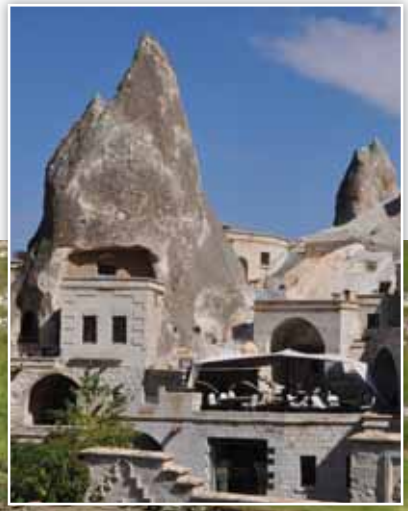
VOL. 8, NO. 1 – 2011

# GEO ExPro

GEOSCIENCE & TECHNOLOGY EXPLAINED



Cappadocia: Civilisations in a Granite Terrain

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EXPLORATION

## New Insights into the Levantine Basin

## North West Atlantic Margin

HISTORY OF OIL

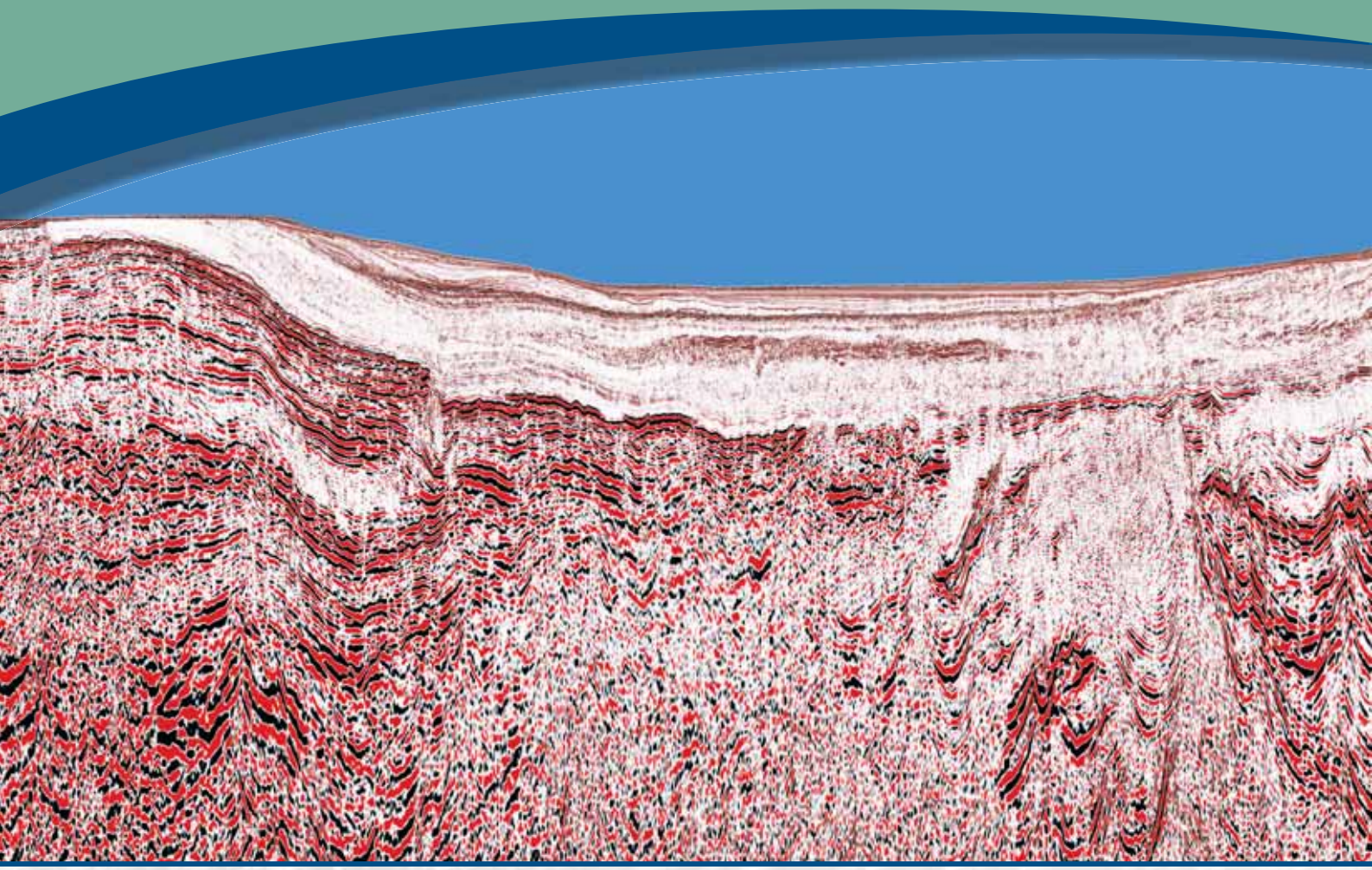
## Ekofisk

TECHNOLOGY

## Looking Beyond Just Seismic

GEOLOGY GEOPHYSICS RESERVOIR MANAGEMENT

# Clarity in Depth



## Sub-basalt PSDM in the West of Shetlands

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*Gravity gradiometry combined with seismic data can help unravel complex geological settings.*

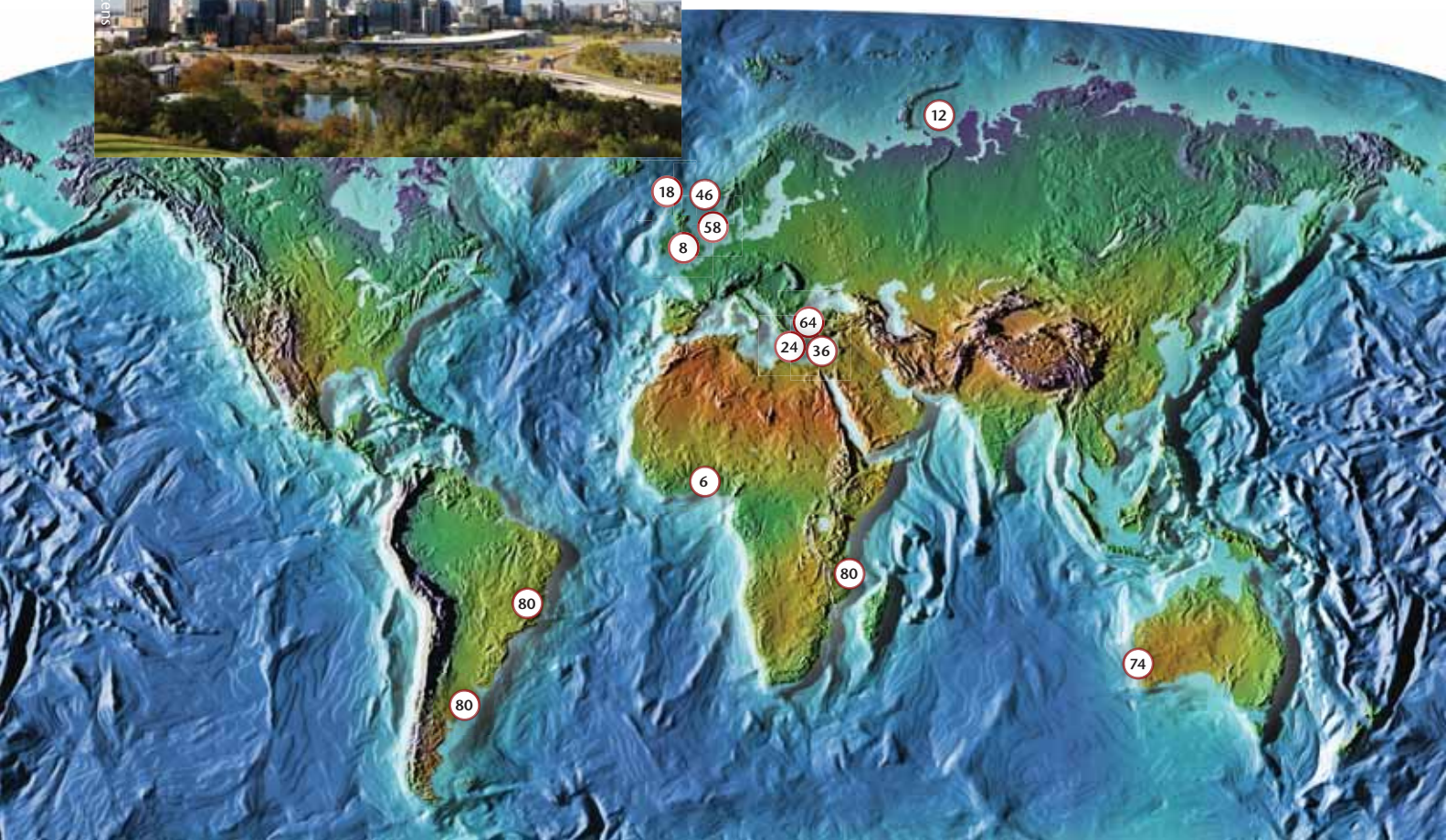
## COLUMNS



## FEATURES




*The easy-going city of Perth in Western Australia, introduces our new column on cities of significance to the oil industry*



# Petrel 2010

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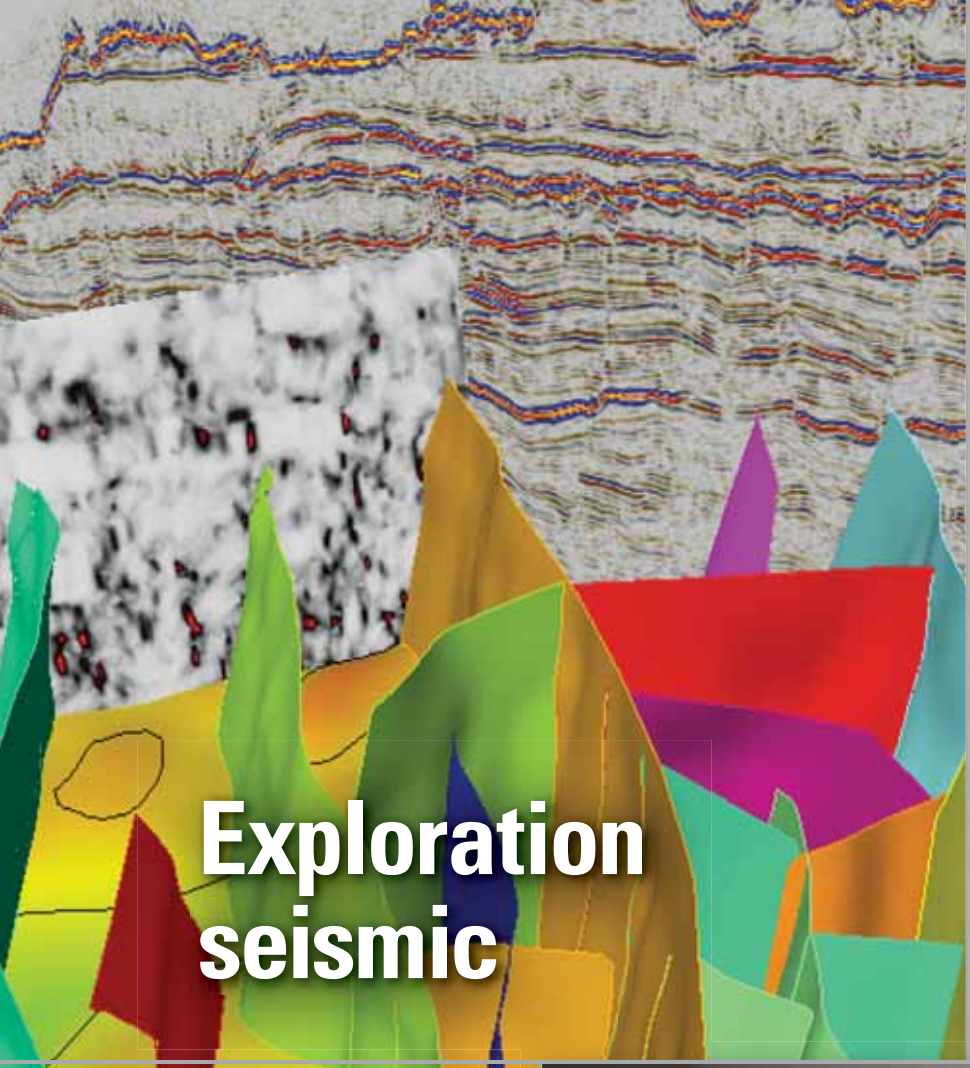


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# What is Energy Security?

Energy security is a term bandied about liberally by politicians, journalists and market analysts, amongst others. But what does it actually mean? The International Energy Agency defines it as "the uninterrupted physical availability at a price which is affordable, while respecting environment concerns". And, obviously, we at the upstream end of exploring for oil throughout the world are at the forefront of the quest for energy security.

But energy security actually means different things to different countries. At the recent GeoIndia conference, Dr. Narendra Taneja pointed out that for Saudi Arabia, with enough reserves to fuel its relatively small population for centuries, energy security concerns the ability to produce and in particular to export oil in order to fund the importation of the commodities it needs. The present political instability in the countries through which it exports is therefore a far greater threat to Saudi's energy security than the physical availability of energy. Russia also has plentiful supplies of hydrocarbons, and is interested in gaining energy security through exporting energy and using it to achieve political ends. Energy security is also a political matter in the USA, strongly tied to the stability of the nations which supply it. France, by contrast, is more than 75% dependent on nuclear generated power: its energy security is therefore tied up with access to uranium and is not dependent on changes in the price of oil.


*What further reserves could the waters of the Eastern Mediterranean hold?*

But for most countries, despite the plethora of alternative energy sources, energy security means ensuring they have enough oil and gas for their needs, both from home sources and internationally. This is particularly relevant in rapidly developing countries such as India, already the fourth largest consumer of energy in the world, and which imports a large percentage of its energy needs. And it is why a country like China is looking all around the world to secure the assets necessary to sustain its economic growth.

The exploration industry is working to help access oil and gas throughout the world, as we can see in this issue of *GEO Expro*. As well as discussing 'hot spots' for 2011, we look in depth at an area that until recently had been written off by many in the industry. Before the discovery in 2008 of the 8 Tcfg Tamar field off Israel, few companies had been clamouring for acreage in the Eastern Mediterranean. Improvements in seismic acquisition and processing have played a major part in this, allowing the imaging of the important sub salt horizons.

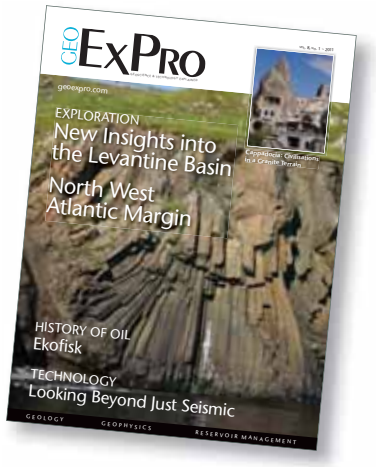
We work in a global industry, which reaches into all corners of the earth. Energy security, with all its definitions, is our business.

**JANE WHALEY**
**Editor-in-Chief**

## FRONTIER EXPLORATION

The cover shows a ponded lava flow filling a river channel, resulting in the fanning arrays of columns, from the Beinisvørð formation, Froðba, on the Faroese island of Suðuroy. Recent exploration in the North West Atlantic Margin suggests that there is considerable potential in the sub basalt plays in this deep water frontier area.

*Inset:* Cappadocia in Eastern Turkey has been the centre of many civilisations and ancient cave houses built in the volcanic rocks can still be seen throughout the region.



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# Jubilant Over Ghana's First Oil

On December 15, 2010, his Excellency **John Atta Mills**, President of Ghana, opened the valve that allowed oil to flow from Jubilee Field wells into facilities on the FPSO Kwame Nkrumah.

Tullow Oil

The event was historic for both Ghana and Tullow Oil. This is Ghana'a first deepwater production and their first real significant oil production. Tullow Oil has laid a foundation as a very capable deepwater operator.

In June 2007, the Mahogany 1 well, drilled by Kosmos, and a second well, Tullow's Hyedua 1 discovered a significant offshore oil field. The find occurred on the 50th anniversary (jubilee) of Ghana's independence for which the field is named. It is a world class discovery containing 490 MMbo gross booked reserves and lies 60 km offshore in deepwater (1,300 to 1,700m). A consortium led by Tullow that includes Kosmos, Anadarko, and E. O. Group has taken only three and half years from discovery to first oil, the fastest ever full-scale deepwater development.

## Promising frontier basin

Ghana's offshore has seen exploration since the late 1960s, but 31 wells drilled by 1998 resulted in the discovery of only three minor oil fields. Only the Saltpond discovery was put into production in 1978, yielding just 3.5 MMbo before being shut-in.

In 1999, Hunt Oil made a minor discovery at Cape West Three Points in 1,000m of water which led to more deepwater exploration in the Tano Basin. Between 1999 and 2004, four deepwater wells were drilled and all four encountered hydrocarbons but not in commercial quantities.

That all changed in 2007 with the discovery of the Jubilee field. Other discoveries quickly followed with the Odum discovery (2008) 20 km east of Jubilee and the Tweneboa field located west of the Jubilee field the following year. These three discoveries represent at least three billion barrels of recoverable oil with a significant associated gas resource.

The most recent discovery was at Dzata in 2010. This field is located 100 km south-east of Jubilee and could be the start of a new exploration trend in the Tano Basin (see *GEO ExPro* Vol. 7, No. 3 pp 46-48).

## Development

Initial flow tests confirmed a highly productive and well connected reservoir. Light (37.6° API) sweet crude oil flowed from stacked net pays of 95m and 41m at rates over 20,000 bopd per well. The excellent, continuous reservoir was demonstrated by water injection tests in 2009 that showed well communication over six km.

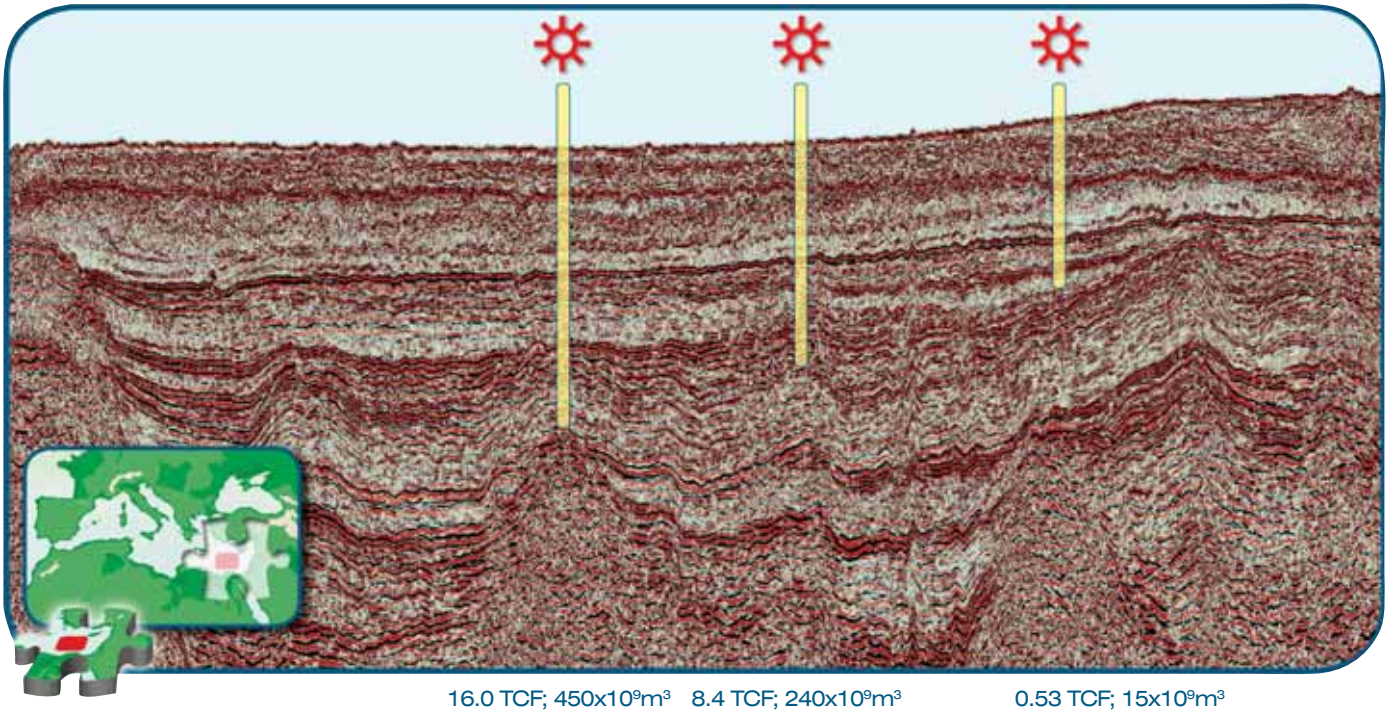
The field appraisal wells were directly linked into the Jubilee Phase 1 development program, which will initially focus on the core area of the field. Installation of subsea equipment commenced in January, 2010. A Floating Production Storage and Offtake (FPSO) vessel will be used to process the liquids and gases brought to the surface from the subsea development scheme. The FPSO conversion started at the Jurong Shipyard in Singapore in November, 2008 and the FPSO 'Kwame Nkrumah' arrived in Ghana in June, 2010. Seventeen wells that include oil producers, water injection and gas injection have been tied back to the FPSO. Initial production was 55,000 bpd and will be increased to 120,000 bpd (the FPSO capacity) in the next few months.

Tullow has development plans for the other fields in the area which could have more oil flowing from Ghana in about a year. This oil is very important and is of great value to the impoverished people of Ghana. However, first things first and Dai Jones, President and General Manager for Tullow Ghana, had this to say about first oil: "…There's huge excitement… some people think we're going to be the next Saudi Arabia the day after First Oil arrives! But it's very important we try to manage the expectations against reality. Often it's said in the media about Ghana's oil industry and where it's going but reality is we are not an oil industry, we are one field which is the first step to creating an oil industry. As Tullow says, this is a 30-year project with a 30-year vision about where we should go."

**THOMAS SMITH**

# Solved: The exploration puzzle in the East Mediterranean...

## ...three world class gas discoveries.



16.0 TCF; 450x10$^9$m$^3$ 8.4 TCF; 240x10$^9$m$^3$ 0.53 TCF; 15x10$^9$m$^3$

The Spectrum library of Multi-Client data incorporates global projects identified by our experienced team of geoscientists. Spectrum recognized the potential of the Eastern Mediterranean and invested in seismic data that contributed to all three of these recent discoveries.

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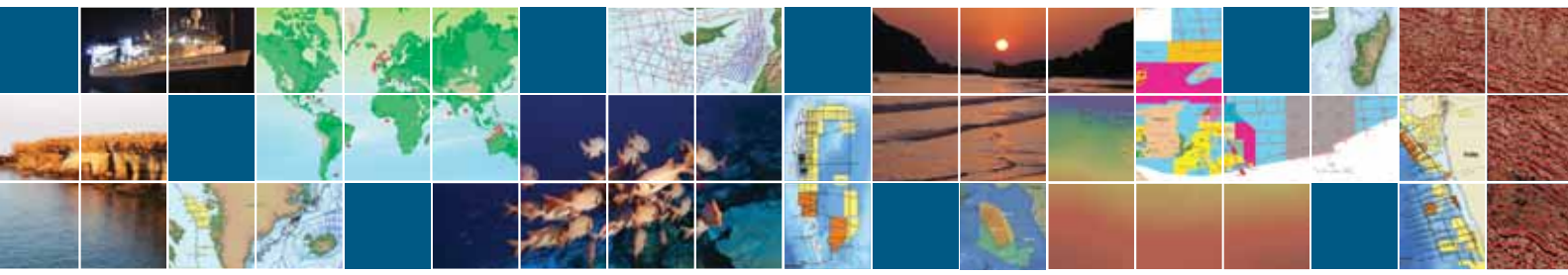

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# Trends in Exploration Discussed at APPEX

***APPEX***, the international ***A***APG upstream ***P***rospect and ***P***roperty ***EX***po to be held in the Business Design Centre in London on 1 - 3 March, is attracting high levels of interest. Over 600 attendees are expected, up 20% on last year, plus existing hot spot and new niche opportunities on offer from over 40 countries.

This year's speaker programme includes both themed and regional sessions, complemented by Prospect Forum presentations from exhibiting companies on their opportunities. The conference will open with the Global Forum titled, "Trends in Global Exploration: The GFC (Global Financial Crisis) and aftermath of the GOM spill considered", with talks by Marlan Downey, Andrew Lodge and Jens Olsen, followed by a forum discussion. The second day features a Finance Forum, with talks exploring key topics such as the current status of funding international upstream projects, trends in global A&D and comparison of prices being paid.

As Mike Lakin, Chairman of APPEX explains; "London APPEX, now in its 10th year, has become a unique, truly international, upstream A&D event which is association driven and run for non-profit. The proven format, including speaker programme and associated exhibit and prospect hall, is not only specially tailored for those established E&P players that attend, but also an increasing number of new companies seeking to buy and sell opportunities. This will include opportunities in the world's existing 'hot-spots' and importantly, potential new niche play areas likely to form the world's up and coming and future exploration hot spots. With its range of new and established E&P companies, countries, NOC's, a senior international audience and opportunities on-show from around the globe, APPEX is a must attend annual event under one roof for all upstream New Venture and A&D managers and their teams."

*APPEX is held in the Business Design Centre in Islington, London, which was originally built as the Royal Agricultural Hall in 1861.*

Mike Lakin

Regional sessions focus on the Middle East, Asia and Europe, including examination of the future potential of India and Oman with talks by Tethys Oil and Rutherford Exploration, as well as by talks on the North Sea Region as a whole. There are also sessions on the Americas, with a presentation on the prospectivity of Jamaica and a status update on the Falklands, and talks on activity in Africa, including the increasingly prospective but under explored areas offshore north-west Africa. Further sessions will then consider opportunities in the Far East and Australia, as well as a look at the future of deep water exploration.

The Prospect Forums will highlight available opportunities from E&P exhibiting companies from around the world, covering both unexplored, but potentially prospective, conventional and unconventional projects. Coyntries covered will include Canada, Syria, Sri Lanka, Malaysia, Vietnam, Australia, New Zealand. Iceland, NW Europe, Alaska, Uruguay, Peru, the Caribbean, Morocco, Senegal and South Africa. The most up to date programme can be found at: www.appexlondon.com.

As well as the programme of speakers, there is a very comprehensive exhibition where visitors can obtain further information at any time during the event. Exhibitors include NOC's, operating companies and service providers. For many exhibitors APPEX is a must-attend event, as Richard Bottomley, Senior Vice President Sales for DI International explains; "APPEX was very successful for us last year and this year promises to be even better. Not only do we get to meet people and companies influencing the future of E&P, but, importantly, we get to speak directly to end users of our information products."

**MARCUS STONE**

## ABBREVIATIONS

**Numbers**
(U.S. and scientific community)

| | |
|---|---|
| M: thousand | $= 1 \times 10^3$ |
| MM: million | $= 1 \times 10^6$ |
| B: billion | $= 1 \times 10^9$ |
| T: trillion | $= 1 \times 10^{12}$ |

**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

# UK Onshore Geophysical Library

Collecting data since 1994, the UK Onshore Geophysical Library holds 98% of all the UK onshore seismic data ever recorded.

"Back in the mid-1990s, before the 7th Onshore Licencing Round, the UK government realised that they had no method of releasing and distributing onshore data," explains Malcolm Butler, Chairman of the UK Onshore Geophysical Library (UKOGL). "But acquiring onshore data in a country as intensively built up as the UK is difficult and expensive, so it is important to archive and distribute existing data. And that is what we have been doing ever since, initially on behalf of the DTI (Department of Trade and Industry) and now for the Department of Energy and Climate Change."

The Library was set up in 1994 as a non-profit making charity run by a board of Trustees, selected to represent the interests of both industry and academia. It has been operated since its foundation by oil industry consultancy Lynx Information Systems Ltd.

"Our first task was to locate and archive all the data which the DTI believed had been shot onshore, and which was now in the public domain after the initial five year confidentiality period," adds Neil Anderton, Operations and Projects Manager with Lynx. "We approached companies to request data, initially survey by survey, until the concept was accepted by the industry. Once they realised the value of the Library, companies were very happy to donate their entire onshore archives. As a result, we now believe that the archive holds 98% of the geophysical data ever shot onshore the UK – 73,000 line kilometres out of a total of 75,000."

"Initially, the collection was funded by donations from a couple of large companies, which were used to archive all their data and make it available for sale. Since then, smaller donations have augmented data sales, with all funds reinvested to find more data. Sales took off dramatically in 2007, in advance of the 13th Onshore Round, building UKOGL's cash resources beyond the level required to archive the outstanding data sets . This means that we now have sufficient funds to develop our internet portal, with downloadable data images, giving people a glimpse into what the archive comprises, which encourages interest in new onshore acreage," Neil continues.

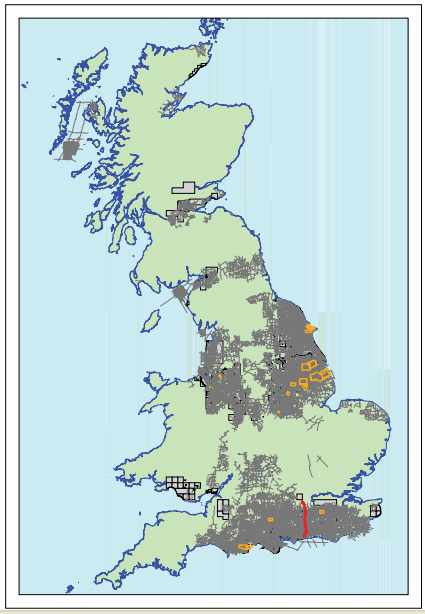
In November 2010 the UKOGL website was relaunched with improved functionality, allowing researchers easier access to high quality JPEG images from the seismic archive, put into context with additional cultural, geological and topographic data. "This allows us to provide value-added products as well as data," Neil adds.. "And in addition to seismic information, we have well tops for about 650 wells from across the UK. Much of the data, including shape files, are available free of charge."

The latest initiative is the creation of regional profiles, amalgamated from a number of lines of various vintages and quality, helping to give a basin-wide understanding of the onshore UK subsurface.

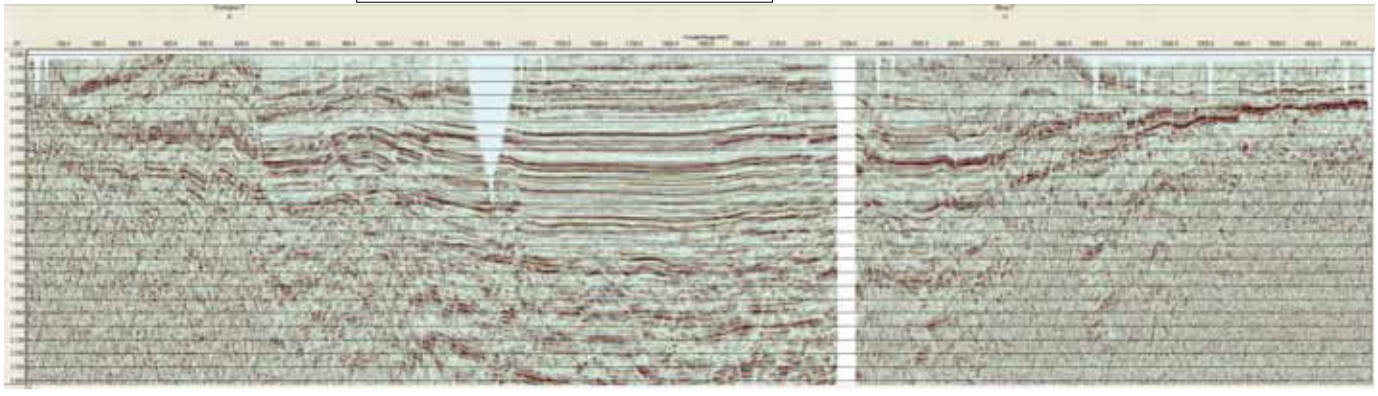
"UKOGL has been very successful both technically and financially, and has proved its worth to the hydrocarbon industry, to academia and to institutions like the British Geological Survey. The rise of shale gas throughout the world means that we expect a lot of interest in the next UK Onshore Round in 2011, and the data will be available to enable companies to make informed bids," Malcolm concludes.

**JANE WHALEY**

*Malcolm Butler is Chairman of the Board of Trustees which runs the UK Onshore Geophysical Library.*



*A composite image using data from various surveys allows interested parties an unprecedented basin-wide view across the Weald Basin, freely downloadable from the UK Onshore Geophysical Library website (line of section shown in red on map).*



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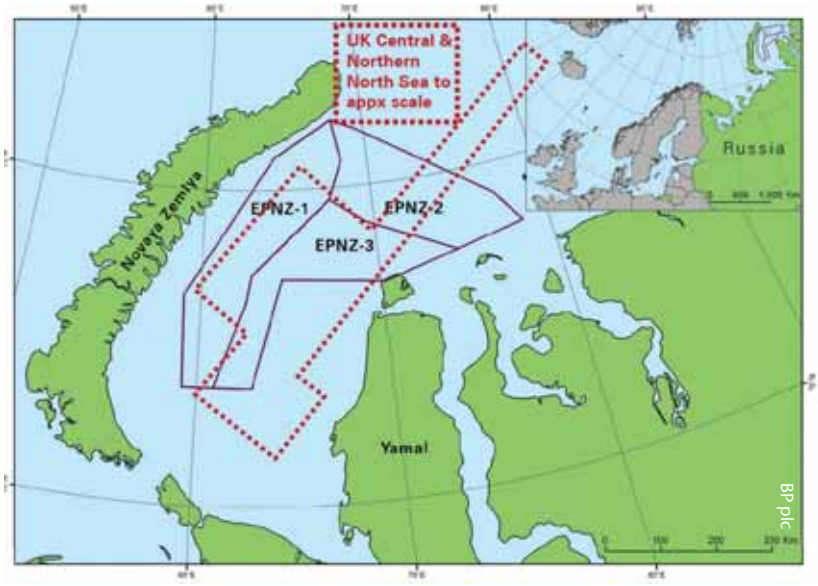
# BP and Rosneft in Strategic Alliance

Two energy giants sign the first major equity-linked partnership between a national and international oil company in order to explore for hydrocarbons in the Arctic.




*The agreement between BP and Rosneft covers the highly prospective South Kara Sea on the Russian Arctic continental shelf.*


*BP chairman Carl-Henric Svanberg with Rosneft President Eduard Khudainatov at BP headquarters in London on January 14, 2011.*

Russia is the world's largest oil and gas producer – and two of the leading producing companies in the country are Rosneft and BP, the latter through its subsidiary, TNK-BP.

So it was an obvious step when these two energy giants signed a strategic alliance, in the middle of January, with the aim of searching for hydrocarbons in the Arctic. They have agreed to explore and develop three license blocks, EPNZ 1, 2 and 3, which were awarded to Rosneft in 2010. These cover about 125,000 km$^2$ in the highly prospective South Kara Sea on the Russian Arctic continental shelf – an area as large as the whole of the UK North Sea. Together, they will form a joint operating company to investigate the area, with a 66.67% Rosneft, 33.33% BP participation.

The companies have also agreed to establish an Arctic Technology Centre which, in co-operation with leading Russian and international research institutes will concentrate on developing innovative technologies to ensure safe methods of exploiting hydrocarbons in this environmentally sensitive area.

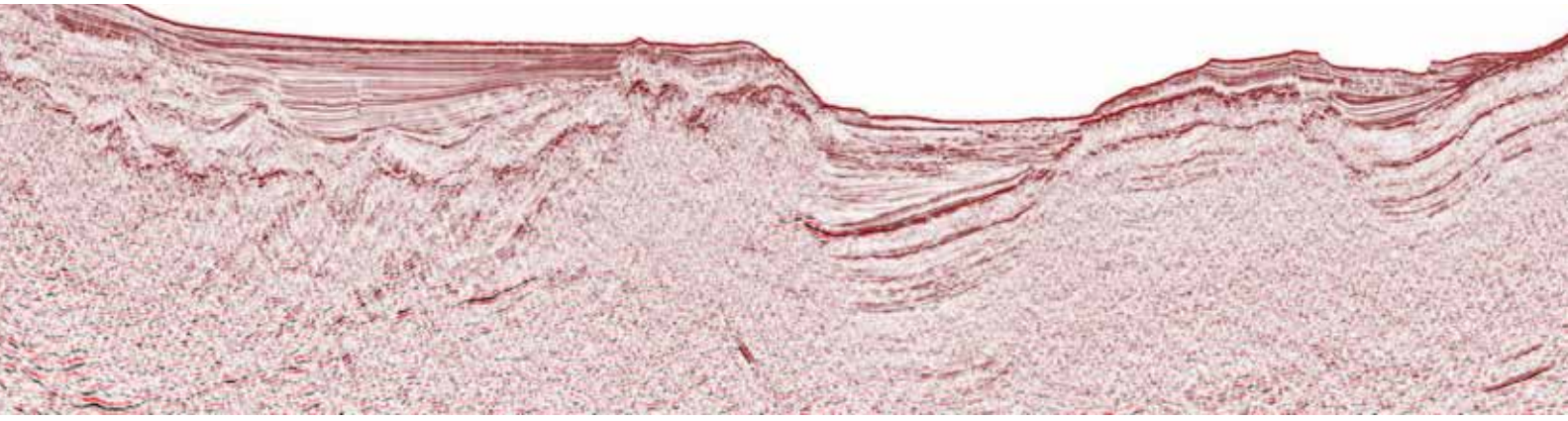
The deal has the support of both the Russian and the UK governments. British Energy Minister Chris Huhne, who attended the signing ceremony in London, said that the deal could have huge benefits "not only for both companies but for the relationship between our countries." Igor Sechin, Deputy Prime Minister of the Russian Federation, who also participated in the signing ceremony, said: "Global capital and Russian companies are clearly ready to invest in world class projects in Russia; and Russian companies are quickly emerging at the forefront of the global energy industry."

This is not the first time that BP and Rosneft have forged an agreement. In 1998, they started an alliance that eventually led to the formation of three joint ventures to conduct exploration offshore Sakhalin, and In 2006, the two companies launched a scientific research study to evaluate the Russian Arctic. They will continue their joint technical studies in the region to assess hydrocarbon prospectivity in areas beyond the Kara Sea.

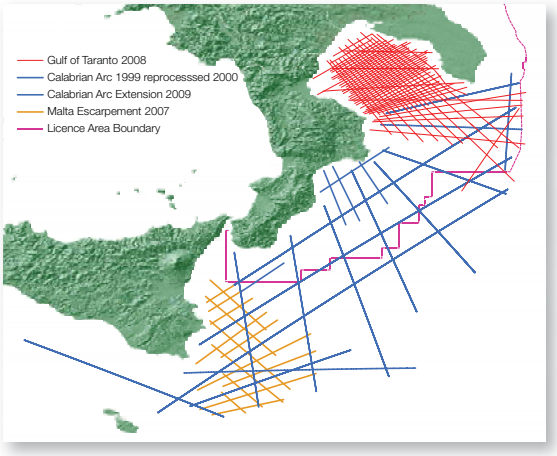
However, this new agreement represents a major change in the relationship, as it includes a share swap, and as such it is the first major equity-linked partnership between a national and international oil company.

**JANE WHALEY**

# SOUTHERN ITALY **2D DATA**...



*Gulf of Taranto - GT08*

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# Turmoil in the Middle East

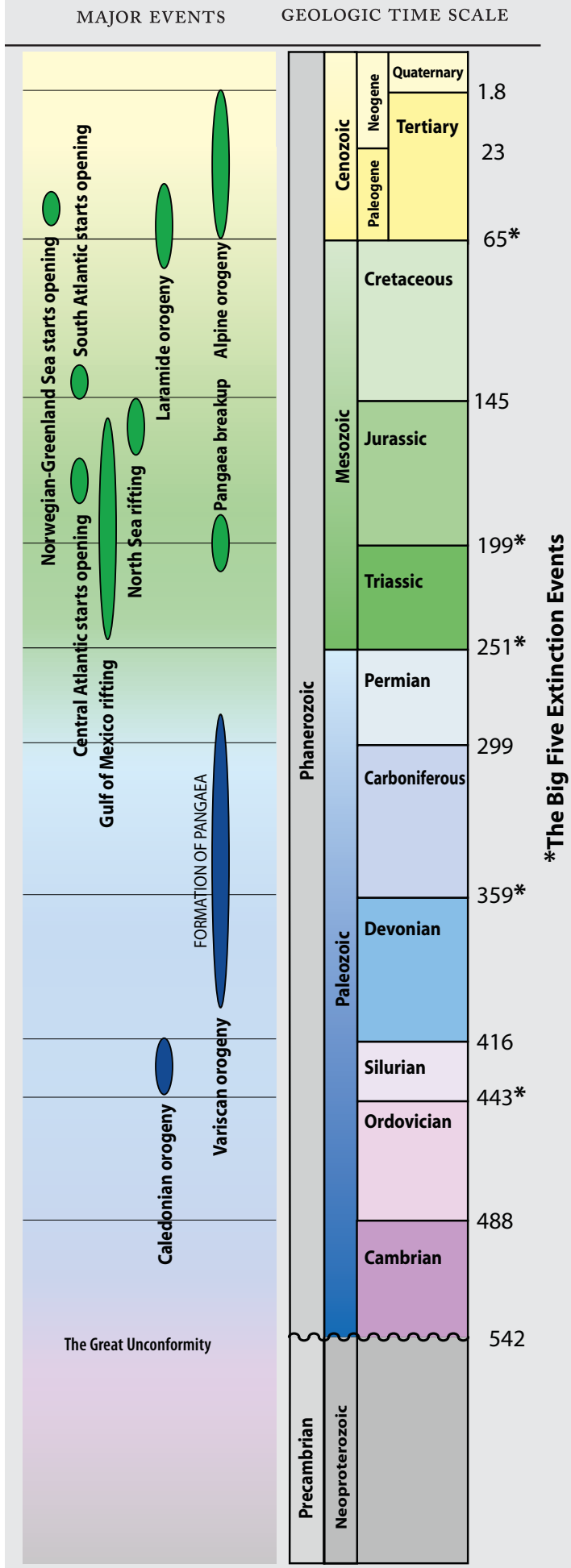
The alarm bells are ringing as political risk moved to the top of the agenda of the international oil market last week. Popular uprisings have occurred in Tunisia, Egypt, Jordan and Yemen, with rumours and discord rife throughout the region. The turmoil in Egypt reminds us once again about the unstable political conditions in vital oil-producing areas in the world and our growing dependence on oil extracted from these areas. Although Egypt does not account for more than 0.9% of global oil production and consumes about the same amount, the growing concern, especially in the Arab world, is the spill-over effect if the protests spread to the oil-producing regimes of the Gulf. The Persian Gulf accounts for around 30% of the world's oil production and controls around 56% of the proven reserves.

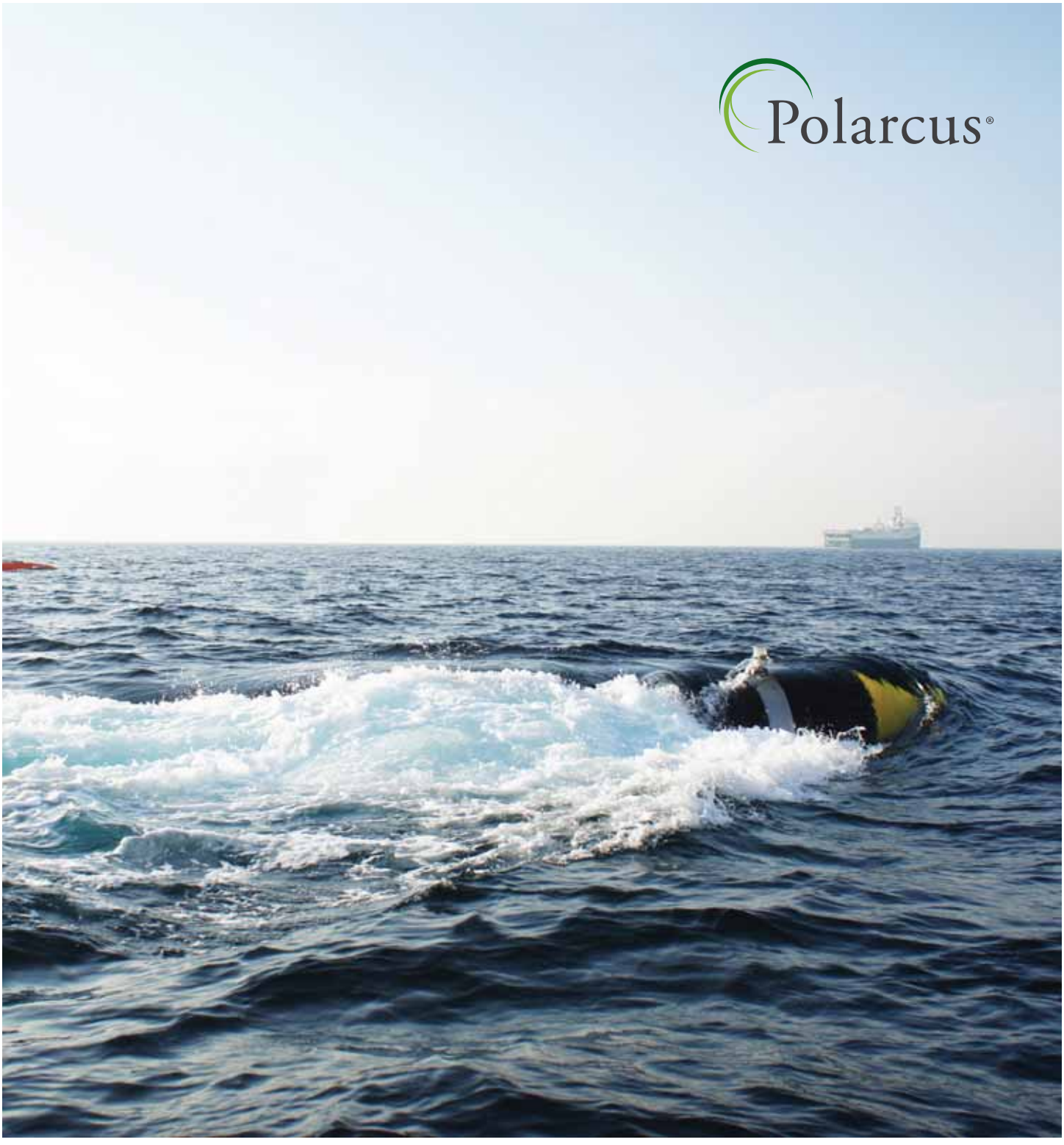
The most imminent danger for the oil market is the closure of the Suez Canal, the key transportation artery linking the Mediterranean with the Red Sea, or the shutdown of the Sumed pipeline, which transports around 1.2 MMbopd. According to PIRA, petroleum tankers accounted for 16% of the cargo traffic in the Suez Canal in 2008 carrying in total around 790,000 bopd; 470,000 bopd going north and 318,000 going south. In addition, 1.3 MMbpd of oil products were shipped through the canal, split roughly equally in each direction.

The lion's share of the cargoes passing through the canal is container ships, making up 50% of the volume, while bulk carriers account for 14% and car carriers for 9%. So not only oil will be affected by a temporary shutdown of the canal, as this would redirect shipping traffic the long way around Africa, pushing up freight cost and increasing delivery times.

**THINA MARGARETHE SALTVEDT Ph. D**
**SENIOR MACRO/OIL ANALYST,**
**NORDEA MARKETS, OSLO**


*Storm clouds are gathering over Cairo*



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# Joint Approach for EOR


*Shell Technology Centre, Amsterdam*

"Much of the world's existing reserves are only producible through enhanced recovery techniques," says Ashok Belani, president of Schlumberger's Reservoir Characterization Group. With this in mind, Schlumberger have joined forces with Shell in a multifaceted research programme aimed at improving the recovery factor of oil and gas reservoirs and extending the life of existing oil and natural gas fields.

The project combines Schlumberger's formation evaluation and reservoir characterisation knowledge with the subsurface laboratory and reservoir expertise of Shell in order to improve field data, develop better and more efficient numerical models, and enhanced field development methods. It will focus on two specific projects. The first will focus on new surveillance tools and techniques designed to deliver more accurate field data and to accelerate EOR feasibility studies and projects, while the second project, known as 'Digital Rock', will investigate ways to forecast displacement and recovery at the macroscopic pore scale, as well as methodologies to scale up core and pore-scale work to reservoir level for both sandstone and carbonate fields. Ultimately the project aims to shorten development cycles, increase production, and enhance oil and gas recovery using novel laboratory scanning technology, fluid dynamics modelling, and high-performance computing.

# INOVA System to Iraq

INOVA Geophysical Equipment Limited, a leading provider of land geophysical technology, has made a major sale to Dubai-based geophysical data acquisition service provider, Terraseis. The deal, which involved 13,000 channels of INOVA's cable-based land recording system, ARIES II, will be used by one of the largest operating crews in Southern Iraq. Deployment of the equipment commenced late in 2010 and the system is expected to be fully deployed by the end of the first quarter this year.

INOVA's land acquisition systems and source products are designed to maximize return on investment by minimizing equipment related downtime and reducing the impact of harsh environmental and operational conditions, such as those routinely experienced by the Terraseis teams in Iraq, Kurdistan and West Africa. Terraseis have become a recognised leader in acquiring seismic data in challenging geographic, economic and political environments

INOVA is a joint venture between BGP (a wholly owned subsidiary of China National Petroleum Corporation) and ION Geophysical Corporation.


*A crew in the Middle East works with INOVA's ARIES II land recording system.*

# New North West Africa Survey


The Mauritania-Senegal-Guinea Bissau-Conakry basin, commonly known as the MSGBC basin, is one of Africa's last relatively unexplored offshore shelf areas. To shed light on this promising region off North West Africa, Norwegian geophysical company Bergen Oilfield Services (BOS) is due to start acquisition of new long offset 2D seismic in the early part of 2011. The company has signed agreements with the authorities in Senegal, Gambia, AGC (Senegal/Guinea Bissau Common Zone), Guinea Bissau and Guinea Conakry to acquire, process and promote this new data to help understanding of this Atlantic margin area.

This new multiclient survey will consist of 15,000 line kilometres, stretching from the north of Senegal to the border between Guinea and Sierra Leone, a distance of over 1,200 km. The long offset cable will deliver improved velocity control and enhanced AVO analysis potential, and modern multiple attenuation processes designed to give better signal to noise ratio will be applied. BOS is working in conjunction with expert consultants Exploration Geosciences Limited to design the survey, which, tied to key wells and unconstrained by national boundaries for the first time, will provide exploration companies with an unrivalled opportunity to gain a unique overview of the region, potentially revealing new exploration leads and prospects.

# New Triggerfish Version

Sercel, a leading designer and manufacturer of seismic equipment, has released a new version of TriggerFish™, its innovative real-time navigation, and data acquisition system. TriggerFish™ allows for flexible control over a distributed fleet of vessels and is designed to provide a cost effective solution for a range of acquisition systems, from towed streamers to ocean bottom, including embedded sea floor and node based seismic systems. It can be used from the transition zone to deepwater and provides navigation, accurate time stamping, helmsman's information, source synchronisation and data input and output in standardised format.

The new version, TriggerFish 1.7, which was unveiled in late 2010, has a number of additional productivity enhancing features. These include multi shooter/multi recorder, advanced radio communications and fleet synchronization and additional safety features through enhanced mapping functionality

Since its deployment in the field in late 2010, the new system has enabled customers to benefit from major productivity-boosting features. The system's multi-vessel function is scalable to allow up to four vessels per radio link, providing improved flexibility and increased productivity. And with the new version, fewer operators are required, reducing the cost of operations, and longer radio network ranges enable more advanced survey designs using larger seabed receiver patterns, longer streamers, and longer wide-azimuth offsets.

# Record Well in Sakhalin

The longest extended-reach well ever was successfully drilled at the Odoptu field, in the Sakhalin-1 area of offshore far east Russia. The Odoptu OP-11 well reached a staggering total depth of 12,502m and a world record horizontal reach of 11,475m and was completed in only 60 days. Sakhalin is one of the most challenging environments for oil exploitation in the world, with a harsh arctic climate and very difficult and remote geographical conditions. Extended reach drilling technology has been designed to reduce the high capital and operating costs of large offshore structures and at the same time minimized the environmental impact in sensitive areas like this.

The well was drilled by Exxon subsidiary, Exxon Neftgas Ltd, using ExxonMobil's specialised proprietary technologies such as Integrated Hole Quality (IHQ) technology and the Fast Drill Process, which maximise effectiveness by taking into account design variables including rock strength, stresses and well-bore hydraulics. It was drilled using the Yastreb land rig, which was designed to drill extended reach wells to offshore targets from land-based locations and is one of the most powerful land rigs in the industry.

The Sakhalin-1 Project is developing three oil and gas fields, Chayvo, Odoptu, and Arkutun Dagi, and the first well was drilled in 2003. Since start up, about 300 MMbo have been produced for export, along with approximately 235 Bcf (6.8 cm) of gas, which is used locally. Odoptu lies about 10 km offshore north-east Sakhalin Island and 75 km north of the Chayvo field and drilling started there in May 2009.


*Exxon Neftegas Limited drilled the world's longest extended-reach well at the Odoptu field at the Sakhalin-1 project, offshore Far East Russia, using the shore-based Yastreb rig.*

# Britain's Best Kept Secret?

A survey undertaken by Oil and Gas UK suggests that, in Britain at lease, considerable work is needed to change the public perception of the industry. The specially commissioned research, carried out by Ipsos MORI in late 2010, compared knowledge of, and attitudes to, the oil and gas industry among adults in Aberdeenshire and Greater London. It revealed major gaps in the knowledge of those interviewed.

For example, many people do not realise how much of the UK's energy supply comes from its own oil and gas production, and a significant number think the majority of oil and gas used in the UK is imported from abroad. And, evidence of the amount of coverage of alternative energies in the press, the majority overestimated the amount by which the country would become less reliant on oil and gas over the next ten years, with few people realising that by 2020 about 70% of primary energy consumed in the UK will still come from oil and gas.

Oil and Gas UK concluded from this survey that the industry needs to raise its profile, believing that the general public's underestimation of the importance of oil and gas production to the UK could have long-term consequences for growth and investment. This is a message that could probably be taken on by the industry throughout the world.

However, a surprising result of the survey was the discovery that over half those surveyed gave favourable opinions on the way the industry conducts itself with regards to the environment, providing jobs, securing UK energy supplies and contributing tax to the government.

# Into the 'White Zone'

# Exploration in the North-West Atlantic Margin

Faroe Petroleum's focussed exploration strategy, concentrated chiefly on the challenging waters of Norway and the Atlantic Margin, is paying off.

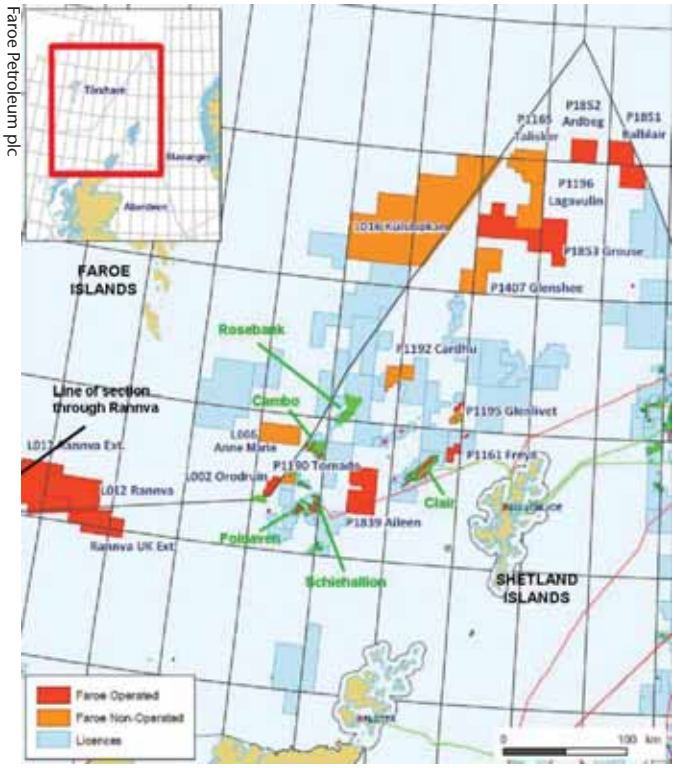
JANE WHALEY

The North-West Atlantic Margin is the area stretching from the western edge of the Norwegian Sea through the Irish continental margin and the UK waters referred to as 'West of Shetlands', all the way to the Faroe Islands, 300 km north-west of Scotland. Although exploration commenced in the 1970s, this vast area has not received much attention from companies exploring for oil, but that is beginning to change, and Faroe Petroleum is at the forefront.

"The area between the Shetland Islands and the Faroes was known as the 'White Zone', until resolution of the boundary dispute between Faroe and the UK in 1999. It could be regarded as one of the only true frontier areas left in North-West Europe," says Graham Stewart, Chief Executive of Aberdeen-based Faroe Petroleum. "After the discovery of Foinaven and Schiehallion in the UK West of Shetlands (WoS) in the 1990s proved the potential of the area, we formed Faroe Petroleum with the specific intention of exploring for hydrocarbons in this challenging but very promising area."

Established in January 1998, and listed on AIM in June 2003, Faroe Petroleum has rapidly increased its holdings from a mere two licences offshore the Faroe Islands to a focussed exploration portfolio with interests spanning Norway, UK West of Shetlands, and UK southern North Sea, as well as the Faroes. The company acquired its first UK acreage in 2004, moved into Norway in 2006, and now is involved in over 40 licenses, both as operator and partner, working with some of the best and largest oil companies in the world. The company's resource potential at present, as defined by independent consultants Senergy, stands at 225 MMboe risked, and 1,360 MMboe unrisked.

Faroe Petroleum plc




*Involved in 17 licences, and operating in eight of them, Faroe is now one of the major licence holders in the Atlantic Margin.*



*Graham Stewart is a Petroleum Engineer by training, but has spent most of his career in the oil industry in the commercial field. Half-Faroese, he has a particular interest in the Faroe Islands.*

## Untapped potential

"When we started Faroe Petroleum with the intention of concentrating on these, at that point, relatively unproductive waters, we felt that they held great potential, despite the fact that by the early 1990s over 100, mainly shallow water wells had been drilled across this huge area without a commercial discovery," explains Graham. "The reservoir challenges of the multi-billion barrel Clair field, discovered in 1977 by BP, were not resolved until the late '90s following an extended well test, using a technology which has since unlocked the potential of many stranded reservoirs – horizontal well drilling."

The first discovery of note WoS after Clair was BP's 380 MMbo recoverable Foinaven field, found in 1992 after modern seismic techniques and AVO analysis indicated a high probability of hydrocarbon-filled sandstones. This was followed by the Schiehallion field, also by BP, with 425 MMbo trapped in submarine slope sandstones of Paleocene age. Despite the challenges associated with drilling in these, storm-tossed waters, the potential had finally been revealed.

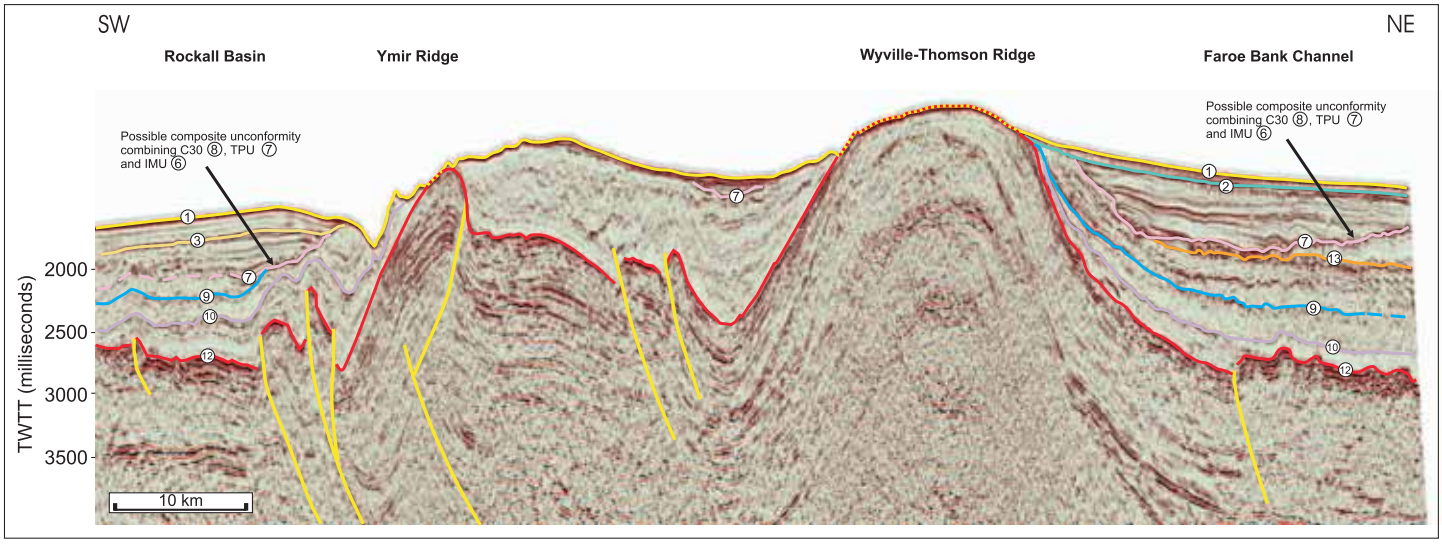
"Since the discovery of these giant fields, the deep waters have been regarded as the most promising source of the huge oil reserves major oil companies are looking for," Graham adds. "They led many companies to consider drilling on similar stratigraphic traps rather than the more conventional and less risky structural traps typically targeted in new basins. However, that approach created many disappointments, and since then a new focus on structural traps has been pursued in more recent exploration wells, resulting in a significant increase in material discoveries, including Chevron's Rosebank and Hess's Cambo."

## Billion barrel prospects

"Our first area of interest was the Faroe Islands, because acreage was only just becoming available, and I had been involved in preparing the Faroese Islands for their first Licensing Round. Also, I have ▶

*Interpreted seismic reflection profile across the Wyville–Thomson and Ymir ridges. Seismic horizons are (1) Sea bed, (2) Intra Neogene Unconformity, (3) C10 Unconformity; (7) Top Palaeogene Unconformity (TPU), (8) Intra-Eocene Unconformity b, (10) Intra-Eocene Unconformity c, (12) Top Paleocene lavas and (13) Opal A-Opal C/T transformation horizon. Line of section shown on Faroe Petroleum portfolio map.*

From Johnson et al, 2005



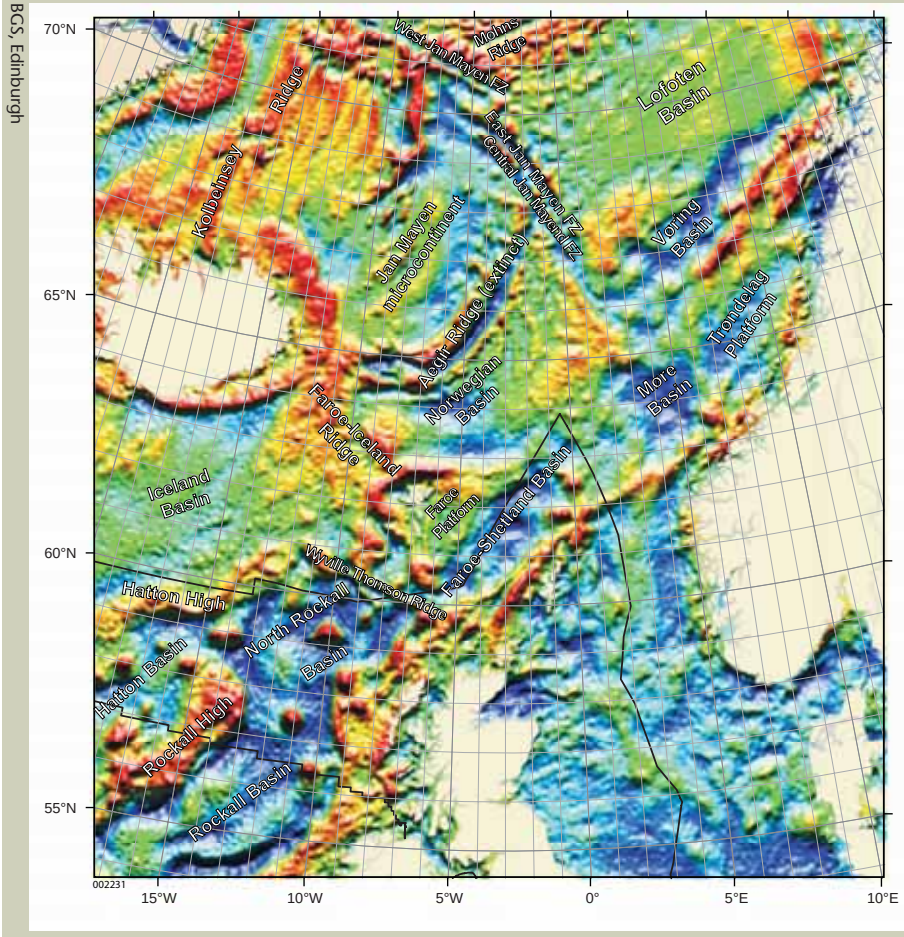
## THE FAROE SHETLAND BASIN

The Faroe-Shetland Basin covers a very large geographical area, similar in size to the UK Viking Graben, but it is considerably less explored. Geophysical evidence suggests that it contains more large undrilled structural traps than the North Sea, but widespread basalt layers mask the deep structures and have historically been responsible for poor seismic data.

The basin has undergone a similar tectonic history to the North Sea, although more recently, with the main Atlantic opening occurring in the Tertiary. Palaeogene subsidence in the Faroe-Shetland Basin resulted in the accumulation of major submarine fan reservoirs, the thickness of which allowed for the maturation of the underlying Jurassic source rocks. The ensuing evaporitic phase resulted in the widespread deposition of Upper Cretaceous evaporates, which form an extensive regional seal.

The source rocks are the same as those feeding many of the North Sea reservoirs; the prolific Kimmeridge Clay, deposited as a result of Jurassic rifting. In the Faroe-Shetland Basin, however, there is thought to be a larger gas kitchen, due to the greater thickness of Cretaceous-Tertiary overburden. There are also probably additional mid-Jurassic source rocks.

Known reservoirs in the Atlantic Margin include high performance Palaeocene reservoirs such as those already found in fields like Foinaven and Schiehallion, which are comparable in quality to many North Sea reservoirs. There are widespread Lower Cretaceous reservoirs and also Pre-Cretaceous reservoirs, although of lower quality than the North Sea. In addition to these, the Clair field is producing from Devono-Carboniferous reservoirs comparable to North Sea reservoirs found in major fields such as Buchan and Stirling.




*Regional gravity map of the North West Atlantic Margin*

a particular interest in the islands; both my mother and my wife are Faroese, and I spend as much time there as possible. It's a wonderful place!"

"We initially formed as a Faroese company in 1998, a year before the dispute between the Faroes and the UK was resolved. We teamed up with Eni and were successful in winning two prime exploration licences in the Faroes. We were off to a flying start."

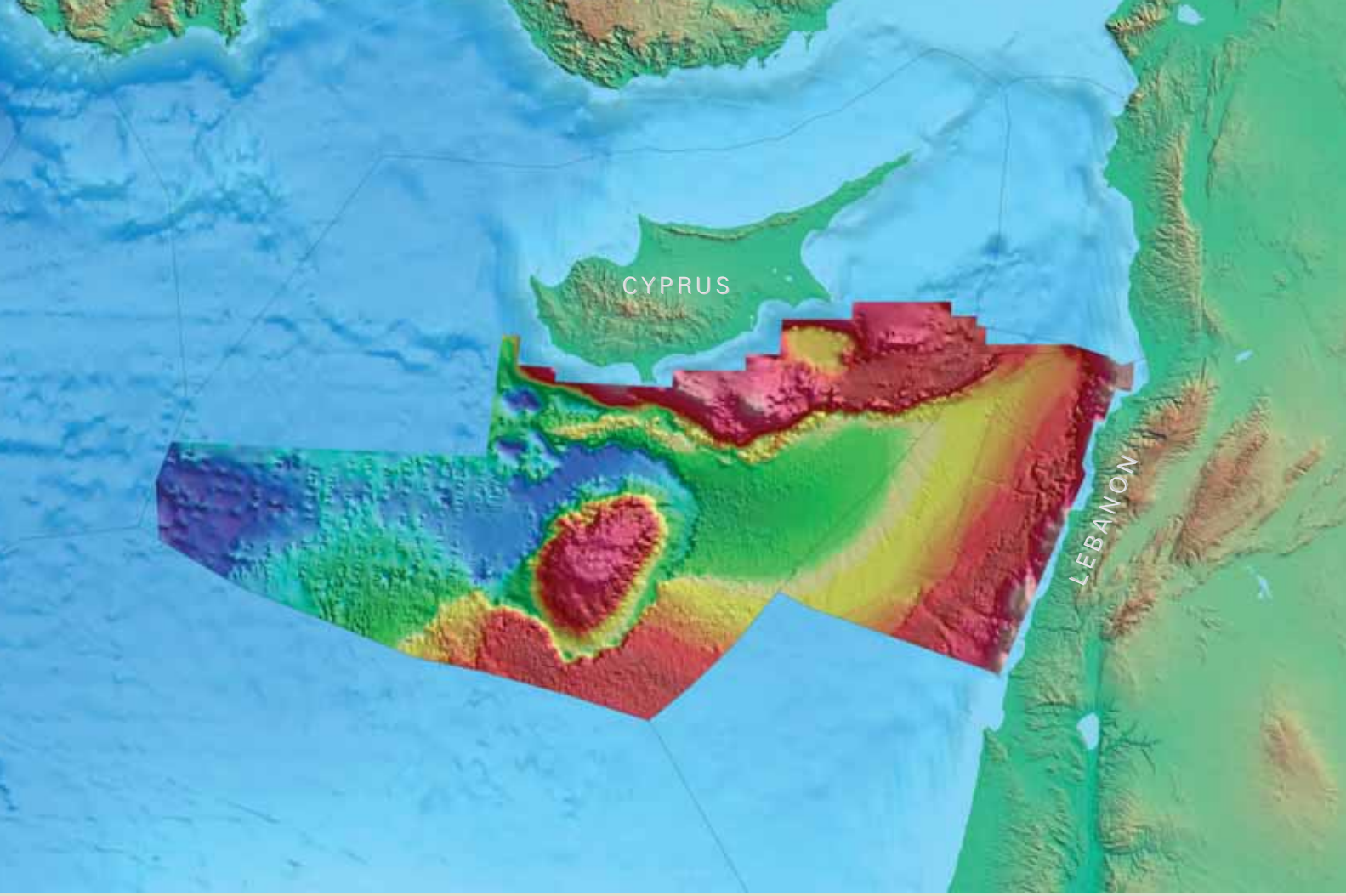
Seven wells have now been drilled in the Faroes, yielding mixed results, though a working petroleum system has been proven. The most recent well was Anne Marie, drilled by Eni in 1,000m of water in 2010, which was announced as a discovery, having confirmed significant presence of hydrocarbons, but unfortunately lacking good quality reservoir rock. (For a discussion on the history of exploration in the Faroe Islands, see *GEO ExPro* Vol. 7, No. 3).

Faroe Petroleum's main operated interest in Faroese waters is the (so-called) Rannva block on the Wyville-Thomson Ridge, which has been described as the largest undrilled anticline in North West Europe. It is visible on the seabed as a positive feature, extends almost 200 km in a west-north-west to east-south-east direction from Faroese into UK waters, and is over 25km in cross section. Forming the physical boundary between the Rockall Trough and the Faroe-Shetland Channel and probably overlying a deeply buried transfer zone, it has been attracting interest for many years.

The company first obtained acreage over the Ridge in 2005 in the 2nd Faroese Licensing Round, extending this in the 3rd round. It also obtained the adjacent blocks over the border in the 25th UK Round in 2010. The geologists believe they have identified two major billion barrel prospects, with Rannva A, in Faroese waters, estimated to hold 1.5 Bbo (P50) and Rannva B, which straddles the border, having an estimated 1.37 Bbo (P50).

### High risk – high reward

"These are 'high risk – high reward' projects," says Graham. "Although the acreage is in relatively shallow waters for this region, less than 500m, the prospects are sub-basalt, and drilling through basalt ▶




# MegaSurveys

## Eastern Mediterranean MegaProject

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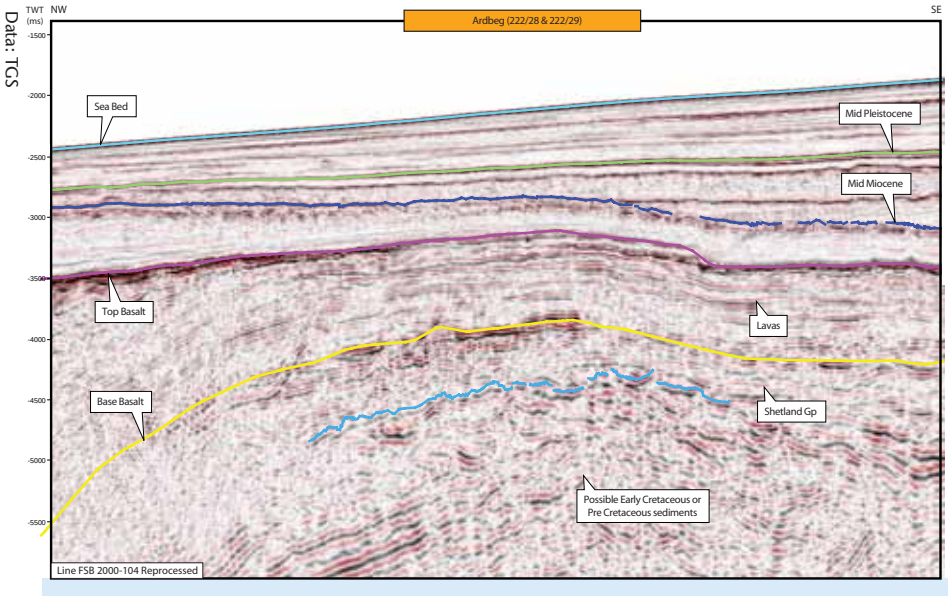



*Line FSB 2000-104 reprocessed in 2009 showing an example of a sub-basalt play – the Ardberg prospect, at 63°N in one of the most northerly blocks available in UK waters. The processing reveals a higher signal-to-noise ratio below the basalt layer. The shallow, low relief Ardbeg structure is clearly demonstrated.*

is expensive. We know the volcanics thin considerably in the vicinity of the Wyville-Thomson Ridge, with a prediction of around 500m over Rannva itself, and we are undertaking further analyses using modern techniques like Marine Magnetotellurics (MMT) to reduce the level of uncertainty before we drill." MMT measures the natural low-frequency electromagnetic field of the earth, and since basalts are highly resistive, a direct measurement for the true-basalt thickness can be derived. Faroe has successfully used this technique on a previous WoS prospect and are confident that it will deliver a result.

"At the moment we view the key risks to success as hydrocarbon charge and migration, since there is no well control within 45 km. On the plus side, however, gravity data suggests that the Wyville-Thomson Ridge structure maybe an inverted sedimentary basin beneath a basalt cap, and we believe that there is significant potential for up to 6 km of pre-basalt sediments."

Faroe Petroleum have been involved in four of the seven wells drilled in Faroese waters. "These have involved using lots of new, modern techniques to test different play types, in various water depths. As a result of our sub-basalt experience in the Faroes and WoS, we probably have as much experience as any other company in the applications of new technologies in exploring sub-basalt plays," says Graham.

## Promising acreage

It is not only in Faroese waters that Faroe Petroleum has promising acreage. It confirmed its commitment to in the UK West of Shetland by taking interests in eleven licenses in the area. Tornado in the UK sector is one of Faroe's recent successes, a gas/oil discovery with up to 300 Bcfg, operated by OMV.

About 100 km west of the Shetland Islands in the Foula sub-basin is the promising Aileen prospect, which explores the Upper Cretaceous turbidite sand play found in the recent Total-operated significant gas discovery, Edradour, about 60 km to the north. Hydrocarbons are thought to have migrated from Upper Jurassic shales, which are the main source rocks for the Foinaven and Schiehallion fields to the west of Aileen and the Clair field to the north-east.

"The Edradour discovery in the same Cretaceous play adds considerable interest to the potential of Aileen. However, we still have a lot of work to do de-risking the prospect before we drill,"says Graham.

"We are also following Palaeozoic plays in two interesting prospects, Freya and Fulla, on the Rona Ridge, about 50 km north-east of the Shetlands. These are just 20 km north-west and on strike with BP's huge 5 Bbo (in-place) producing Clair Field," Graham explains. "Mature Jurassic source rock is found to the west of the Rona Ridge and the Devono-Carboniferous Palaeozoic sediments which form the reservoir in Clair were found in the Freya discovery well, drilled by Mobil in 1980, in search for an extension to Clair, in which they were not an equity holder. The well found a 300m oil column and although tests were inconclusive, we believe there is good potential here. Early Clair Field vertical appraisal wells had similar results, until technology advances in horizontal drilling achieved a breakthrough in Clair by intersecting fractures and favourable permeability."

A similar scenario is expected on the Fulla prospect, just a few kilometres north-east of Freya, where again the trap is a rotated fault block, with dip and fault closure. This is due to be drilled by Faroe, (operator with 50% equity) during 2011 and success here will both de-risk Freya and potentially sufficient resource will be identified to justify a standalone development.

"Overall, these are low risk opportunities, but with gross potential in-place STOIIP of over 250 MMbo," Graham says. "We believe in having a balanced portfolio, with a range of risk – but even wells drilled on so-called 'low risk – low reward' prospects can come up with nice surprises, as we discovered last year with our Marie discovery in mid Norway!"

## Testing the limits

Much of the recent interest in the Western Approaches has developed around the successful exploration and exploitation of sub-basalt plays, as found in Chevron's Rosebank discovery, 100 km north-west of the Shetlands. As well as chasing this play in Rannva, Faroe Petroleum is pursuing it in the North Corona area, over 300 km north of the Shetland Islands and the most northerly extremity of UK waters.

A number of prospects have been identified in this area, including Lagavulin, where drilling on the Pilot Whale anticline commenced in late 2010, and is still ongoing at the time of press. These are high risk prospects, because the area is 150 km from the nearest proven well to have penetrated the Upper Jurassic shales, but encouraging geophysical evidence for hydrocarbon charge has been observed. "This well proves our commitment to the area – and our courage!" Graham says. "At 1,569m, the water is the deepest to have been drilled West of Shetlands, and it is also the furthest north. And we are drilling in winter!"

## Significant upside potential

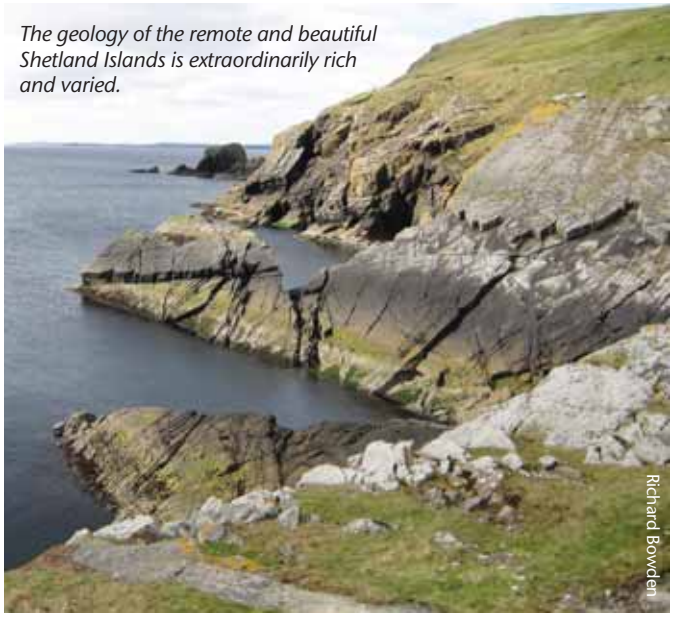
"We believe that the Atlantic Margin has such potential that we have built a whole company around it," he continues. "We have a focussed exploration portfolio and a multi-well exploration and appraisal drilling

programme, partially funded by moving into producing fields in the UK and Norwegian North Sea. With our partners we have had four discoveries in a row in the past 18 months, and we expect to report on three Atlantic Margin wells in 2011 alone, with many more planned for the future.

"We are now known as successful frontier explorers. Our key strengths lie in our strong exploration and excellent commercial teams, all of whom have experience of working for successful independents and majors. They are the reason why we have a reputation for excellence in the industry and major oil companies are keen to partner us. We do almost all our own work, both technical and commercial, relying little on outsourcing in our key disciplines, to ensure we build and maintain an outstanding knowledge base. Everyone in the company is a shareholder, crystal clear on our strategy and strongly focused on pushing out the boundaries."

"It's very exciting – and very rewarding," Graham Stewart adds. "Our geoscientists get to identify prospects, work them up, and see them drilled, frequently with good results. What more could you want?"

**REFERENCE:** *JOHNSON, H., RITCHIE, J. D., HITCHEN, K., MCINROY, D. B. & KIMBELL, G. S. 2005. Aspects of the Cenozoic deformational history. In: DORÉ, A. G. & VINING, B. A. (eds) Petroleum Geology: North-West Europe and Global Perspectives—Proceedings of the 6th Petroleum Geology Conference, 993–1007. ©Petroleum Geology Conferences Ltd. Published by the Geological Society, London.*



*The geology of the remote and beautiful Shetland Islands is extraordinarily rich and varied.*

Richard Bowden

# New Insights into the Levantine Basin


ØYSTEIN LIE, CECILIE SKIPLE AND CAROLINE LOWREY,
PETROLEUM GEO-SERVICES

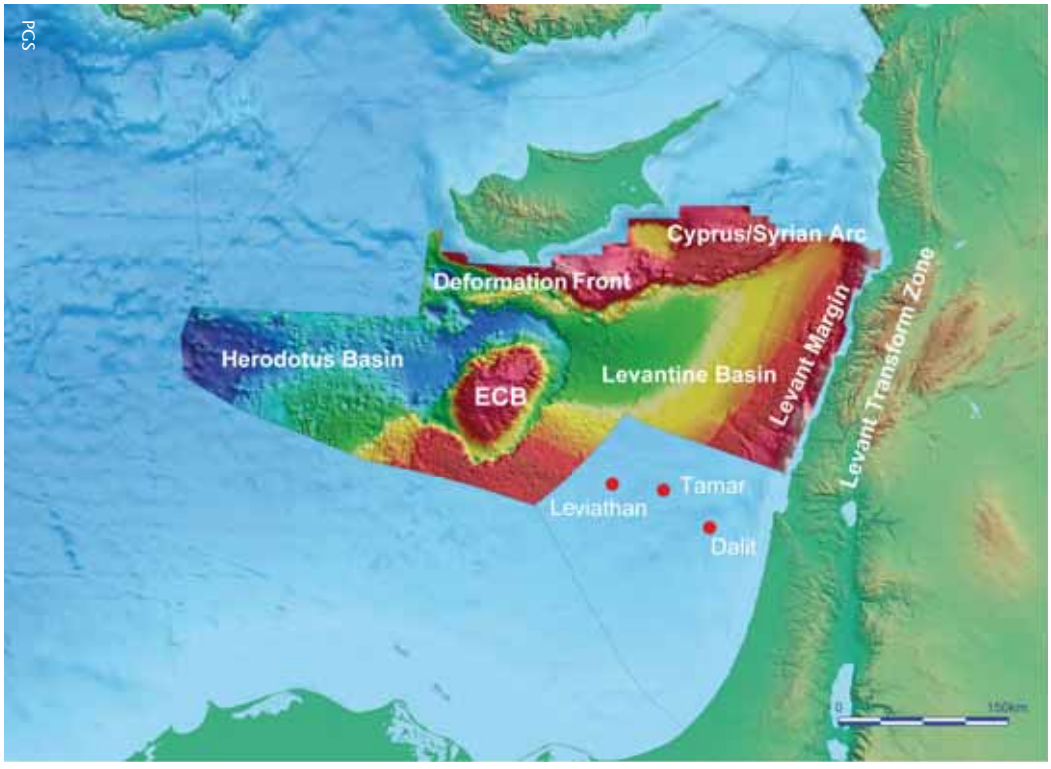
Currently no exploration wells exist in offshore Cyprus and Lebanon, although huge gas discoveries have been made in the vicinity, but continuous seismic coverage from Cyprus to Lebanon provides an excellent starting point to understand the development of the Levantine Basin.

*The picturesque village of Omodos in Cyprus (above) is overshadowed by the Troodos Ophiolite Massif, created in the Upper Cretaceous as a result of the collision of the African with the Eurasian plate. The Levantine Basin lies between Cyprus to the north and Lebanon and Israel to the east.*

## The Levantine Basin and the Levant Margin

The Levantine Basin, a deep marine basin with water depths of 1,500 – 2,000m and an area of 83,000 km$^2$ , is one of the world's significant underexplored regions. It is the only basin in the eastern Mediterranean where deepwater offshore wells have been drilled. Industry faith in this offshore area as an exploration target has been justified in recent years by three significant finds; Tamar, Dalit and most recently Leviathan. These have proven the existence of good (subsalt) reservoir sands within the Miocene strata.

The Levantine Basin has been in existence since the Late Palaeozoic, and is believed to contain a thick infill of sediments. The Levant Margin is a passive continental margin located to the east of the Levantine Basin, which has persisted since at least the Mesozoic and today comprises a narrow marine shelf and a broader terrestrial area. A variety of processes have influenced the development of the margin and




*The Seabed grid of the Eastern Mediterranean MegaProject illustrates the water depth variation between the different basins and provinces.*

the thick sedimentary succession deposited. These sediments are predominantly shallow marine and include carbonates, marls and clastics in which hydrocarbons are proven to be present.

Interpretation of regional seismic data has greatly improved the understanding of the stratigraphy of the Levantine Basin. Key horizons have been interpreted and used to produce time and depth grids and the interpreted horizons can be seen to separate distinct seismic sequences with particular seismic characteristics. ▶

## EASTERN MEDITERRANEAN MEGAPROJECT

*PGS's Eastern Mediterranean MegaProject merged dataset was created in order to provide additional geological information, increased understanding of plays and prospects, and a clearer understanding of the hydrocarbon potential of the region. In order to obtain a smooth interpretation, over an area that is covered by seismic data of different vintages, the seismic was matched in time, amplitude and phase using the recent dual-sensor data as the base survey. Publicly available information was used for improved understanding of the sub-salt stratigraphy. Depth maps and isopach maps were created and provide valuable depositional information.*

# East Mediterranean Stratigraphy and Petroleum Systems

## A Middle Jurassic to Senonian Unconformity

*The deepest horizon interpreted in the Levantine Basin is believed to be a Middle Jurassic event and the subsequent Jurassic and Cretaceous sedimentary infill probably consists of shales, marls, and carbonates. The Late Cretaceous Senonian Unconformity marks the onset of clastic deposition in the deeper parts of the Levantine Basin and defines the structural outline of the basin. On the Levant Margin this Senonian event represents the near top of the Cretaceous carbonate facies.*

*Source rocks within this interval include the Middle Jurassic open marine shales (Barnea formation), interpreted as the principal source for the Helez field in Palestine. Cretaceous source rocks include organic-rich black shales which can be correlated to the oil prone Geva'am formation in Palestine. There are also organic-rich Senonian sediments and analysis of the asphalt seep at Hasbaya in Lebanon indicates that it is probably derived from a Senonian source rock.*

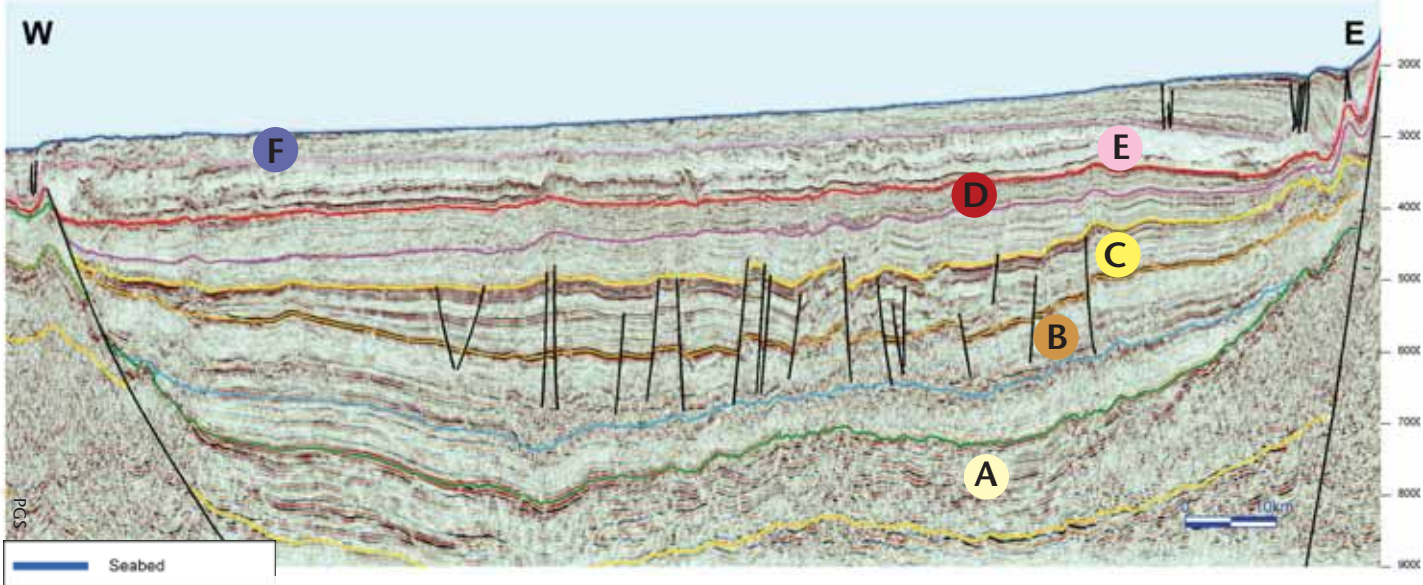
*On the Levant Margin, the Middle Jurassic – Middle Cretaceous platform carbonate sequence contains thick dolomites and sandstones that may be potentially good reservoirs. Other potential reservoirs include carbonate reefs, marine sandstones and fluvio-deltaic sediments. Possible Cretaceous fore-reef talus fans and Jurassic (Triassic?) alluvial fans can be identified in the north-eastern part of the basin up against the main fault at the margin and these could also be potential reservoirs.*

## B Senonian Unconformity to Base Miocene

*This interval is likely to be dominated by distal turbidite sequences of alternating sandstones, shales and carbonates. The seismic reflection continuity varies across the Levantine Basin but the upper boundary, Base Miocene, is a high amplitude event separating Oligocene lowstand sediments from Lower Miocene deep water sediments. An internal high amplitude event interpreted as the Eocene Unconformity represents the boundary between Eocene shales and more sand prone Oligocene deposits in the basin. The Oligo-Miocene section is faulted, but all the faults are seen to die out towards the Eocene Unconformity.*

*An Oligocene–Lower Miocene organic-rich source rock interval, which is a proven gas source in the Nile Delta, is of great significance for the area. Potential reservoirs occur in the sandier sections of the Oligocene.*

*A regional line in the Levantine Basin with the margin of the ECB in the west and the Levant Margin in the east, showing key horizons and major faults.*





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## F Base Pliocene to Seabed

*The Base Pliocene can have a conformable or an erosive character. It correlates to the top of the Messinian evaporites and marks the onset of deep water clastic deposition in the Mediterranean. The uplift of onshore Lebanon influenced the Pliocene, with gravitational slide of the Messinian evaporites causing extensional salt rollers in the proximal areas and compression in the distal areas toward the Eratosthenes Continental Block. The onset of the Pliocene is marked by a meandering channel system which is mappable in the 3D area and in the mid-Pliocene there is a slightly chaotic high amplitude feature to the east that is thought to represent channels. The Base Pliocene to Seabed is thick at the margin and thins out in mid-basin.*

## C Base Miocene to Base Middle Miocene

*The Base Miocene to Base Middle Miocene interval is currently regarded as the most prospective interval in the Levantine Basin and is dominated by deep-water clastics. In the middle of the basin the Base Middle Miocene marks the top of a series of high amplitude reflectors. The isopach map shows the depocentre to be oriented NNE-SSW, roughly parallel to the basin axis. The well defined seismic character of the interval allows correlation of the Lower Miocene from the Levantine Basin to a small sub basin west of the Eratosthenes Continental Block and on to the Cyprus Arc.*

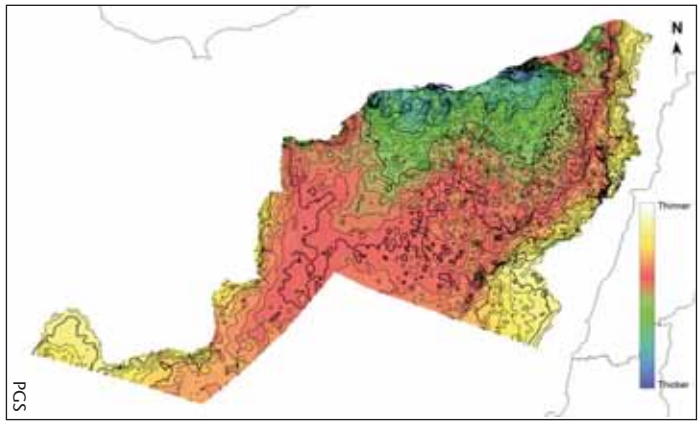
*The recent giant discoveries in the Levantine Basin (Dalit, Tamar, Leviathan) have good quality Lower Miocene reservoir rocks with thicknesses of 30 to 150m. At the time of deposition the area lay predominantly in a distal turbidite setting where continuous reservoirs are most likely to be located in coalescing basin floor and toe of slope fans developed during eustatic lowstands. Syrian Arc anticlines form potential traps and these include the narrow, high relief, NE-SW trending folds and lower relief, broader NNE-SSW trending anticlines. Potential pinch-out traps are present towards the Levant Margin in the east and the Eratosthenes Continental Block in the west.*

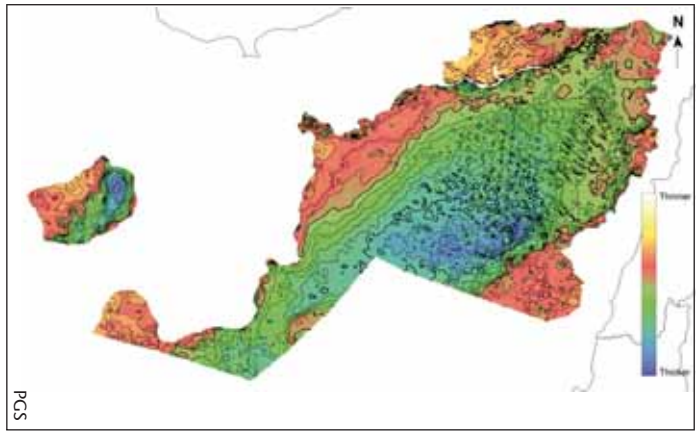
## D Base Middle Miocene to Base Messinian

*The Upper Miocene interval generally has lower continuity and amplitude than the Lower Miocene. However, prograding systems can be identified and in the north-easternmost part of the Levantine Basin there are high amplitude events and erosional features that could indicate basin floor fans and channel complexes. This Upper Miocene interval has a similar set of anticlinal structures to the Lower Miocene but the depocentre has moved slightly north-east towards the Levant Margin. Observed, minor syn-depositional faulting could have assisted in ponding turbidite sands in topographic lows on the seafloor, prior to evaporite development.*

## E Base Messinian to Base Pliocene

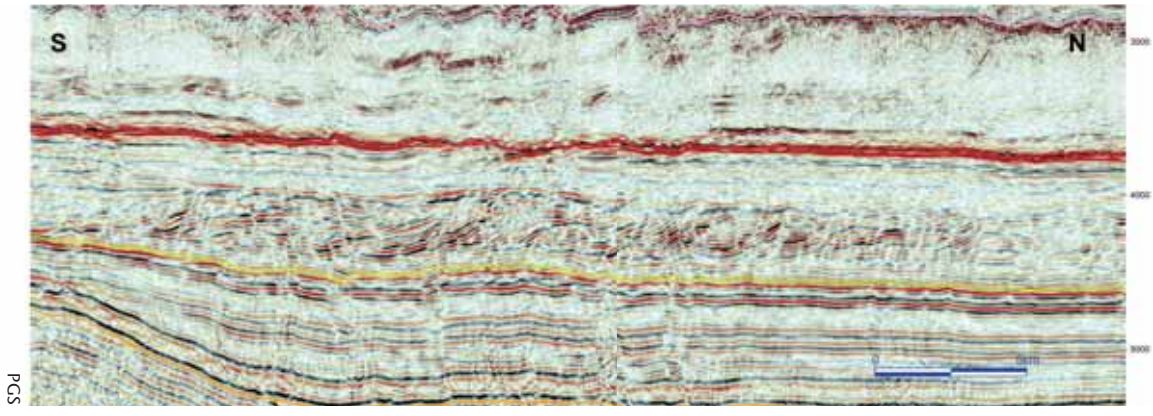
*The base of the Messinian succession is a distinct seismic event in the Levantine Basin. It marks the onset of the regional deposition of more than 1,500m evaporites during the Messinian salinity crisis. The strong internal reflectors that occur are likely to represent different types of evaporites or clastics locally. These reflectors are highly deformed in places, confirming the stress regimes in the region. The thickness of the interval is consistent over the greater part of the Levantine Basin but with thinning towards the margins and the Cyprus Arc. Over the Eratosthenes Continental Block only some tens of meters of Messinian evaporites are expected.*




*Thickening towards the north can be seen on the Senonian Unconformity to Base Miocene isopach map (top). The Base Miocene to Base Middle Miocene isopach (below) shows a NNE-SSW depocentre orientation.*

*A prograding clastic system in the Upper Miocene interval.*



# Hot Themes and Hot Spots

DAVID BAMFORD

As the dust begins to settle after the spring and summer's events in the Gulf of Mexico, what can we say about exploration around the globe in 2010. And what about looking forward to 2011 and beyond?

Perhaps the most surprising announcement of 2010 was what I would call my 'Surprising Niche I' – the Levantine and Tabar biogenic gas discoveries offshore Israel, clearly extending the "Nile Delta" system. A massive find – or massive hype? If the latter, it has some close challengers for the prize that might have been offered by Kipling!


ION

*The Arctic offshore will remain a 'hot spot' in 2011 and beyond, although exploration will proceed slowly.*

reminds us that it is not just small companies that might win this prize!

To give some structure to my thoughts, I have been reviewing the "Hot Themes" that can be discerned by counting Internet news items – rough statistics, admittedly, but nonetheless a guide to what companies are thinking about. Also presentations by companies to investors offer useful insights and these are freely available on company websites.

As a result, my "Hot Themes" are: Deep Water, the Arctic, Unconventionals and Mid-continent Onshore. We will look at each of these in turn.

## Deep water

Of course, the most significant event in 2010 was the Deepwater Horizon tragedy and its impact on exploration offshore the USA.

Although the drilling moratorium in the Gulf of Mexico (GoM) has been 'lifted', the brakes are still being applied in the form of incredibly slow permitting instead of an outright ban. Some in the industry have suggested that it may be 2012 before deep water GoM exploration gets back to anything like normal. However, the U.S. official in charge of regulating offshore oil drilling said on 13th January 2011 that the speed with which his agency approves new drilling permits would "probably never" return to the pace seen prior to last year's Deepwater Horizon spill.

Meanwhile, deep water activity has continued offshore Brazil, Ghana, Sierra Leone, Liberia, Guyana, French Guiana, China, Angola, Australia, and in the UKCS West of the Shetlands, with Brazil and Ghana providing the 2010 highlights. Far to the south, in a hostile, though only partly deep water environment, drilling results around the Falkland Islands have been disappointing so far.

Looking forward to 2011, the South Atlantic, both the African and South American sides, promises to be especially active: more in Brazil sub-salt (Petrobras and BG), more Ghana, and the whole West Africa Transform Margin (Tullow*, Anadarko), potentially Guyana and French Guiana, maybe also Mauritania.

## The Arctic

There is a long history to Arctic exploration and production but now the offshore Arctic is beginning to open. First results from Greenland have been disappointing but Russia and Norway have reached an agreement that should open the Barents Sea up for further exploration (see *GEO Expro* Vol. 7, No. 5). However, the USA Arctic segment is suffering from the generalised drilling moratorium – and who can tell what is happening in Russia?

In 2011 and beyond, we should expect more of the same: Cairn is planning to ▶


Tullow Oil

*A new province has opened in Ghana, with first oil from the Jubilee Field on 15th December 2010.*

*"I despise exaggeration – 'tain't American or scientific."*
from *The Captive*

However, I shouldn't spend my time writing, and your time reading, about what AIM-sized companies may or may not have discovered – and thinking back to the Shell reserves fiasco of 2002

spend US $500m in Greenland in 2011, hard on the heels of its US $400m in 2010; the Barents Sea will probably see increased multi-client 3D seismic activity. Not much will happen offshore the USA and Russia, however. And It will take a while before the new strategic alliance between BP and Rosneft – see below – leads to exploration of their Kara Sea acreage.

## Unconventionals

The pursuit of unconventional gas – predominantly Shale Gas – remains very active in North America, despite relatively low gas prices, threatened state taxes and environmental concerns: much resource exists – whether and when this can be converted to commercial reserves is open to question. The low availability of drilling rigs capable of drilling the required horizontal wells and of hydraulic fraccing equipment will curtail widespread replication elsewhere for the foreseeable future.

However, because of the higher prices and therefore fundamentally better economics, Shale Oil will develop real momentum, especially in the northern USA.

My 'Surprising Niche II' will be the pursuit of unconventional gas in northwest England – Shale Gas (the Namurian Bowland Shale) and Coal Bed Methane (classic Carboniferous). Alkane's and IGAS's identification of a Coal Bed Methane opportunity is perhaps unsurprising – the Lancashire coal fields had a long and productive history, and generally speaking, where there is coal there is methane. That the Bowland Shale is a potentially rich source of Shale Gas was news to me; Cuadrilla drilled a successful exploratory well a few miles to the east of Blackpool last year.

## Onshore Mid-Continents

Exploration in Russia is withering on the vine due to a punitive tax regime that does not appear to be about to change. In principle, the agreement for a new Russia-China pipeline should re-energise exploration in East Siberia – but not until the economics are made more attractive by a change in the tax regime.

In onshore Africa, the interior rifts will continue to attract attention. Perhaps some will be attracted to the true interior basins – but maybe host governments need to change their expectations first!

In all onshore areas – the Former Soviet Union, Kurdistan, western Iraq, central


*Drilling for shale gas in the USA*

Africa – the lack of relatively inexpensive 'exploration 3D' is a major constraint on efficient and effective exploration.

## Strategic relationships

Global exploration feels quite fragile, especially for the majors who are on the 'treadmill' of reserves replacement. On the other hand, as the oil price threatens to charge past US $100 a barrel once more, there is every reason to think that the mad scramble for acreage that sees the inflated expectations of many host governments actually being met will continue.

The continued deep water activity everywhere apart from the Gulf of Mexico has been, and looks to continue being, the main bright spot. However, apart from in the GoM, the majors seem to be relatively uninvolved.

Thus fresh, transformed, access to resources provides some of the context for BP's recent strategic global agreement with Rosneft (*see page 12*), not least important being that this access is outside the USA where there is a general slow-down and where BP might feel it is disadvantaged, at least in the short term. It should also be seen in the context of global exploration becoming more difficult and it making sense for western majors to pursue strategic relationships of "mutual advantage" with resource-rich NOCs.

Will this pursuit of strategic relationships be a fifth "Hot Theme" for 2011? Will BP's action trigger other majors to go down the same path, much as BP's 1998 takeover of Amoco triggered the subsequent merger wave of Exxon and Mobil, Total and Elf, Chevron and Texaco, Statoil and Norsk Hydro? Only time will tell! ■

** David Bamford is a non-executive director of Tullow Oil Plc.*


*BP and Rosneft, with appropriate government support, shake hands on their historic deal.*

# Learning at a distance

In times of austerity, formal learning for many staff is put on hold, but staff still need to be trained and given opportunities to develop their skills and knowledge. E-Learning is one solution.

PAUL WOOD


*Using e-Learning methods, staff throughout an oil company can be trained in key skills and learn about different facets of the industry without leaving their workplace.*

In times of economic uncertainty and fluctuating oil prices, cost savings assume a high priority in the oil and gas industry. In-house training programmes can be expensive in their own right and made even more so by the associated travel time and costs. They are often among the first targets of company austerity drives. As a result, formal learning for many staff is put on hold. But if a company is to flourish and grow, these staff still need to be trained and given opportunities to develop their skills and knowledge.

## Cutting costs and saving time

One means of making training more efficient and less expensive is distance learning, where company staff can use the Internet or other global communication methods to take training courses remotely. Learning can be done at the student's own location and at suitable times that fit in with operational demands. An extension of this approach, often called blended learning, involves first using electronic courses to help students achieve a baseline level of understanding, and then following up with face-to-face learning at central facilities or on-site.

IHRDC (International Human Resources Development Corporation) offers such solutions through 'e-Learning' products and services. This organisation may be familiar to many in the oil and gas business as it introduced one of the early forms of distance learning through video-based tutorials and lectures. The corporation was therefore well positioned to move its electronic approach online once higher bandwidth and better browsers became available on the Internet.

Tim Donohue, IHRDC's Vice President of e-Learning Solutions, explains the company's philosophy: "There are three core elements to our learning portfolio," he says. "Instructional Programs, which are a blend of traditional classroom courses and interactive workshops mainly directed at management of the oil and gas business; our suite of modular e-Learning products; and Training Services focused on assessing and building workforce competency."

One of the advantages of the modular approach of e-Learning is that preparatory modules can ready people for more specialist, classroom-based courses by getting them all to the same level of understanding. Participants need only take the modules they require to deal with gaps in

their knowledge – more difficult to address in a classroom situation where the students may have varying levels of knowledge. Instructors can then be confident that all participants have the required level of understanding prior to attending the course.

## Tailored learning

To cover the broad spectrum of oil industry e-Learning requirements, IHRDC offers a number of routes and methodologies. Its flagship product for upstream petroleum engineering and geosciences technology is IPIMS (International Petroleum Industry Multimedia System), consisting of two levels which it calls Background and Action Learning. The former has self-guided modules in the four primary disciplines of petroleum geology, geophysics, engineering and formation evaluation. Within these, there are many individually searchable topic areas that can, if desired, be integrated into the internal databases of client companies.

Action Learning takes students through simulated job assignments using actual data supplied by a major national oil company. These assignments are similar to those that oil company staff would experience in their day-to-day work. Students can either continue the learning electronically, with on-line mentors, or follow a more 'blended' approach where the tuition is taken to workshops on clients' sites and tailored to their own requirements. At present there are 48 modules covering the range from reservoir management, drilling and well completion to production engineering and operations, and the company is currently building a number of additional modules for geosciences disciplines.

IHRDC also offers Petroleum Online, which provides an in-depth introduction to the oil and gas business. This is specifically designed for non-specialists who want an overview of the whole industry and the specific areas in which they will be working. An accounting firm with oil industry clients might make the modules available to their employees, for instance, while the IT staff in an oil and gas exploration company could learn more about the specific discipline areas for which they are providing support. Modules cover the full value chain, from a general overview of the industry through the Upstream, Midstream and Downstream sectors. For example, in the Upstream area, the module 'Petroleum Geology and the Exploration Process' covers the formation and occurrence of hydrocarbons and the methodologies and tools used to find them, from reconnaissance to drilling an exploration well. A business game integrates the subject matter of all the modules.

It is also possible for technical staff to gain key business skills through the Business Essentials e-Learning modules, which cover finance, communications, human resource management and project management. Based on real-world industry examples, they are ideally suited to those progressing up the managerial ladder. And in addition to this wide range of e-Learning topics and products, IHRDC has just made available the Operations & Maintenance e-Learning library, a comprehensive resource of over 250 courses covering Process Operations, Health Safety & Environment, and Maintenance and Control Systems.

## Managing competency

The glue that binds all these modules together is the CMS or Competency Management System, which offers a way to track the job competency requirements of companies against the learning and experience of their workforce, while allowing staff to discover skill gaps, identify suitable learning to close these gaps and provide opportunities for career growth. This learning may be from IHRDC or from other sources identified as better meeting the needs. The reporting systems can be ▶


*Traditional classroom learning, like this at Shell Upstream Learning Centre, The Netherlands, can be supplemented by e-learning tailored to individual needs.*

used for individuals, groups or an entire organisation.

"Of course, we realize that individual distance learning isn't everything", says Tim Donohue. "There is also great benefit to be drawn from working in groups in a classroom environment and exchanging ideas and experiences. We work with clients who want the blended approach, with some e-Learning and then, maybe, a team-based Action Learning event. We can provide tutors or train up client facilitators".

## How does it work?

All of the e-Learning modules are SCORM (Sharable Content Object Reference Model) compliant, which is a system of standards and specifications for web-based e-Learning. This means that the IHRDC modules can interface with the computer systems and Learning Management Systems that many companies use to manage their learning programmes. The content works on standard web browsers and uses generally available plug-ins like Flash video or WMV and the modules can be run from IHRDC servers or on client intranets. All of the modules are available in English, and many are available in other languages such as Spanish, Portuguese, Arabic, Russian, and French. More will become available over time.

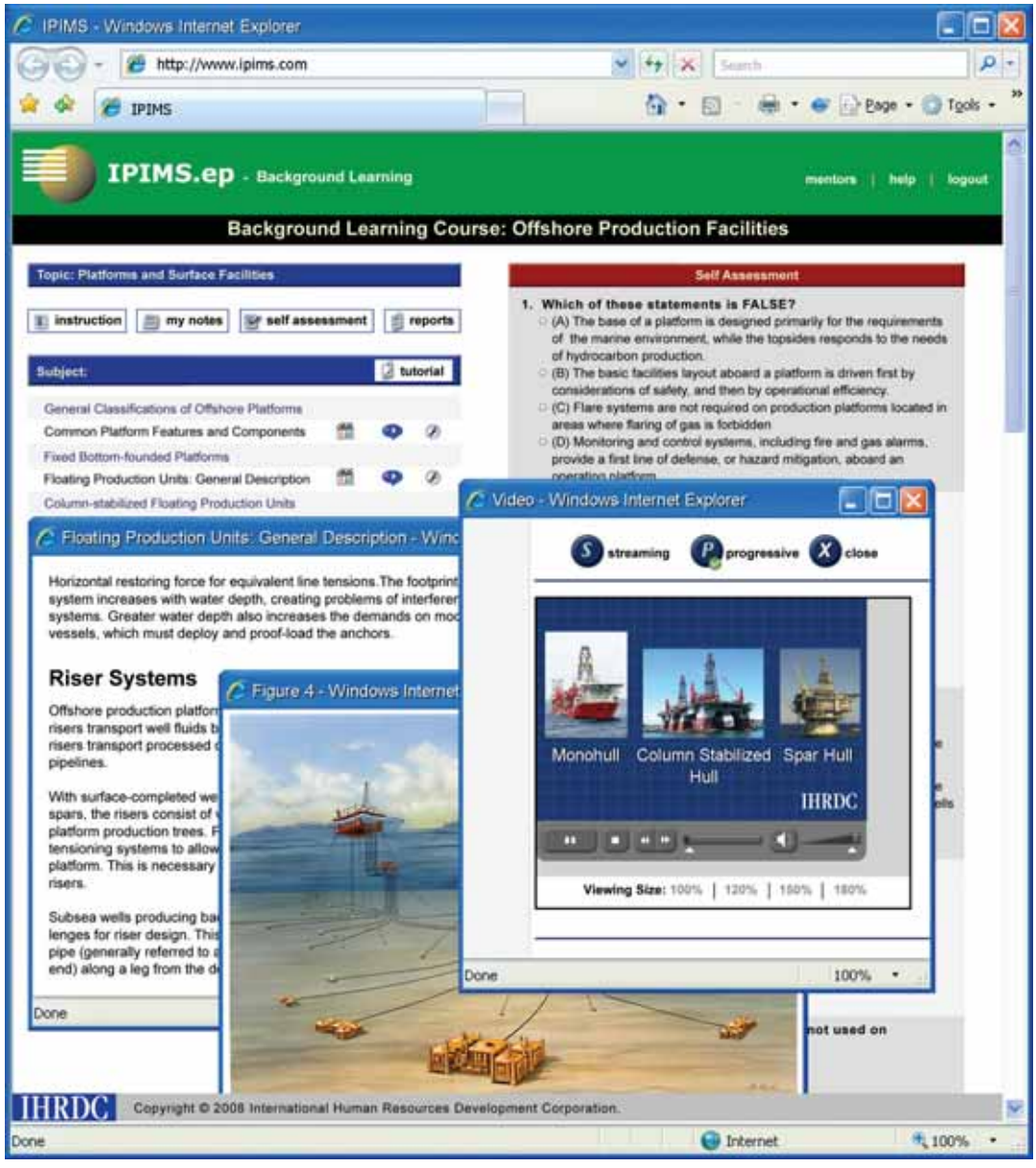
IHRDC, together with Nautilus and NExT, is a member of the Plato Alliance. This group was formed as a Schlumberger initiative after they had been using the IPIMS products. It brings together three of the world's leading E&P learning providers to offer a comprehensive integrated portfolio of products. It also aims to bring a greater experience pool together to help solve problems of the future, such as acquiring the new skill sets and technology understanding needed in unconventional plays.

Henry Edmundson, Director of Petro-technical Expertise at Schlumberger and founder of the Plato Alliance, says that "over 2,000 petro-technical professionals in Schlumberger actively use IPIMS for self-study through the Internet. It's a very valuable component of their learning portfolio. And having IPIMS as part of the Plato Alliance offering is proving equally attractive to oil and gas companies worldwide."

## Remaining challenges

Tim Donohue concludes; "as well as meeting the need for skills for the future, which we are approaching through bodies like the Plato Alliance, we also have challenges with our current offerings. In the past few years, Internet speeds and capacities have improved to the point where our product line can be offered globally, on-line. But now we are looking at how we can deliver e-Learning to places where the Internet isn't possible or even onto new platforms like the slim tablet. To this end, we have, for example, been installing modules on clients' remote systems, such as seismic acquisition vessels."

One thing remains certain: in a world of ever-increasing energy demand, but where resources are becoming scarcer and more difficult to locate, acquiring the skills to find and produce those resources will be more vital than ever before. And in a financially constrained world, where time and money are also critical, e-Learning looks set to have a bright future. ■




IHRDC

*e-Learning allows staff to plug gaps in their knowledge at their own pace.*

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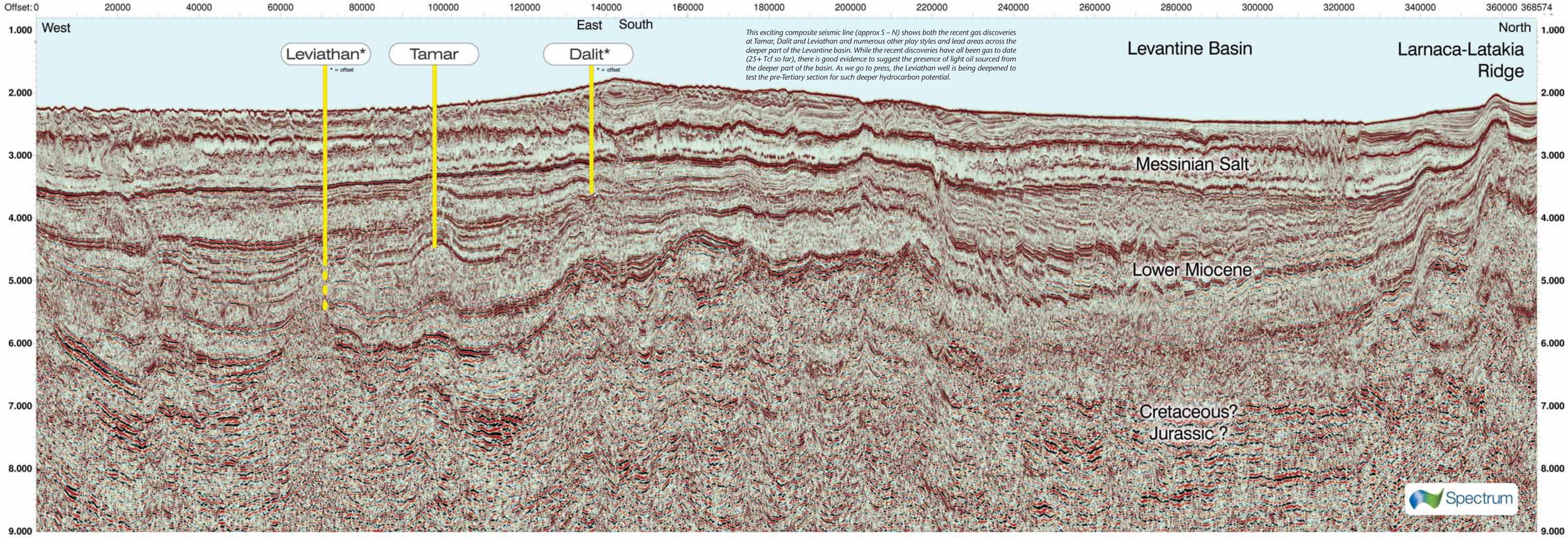
# EASTERN MEDITERRANEAN

# The Hot New Exploration Region

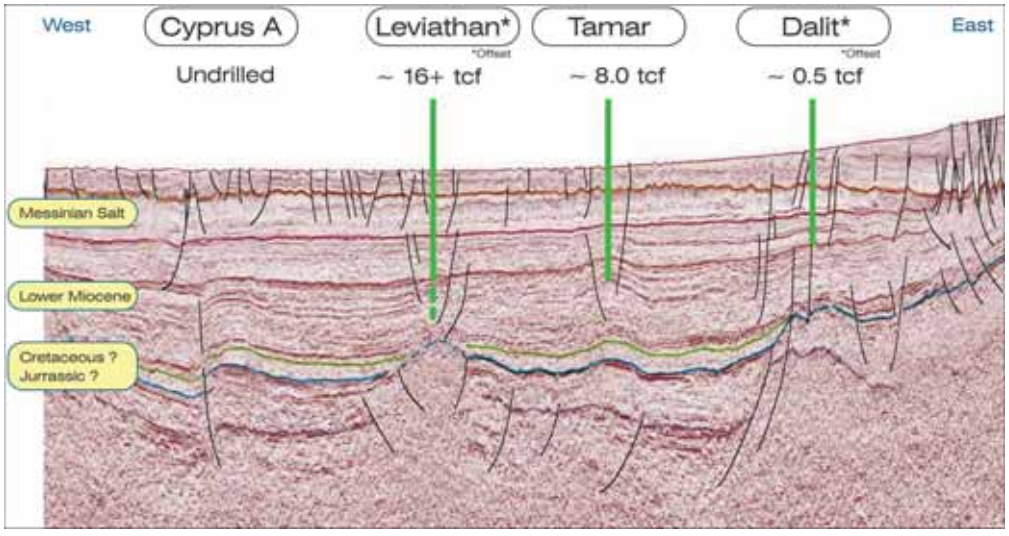
With three new gas discoveries in the last year containing estimated reserves of 25 Tcf (700 Bcm), the Levantine Basin in the Eastern Mediterranean has now come of age and contains some of the hottest new exploration plays in the Europe, Africa & Middle East (EAME) region. With licence rounds being planned offshore Cyprus, Lebanon and Syria, the region seems set for an exciting period of new exploration activity.




*This exciting composite seismic line (approx S – N) shows both the recent gas discoveries at Tamar, Dalit and Leviathan and numerous other play styles and lead areas across the deeper part of the Levantine basin. While the recent discoveries have all been gas to date (25+ Tcf so far), there is good evidence to suggest the presence of light oil sourced from the deeper part of the basin. As we go to press, the Leviathan well is being deepened to test the pre-Tertiary section for such deeper hydrocarbon potential.*

# Looking Offshore

DAVE PEACE, EXPLORATION DIRECTOR, EASTMEDCO




EastMedCo

*Regional East-West seismic line illustrating the recent gas discoveries. These prove the presence of an extensive gas generation system in the south of the Levantine Basin, which has generated highly commercial volumes of gas into nearby reservoirs. This hydrocarbon system is expected to extend throughout the entire Levantine Basin into offshore Cyprus, Lebanon and possibly as far as Syria.*

The Eastern Mediterranean has been one of the largest commercial and trading hubs of the entire EAME region for many centuries. More recently, during the last 20 years, the southeast of the region has also become successful for oil and gas exploration, particularly offshore in the Nile Delta Cone and to a lesser extent in South East Turkey around Iskenderun Basin. However the extensive area in between was almost entirely overlooked until the BG Group extended their successful Nile Delta exploration campaign into the southern Levantine Basin, where they discovered a number of biogenic Pliocene gas fields. These discoveries amounted to a modest volume of gas, some of which have now been in production for several years.

The large central and generally underexplored region comprises the Levantine Basin, the Larnaca-Latakia thrust belt to the north and the Erastothenes Seamount and Herodutus Basin to the West. The southern part of the Levantine Basin has recently become the focus of a very successful drilling campaign by the Noble-Delek group who have discovered three new large gas fields at Dalit, Tamar and Leviathan (the latter still drilling deeper at time of press). These three new finds have estimated reserves in excess of 25 Tcf (700 Bcm), making them both the largest discoveries in the region and the largest in Noble's portfolio.

These recent world class gas discoveries are located in Lower Miocene – Oligocene sands with reservoir thicknesses in Tamar ranging from 33m to 140m, with stacked reservoir potential. Press articles state the sands are of high quality with excellent porosity and permeability characteristics and high flow rates when tested. Water depths vary from 1,000m to over 1,645m at the Leviathan location, which is 128 km from the coast. Leviathan is the largest of the recent discoveries with an aerial extent of approximately 325 km$^2$.

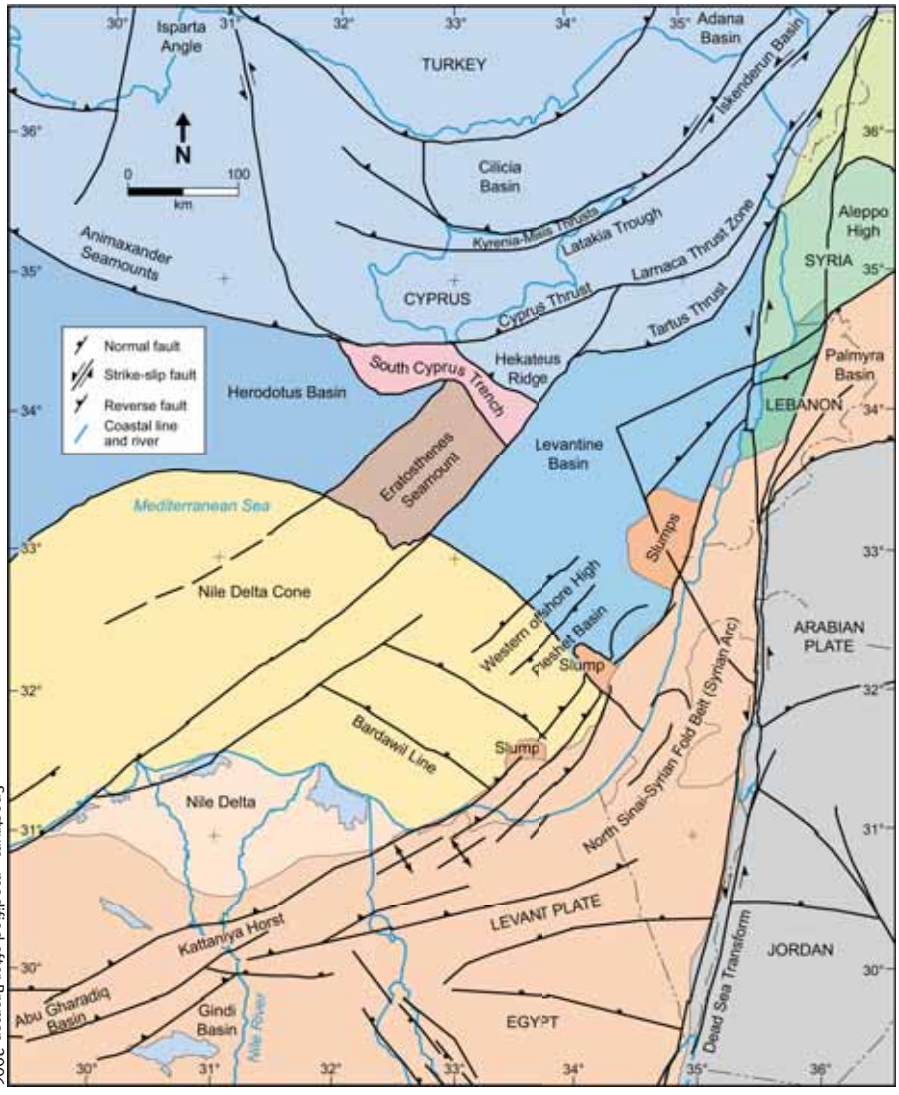
Spectrum and EastMedCo have been evaluating the greater East Mediterranean region jointly for the last 10 years. The project commenced with an evaluation of a 1975 Sefel and Associates regional seismic survey (known as the EMED-75 survey) reprocessed by Spectrum in 1999 to create a wide regional framework. Spectrum & EastMedCo evaluated the reprocessed data, and in 2000 Spectrum acquired a further 12,300 kms of new 2D regional data over this framework (EMED-00). This dataset has been very successful and was further augmented in 2002 by the acquisition of an inshore infill survey off the Lebanese coast to provide links to the Eastern edge of the basin (LEB-02). The EMED-00 dataset was depth migrated in 2007 to provide enhanced imaging of the deeper data and to better understand the evolution of the basin and hydrocarbons systems within it.

EastMedCo made a full interpretation and evaluation of the data and not only identified the structures containing the recent discoveries many years before they were drilled, but also catalogued a significant number of leads and prospects throughout the whole East Mediterranean region where many similar structures are present. (See Roberts & Peace *GeoArabia* 2007 for fuller descriptions of the many other play styles present.)

## Oil potential as well ?

The recent discoveries have all contained gas, but there is good evidence to suggest that there also exists significant oil potential in the Levantine basin.

In the adjacent Nile Delta, many of the early successes consisted of discoveries of post-Messinian biogenic gas. However, as companies have drilled deeper, into the pre-salt section, the hydrocarbons discovered have included both thermogenic gas and, more recently, thermogenic oil. There are also two older




Spectrum, modified after Breman 2006

*Structural and tectonic elements of the East Mediterranean. The main elements defining the Levantine Basin include the Nile Delta Cone, Eratosthenes Seamount, the Cyprus/Larnaca Thrust Zone and the coastal margin faults along the Eastern margin of the Basin.*

wells that tested shallower Jurassic plays on the Southern Levantine basin margins and found approximately 800 bopd light Jurassic oil when tested. As these wells are located on the edge of the basin it seems reasonable to anticipate that the source kitchens are located to the west, in the central part of the Levantine Basin. The oil has migrated from the kitchen to the basin margins to the east, west and north.

EastMedCo has evaluated the hydrocarbon oil potential through seepage studies. Numerous oil seeps have been found in the greater East Mediterranean region from Southern Turkey to the Nile Delta indicating a potential widespread oil source. Many of these can be correlated with clear migration pathways on seismic data. (Johnson and Peace *APPG Denver* 2002).

The current Leviathan well is targeted to investigate this deeper oil potential, with recent press announcements stating the well has discovered a minimum of 67m of gas bearing reservoirs of the same Lower Miocene sands as Tamar and Dalit. It is reported the well is now continuing to a target depth of around 7,200m to test the remaining Tertiary section and possibly the Cretaceous and Jurassic.

## New licence rounds

The new gas discoveries are all located in deep water in the southern Levantine Basin, having obvious implications for future exploration offshore Cyprus, Lebanon, Syria and Turkey. First licence rounds have already been held in offshore Cyprus and Syria over the last few years, but took place before the recent discoveries and only attracted limited interest. Only one award was made offshore Cyprus (to Noble with the Cyprus A block) and no awards at all were made offshore Syria.

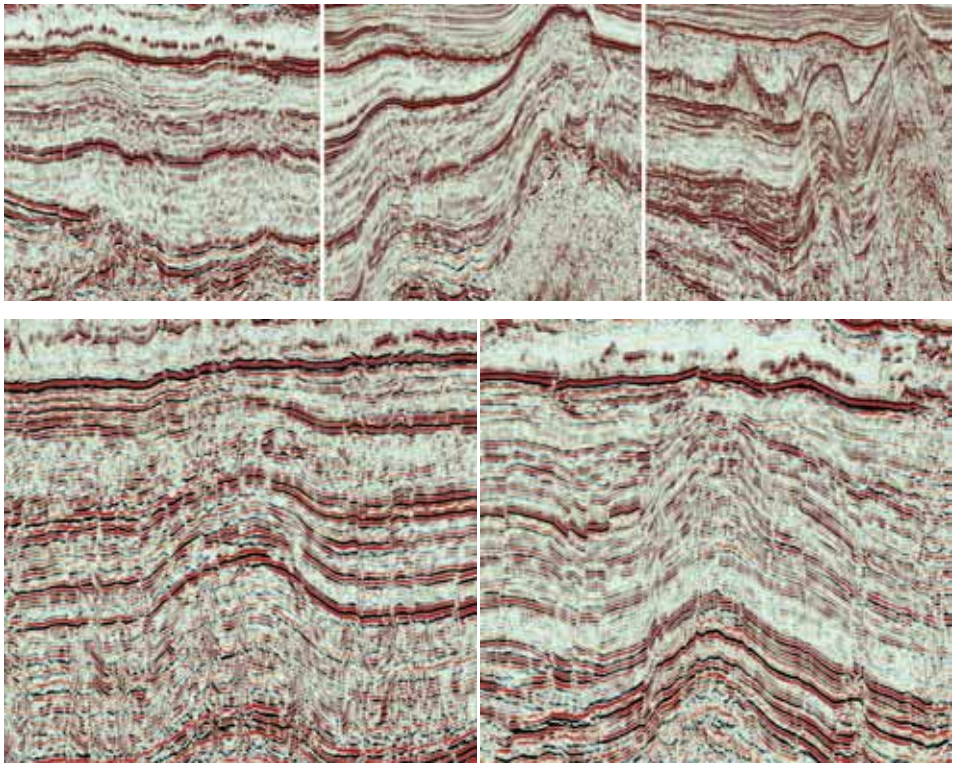
The recent discoveries have sparked renewed interest, and bid rounds are planned for both offshore Cyprus and Syria in 2011. In addition, Lebanon has recently announced the approval of its new energy law and new border agreements with neighbouring countries, which will facilitate the first ever licence round to take place in Lebanon in the near future.

To assist with these rounds, Spectrum Multi Client library includes approximately 22,500 line kilometres of seismic data in the Eastern Mediterranean with a record length of 12 seconds twt. The EMED-00 original PSTM (pre stack time migration) dataset proved the presence of the deeper part of the Levantine basin. Further imaging improvements were achieved with PSDM (pre stack depth migration) reprocessing especially where structuring is more complex. Spectrum is currently reprocessing the EMED-00 survey through PSTM to produce a fully AVO compliant dataset. For companies interested in exploring the areas further or joining a pre licence evaluation group please contact davepeace@eastmedco.com

## Underexplored Levantine Basin

The huge underexplored area of the Eastern Mediterranean has all the elements of a significant hydrocarbon province in the EAME region. Good seismic datasets are available, leads and prospects have been identified and new licence rounds are imminent.

*Acknowledgements: Thanks to Richard Spoors, Gary Scaife and Debbie Sewell of Spectrum GEO for their assistance with this article.*



*Three examples of undrilled leads (top) identified in the Eastern Mediterranean area, compared to seismic sections over the Tamar (below left) and Dalit (below right) discoveries*

# Looking Beyond Just Seismic!

## Gravity Gradiometry and its Application in Complex Geologies

PHILL HOUGHTON, ARKeX


*The tight integration of GGI data with pre-stack seismic data establishes an accurate velocity/density relationship and can generate the salt surface shown in blue.*

Using the right tools for the right job is an old adage that rings true for many a situation. And using the right geophysical technology in the right environment has never been more important than when exploring complex geological settings.

## The search for a complete exploration data set

2D and 3D seismic continues to be the principal geophysical technique of choice for explorationists. Advanced seismic acquisition and processing techniques, such as enhanced-azimuth acquisition and 3D pre-stack depth migration, have garnered widespread attention as operators look to generate a better subsurface understanding of increasingly complex and remote geologies.

However, conventional seismic also has its limitations, ranging from the high cost, long turnaround times, and access issues through to many areas of the world characterized by a poor seismic response.

From the sub-salt discoveries deepwater offshore Brazil and the Gulf of Mexico to the deserts and mountains of Africa, all too often the seismic wavefield is distorted and illumination irregular. The result is an incomplete ray distribution for seismic migration, a sub-optimal velocity model and lack of clarity in the sub surface image.

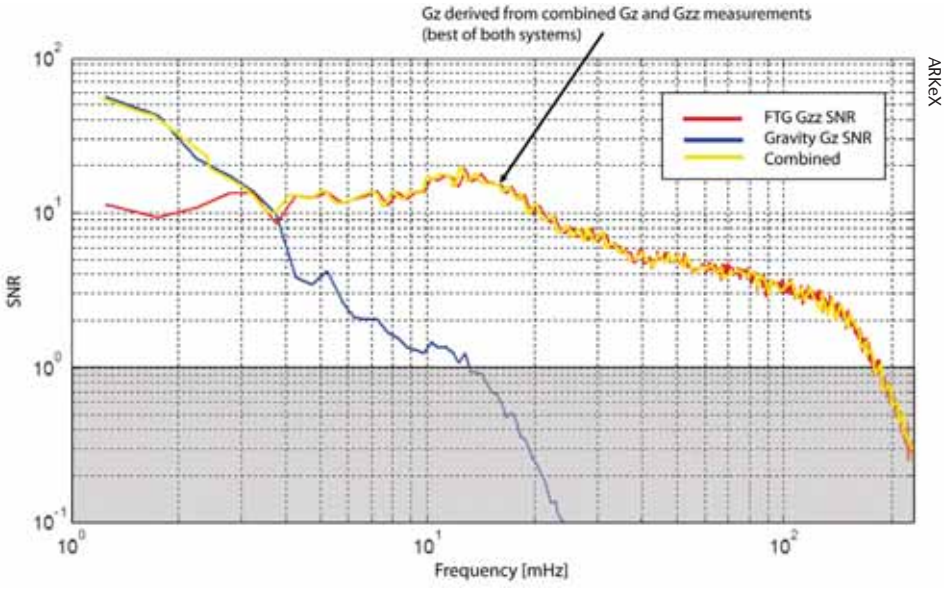
Advances in acquisition methods and processing techniques go some way to overcoming these limitations and whilst seismic developments will continue, the explorationist is turning to other sources of geophysical data in an attempt to reduce overall exploration risk. Data that is complementary with seismic and easily integrated into existing workflows is beginning to provide some of the answers. One such data source is Gravity Gradiometry.

## The emergence of Gravity Gradiometry

Gravity Gradiometry Imaging (GGI), which can be acquired in airborne or marine modes, maps small density variations in underlying rocks by measuring the gradient of the earth's gravity field.

The non-invasive, passive nature of the technology allows for the exploration of vast regions quickly, accurately and cost effectively, with no adverse environmental impact.

Today, some of the world's leading international and national operators are specifying that GGI should be part of their exploration plans. They are using GGI as an effective complimentary technology to seismic in some of their most complex and challenging geological situations. In addition to the clear cost and efficiency benefits, there are a number of other important reasons why they are graduating towards GGI.




*Conventional airborne gravity (Blue) and airborne Gravity Gradiometry (Red) response to a broadband geologic signal onshore West Africa. When combined (Yellow) best data fidelity at all frequencies is available.*

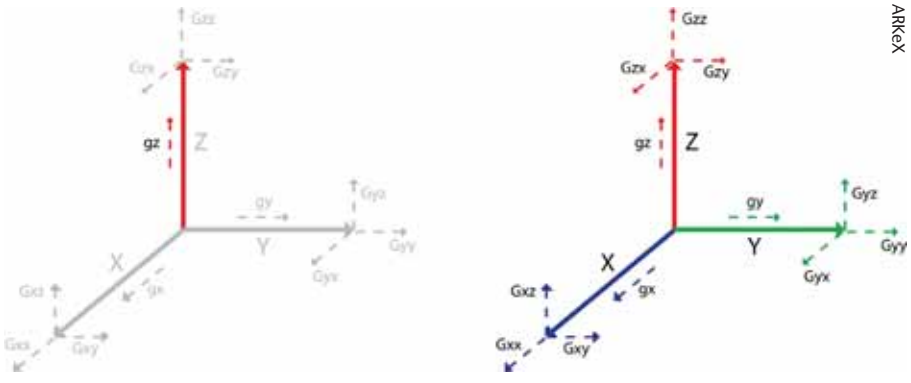
Gravity Gradiometry provides an increased signal-to-noise ratio and wider bandwidth over conventional gravity measurements acquired from a moving platform. The response of a conventional airborne gravity system decays rapidly at higher frequencies compared to the Gravity Gradiometry system, which recovers significantly more bandwidth with increased signal-to-noise.

It can be seen however that the gravity response at lower frequencies exhibits a higher signal-to-noise ratio. Using advanced processing techniques, the signals can be combined to offer the very best data fidelity at all frequencies. The resulting high resolution and wide bandwidth data provides a 3D spatial awareness of the subsurface that can impact data at the seismic scale.

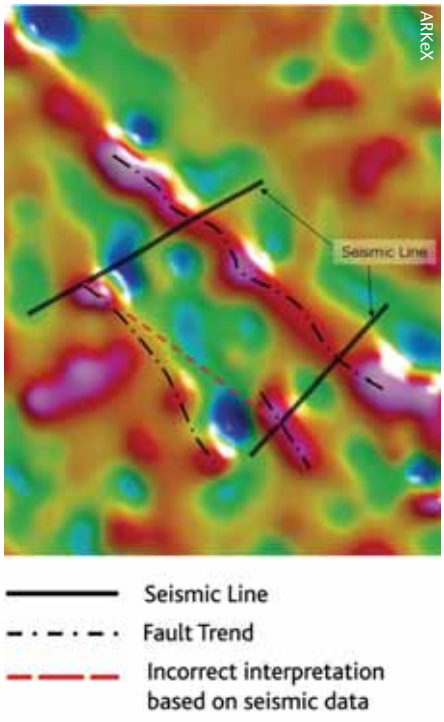
## A more complete picture

Furthermore, compared to a conventional gravity survey which records only a single component of the gravitational force, usually in the vertical plane, full tensor Gravity Gradiometry measures all three components in all three directions.

The problems associated with 2D seismic data are also well understood. No matter how careful the design and layout of a 2D program, there are always limitations and compromises. The inclusion of offline or sideways looking information from GGI is important to reduce the uncertainty in ▶




*Conventional Gravity measures ONE component of the gravity field Gz (LHS), but Gravity Gradiometry measures ALL components of the gravity field (RHS).*




*Example from the Gulf of Mexico demonstrating that where sparse 2D seismic cannot connect independently interpreted faults, GGI clearly defines the fault trend.*

a 2D measurement and can provide an enhanced interpolation solution between sparse acquisition lines.

By just using sparse 2D seismic alone, two independently interpreted faults may or may not be connected, but by the addition of GGI data, the fault trend is clearly defined, as shown in the example. In short, GGI can provide a more complete picture of the fault geometry and a greater understanding of the structural fabric.

In addition, when taking any 2D seismic data to depth, it is important to understand the complex velocity field. Out-of-plane issues that could affect a 2D depth migration are difficult to resolve without any independent knowledge of the spatial context of the geology. Here, GGI can act as an intelligent 3D geologic interpolator providing valuable information at the seismic scale and helping to improve the overall subsurface image.

Let's take a look at some examples of GGI in practice addressing complex geologies. This will take us from Africa to the Middle East, continental North America, and then to the largest continental rift system on earth.

## The issue of salt

The increasing demand on seismic technologies to deliver over sub-salt discoveries has led to many operators looking to GGI to help.

The relatively low density of salt in comparison with typical host material and the typical morphology of salt bodies (the principal causes of problems when creating a clear sub-salt image with seismic imaging) are far better suited to being detected and then modelled using high resolution GGI. The technique can accurately map the density interface between salt and the surrounding rock and add 3D structural and velocity constraint to the otherwise interpolated fields.

The example on page 42, from an onshore survey in West Africa, shows how a well constrained salt map in 3D has been developed in an area where 2D seismic data is sparse and of poor quality. Through the tight integration of GGI data with the pre-stack seismic data, the interpreter was able to establish an accurate velocity/density relationship which was then used to improve the seismic image and generate the salt surface shown in blue.

## Complex thrust environments

GGI has also been playing a key role in other geologically complex areas such as thrust belts.

In the Northern Oman Mountains of the United Arab Emirates, GGI was used to survey a complicated thrust environment with a poor seismic response. A series of 2D seismic lines were iteratively interpreted by integrating acquired GGI data with existing seismic interpretations and well data. The interpretation was driven by the need to match both the density profiles (guided by the gravity response) and the structurally balanced cross-sections.

The integration of the data allowed for a better understanding of the thrust linkages at different levels, and a better insight into the interaction of thrusts, backthrusts, detachment levels, imbricated zones, and lateral ramps. The high resolution GGI data also facilitated the accurate investigation of the 3D Shallow Earth Model (SEM), with the modelling of seismic sections constrained by GGI and magnetic data and producing a more geologically realistic SEM.

Another complex thrust environment is the Utah Hingeline, part of the North American thrust belt, and a trend that begins north-east of Salt Lake City and runs south-west across the state. The area's geological complexity and sparse seismic data means that it continues to remain a challenging place for oil and gas exploration, with a need for more detailed geological information to unlock its potential.

ARKeX partnered with Houston-based JEBCO Seismic to conduct a multi-client airborne geophysical survey along the Hingeline. The main survey objective was to provide a 3D image of the anticline along which the Covenant field was discovered. The GGI data, along with supporting magnetic and digital terrain mapping (LiDAR) data, provided essential information on the location of the axis of the anticlinal structure, the depth of the fold and the presence of structural highs, the lateral continuity and quality of the prospect, the occurrence of horizontal offsets, and heterogeneities in the shallow levels.

The initial pilot was so successful that an additional 3,370 km$^2$ of data was collected and an integrated workflow designed to highlight areas of interest for further exploration.

Finally, in the Muskwa-Kechika area of British Colombia located along the thrust front of the eastern Rocky Mountains, ARKeX partnered with JEBCO to conduct another multi-client GGI survey. The high resolution airborne GGI, magnetic gradiometry and LIDAR data was analysed and inversion and back-stripping techniques were used, along with qualitative mapping of target wavelengths. This resulted in a first pass structure


*A high resolution airborne GGI, magnetic gradiometry and LIDAR survey over the Muskwa-Kechika area of British Colombia revealed new and detailed information of geological structures over this expansive area.*

contour map, showing how GGI could be used as an initial screening tool to provide detailed structural information on which to plan future exploration programs.

## The East African Rift System

The East African Rift System, which extends from Ethiopia in the north to Mozambique in the South, is an area of vast potential where less than 200 wells have been drilled in an area of 2.3 million km$^2$. Many companies are now beginning to explore in the area and the need for geologic information upon which to base future exploration activities is critical. GGI is being used to map the architecture of the rift by identifying the contrasts between the basement and sediment cover. This combination of structural and stratigraphic mechanisms within the rift and the structural traps, that often develops when soft sediment drapes over the ridges and gets compacted, make it an ideal geological setting for full tensor GGI.

To date, companies, such as Tower Resources and Tullow Oil, have already seen the benefits of GGI in the Ugandan Rift System, highlighting the importance of GGI technology in this environment.

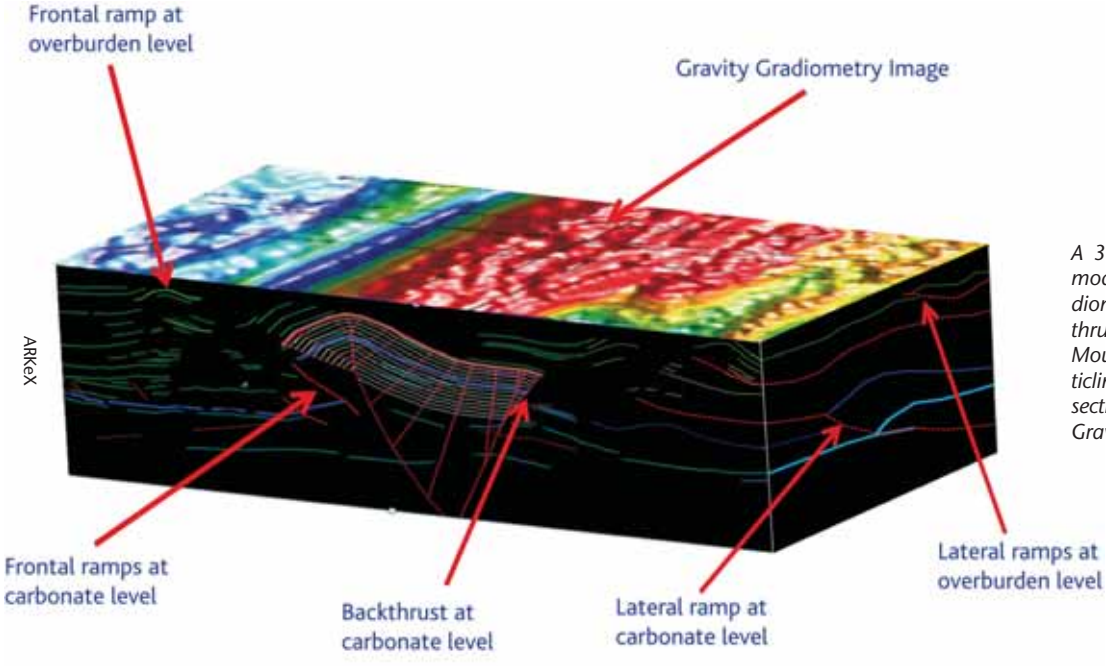


## What next for GGI?

Gravity Gradiometry is now being used successfully across the world in both pre- and post- seismic acquisition – filling gaps, verifying prospects, overcoming imaging difficulties but also helping to plan and refine the locations of future seismic surveys.

The true value of GGI is only just beginning to be realised, with data integration an essential component to unlocking its benefits. By developing workflows and integrating modelling methods, GGI can sit seamlessly alongside other geophysical data within a standard interpretation and processing workflow, delivering value at various stages throughout the exploration cycle.

What is clear is that, as geophysical exploration becomes more difficult and continues to be applied to complex geologies across the world, it's important to look beyond just the seismic! ■




*A 3D cube image linking the 2D modelled lines with a Gravity Gradiometry image, in the complicated thrust environment of the Oman Mountains, showing how the anticlines on the seismic based cross section can be traced along the Gravity Gradiometry surface.*

# First Commercial North Sea Oil Discovery

*The Ekofisk Complex on an exceptional day with sunny sky and calm water.*

HALFDAN CARSTENS

The discovery of the Ekofisk Field in 1969 marked the beginning of a new era in the oil industry. Max Melli, the Italian well site geologist, was the first to see the evidence.

Phillips Petroleum

Halfdan Carstens

"I thought we had found a gold mine instead of an oil reservoir!"

The statement belongs to Max Melli, well site geologist for Phillips Petroleum on well 2/4-2 in the Norwegian sector of the North Sea. Max had been describing cuttings since early in the morning on October 25, 1969. At 7 am sharp the magic moment arrived.

"While we were expecting Palaeocene sandstones, as in a nearby marginal discovery made the year before, we had drilled into what we first described as a calcarenite or calcareous sand. More important, it had an intense golden glow under ultraviolet light. I had never seen such oil and gas shows before," Max recalls.

Well 2/4-2, the 34th exploration well in the Norwegian sector, turned out to be the discovery well of what was later termed the Ekofisk field. At that time more than 200 exploration wells had already been drilled in the hostile North Sea, but none of them had found oil in commercial quantities.

## Almost a blow-out

Max, an Italian geologist who had not yet turned 30, was an experienced mud logger with a track record from both the Libyan desert and the North Sea. He arrived in Norway in the spring of 1968 and was the first to spot hydrocarbon shows in well 7/11-1, that found what was much later to be developed as the Cod field. Since then he had sat on several wells and made a good reputation for himself. In 1969 he was therefore offered a job as well site geologist for Phillips.

His first assignment for his new employer, well 2/4-1 (the original name is 2/4-1X), nearly ended up as a terrible disaster. The well was spudded on August 21 with *Ocean Viking* and Max was there from the very first turn of the drill. He was prepared to describe cuttings through a 3,000 m thick section of boring clay and shale before entering the reservoir. The Quaternary and Tertiary clay is soft and the drilling fast. After only one week casing had been set at 146m (30") and 623m (20"). Drilling had resumed and at 1,663m, on Sunday morning August 31, the formation pressure increased tremendously and oil flowed into the wellbore and the mud tanks.

"Oil was gushing out of the borehole and it took a while to control it, to the point that we eventually lost the well," says Max of this dramatic moment. ▶

*Max Melli was the well site geologist on* Ocean Viking *when the giant Ekofisk field was discovered in 1969.*

No one was prepared for this, meaning that the mud weight had been too low to resist the formation pressure. Thanks to a highly competent drilling crew, the "kick" was controlled before it ended up as a blowout. "The incident was reported in the Norwegian press as a near blow-out. Thanks to Ed Seabourn, the famous Phillips rig supervisor, it was excellently controlled," Max says.

## The Oslo team

"When in Oslo, in the Phillips office, I was the junior member of the exploration team led by Hank Heikkila, an excellent geologist, an American of Finnish origin. He was a blond , tall, always smiling scientist who was leading the search for oil and gas in Norway," Max remembers

"There was another geologist, older than me and married with children, Sid Warner. Sid took care of a lot of office work, while I was spending most of my time on the rig. My job, when in the office, was to prepare the "Composite Log ", a log that recorded the gas shows, the lithology, the drilling depth , the speed of drilling and the electric logs recorded at the end of the well."

"Hank's job was to correlate the wells with other wells in the neighbourhood and assign ages to the rock's horizon and to the pay zones. He was also an excellent seismic interpreter who correlated the results of the wells drilled with the seismic horizons that we were mapping. Under his guidance I was allowed to play with some seismic interpretation and build some maps of my own, in the spare time from my other duties."

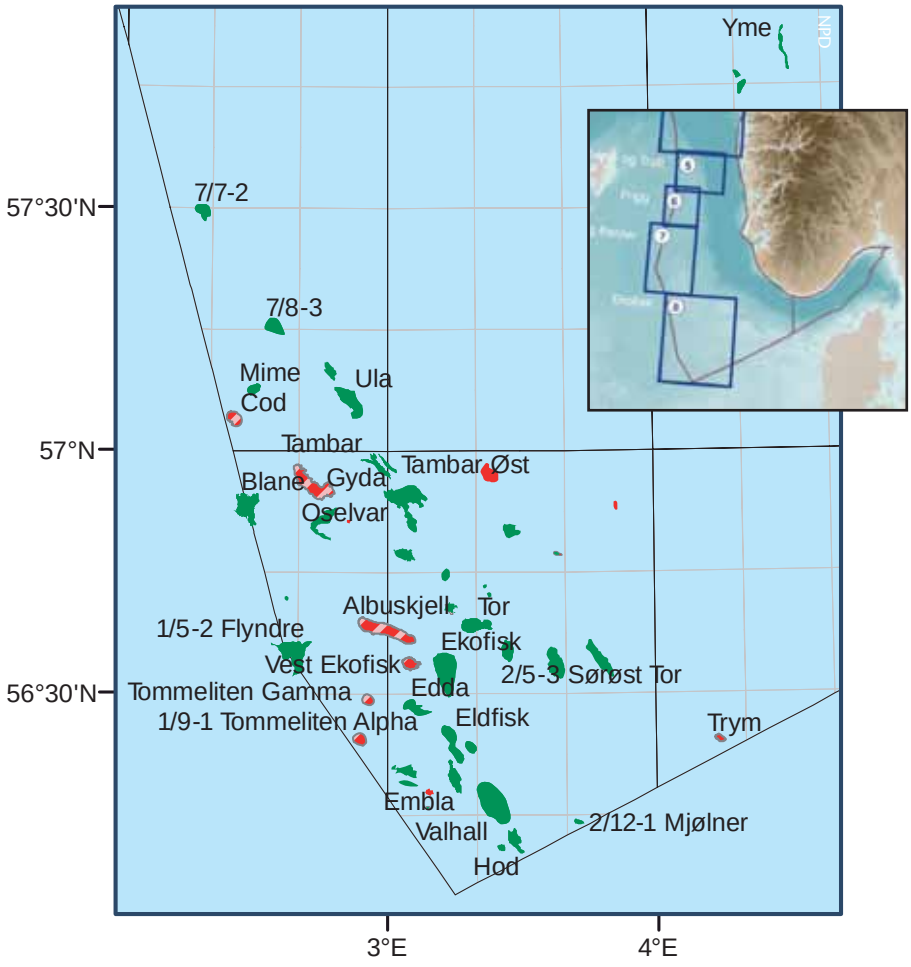
## The last attempt

As the story has been told many times, exploration efforts in the North Sea were rapidly declining by fall 1969. A total of 32 wells had been drilled in the Norwegian sector since Esso completed the first exploration well (8/3-1) as dry in 1966.

Oil had been discovered in the second well, 25/11-1, also operated by Esso, but it was judged to be non-commercial at the time. We now know that this borehole actually was the discovery well of the Balder field that was put on production in 1999, 32 years later.

Phillips Petroleum was also encouraged at an early stage by a condensate discovery with well 7/11-1, later developed as Cod, but after subsequent dry holes in other blocks, the company was ready to pull out in mid-1969.

It was therefore the contract obligation on the drilling rig that resulted in the drilling of well 2/4-1. Attempts by Phillips to avoid the obligation for this well were refuted by the Norwegian authorities. Phillips therefore made the decision that it was better to drill one more exploration well instead of paying USD one million as a "fine" as well as paying for the rig lying in dock.




*The Ekofisk field is situated in the Central Graben of the North Sea and in the southernmost part of the Norwegian sector of the North Sea. It is surrounded by several other fields with oil reservoired in Upper Cretaceous and Danian chalk, including another giant, the Valhall field operated by BP. There are also fields with chalk reservoirs in the Danish sector to the south but none in the UK sector to the west.*

## One more try

Well 2/4-1AX, which was later reclassified as 2/4-2, was spudded on September 18 with the same drilling rig, the same drilling supervisor and the same well site geologist as the near blow-out 2/4-1 well. The two wells were located only one km apart. Drilling continued for more than a month, and to everybody's surprise the well did not encounter any oil under high pressure at shallow depth as the first well had done. The shaly limestones – full of oil – were just not present in the second well on this anticlinal structure.

In retrospect, we know that the first well was drilled right into a seismic anomaly. Below a bright zone the seismic signals were highly disturbed, and the structure at target level looked very much like a collapsed zone.

The second well on the structure was therefore drilled outside the anomaly, and this explains why it did not hit oil in the Upper Tertiary section. We now also know that the poor seismic on the crest of the structure is caused by gas leaking from the reservoir into the shale section above. The gas slows the seismic signals and makes the crest look like a hole or a collapse zone.

"There were no seismic reflectors. Obviously, the presence of the gas itself indicated the existence of hydrocarbons, but it was very difficult, given the limitations of seismic processing at the time, to build a useful geological model in our heads," Max says about the disturbed zone.

After drilling for 38 days, the moment at which Max saw the oil for the first time arrived. "We had penetrated into the famous Danian chalk, a rock consisting of the skele- ▶

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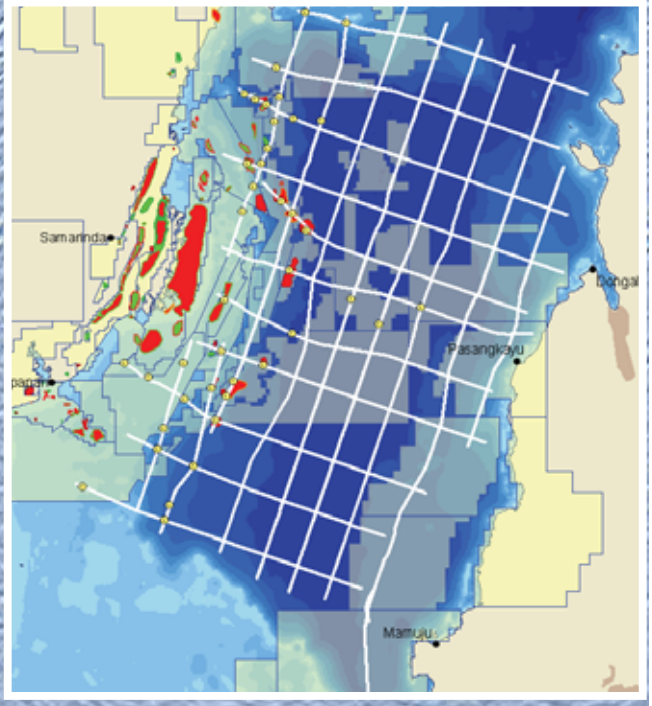


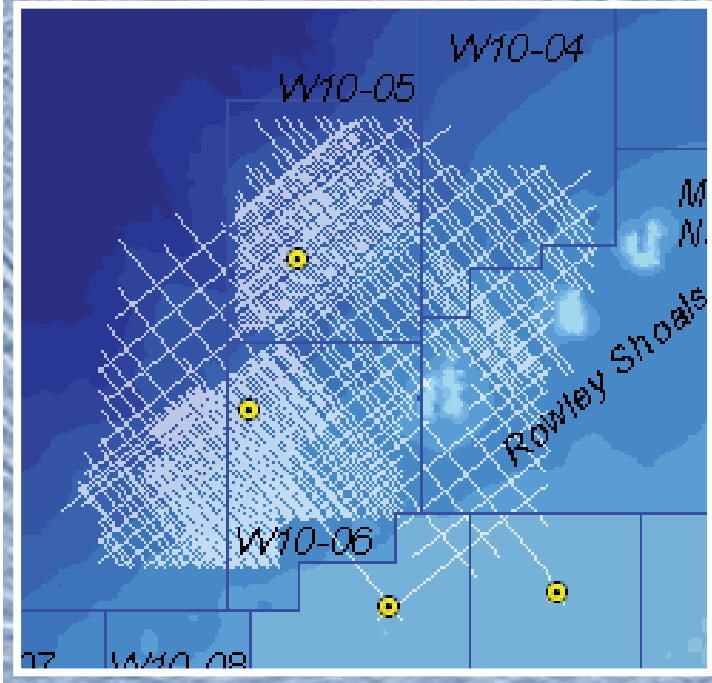


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## EKOFISK TIME LINE

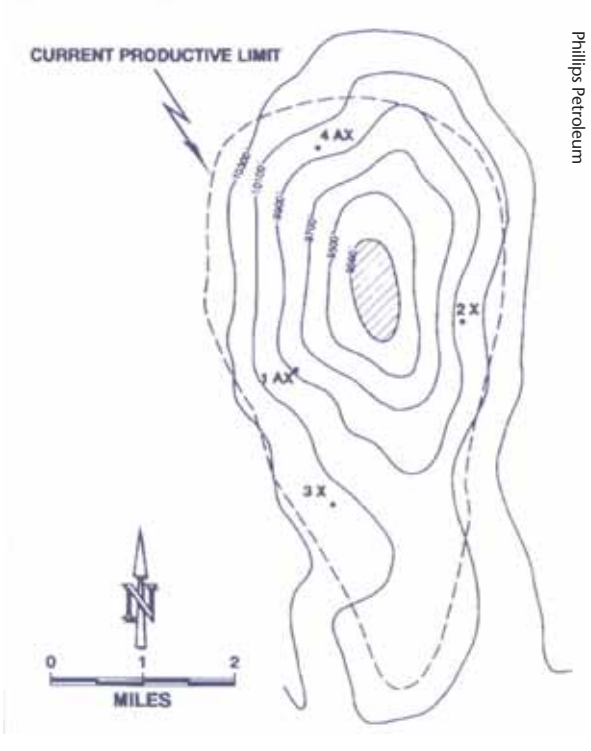
| | |
|---|---|
| 1969 | October 25: Discovery with well 2/4-2 drilled by *Ocean Viking* |
| 1970-71 | Three appraisal wells drilled |
| 1971 | Test production started on June 15 from 4 wells producing a total of 28MMbo in three years |
| 1972 | Decision to develop the field and drill 30 wells from three platforms in order to produce 300,000bopd |
| 1974 | Development drilling started |
| 1976 | Oil production peaked with 350,000bopd |

tons of tiny unicellular plankton animals, coccoliths, that had again blossomed after the Late Cretaceous mass extinction that wiped out the dinosaurs,"

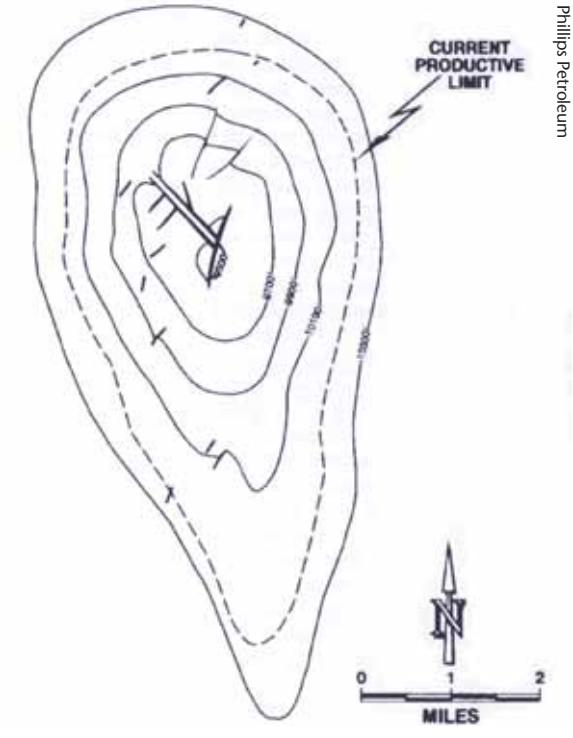
"The chalk reservoir consisted of two units, the Danian chalk (later named the Ekofisk Formation), the thickest and most porous portion and the Upper Cretaceous chalk (later named the Tor formation), separated from the first by a tight zone of cherty limestone. We took cores of the reservoirs and, in spite of looking very porous the rock appeared to have poor permeability. However we were relieved to see many small fractures that could have compensated for the lack of permeability," Max recollects.

### Unbelievable!

"Following the drilling of the pay section we ran logs to find out what exactly we had found. During the logging, done by Schlumberger's engineers, I was in constant contact via radio with Hank, the exploration manager, and Sid, the geologist, in Oslo. We were discussing in code, to avoid being




*Structure map (above) at top Ekofisk as outlined in 1971. Note the hatched area in the centre which was assumed to represent a depression. The dashed line shows the estimated production limit.*




*Structure map (above) at top Ekofisk as outlined in 1991. The dashed line shows the estimated production limit. The major north-south axis of the field is approximately 10 km and covers an area of 50 km$^2$.*

heard by competitor companies, but as soon as I had the Schlumberger logs, I flew to Oslo carrying them. We spent all night in the office calculating porosities and water and oil saturations. We could not believe it," Max says.

"An experienced Irish geologist, Pat McGuire, had joined us from London. The calculations were done over and over again. We had up to 50% porosity in the upper part of the reservoir and almost zero water saturation. Obviously the coccolith shells were like tiny egg shells, empty inside, but full of oil. The oil had prevented the rock from compacting, creating a high pore pressure that counteracted the geostatic pressure of the overburden. Visual permeabilities were poor, but this fact was compensated by the high degree of fracturing of the rock. It was very brittle and showed many hair-line fractures under the microscope. We calculated giant size reserves, since the mapped seismic structure was very large."

Big shots from Bartlesville in Oklahoma, the Phillips Petroleum head quarters, then started to arrive in Oslo. Many bosses from the partner companies also joined the team who started celebrating. And they had good reasons to do so. Phillips was the first company to discover what looked like a commercial oil field in the Central North Sea.

"We proved that the North Sea had a great potential as an oil province," Max claims.

"Hank, knowing that I had a certain inclination for artistic copper work, asked me to prepare a copper picture of the Ekofisk, a mythical fish of his invention that lived in the Norwegian Sea 60 million years ago. I made my masterpiece in copper and silver, a Picasso-style fish that looked like a chicken. We put a frame around it and gave it as a present to the President of exploration, Ward Dunn, with the compliments of the Oslo exploration team. More than my well site skills, my Italian artistic ability is the one quality that was mostly appreciated by my bosses."

Following the drilling of the three appraisal wells, the Ekofisk structure was still not fully understood. The centre of the structure was thought, on the basis of the seismic data, to be depressed and was avoided by the discovery and appraisal wells. The drilling of the vertical well 2/4C-8, however, showed that the seismic data were affected by a gas cloud over the centre, and that the structure was therefore a perfectly normal anticline of which the crest had now been penetrated. The collapsed structure had turned into a "collapsed velocity zone". Sonic logs from the well detected an anomalous low-velocity shale section from 1,768 to 2,191 meters.

## A Norwegian gem

"Nobody finds oil alone," Max claims. "It is always the result of team work. Somebody in London made the geophysical interpretation of the structure, while Hank prioritized the exploration effort. I did most of the well site work, described cores in minute detail and made the composite logs. Sid prepared most maps and cross-sections."

"What happened to our exploration team? You would expect us to be rewarded, but this is not the logic of big finance and capital intensive projects. People don't count. Sid was fired at the end of 1970 and returned with his wife and kids to Colorado. Hank was demoted from Exploration Manager to Chief Geologist and transferred to London."

Max himself, exactly one year after joining Phillips, was transferred to Lagos, Nigeria, a "holiday paradise in the Gulf of Guinea". He took with him a souvenir from Norway, his girl-friend. In October 1970, they were married by a Nigerian civil servant.

And Ekofisk is still going strong. ■

The g Hotel, Galway, Ireland

# From Outcrop to Boardroom:

# Data Solutions for the Future

Thomas Smith

THOMAS SMITH

A new information technology architecture under development will allow the flow of information across all upstream oil and gas business units; exploration to management

Oil and gas exploration and production businesses are facing an array of complex issues, from finding new reserves to dealing with geopolitics around the globe. The business is data-driven and deals with exponentially increasing data volumes. The challenge is to make this data available and usable to all facets of the industry. This is why Microsoft and its industry partners are embarking on a journey to define a new, industry-driven IT architecture that will ultimately result in higher efficiency and lead to cost savings in operations, from start to finish.

As of October, 2010, 25 of Microsoft's oil and gas partners are involved in the Microsoft Upstream Reference Architecture (MURA) Initiative, working to integrate data and workflows from a host of different technologies. Suresh Madhavan, president and CEO of PointCross, one of the original MURA partners, puts the problem in prospective, "We have production people using data by the millisecond, planners weekly, and strategy decisions made monthly and yearly. We all use the same data and need a means to connect this data. This is why we are working on a new type of ecosystem that will become an E&P business operating system."

## Information overload

The digital oilfield has helped companies streamline operations, but also created informational overload, making it difficult to find, use, and share oilfield information.

According to a recent Microsoft-Accenture survey of 173 industry professionals, 44% said the upstream data explosion continues to have a negative effect on their ability to get their work done. They cited difficult and time-consuming searches through diverse systems, data not easily captured or archived, data stuck in individual repositories, and too much redundant and/or unnecessary data. Most respondents said a simpler and more unified computing environment would be very valuable to their job performance

and see an industry-wide collaboration as the best way to accomplish the needed improvements.

The industry therefore needs a common IT approach that allows exploration companies to use more flexible and cost-efficient technologies. If a technology supplier comes up with a better seismic viewer, the architecture should allow that solution to be deployed quickly and economically. This approach will reduce the constraints on IT, gives companies access to a range of options, and can reduce the time needed to deploy new solutions from years or months, to just months or even weeks.

## Data integration challenge

For example, a group of geoscientists in a large global E&P company needed to rapidly access and analyze a series of technical and business data in the right context to make an effective "drill or not-to-drill" decision. For these geoscientists, the data integration challenge is critical, as they rely on workflows, data-driven events, and automated analysis to identify risks and help manage the exploration portfolio. These professionals also need integrated views that reveal all relevant data, both structured and unstructured, for a particular situation.

Technical data, including information from seismic and gravity surveys, reservoir characteristics, structural analysis, well data and GIS surveys, all sat in different geophysical applications. In addition, the relevant financial reports, drilling costs, health, safety and environment (HSE), and risk analysis reports were stored in the document management system. Through the collaboration of several initiative participants, including PointCross, OpenSpirit, (a TIBCO Software Group) and Microsoft, the team was able to rely on a new data services layer within their IT systems architecture that integrated key business data stores with the sub-surface data stores. The integration of this disparate information allowed the geoscientists to make the most informed decision without losing valuable time trying to find, access, and use the relevant data. This is just the start of an entirely new concept of data management.

## Important concept

The data services layer with a built-in, smart data exchange will allow an E&P company to use all data sourced from processes and decision-making in business. The layer connects and transforms disparate types of data sources that represent drilling, production, and geophysical data. It also connects documents and reports, specifications and drawings, and contracts related to construction of major capital expenditure facilities, presentations and proposals for deals. It is quite like a nerve system for data networking and communication.

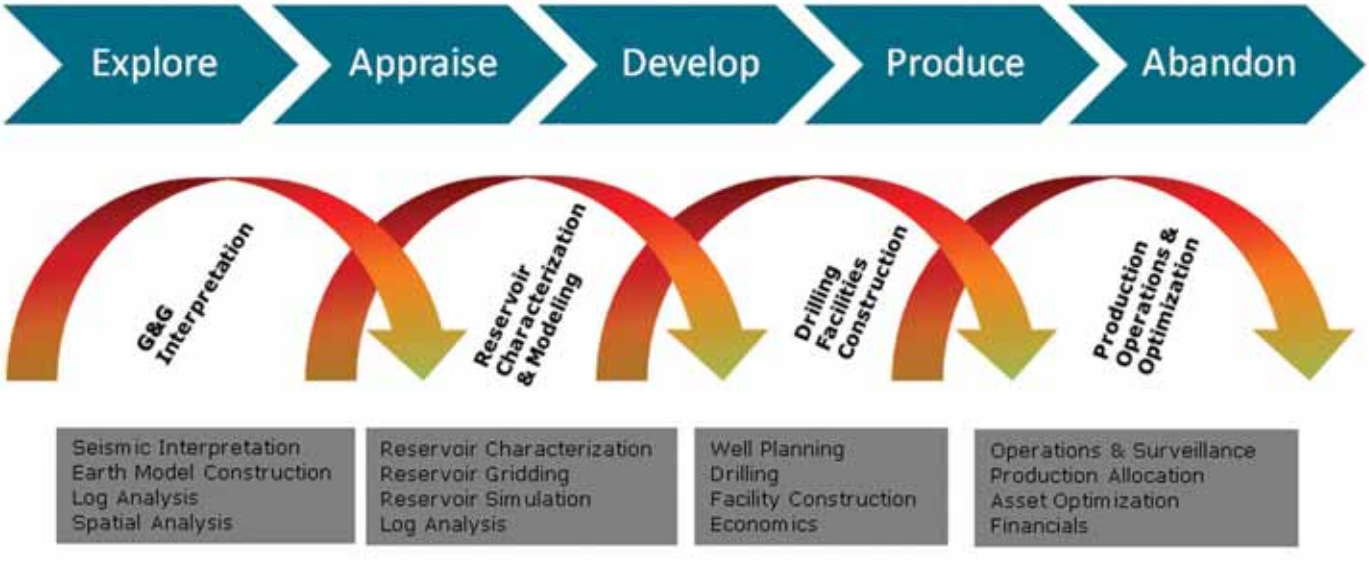
Managing all the data from these types of disparate data types and their relationships is the role of the metabase layer or 'ontology engine'. This creates relationships between business contexts which contain information, people who work on that information, and definitions that give semantic meaning. When the information is given this type of context, including location and meaning, it is labeled as metadata and is able to be referenced, refined, validated and enriched.

Technology from OpenSpirit provides adapters that enable unified access to multiple subsurface data stores. Geoscientists can also perform technical and parametric searches to quickly locate structured data, including sub-surface reports, through PointCross solutions. For security purposes, the data gathered is accessible only to those individuals who have been authorized access. Microsoft collaboration portal, SharePoint, provides a user interface for easy information viewing and sharing, while Esri technology supports geophysical mapping capability.

## Vendor and client working together

In the example above, several technology providers and industry solution vendors worked collaboratively to provide the best capabilities for each of their solutions to solve one team's information workflow challenges. This concept is being duplicated on other levels by additional companies within the Microsoft Upstream Reference Architecture Initiative.

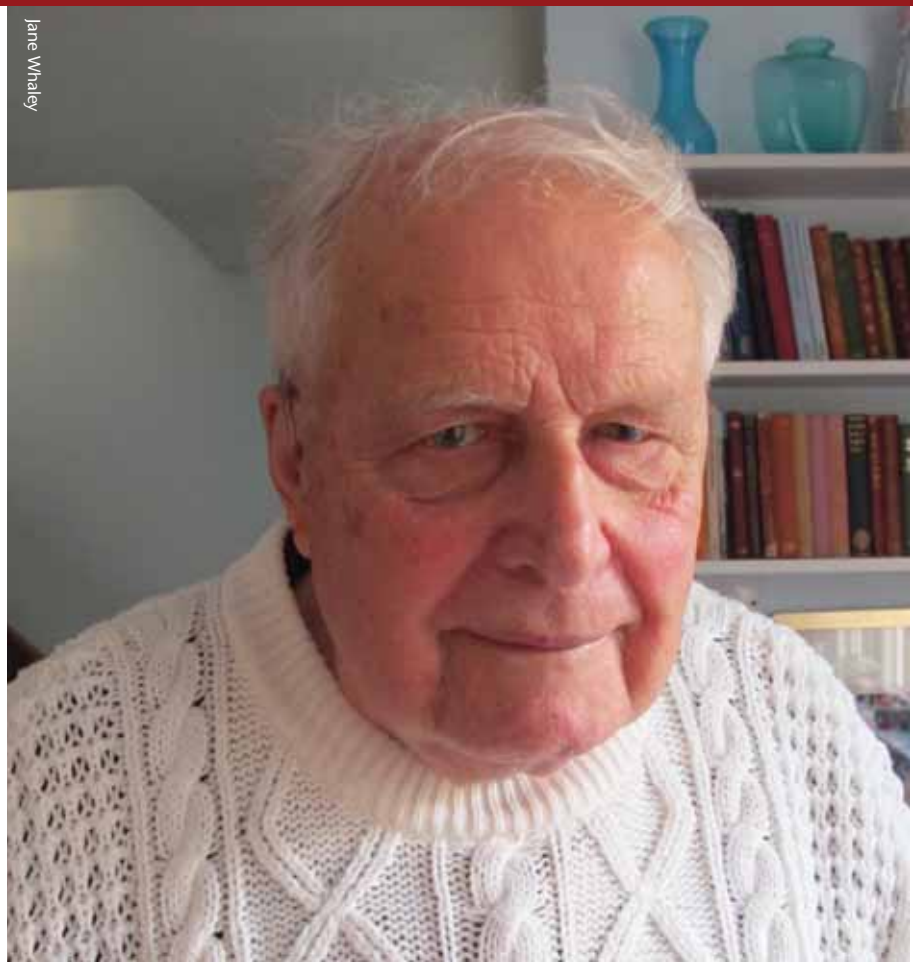
Combining each of these vendor technologies together quickly and efficiently into a composite application will remain a primary goal of the initiative. As a result, upstream E&P companies will have access to oilfield information based on their needs instead of being dictated by the constraints of application architecture. ■



# An Extraordinary, Diverse and Rewarding Career

JANE WHALEY

*"If I had my life again, I'd still be a geologist"*


Jane Whaley

In this edition, *GEO ExPro* Magazine celebrates **Dr. Joe McCall**, a man whose life summarises the sense of adventure, excitement and love of life which epitomises the geologist – and who has just been recognised with a Distinguished Service Award from the Geological Society of London.

"If I had my life again, I'd still be a geologist," declares Dr. Joe McCall. And having spent 65 of his 90 years as one, he should know!

But Joe did not initially realise that geology was to be his calling. Born in 1920, the last of seven children (a prolific family – his mother was one of 15 and his grandfather, who was Prime Minister Disraeli's doctor, had 19 siblings!), he initially went to Imperial College in London to study Chemistry. But while there, he attended a couple of lectures on geology given by the legendary H. H. Read, and immediately knew that it was the subject for him.

It was several years before he could follow this realisation, because World War II intervened and in 1940 he was called up to join the Army. There followed five years in the Royal Army Service Corps, much of it spent in East Africa, where he was involved in capturing Madagascar from the Vichy French forces. Working with African troops in Kenya and Tanzania, he learnt Swahili – a skill that was to later prove surprisingly valuable in his geological career. Joe eventually returned to England in April 1946 "by boat to Egypt and then to Toulon and across France by train. I had spent four years overseas, away from my family."

Finally able to realise his ambition, Joe returned to Imperial College to study geology the same year, obtaining First Class Honours in 1949, and also the Watts Medal for Geology and the Wheeler Prize for Mining Geology from Imperial College. "I was incredibly lucky to be taught by someone of the calibre of H.H. Read," Joe says. "When he asked me to stay and do a doctorate with him I jumped at it, especially as my fellow Ph.D. students were Janet Watson and John Sutton." (For the uninitiated, these names are all well known to student geologists for their textbooks on geology. Janet Watson went on to become the first woman President of the Geological Society). "I studied the extension of the Scottish Dalradian into Donegal, establishing the succession, structure, and metamorphic history of the rocks there. The area had been mapped years earlier by the Irish Geological Survey, but there was no formalised stratigraphy."

## Mapping carbonitites

Having achieved his doctorate in a record two years, Joe applied to join the UK Geological Survey. "However, they noted that I spoke Swahili, and suggested that I joined the Colonial Service instead. In 1951 I consequently found myself in Kenya, working at the Hydrological Branch of the Power and Water Directorate in Nairobi, siting boreholes all over western Kenya and studying the groundwater conditions around Nakuru in the Rift Valley."

After a couple of years, he moved to the Geological Survey in Kenya, to map volcanic terrains around Lake Victoria and the Rift Valley. "I became something of an expert in carbonatites – rare, carbonate igneous rocks, full of radioactive material. These were first seen in the throat of a large Miocene volcano in the Kavirondo Rift Valley, which is separate from the main Rift and runs east -west. No one had mapped these before, and I identified and mapped five of them."

Joe was probably doing the sort of fieldwork many geologists would envy, but it was not without its hardships. "We mapped an area of 1,200 square miles (about 3,100 km$^2$) each year, spending six months of each year in the field, dodging wild animals, snakes and malaria, and away from my wife, who had joined me in Kenya after we married in 1956," he explains. "We then had six months of writing up, and our boss, William Pulfrey, was a hard task master!" Joe was eventually responsible for deriving the entire sequence of volcanic rocks in the Central Rift Valley, from the Miocene to the Recent.

"I also carried out a gravimeter survey of the Central Rift Valley, only the second such survey to have been undertaken in Kenya – the previous one was done many years earlier by Sir Edward Bullard, using pendulums, and had missed the important positive anomaly in the centre of the valley."


*H. H. Read, Professor of Geology at Imperial College, who inspired Joe to study geology.*

## Meteorites and moon studies

By 1960, at the top of his pay scale in Kenya, with no chance of promotion and unsure whether he would even be able to stay in the country after independence in 1963, Joe decided it was time for another challenge, and moved to Perth to become a Senior Lecturer in the University of Western Australia. "Although I hadn't taught before, I found it most enjoyable," he says. "I had some very good ▶

*Janet Watson and John Sutton were contemporaries of Joe McCall at Imperial College, London. The man in the left is probably Don Bowes, an Australian postgraduate student who studied with them.*

students, and taught petrology, structural and economic geology, also supervising various doctorate theses on the PreCambrian Archaen rocks of Australia."

"I also developed a great interest in meteorites, and analysed and catalogued the huge collection of these at the Western Australian Museum. There are literally hundreds of meteorites of all sizes scattered over the vast Nullabor Plain in Southern Australia, a limestone desert where the arid conditions mean they don't deteriorate. Some of the best examples were actually collected by a rabbit trapper on the Plain – one of them weighed twelve tons! Meteorites are important, because they are the basis of many of our studies on the origin of the universe and the solar system."

His interest in meteorites extended into moon research, and he became an early expert on lunar geology, attending two lunar conferences in the US prior to the first Apollo Landing.

## Moving into industry

However, after ten years in academia, Joe decided it was time to try something new – so he went into the mining industry. "The nickel boom in Australia was at its height, so there was lots of work. It was certainly a bit of a change from lecturing. Industry is harder than the academic life, as you really have to produce results, but it was very exciting."

Amongst other achievements, Joe established the Eneabba deposit, which is the largest rutile deposit in the world, and undertook exploration for gold and nickel, as well as being involved with the team which found the Ashton diamond deposits, in the extreme north-eastern part of Western Australia, "one of the biggest diamond deposits in the world, with diamonds being found in alluvium and in pipes, but not in kimberlites."

Eventually however, it was time to come home. "Well, the family, now with three children, returned to England," Joe continues. "Within a week, I had left for Iran, to undertake regional geological mapping of the Makran range in the south of the country. We used helicopters to identify areas of interest and would drop off the geologists so they could map a traverse and be picked up at the end point. We mapped an area the size of England in only two years. We had just completed the field work when the revolution happened in 1978 and the Shah was deposed. Luckily for us, the new government decided to support the project, so I was able to complete the write-up – although, having watched the revolutionaries burning banks and other buildings in Tehran, most of this was done back home in Hereford."

There followed three years in Canada, working on a gold mine in Quebec, before Joe finally returned to England permanently, to work as a consultant editing reports on North Sea oil related projects and in the new field of Environmental Geology.

## Busy Retirement

Joe officially retired in 1991, but 20 years later he is still as active as ever. Among his many activities, he has been an editor of the Geological Society's magazine 'Geoscientist' since 1992, still regularly contributing articles; attended meetings all over the world on topics ranging from climate change and geohazards to meteorites; and he was Consultant Editor for the Elsevier Encyclopedia of Geology (2005). "In my spare time I have been active in the local Gloucester Geology Trust, writing geological town trails. And I've taken up choral singing, which I love."

Joe has authored or edited 17 books and hundreds of papers, and in addition to the most recent Geological Society award, he was awarded the Geological Society's Coke Medal in 1994 and the Distinguished Service Award of the International Union of Geological Sciences in 1997.

A life of adventure, challenge, excitement and satisfaction, fuelled by that initial awakening to the joys of geology revealed by a brilliant teacher; an enthusiasm which he still carries and which continues to stimulate him every day. As Dr. Joe McCall summarises it simply:

"I have had an extraordinary, unusually diverse, and very rewarding life in geology." ■

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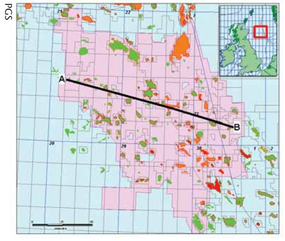
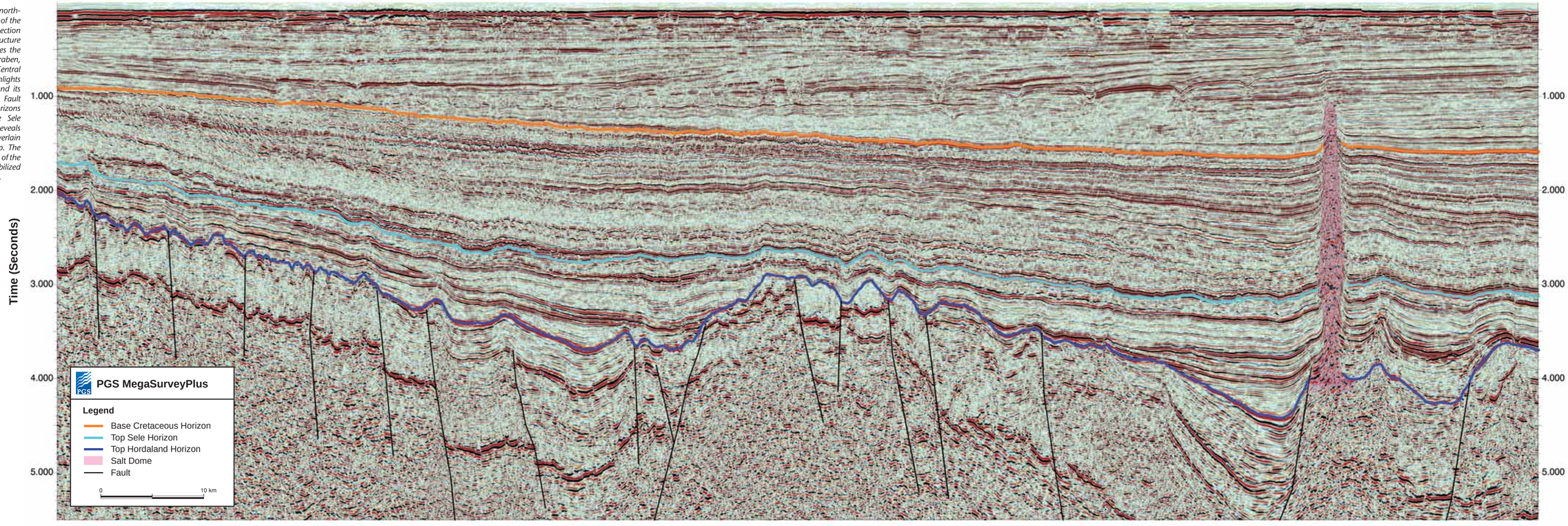



# CENTRAL NORTH SEA: Regional Dataset Supports Continued Exploration

The Central North Sea (CNS), although a mature hydrocarbon province, continues to provide new exploration prospects and reserves. The United Kingdom's 26th Licensing Round revealed increased demand for CNS acreage combined with a number of recent discoveries including the Culzean, Shaw and Catcher fields. A change in the focus of exploration from structural traps to stratigraphic traps, such as the submarine fans of the Forties Sandstone, has highlighted the demand for accurate seismic data.

The PGS MegaSurveyPlus is a regional pre-stack merged and state-of-the-art reprocessed seismic dataset covering nearly 17,000 km$^2$ of the core CNS area, combined with regionally consistent horizons tied to well control and AVO attributes, all of which contribute to the search for new reserves.

*This seismic cross section trends north-west to south-east, crossing 150 kms of the core of the Central North Sea. The section reveals the horst and graben structure of the Central North Sea and crosses the Western Platform, Western Central Graben, Montrose-Arbroath Ridge, East Central Graben and Cod Terrace. It highlights the Base Cretaceous Unconfomity and its truncation of tilted Triassic-Jurassic Fault blocks. Subsequent Cretaceous horizons onlap and are truncated by the Sele formation. The Top Hordaland group reveals a regional unconformity that is overlain by sediments of the Nordland group. The section also reveals the Zechstein Salts of the Cod Terrace that appear to have mobilized along an existing Permo-Triassic Fault.*



# Recent Discoveries in the Central North Sea

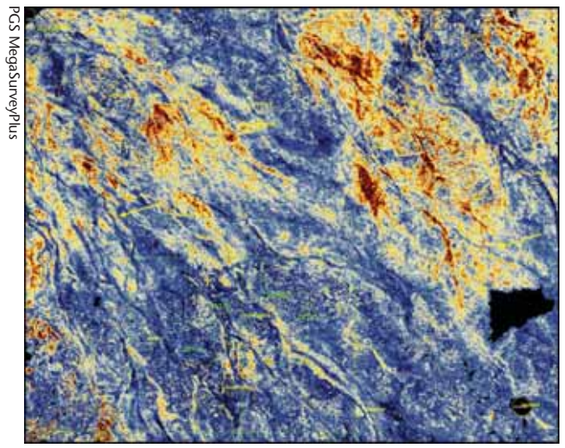
MATT JAMESON, SAIRA RAGBIR, CHRIS LOADER, TIM BIRD, CATHERINE SMITH & CYRILLE REISER (PETROLEUM GEO-SERVICES)

The Central North Sea (CNS) has been a focus of hydrocarbon exploration and production for decades. Even now the area remains a hive of activity, with an estimated 5 billion barrels of oil and gas undiscovered (UK DECC Estimates of Undiscovered Resources, 2010).

Recent discoveries in the CNS include the Culzean Gas and Condensate field (block 22/25a) by Maersk Oil, and the Shaw Discovery (block 22/22a) by Marubeni and Talisman in 2009. In 2010 EnCore announced the Catcher and Catcher East discoveries (block 28/9) with estimated reserves of ~300 MMBoe, representing one of the largest discoveries in the Central North Sea for over a decade.

In 2010, 144 Licenses were awarded in the United Kingdom's 26th Licensing Round. With increasing exploration and investment in the CNS there is greater demand for high quality, increasingly detailed and innovative seismic data to assist in the exploration, understanding and de-risking of this prolific hydrocarbon province.

Petroleum Geo-Services (PGS) has been working in the Central North Sea for nearly 20 years. Since 2002, the company has been delivering merged 3D seismic data known as the MegaSurvey, which has mapped, in both regional and prospect level detail, 60,000km$^2$ of the Central North Sea. This has now been upgraded to the MegaSurveyPlus; a pre-stack merge of nearly 17,000 km$^2$ of Central North Sea seismic which, with horizon interpretation and highlighted AVO anomalies, allows rapid regional screening for prospect and lead identification.




*RMS Seismic Attribute of the Forties member, showing deep marine channels.*

## Hydrocarbon plays

The Central North Sea is a focus of exploration for structural, stratigraphic and combination traps. A range of structural traps are present in the CNS, ranging from tilted fault blocks to crestal slumps. However as exploration and development has progressed, significant new structural closures are increasingly rare. The PGS MegaSurveyPlus covers a number of large scale Cretaceous slumps similar to the productive Centurion field, representing a new play type in the CNS.

Stratigraphic traps are thought to hold up to 75% of the undiscovered oil in the UK continental shelf. Stratigraphic traps range from onlap to pinchouts, spanning single seal and polyseal traps. The Forties sandstone stratigraphic trap in the Callanish Field is an example of deep water mounded turbidites that have suffered differential compaction and pinch out towards the south-west. Combination trapping mechanisms combining structural and stratigraphic features are also present, for example in the Britannia field in the Lower Cretaceous.

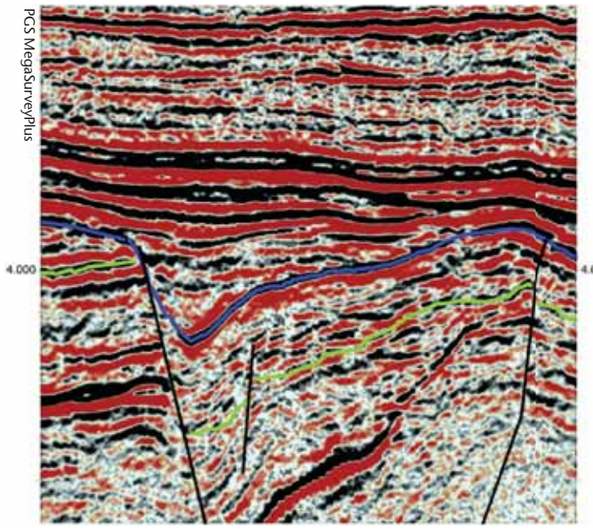
Although a range of hydrocarbon play types exist in the CNS, this article focuses upon deep water Paleocene and shallow to deep marine Jurassic plays.

## Paleocene and Jurassic plays

The Catcher discovery (~300 MMboe) has highlighted the potential of Paleocene plays in the Central North Sea. The Forties and Maureen Sandstone are key reservoirs and represent a series of deep marine sand rich submarine fans. Fields producing from these reservoirs include the Forties (~340 MMboe), Arbroath (~170 MMboe) and Montrose (~236 MMBoe). Paleocene reservoirs are charged by the Heather and Kimmeridge Clay formations. The Lista and Sele formation shales represent a key upper seal to Paleocene reservoirs which are also underlain by hemipelagic shales forming a bottom seal. The MegaSurveyPlus has highlighted the distribution of the Forties member in a regional context, with increased accuracy attributed to the reprocessing of field tapes on a regional scale.

Paleocene plays are dominantly stratigraphic traps, although some combination traps associated with salt doming are also present. Combination traps are favoured targets due to a higher chance of success.

Jurassic plays represent key targets in the Central North Sea. Jurassic traps may be structural or stratigraphic with key reservoir intervals spanning the shallow marine facies of the Fulmar formation and deep marine, turbidite facies of the Kimmeridge Clay. The Fulmar differs from the Kimmeridge Clay in that it represents a high pressure, high temperature reservoir (Erratt *et al.*, 2005), but despite this added risk the Fulmar remains a popular play in the Central North Sea.




*Fulmar formation (green) and Base Cretaceous (blue) Horizons displaying a combination trap of tilted fault blocks truncated by the Base Cretaceous Unconformity.*

Fields producing from Middle to Late Jurassic reservoirs include the Fulmar (~567 MMBoe), Clyde (~130 MMBoe) and Kittiwake (~74 MMBoe) fields. Jurassic reservoirs are charged by the Heather and Kimmeridge Clay formations. Seals are abundant, from intraformational shales to the source-seal Kimmeridge Clay, Cretaceous Shales, Chalk and overlying Cenozoic clastics.

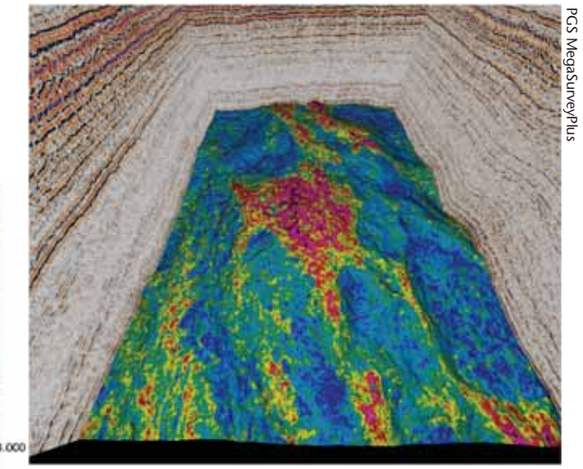
The MegaSurveyPlus reveals the distribution of the Middle - Upper Jurassic reflectors and has also been reviewed for AVO anomalies. Several additional horizons have also been interpreted for the MegaSurveyPlus, aiding in the exploration of subtle stratigraphic traps.

## Reservoir characteristics

The previous sections have outlined the regional coverage of the MegaSurveyPlus, however the dataset can also be utilised at reservoir level.

To attain details at reservoir level the PGS Prospect Scanner workflow was used in the identification and mapping of AVO related anomalies over the dataset. Prospect Scanner combines seismic AVO analysis and inversion technology to derive relative elastic properties (i.e. P and S-wave impedances, Vp/Vs ratio).

Further analysis of the MegaSurveyPlus at various reservoir intervals reveals lithology trends of play fairways, local fluid effect anomalies corresponding to discoveries, and in some cases undrilled stratigraphic features.




*3D view of part of UK Quad 22 looking North, showing Envelope Attribute of extra far offset stack at the Top Forties TWT structure horizon. The image shows high amplitudes (red) corresponding to field outlines of Montrose field (centre rear, showing two prominent channel trends) and Arbroath field (centre). There are also several bright anomalies below the Arbroath field, located on undrilled structural culminations.*

## The future of the CNS

This article has briefly covered the recent discoveries and plays of the Central North Sea and demonstrates how the upgraded data coverage of the MegaSurveyPlus can help to identify more leads and prospects with a level of confidence never possible before. With an estimated five billion barrels of oil and gas undiscovered and significant in-situ infrastructure, the Central North Sea is still a very attractive area to explore and operate.

As exploration continues in this prolific hydrocarbon province, comprehensive, state-of-the-art data is essential for delineating prospects and reducing risk. The application of pre-stack seismic data combined with refined well-tied horizons and AVO anomalies provides a wealth of information. Furthermore, the future application of PGS' GeoStreamer® (dual-sensor towed streamer technology) will further enhance data coverage of the Central North Sea and continue to add value at the reservoir level.

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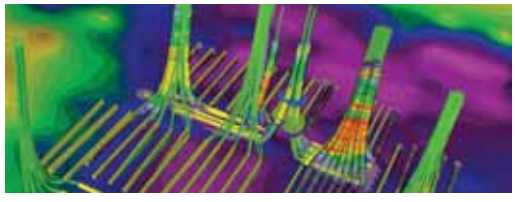
[1] Welling & Company Geological & Geophysical Software Study, 2009



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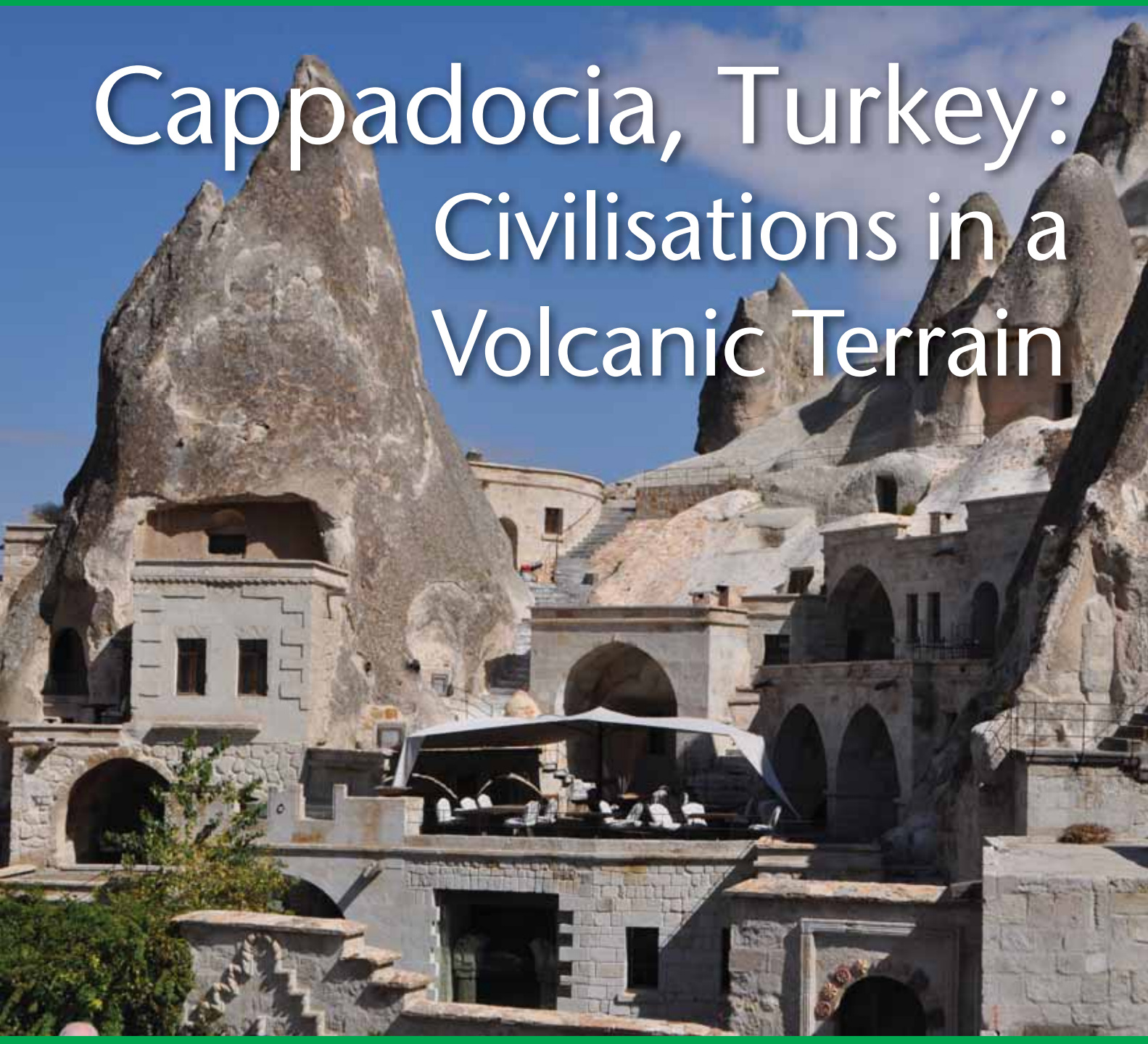
# Cappadocia, Turkey: Civilisations in a Volcanic Terrain



RASOUL SORKHABI, Ph.D.

With mountains, springs and ancient civilisations, Cappadocia is one of Turkey's most fascinating areas for tourists, historians, archaeologists and geologists alike.

Neogene-Quaternary volcanic rocks, atop or around sedimentary basins, cover an extensive tract of the Central Anatolian Plateau. These rocks in concert with faults, water and wind have created lofty summits, valleys, hot springs, a picturesque landscape, as well as cave houses and temples for several civilisations inhabiting this region known as Cappadocia. This is one of Turkey's most fascinating areas for tourists, historians, archaeologists, and geologists.

Rasoul Sorkhabi

*A view of ancient cave houses blended with modern settlements in the town of Göreme, Cappadocia. This town is the tourist heart of Cappadocia.*

## Turkey: Tectonic crossroads

The country of Turkey (historically known as Asia Minor and Anatolia) sits on tectonic crossroads of colliding plates and active faults, and presents a fascinating geology for investigation.

The country is essentially a high plateau surrounded by the orogenic belts of the Pontides to the north and the Taurides to the south. Throughout the Cenozoic, Anatolia has been a region of head-on convergence between the Afro-Arabian plate to the south and the Eurasian plate to the north. The subduction of the Neo-Tethys Ocean located between these two plates during Eocene-Miocene times was followed by continental collision, mountain uplift, and deformational structures including folds and thrusts, strike-slip faulting, and extensional tectonics. The name "Tethys" (whose basins account for 70% of the world's proven oil reserves) should make Turkey an appealing country for oil exploration, but active tectonics and high mountain uplift has complicated (and in places obliterated) its potential petroleum geology. Ocean-floor subduction along the continental margin is presently taking place in the Mediterranean Sea while tectonic stresses have produced an earthquake country criss-crossed by active faults.

## Cappadocia volcanic country

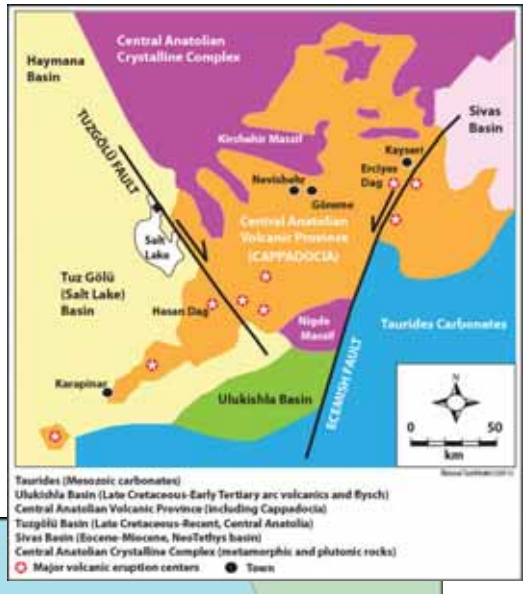
A remarkable feature of Turkey's geologic landscape is several clusters of Middle Miocene to Quaternary volcanic rocks (14-0 Ma), including those in the Central Anatolia Plateau where Cappadocia is located. The region is about 300 km long and spans from the town of Kayseri in the east to Karapinar in the south-west, oriented in a north-east – south-west direction. Cappadocia is at a mean elevation of 1,050m, and covered with volcanic or volcaniclastic rocks.

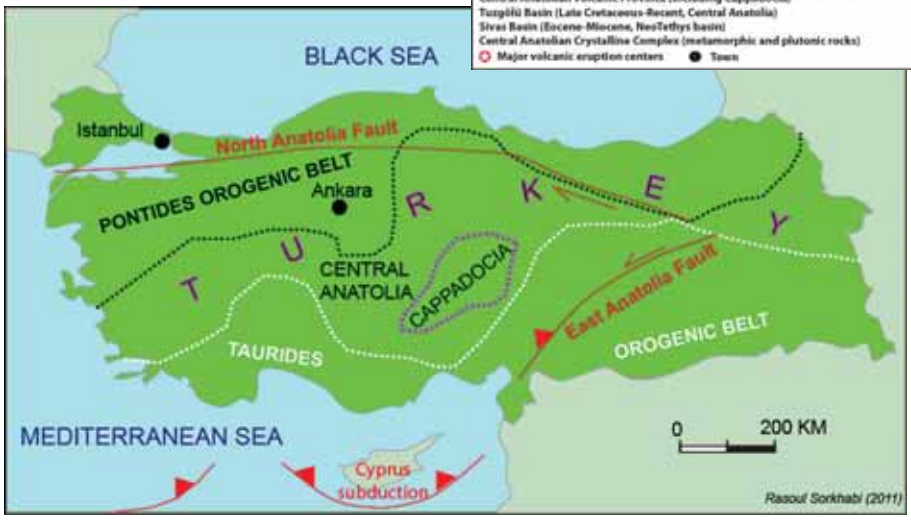
This volcanic terrain is surrounded by and superimposed upon sedimentary basins of Cretaceous-Cenozoic age. However, hydrocarbon prospectivity of these basins and the thermal effect of volcanic activity on the sedimentary rocks have been little explored or quantified.

The origin of the post-collision volcanism in Cappadocia has been debated for a long time, but geochemical data indicate that it is calc-alkaline arc volcanism (for example, the study by Pinar Sena and her colleagues reported in *Geological Magazine*, 2004). It was probably generated from a lithosphere mantle source, a residual of the previous ocean-floor subduction between Afro-Arabian and Eurasian plates, which later erupted due to crustal extension and normal faulting in the upper plate.

Major strike-slip and extensional faults both surround and occur within Cappadocia. Mapping by geologists such as Vedat Toprak of Middle East Technical University in Ankara has shown that two fault systems dominate Cappadocia: (1) The strike-slip faults of Tuzğolü (right-lateral) and Ecemish (left-lateral) bounding the volcanic province and other smaller faults within the region but parallel to these two major structures: and (2) a series of faults trending N60-70°E along the axis of volcanic terrain. ▶

*A simplified geologic map of Cappadocia (modified from Toprak and Göncüoğlu,* Geological Journal*, 1993, v. 28, pp. 357-369)*




Rasoul Sorkhabi

*A snowy view of Hasan Dâg ("Mount Hasan,"), a 3,253m volcanic mountain in Cappadocia.*

Major eruptive centres in Cappadocia are located close to or at the intersections of these fault systems, and are thus tectonically controlled. The volcanic rocks in Cappadocia come in various forms, including:

**Volcanic Complexes:** These are circular to ellipsoidal features, 5-40 km in diameter, and correspond to major eruptive centres. Nineteen volcanic complexes have been mapped and named after the provinces in which they occur. The volcanic complexes form lofty mountain summits ("dâg" in Turkish) such as Erciyes Dâg (3,917m, the highest and home to a popular ski resort) and Hasan Dâg (3,253m). The majority of these volcanic complexes are stratovolcanoes (composed of several volcanic strata) made up of basalt and andesite.

**Cinder Cones:** A cinder cone is a conical hill of volcanic glass fragments (cinders or scoria) and lava flows that surround a volcanic vent. Cinder cones usually occur on the flanks of volcanic complexes. More than 500 cinder cones have been mapped in Cappadocia.

**Fairy Chimneys:** These are Cappadocia's most attractive features. The result of particular erosion of ignimbrites (pumiceous pyroclasitc deposits), they come in various shapes such as column, mushrooms and cones.

**Volcaniclasitc Rock:** A sequence of volcanic rocks intercalated with lake or river sediments cover a vast tract of Cappadocia and fill its depression. These volcaniclastic sediments have been named the Ürgüp Formation, deposited over the past 14 million years or so.

## Civilisation after civilisation

The name "Cappadocia" (pronounced Kapadokia) is a mystery. We do not exactly know what language this word originally comes from and what it means. Many sources mention that it is an Old Persian word, Katputka, meaning "the Land of Beautiful Horses," obviously in reference to the long tradition of raising fine horse in this part of Anatolia. The earliest record of the word is from inscriptions of the Persian kings (Achaemenid Dynasty) in the early sixth century B.C., when Anatolia was part of their empire.

The Central Anatolian Plateau was once largely covered by great lakes, which dried up and the present Tuz Golü (Salt Lake) is a remnant. Human settlement in Cappadocia goes back to Neolithic ("new-stone age") and Kalkolithic ("copper age") culture, spanning 9,000-5,000 years ago. Obsidian stone tools and Mother Goddess figures have remained from these ancient cultures. The kingdom of the Hittites ruled the region from 1800 to 1200 B.C. and the Persians took over Anatolia in about 550 B.C. Interestingly, when Alexander the Great defeated the Persian Achaemneid Dynasty in 330 B.C., the Cappadocians put up a severe resistance against the Greek army, and thus remained under a Persian governance, called the Cappadocian Kingdom, until 17 B.C. when it fell to the hands of the Roman Empire with the city of Kayseri ("Caeserea") as the capital of Cappadocia.

The region became a refuge for early Christians and, especially during the Byzantine Kingdom from the 4th through to the 11th centuries, Christianity flourished in Cappadocia where remnants of many churches in volcanic caves can be seen today. In the 12th century, the Muslim Turks invaded and took over Anatolia.

In this way, various civilisations and ethnicities have shaped the cultural history of Cappadocia. This region was also part of the ancient Silk Road from China to Europe.


Rasoul Sorkhabi

*A view of Byzantine houses and churches built in the caves of Cappadocia's volcanic rocks.*


Rasoul Sorkhabi

*The ancient Uchisar Castle in the town of Uchisar in Cappadocia. The rock type is ignimbrite. The castle was probably first built by Hittites and later used by Romans and other civilisations in the region, showing the strategic importance of Cappadocia during its long history.*

## A visit to Cappadocia

Cappadocia has a semi-arid continental climate, with little rainfall, dry hot summers and cold snowy winters. Kayseri is accessible by flights from Istanbul, Ankara and Izmir. There are also trains and bus services from Turkey's major cities to Kayseri and Nevishehr in Cappadocia. A bus ride not only costs less but also provides an opportunity to view the landscape.

One can easily spend weeks in Cappadocia as there are so many sites to visit. For a short stay and yet a comprehensive view of what Cappadocia typically offers, the town of Göreme offers the best and most popular option. The town, literally built in volcanic caves and fairy chimneys, has numerous hotels and an open-air museum and is registered as a World Heritage site by UNESCO. If you intend to visit the Byzantine churches in Cappadocia with some knowledge in advance, the books *Caves of God: Cappadocia and Its Churches* by Spiro Kostof (1989) and *Kingdom of Snow: Roman Rule and Greek Culture in Cappadocia* by Raymond Van Dam (2002) offer excellent sources of information. And for a fascinating bird's-eye view of amazing Cappadocia take an early morning hot-air balloon flight. ■

*A view of Achigöl ("Bitter Lake" in Turkish), a 1,400m diameter Quaternary lake ("maar") in Cappadocia. This is one of the region's seven maars formed as the craters of volcanic eruptions filled with water. Unlike the other volcanic complexes in Cappadocia which are made of basalt or andesite, Achigöl's volcanic rocks are rhyolite.*


Rasoul Sorkhabi

# Marine Seismic Sources

## PART VI: HIGH FREQUENCY SIGNALS FROM AIR-GUNS

Only a few studies have been published which describe measurements of the air-gun signals in the kilohertz (kHz) frequency range. In this article we propose and discuss models for the generation of these high frequencies from air-gun arrays.

MARTIN LANDRØ AND LASSE AMUNDSEN

*Lasse Amundsen is adjunct professor at the Norwegian University of Science and Technology (NTNU) and at the University of Houston, Texas.*

*Martin Landrø is professor in Applied Geophysics at NTNU, Trondheim, Norway.*

In 2003 scientists conducted a broad-band (0–80 kHz) study of various gun arrays at the Heggernes Acoustic Range near Bergen, Norway, an institution operated by the Norwegian, Danish, Dutch and German navies for noise measurements of military and civil vessels. The spatial dimensions and volumes of the source configurations were small, on average 10–20 dB lower than arrays used by the exploration industry. Additionally, the noise generated by the seismic vessel itself was recorded.

### Ship-generated noise

Most of the emitted source energy had frequencies below 150 Hz, far in excess of the low-frequency noise generated by the source vessel. Spectral source levels (measured in decibels) were highest below 100 Hz, dropping off continuously with range and frequency so that at 1 kHz they were approximately 40 dB, and at 80 kHz approximately 60 dB lower than the peak level.

Above 1 kHz, spectral levels agreed almost completely with the noise generated by the vessel, meaning that if low-level, high-frequency (>1 kHz) spectral components were emitted, they were masked by ship-generated noise. This is of particular importance for marine mammals with pronounced high-frequency hearing sensitivity like toothed or beaked whales. The results indicate that any high frequency signals created by these relatively small air-gun arrays are so weak that they would not disturb these marine mammals significantly more than normal ship traffic.

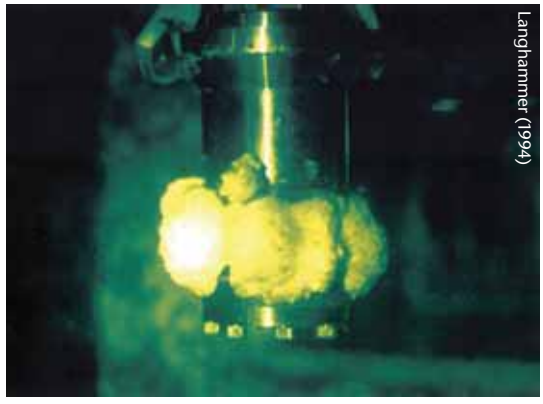
### Air-gun high frequency signals

What causes high frequency signals from an air-gun? Here, we give you the current understanding.

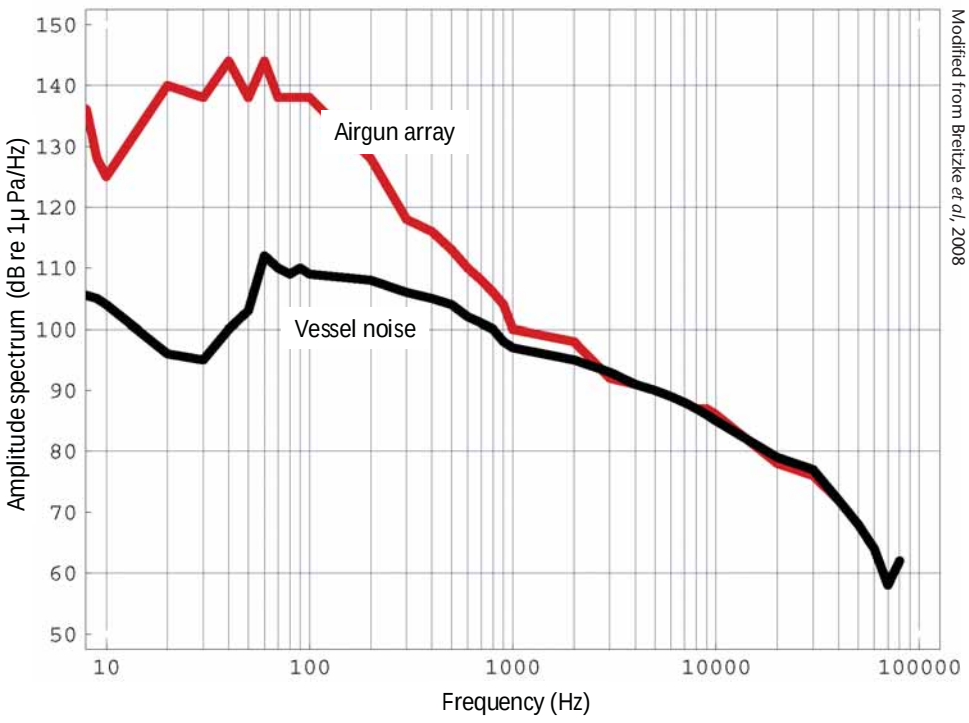
The first and most obvious cause is that the rapid movement of the air escaping through the air-gun ports creates cavities in the water close to the gun. This effect is the same as cavities created on propellers, or those associated with turbulent flow in water, as shown on the photographs in the box on page 64. Since we believe that these cavities are created close to the source, it is reasonable to assume that the amount and strength of the cavities are dependent on the design of the air-gun. Hence, there might be differences between high frequency noise from air-guns produced by different manufacturers. It is also evident that the triggering mechanism, the so-called solenoid, which is an electrical coil sitting on each individual air-gun, creates high frequency noise.

Furthermore, the air-gun shuttle, which is the piston that pushes the air out of the gun, creates high frequency noise during the rapid movement and sudden stop of the shuttle. Finally, all air-guns jump as a result of the bubble movement, and this jumping will create mechanical shaking of the air-gun which again creates mechanical high frequency noise.

All these mechanisms occur close to or in the vicinity of each air-gun.




*Photograph of an air-gun fired under water. Notice the four bubbles emerging from the ports of the gun.*




Modified from Breitzke *et al*, 2008

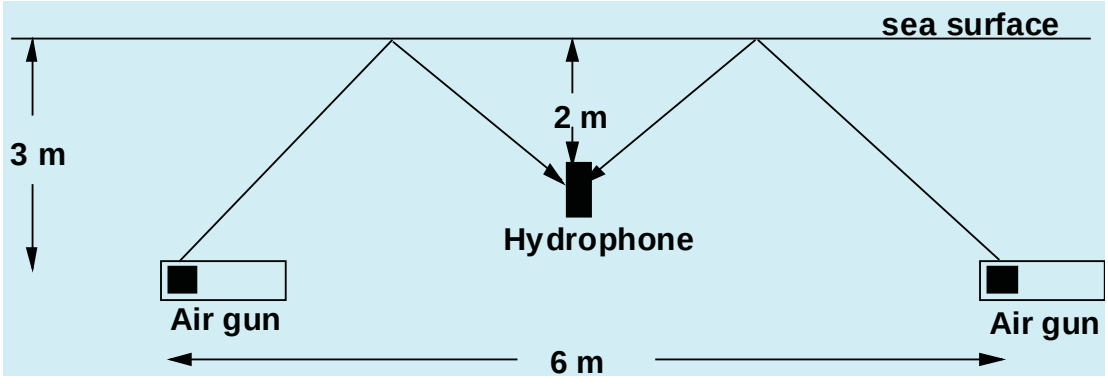
*Broad-band smoothed amplitude spectra from 38.2 litre-gun array at 550m range, received by a hydrophone at 35m depth, compared to noise generated by the seismic vessel. Below 1 kHz the amplitude spectrum of the air-gun signal differs significantly from the vessel's noise spectrum due to the low-frequency energy emitted by the air-gun, while above 1 kHz the amplitude spectrum of the air-gun signal coincides with the vessel's noise almost completely. This indicates that the slow spectral level decay is mainly caused by ship-generated noise.*

## Cavitation due to ghosts?

Another, far more sophisticated and at the moment speculative cause for high frequency emissions from air-gun arrays is coupled to the effect of reflections from the sea surface. If two air-guns emit a strong signal of, for example, 4 bars, the pressure in the water between the two guns might approach zero since the reflected signals from the sea surface are negative.

In the example shown, we have assumed that the signals from the two air-guns can be linearly superimposed. However, as the water pressure approaches zero, non-linear effects will be more prominent, meaning that it is not straightforward to estimate exactly for which pressures cavitation will occur. Despite this, it is reasonable to assume that for compact and large air-gun arrays, we have a risk of cavitation formation in the area where the ghost reflections from several air-guns coincide in time and space.

This type of cavitation will be independent of the type of air-gun used, since it is simply a function of the geometry of the array. And this is the good news: if the major part of the high frequency signal generated by an air-gun array is generated by cavitation between air-guns, this effect can be eliminated simply by increasing the distance between the guns. ▶




Landrø (2000)

*If these two air-guns generate a peak pressure of 4 bars at 1m, the reflected signal from the sea surface measured at the hydrophone between the guns is approximately –1.3 bars, assuming linear theory. The hydrostatic pressure at the hydrophone position is 1.2 bars, which means that the total pressure – assuming that the pressure contribution from each source can be added linearly – is negative. Then, cavitation will occur.*

Plesset and Ellis showed in 1955 that it is indeed possible to generate cavities by acoustic stimulation, as shown on the figure in the box below. It is therefore reasonable to assume that similar cavitation phenomena might also occur for an air-gun array.

Generally, the strength and length of this high frequency cavitation signal will therefore increase with the size and compactness of the air-gun array.

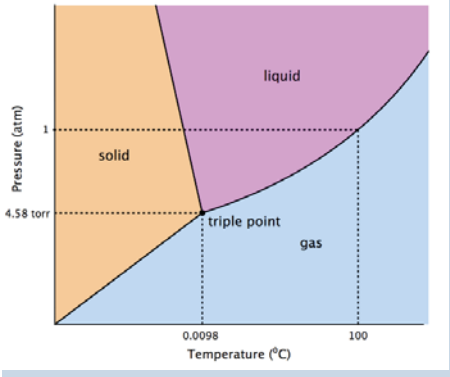
To assess this potential mechanism further we plan to conduct a number of experiments where we gradually increase the distance between the subarrays in the airgun array, and where we gradually displace the subarrays relative to each other in the sailing direction. If our predictions are correct, we should measure that the amount of cavitation and the associated high frequency noise gradually decrease.

Further discussion on this topic has been submitted to *Geophysics* for publication. ▶

## CAVITATION

Cavitation is the sudden formation and collapse of low-pressure gas bubbles in a liquid. When this occurs in water, the interior of the bubble is filled with water vapor. A cavity is formed as the water pressure is approaching zero, or more accurately as the pressure is equal to the vapour pressure. This pressure is given by the phase diagram for water, and it depends on the water temperature. For instance, for a water temperature of 17° C, the vapour pressure is 0.03 bar, practically zero. Although the physical mechanisms behind cavity formation might vary, they are usually found to be associated with rapid velocity changes in the water.

As the cavity collapses due to the hydrostatic pressure surrounding the cavity, the water vapour turns into fluid water again, and this phase transition is very rapid. During the collapse of a cavity a micro-shock wave is formed, and this is often strong enough to damage nearby material such as metal objects. Therefore, cavitation is usually regarded as an unwanted and undesirable effect.




*Phase diagram for water. At 0.01°C the vapor pressure is 0.006 bar, which is close to zero pressure. At 17°C, the vapor pressure is 0.03 bar, and for 100°C it is 1 bar.*

In addition, the violent collapse of cavitation bubbles results in the production of crackling noise. This is one of the most evident characteristics of cavitation to the observer and therefore often the primary means of detecting the phenomenon.

In marine seismic applications, the water gun is one example where the cavities created by the gun are desirable, since it is the main source for the acoustic sound. However, for air-guns water vapor cavities are not useful, since the main acoustic signal is created by the air bubble being ejected by the gun.

The photos here show underwater examples of bubble cavitation. It is very likely that the cavitation occurring close to an air-gun is of this type. Bubble cavities collapse violently and are therefore very noisy, and if close to metal objects like propellers and air-guns they might have an erosive effect.

Since marine mammals have a very broad hearing sensitivity, up to 100 kHz, acoustic waves created by cavities might be of importance. Since the phase transition from water vapor into water is extremely rapid, a collapsing cavity is capable of creating extremely high frequencies, it is similar to a dynamite explosion in that respect. Lord Rayleigh showed in 1917 that the collapse time of a water vapor cavity is equal to

$$T = 0.915R\sqrt{\frac{\rho}{p_h}}$$

where $R$ is the initial cavity radius, $\rho$ is the water density and $Ph$ is the hydrostatic pressure surrounding the cavity. The strength of the signal generated by the collapse of a cavity is also related to the size of the cavity (Landrø et al, 1993). Therefore, depending of the sizes of the cavities generated between the air-guns, they will collapse at different delay times, and with various strengths.


*Picture of bubble (top) and propeller cavitation.*


*Photograph of a transient cloud of cavitation bubbles generated acoustically.*

## Field data observations

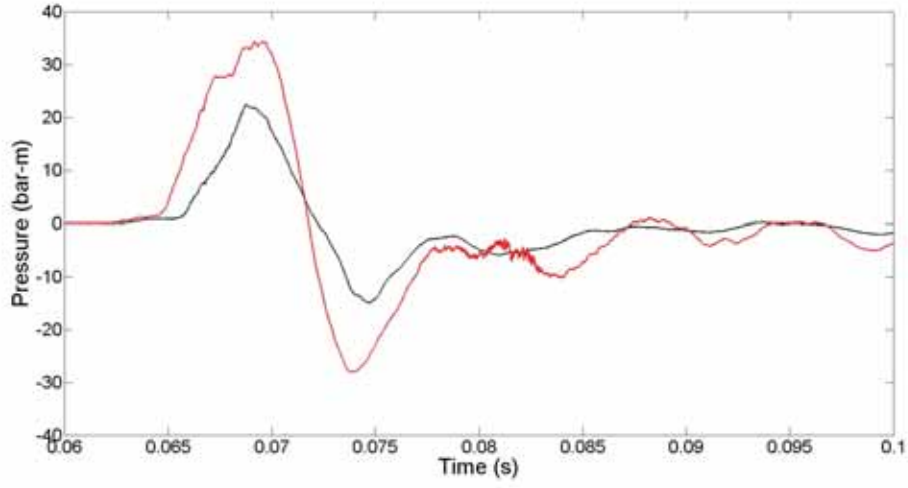
Is this effect observed on air-gun signature data? Normally, the answer is no, since the sampling frequency is typically 250 Hz.

However, the figure below shows far-field signatures sampled at 60 kHz vertically below both a small single string air-gun array and a big multi-string array towed at 5m depth. The peak-to-peak amplitude for the small and big arrays are 37 and 62 bar-m, respectively (corresponding to 251 and 256 dB re 1 μPa). It can be seen that the amount of high frequency noise is negligible for the small array, while it is more prominent for the full array configuration. The most prominent part of the high frequency noise is centered around 0.08 seconds. Its amplitude level is approximately 1-2 bar-m (220-226 dB re 1 μPa).

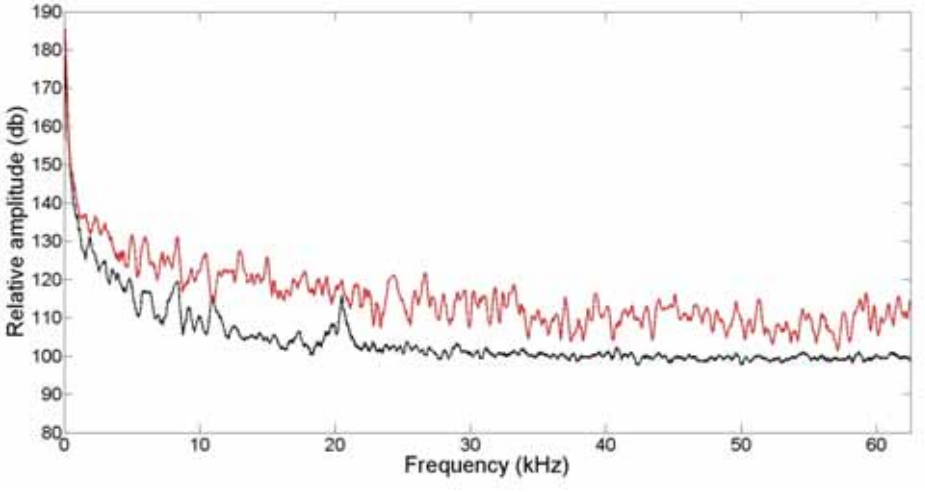
A frequency spectrum comparison shows that there is a significant difference between the signatures of the two arrays. A deviation up to 15 to 20 dB is observed in the frequency band between 10 and 20 kHz. For frequencies above 30 kHz this deviation decreases to approximately 10 dB.

More measurements are required to quantify and assess which of the above-mentioned mechanisms for high frequency noise are most significant, and whether there are other effects that have not been discussed in this article.

We believe, however, that a thorough understanding of the causes for high frequency signals from air-gun arrays are important, both in order to assess their environmental impact and potentially to diminish these effects. ■




*Source far-field signatures from a single string array (black line) and a multi-string array (red line). Notice the high frequency noise appearing at approximately 0.08 seconds for the big array.*




*Smoothed frequency spectra of the source signature measured from the small array (black line) and the big array (red line).*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Introducing a new regular feature in ***GEO Expro*** – Oil Capitals of the World. We look at their history, what first brought them into the oil world, their exciting features and what life is like for geoscientists in and around a GeoCity

# PERTH – Geocapital of Australia

Ingvild Ryggen Carstens

INGVILD RYGGEN CARSTENS

Over 2,000 km from the nearest city, Perth is one of the most remote urban centres in the world. But this vibrant and modern city in the south-west corner of Australia, whose recent growth owes much to the oil industry, has plenty to offer the visitor.

According to the celebrated travel writer, Bill Bryson, Perth is the most remote city on Earth. But despite its distance from other cities, it is refreshingly vibrant and pleasant. If you should find yourself here on business some time, I would recommend spending a few days extra to experience the city and its surroundings. It has lots to offer, particularly for someone working in our industry. Because the area is rich in geology, and some of it is not even that far a drive from the city!

Perth was the first European settlement in Western Australia, founded in 1829 by the British, and was initially known as the Swan River Colony. The city grew up around the Swan River (named for its infamous black swans) and the city centre is located on the Swan coastal plain, which lies between the Darling Scarp and the Indian Ocean – a mere 4,400 km by road from the Australian capital, Sydney.

The city is named after Perthshire, the birthplace of Sir George Murray who was British Secretary of State for the Colonies at the time. Unlike previous settlements in Australia, Perth was not destined to be a penal colony, but was populated by settlers from Europe in search of a better life – although that proved to be at the expense

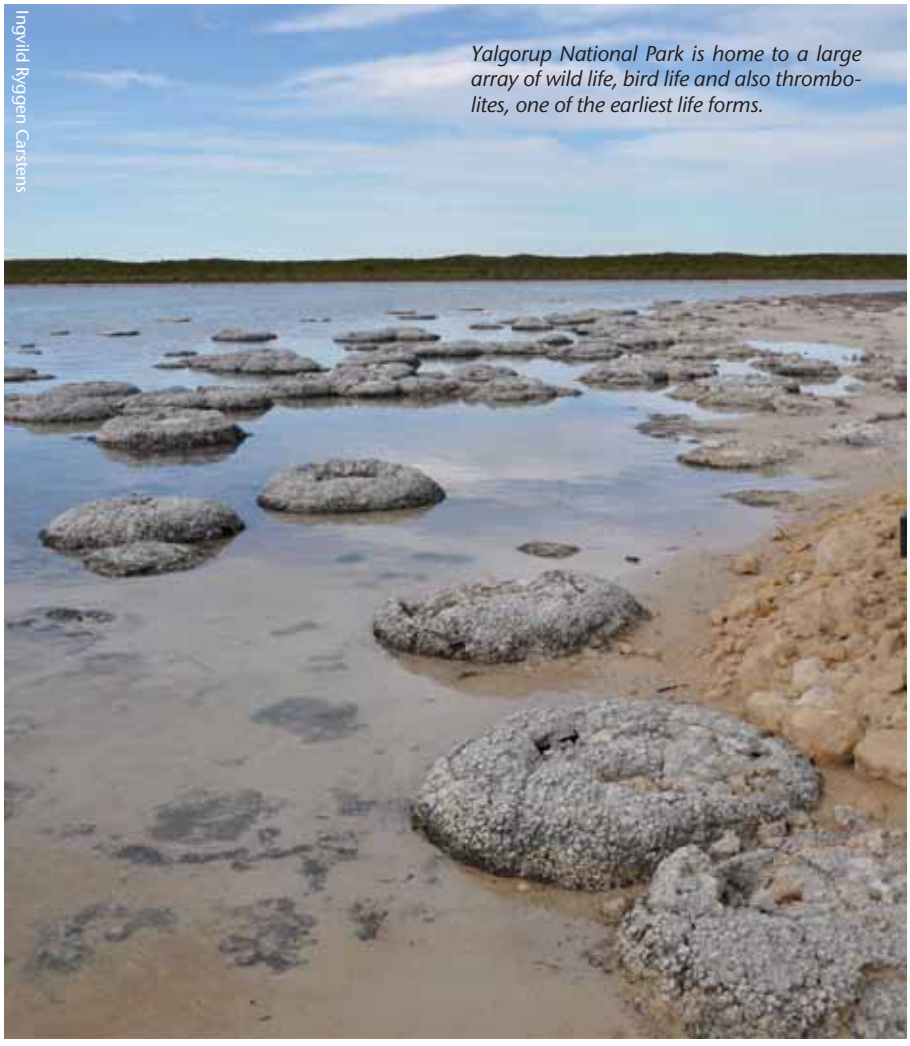
of the indigenous Aboriginal community, who had lived there for 40,000 years.

The early growth of the city was slow, so that by 1891 the population numbered less than 9,000. However, the arrival of the Trans-Australian Railway in 1917 and the early success of the gold mining towns, as well as immigration from Britain, meant that by 1981 there were over 800,000 people living in Perth and its suburbs. But of recent years the population has grown rapidly, so that there are now about 1.5 million people in the city – about 75% of the total population of Western Australia, meaning that it has therefore become the economic centre of the territory. Much of this growth has been due to the oil industry.

## Rich in resources

Western Australia is a territory rich in natural resources and, even before oil was struck in the 1950s, exploitation of these had already begun. But because Australia had at the time no naturally flowing oil, the common belief was that this was a resource they were lacking. However, a pioneering spirit strongly advocated the exploration for oil and gas; his name was William Walkley, the founder of Ampol (Australian Motorists Petrol Company). He believed in the potential for finding oil in Australia and took up large leases covering the Perth Basin, Carnarvon Basin, Canning Basin and the Bonaparte Gulf Basin.

To lead the mapping of the area, he brought in the American geologist Eric Craig. Together with local geologists from the Commonwealth Bureau of Mineral Resouces (BMR), they started mapping out the Rough Range in the northern part Western Australia, because the area strongly resembled Saudi Arabia with its large anticlinal structures. In 1953 they struck oil close to Exmouth. Although this is 1,000 km north of Perth, because of its status and location the city became the natural centre for the oil industry in the whole country. The discovery of gas at Dongara, only 300 km north of Perth, confirmed this position.



Ingvild Ryggen Carstens

*Yalgorup National Park is home to a large array of wild life, bird life and also thrombolites, one of the earliest life forms.*

## Relaxing city

There is much to like about Perth. First, there are miles and miles of bike paths, winding through the city and along the Swan River. In addition to the pleasant exercise, you get to experience the city they way the locals do. The bike paths are used for transportation and sports, and on your way you will meet a variety of people enjoying the fantastic routes and surroundings.

There are also several sights to visit – like the Bell Tower on Riverside Drive, a rocket-like structure which adds a futuristic edge to Perth's skyline. It houses the 600-year-old bells which rang out on Captain Cook's return to Britain after his landfall in Australia in 1771, and which were presented to Western Australia during the Australian bicentenary in 1988.

Alternatively, you can make a day out of it and bike down to the historic city of Fremantle, about 20 kms away. If you are in for a more peaceful get-away from the bustling city, King's Park is a great destination, with its amazing collection of Australian native plants, bushes and trees. Or why not enjoy a cruise on the Swan River?

## Geological sightseeing

There are also a number of interesting places to visit for some geological tourism within easy reach of Perth. Rottenest Island is well worth a visit, being easily reached by ferry from Freemantle, about 20 km to the east. The island used to be a part of the Swan Coastal Plain and is young in geological terms – only 140,000 years old.

Just outside the city in the Perth Hills you can visit the Darling Scarp, a fault dividing the Yilgarn Craton from the Perth Basin. The fault is more than 1,000 km long and is easily identified in the landscape, and even from space. Several National Parks are located around the fault, with well-developed paths and walkways that can take you to some wonderful cascading waterfalls.

A little further afield is Yalgorup National Park, about 100 km south of Perth, where you can see thrombolites, which, while not as famous as their stromatolite cousins in Shark Bay, are spectacular in their own way. They were formed by a variety of microorganisms, which photosynthesize, depositing calcium carbonate into rock-like domes. They are believed to have contributed to the creation of an atmosphere that enabled other life forms to evolve.

No matter what your interest is, you can find something to keep you occupied in the remotest city on the planet!

Karim Merie KMPhotos.com

JANE WHALEY

# A Window to a Brilliant Future

## How can we connect with the next generation of geoscientists and engineers to bring them into the hydrocarbon industry?

"We have been actively working with universities to help place graduates in the oil industry since 1997," says Deirdre O'Donnell, Managing Director of specialist oil industry recruitment company, Working Smart. "This has involved running career days and workshops on university campuses, helping students write CVs and letters and providing information and interview technique advice. We took this a step further with the Graduate Career Centre, at the PETEX Conference and Exhibition in London in November 2010."

The idea was first suggested for PETEX 2008, but although many of the universities approached were enthusiastic, it proved difficult to secure the sponsorship needed from oil and service companies to go ahead with the idea in the timeframe available. "In 2008 with recession looming and the economic situation declining dramatically, graduate intake was not seen as a high priority by companies," Deirdre concludes. "We were disappointed, but not really surprised – in 1999 when the oil price plummeted, the oil industry had reacted in

the same short-sighted way – hence the major skill gap in the market today."

Deirdre, with the backing of the Petroleum Society of Great Britain (PESGB), which organises PETEX, was determined to see a Graduate Recruitment Centre at the 2010 conference, where graduates or soon-to-be graduates would be able to learn about, meet and even have interviews with potential employers in the industry.

## Introducing the industry

"We approached a wide range of people involved with the conference, and feedback was very positive about encouraging students to attend," she continues. "Exhibitors welcomed their presence, aware that for many students this could be their first proper introduction to the oil and gas industry, which often gets negative coverage in the press. Our survey in 2006 showed that, for first degree graduates studying oil related degrees such as geology, geophysics and petroleum engineering, only 24% took up jobs in our industry, with 52% taking jobs elsewhere. Attending PETEX would give graduates a chance to realise the wide range of employment opportunities available, not just to those from the geosciences, but from many other disciplines. Many mathematics students, for example, have little idea of the number and range of jobs available to them in both the technical and business side of the oil industry."

When Working Smart approached universities and lecturers to talk about the 2010 Career Centre, they were met with enthusiasm, and eventually more than 370 undergraduates and post-graduates from twelve of the UK's top geoscience and engineering institutions attended. As Roger Clark, Senior Geophysics Lecturer at the University of Leeds, said "Our students clearly considered it worth getting up at 5 this morning for! We overfilled the coach and some had to take the train."

## Securing sponsorship

Working Smart found the attitude of potential employers, however, somewhat different. "When we approached large oil exploration companies and offered them access to this pool of talent through sponsorship of the event, they thought it was a good idea in principle but actual commitment was lacking," Deirdre says. "Many companies said they either had no graduate programmes in place, could satisfy their requirements through advertising, did not have the budget (though the cost was very low) or due to tight work commitment were only looking for experienced staff and did not have the time to support and mentor graduates."

Undeterred, Working Smart decided to extend their search to small-to-medium-sized oil companies and some major service companies, and were delighted by the response. With less bureaucracy, greater budget flexibility and a more long-term view, a number of companies were quick to see the advantages of the Graduate Career Centre. The eventual line-up was a mixture of large and small: oil companies ExxonMobil, GDF-Suez, Hess and Afren with the service sector represented by CGGVeritas, PGS and ffA, in addition to Working Smart and the PESGB.

"Having secured sufficient sponsors, we set to work creating online functionality for the students attending the event to register their academic background, work experience, skills, interests, competencies and expectations via our Graduate Smart website. This allowed sponsors to screen all attending students online and pre-select those they wished to talk to or interview before the event. CVs, Interview Schedules and notifications were all accessible online. CGGVeritas, for example, pre-selected 39 candidates for interviews across a variety of roles and we understand that they are seriously considering ten candidates for employment on graduation."

## Successful venture

The Graduate Careers Centre was busy throughout the three days of the conference – in fact, one of the few complaints made was that participants would have preferred a larger amount of space, as the Centre, which included booths for sponsors, a reception area, two interview rooms and a networking area, was often quite crowded. "Everyone who participated saw a lot of value from this event," says Deirdre. "We undertook some research afterwards and established that all the companies involved said they would sponsor again, and two thirds expect to make job offers to students they interviewed. In fact ffA have already recruited a recent graduate they interviewed during PETEX, who started work in January."

"It's been fabulous," Karen Reid, Senior Recruitment Adviser for CGGVeritas, commented in feedback to Working Smart. "Our Managers were very impressed with the calibre of the students and the event gave us access to several hundred high quality students we would not otherwise have been able to contact." Geoffrey Bent, Geologist – Exploration North Africa said: 'Hess found the graduate careers centre at Petex an excellent tool for raising awareness of our company among the undergraduate and graduate community, and promoting energy industry careers to students at some of the UK's top geoscience Universities.'

David Nicholson, HR Director for PGS Reservoir said "we would definitely do it ▶


*The Graduate lunch held during the event is a chance for young geoscientists and engineers to talk to oil industry professionals, encouraging them to consider a career in this area*

again. It was a singularly good opportunity to promote PGS, and a most worthwhile exercise".

Working Smart also researched the students who participated, and received some excellent feedback on their perception of the event, with the majority stating that it provided a great opportunity to connect with potential employers and to learn of the industry players. In fact, 92% of the graduates said they would like to see more of these events. Their comments included: "invaluable for learning about different oil companies and for making contacts within the Industry;" "the career centre and the organised interviews were a great opportunity;" and "events like PETEX offer a good insight into the oil industry which new professionals are going to join tomorrow. It is like peeping out of a window for a brilliant future."

The universities were equally pleased with their attendance at PETEX, with Professor Jonathan Redfern saying "The University of Manchester, one of the largest petroleum geoscience research and teaching centres in the UK, sent nearly 50 students to PETEX, as we think it's very important for the students to get exposure to professionals from industry, and for industry to see how many quality students there are out there looking for jobs. Maybe events like this will encourage a step-jump in approach and a return to increased graduate employment as a key investment both in the students and the future prospectivity of the industry in the UK. Without quality and experienced staff, all the advanced software in the world is no more than a computer game in the wrong hands!"


*The Graduate Career Centre held during PETEX 2010, proved very popular with both potential employers and employees.*

*Deirdre O'Donnell, Managing Director of Working Smart which organised the Graduate Career Centre, addresses the young people at the Student Lunch.*


## Key message

And that is a key message that Deirdre is very keen to get across to the industry, and in particular to the major oil companies. "On the back of the success of this venture, we want to address the industry challenges in recruitment – the "big crew change", as it has been described. We are planning more events at national and international level and various organisations have approached us with a view to hosting similar graduate career centres."

"But to engage successfully with the next generation of young graduates, to entice them into the industry, a lot more support is needed from those already involved. Before the PETEX event, we approached over 200 companies: only seven committed to participating. The industry also needs to be actively involved with the universities; there is no excuse for graduates not to have access to the technology in use today. And not only at MSc and Ph.D. level – companies should be concerned at undergraduate level too. A more proactive, coherent approach is needed from the industry with all players rising to the challenge. "

"Hopefully, 2011 is the year this will happen," Deirdre O'Donnell concludes. "We as an industry have talked about it long enough! Time for action!" ■

*Read Deirdre's article 'Replenishing the Petroleum Workforce' in* GEO Expro Vol. 7, No. 5.

# Editorial and Events Calendar 2011

## 2011 CONFERENCE CIRCULATION SCHEDULE:

**No 1** **New and Emerging Plays in the Eastern Mediterranean**, London, UK, February 23 – 25
**APPEX**, London, UK, March 1 – 3
**Focus on the Eastern Mediterranean and Exploration**

**No 2** **AAPG Annual Meeting**, Houston, Texas, USA, April 10 – 13
**Recovery 2011**, CSPG, CSEG, CWLS Convention, Calgary, Alberta, Canada, May 9 - 13
**Focus on North America and Australia and Geophysical Technologies**

**No 3** **EAGE** Annual Meeting, Vienna, Austria, May 23 – 26
**Focus on North West Europe and Reservoir Management**

**No 4** **PESGB Africa Conference**, September 7 – 8
**SEG, Annual Meeting** San Antonio, Texas, USA, September 18 – 23
**Focus on Africa, Geophysics and New Technologies**

**No 5** **ATCE** Denver, Colorado, USA, October 30 – November 2
**AAPG International**, Milan, Italy, November 23 – 26
**Focus on Europe and Exploration**

**No 6** **PROSPEX 2011**, London, UK, December 14–15
**NAPE 2012**, Houston, Texas, USA, February 17 – 18, 2012
**Focus on North and South America and Frontier Exploration**

While we do not anticipate schedule changes, they may occur without notice.

## Schedule

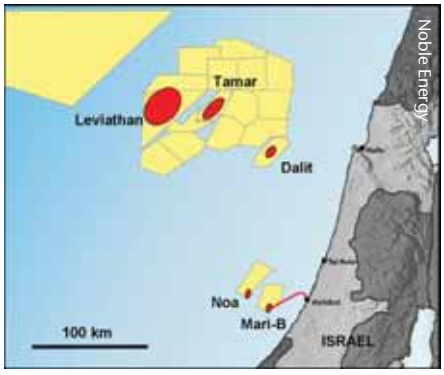
| | Ad deadline | Publication date |
|---|---|---|
| 2011 GEO ExPro 02 | March 4 | March 21 |
| 2011 GEO ExPro 03 | April 15 | May 9 |
| 2011 GEO ExPro 04 | August 12 | August 29 |
| 2011 GEO ExPro 05 | September 30 | October 17 |
| 2011 GEO ExPro 06 | November 18 | December 5 |


GEO ExPro
GEOSCIENCE & TECHNOLOGY EXPLAINED

# ISRAEL: Gas Exporter Soon?

As has been noted elsewhere in this issue, one of the areas for hydrocarbon exploration being looked at with keen interest at the moment is the Eastern Mediterraean. This was given a further boost with the announcement by Noble Energy that drilling at its **Leviathan** well offshore Israel has shown very promising interim results.

This deepwater well, drilled in over 1,600m of water about 130 km offshore Haifa in Israel, confirmed the pre-drill estimates of a massive 16 Tcfg (453 Bcm) gross mean reserves. Several high quality Miocene sub salt reservoirs were identified, with about 67m net pay. The field has an aerial extent of 324 km$^2$, and is 47 km south-west of Noble Energy's first major discovery in the area. Gross reserves for Leviathan, **Tamar** and the smaller **Dalit** discovery, 40 km south of Tamar, are estimated to be 25 Tcf (700 Bcm). Leviathan will require at least two further wells to evaluate it it, the first expected to be drilled in the first quarter of the year, 13 km to the north-east.




*The 16 Tcf Leviathan discovery is about 130 km west of Haifa in Israel.*

As of late January, 2011, drilling was continuing at Leviathan to a planned depth of 7,200m in order to evaluate two additional intervals, although these are not considered prime targets.

Noble and its four Israel-based partners, Delek Drilling, Isramco Negev-2, Avner Oil, and Dor Gas Exploration, drilled the discovery well on Tamar in November 2008. The field was found to contain an estimated 8.4 Tcfg (237 Bcm), in reservoirs with excellent permeability and porosity of 1D and 25% respectively. Leviathan is expected to have similar reservoirs, but has twice the aerial extent. Noble Energy also has neighbouring acreage, holding over 12,000 km$^2$ in the Levantine Basin. It has acquired new seismic over the area and has identified 19 further prospects and leads, with gross unrisked potential of more than 14 Tcfg (396 Bcmg).

A development plan for Tamar has been approved, production should commence in 2012, and both Noble Energy and Israel are evaluating export scenarios, although the country has major internal energy requirements, as the majority of its electricity is gas generated.

# ARGENTINA: Shale Gas Discovery


*The major shale gas discovery is in the sub-Andean Neuquen Basin.*

At the tail end of 2010 YPF, the local unit of Spanish oil major Repsol, announced what is possibly the largest unconventional gas discovery in Argentina to date. It would appear that the discovery, which could contain as much as 4.5 Tcf (127 Bcm) of shale gas, was made at YPF's **Loma de la Lata** conventional gas field in the Patagonian province of Neuquen. And since the discovery wells were drilled over a limited area, there are hopes that the find could be even larger.

The 137,000 km$^2$ Neuquen Basin is part of the Sub-Andean trend which extends the entire length of South America. It is the leading producer of hydrocarbons in Argentina, holding about 35% of the country's oil reserves and 47% of its gas. The majority of production comes from the Loma de la Lata field, which is one of the largest gas fields in South America, with a reported 8.7 Tcfg (245 Bcm). Hydrocarbons are found in a combination structural – stratigraphic trap containing an oil and gas reservoir partially underlain by a separate gas condensate reservoir.

The shale gas find is reported to be the country's largest discovery in 35 years, and Argentine President Cristina Fernandez said the discovery should help the country certify reserves for the next 16 years. It is needed, as demand has risen sharply in Argentina in recent years, while production has fallen, forcing the country to become a net importer.

# BRAZIL: More Discoveries

Brazil has been hitting the headlines again with further exciting discoveries both above and below the salt. On January 26, a consortium consisting of Petrobras, as operator, together with BG and Repsol, announced a major discovery of light oil in Block BM-S-9 in the Santos Basin, about 275 km off the coast of Sao Paulo. The well, informally known as **Carioca North-East**, was drilled in water over 2,100m deep and found a reservoir section of at least 200m below the major salt layer. Further testing will follow, but initial results suggest that it is a larger than anticipated pool of good quality 26° API oil, although no reserves figures have been given.

This well is nine kilometres north-east of, and in the same block as the **Carioca** field, discovered in 2008 and which has been reputed to hold as much as 33 Bbo.

Anadarko, in conjunction with Ecopetrol, also announced a substantial discovery in Brazil, but in the post-salt horizons in the Campos Basin. Well **Itauna #1** on offshore block BM-C-29 in relatively shallow waters of 75m encountered in excess of 83m of oil and gas pay in two separate post-salt zones.

# TANZANIA: Deepwater Gas Discoveries


*Chumbe Island, off Zanzibar, is a low lying coralline island, similar to Songa Songa, which is the site of Tanzania's main producing gas field, about 80 km due west of the new discoveries.*

Not as large as finds elsewhere in the world, but of significance to the country, are the two recent discoveries off Tanzania. **Pweza 1** in the offshore Mafia Basin, about 150 km south-south-west of Dar-es-Salaam, found a thick section of gas-bearing sands in October last year. This was followed in early December by a second successful well, **Chewa 1**, eight kilometres north-west of Pweza.

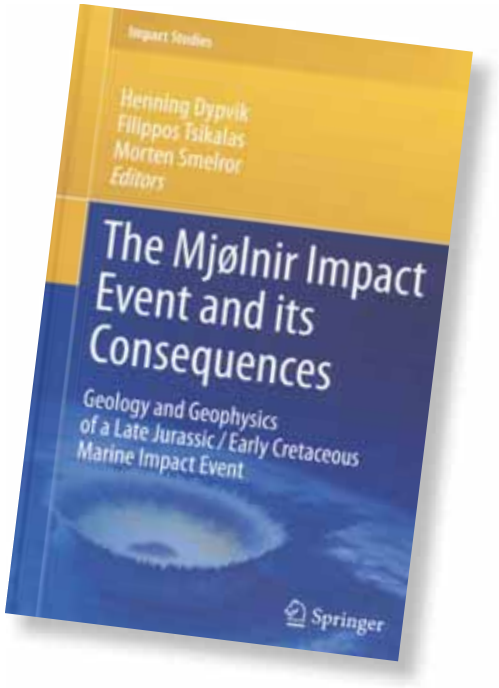
Operating in waters of over 1,300m, this is the first ever deepwater drilling campaign in Tanzania, and the companies involved, BG and Ophir, believe that this is the start of a major new play in the region. They are also investigating to see if these discoveries have any link with the recent gas discoveries in the Rovuma Basin in northern Mozambique.

Both wells are located in Block 4, which is 85 km from the Tanzanian coastline.

At the moment Tanzania produces gas from the Songa Songa field at the rate of 70 MM cfpd, limited by the processing facilities. It was recently announced that plans are underway to expand the processing capacity to 140 mm cfpd so that more gas could be shipped to Dar es Salaam for additional power generation and domestic use.

# Out of the Blue

## A new book about a major meteorite impact in the Barents Sea has plenty to teach us about effects of such events




The Mjølnir Impact Event and its Consequences

Edited by Henning Dypvik, Filippos Tsikalas and Morten Smelror
Springer 2010

This book is about Ragnarok: the natural disasters that followed a titanic splash into a long gone epicontinental sea which is now part of the sedimentary succession of the Barents Sea.

The book contains the fascinating story of a meteorite that struck the Barents Sea some 142 million years ago. And a whole lot more, because you also get all the geological and geophysical details that have come out of nearly 20 years of intensive research by a multidisciplinary group of geoscientists. Numerous figures, including both seismic and photos, make it a comprehensive book that can also be appreciated by non-specialists, i.e. most of the petroleum geoscience community.

The first lesson to learn from this book is to your keep eyes wide open when trying to interpret the secrets of the subsurface. A long standing enigma was resolved when Steinar Thor Gudlaugsson, an Icelandic geologist working in the Norwegian academic circles in the early 1990s, had the idea that a "peculiar inverted sombrero structure in the central Barents Sea had been created by an impact". It was clearly evident on regional seismic data acquired for the purpose of petroleum exploration. With only one well in the vicinity with relevant geological data, the idea led to the acquisition of new geological and geophysical data. This included the drilling of one tailor-made well to prove the presence of impactites. This well is the only well from inside the crater and gives "firm evidence for the impact origin".


*The Meteor Crater was created when a meteor struck the Arizona desert some 50,000 years ago.*

Altogether 176 impact craters have been discovered on Earth. Most of them – 149 – are on land. That leaves only 27 buried below the sea with a possible marine origin. Only a couple of these have been studied in great detail, according to the editors. The most famous, by far, is of course the Chixulub outside the Yucatan Peninsula in Mexico, also discovered thanks to the petroleum exploration industry. It turns out that the Mjølnir impact structure is one of the 20 largest such features discovered so far.

The age of the impact is of some interest. Detailed palynological analyses place it at the Jurassic-Cretaceous boundary, known as one of the ten largest biological extinctions throughout the Earth's history. But the impact was not detrimental enough to have caused this extinction. According to the authors, however, the occurrence of other roughly simultaneous impact events opens up the possibility that they together triggered a catastrophe on a global scale.

Regardless, the impact from the Mjølnir meteorite was colossal, proven by the ejecta deposits found in remote places like Svalbard, Greenland and even Siberia. It also created a mega-tsunami, the first wave of which may have measured more than 200m. Even more spectacular to our imagination is the immense fire (!) that the impact caused when striking into thick organic rich clays. As it happened, this was during the deposition of the Hekkingen Formation that we now know to be the source rock for several discoveries in the Hammerfest Basin of the Barents Sea. It is also time-equivalent to the Kimmeridge Clay Formation that is responsible for most of the oil in the North Sea.

The Mjølnir impact structure is named after the hammer of Thor, the god of thunder, in Nordic mythology. The impactites are, in line with old Norse traditions, named the Ragnarok Formation, Ragnarok being a natural catastrophe of devastating consequences. The ejecta layers have been named the Sindre Beds, Sindre being the blacksmith who made Thor's hammer.

I strongly recommend this book to all curious geoscientists who have a desire to expand their knowledge. The reading is fun, in particular if you leave out some of the details that are meant for the specialists.

**HALFDAN CARSTENS**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# Negotiating the Oil Industry


Jeanne Douglas

Chris Moyes, who has over 40 years experience in the energy sector, is President of the Association of International Petroleum Negotiators (AIPN), an independent professional membership association supporting international energy negotiators around the world. He talks to *GEO ExPro* Magazine about the organisation and how the market for deals is looking in 2011.

***How long have you been working in this aspect of the industry?***

I started working in the industry in 1968 as a geologist with West Australian Petroleum Pty Ltd. In 1974, after completing a reservoir engineering M.Sc. at Imperial College, I moved to Gaffney Cline and Assoc., and in 1982 founded Moyes and Co. Group of companies in Dallas. My interest in the transaction and valuation area of the industry was sparked by two transactions I managed in the early 80s; a sale of oil and gas interests in the Malacca Straits, Indonesia, and the Dome transactions in the Hudson Bay International assets.

***Do you see a difference in levels of activity and optimism across the globe?***

There is great interest in Brazil, Kurdistan and Iraq, while Asia also continues to be very active. The onshore US is focused on the oil plays while the offshore activity has slowed, waiting for new government regulation. Onshore Europe will have an active and deciding year in 2011, exploring the unconventional in many licenses. However, investment activity in a number of regions is hampered by government regulation and policies - Venezuela, Bolivia and Ecuador come to mind. There is a strong correlation between clarity and stability of the legislation and regulation governing investment, and the amount, cost and term of financial commitment.

***How is the market for deals shaping up in 2011?***

The 2010 year finished on a strong note. We had three transactions closing over through New Year and in the first four weeks of 2011 we have offers in two new international projects and a project in the unconventional Barnet Combo play in North Texas. The coming year promises to be very active in many international sectors.

***Does the increasing strength and presence of the NOCs effect the business of deal making?***

We work with many NOCs, particularly in China, India, Russia and South East Asia, advising in asset, corporate valuation and transaction execution. These groups have mandates to acquire, and deep pockets to aggressively pursue and close acquisitions in the international arena. The internal decision-making process is not as streamlined, they are still learning about international processes outside their comfort zone, and there are currency control issues in multiple jurisdictions. At home they are working with the regulators and legislators to incorporate international business practices into the domestic processes, potentially a highly politicized process, as can be seen in the evolution of the new Mexico Integrated EP contract. The NOCs have a significantly different political risk and economic baseline from the International Oil Companies, which provides an advantage in certain countries.

***What is the function of AIPN?***

The primary mandate is education though networking - very important as it makes for more efficient negotiations if you know your counter party. The Association supports over 3,000 professional members in more than 80 countries. We have strong outreach programmes to government entities, to young people entering the industry and in the student bodies of tertiary education institutions. The Organization has developed some twenty Model Agreements with associated Term Sheets, Guidelines for use and Education Modules for the hydrocarbon industry. The Committee has seven contract revisions underway and eight new contracts scheduled for the committees to start on in 2011.

***Why do companies support the AIPN?***

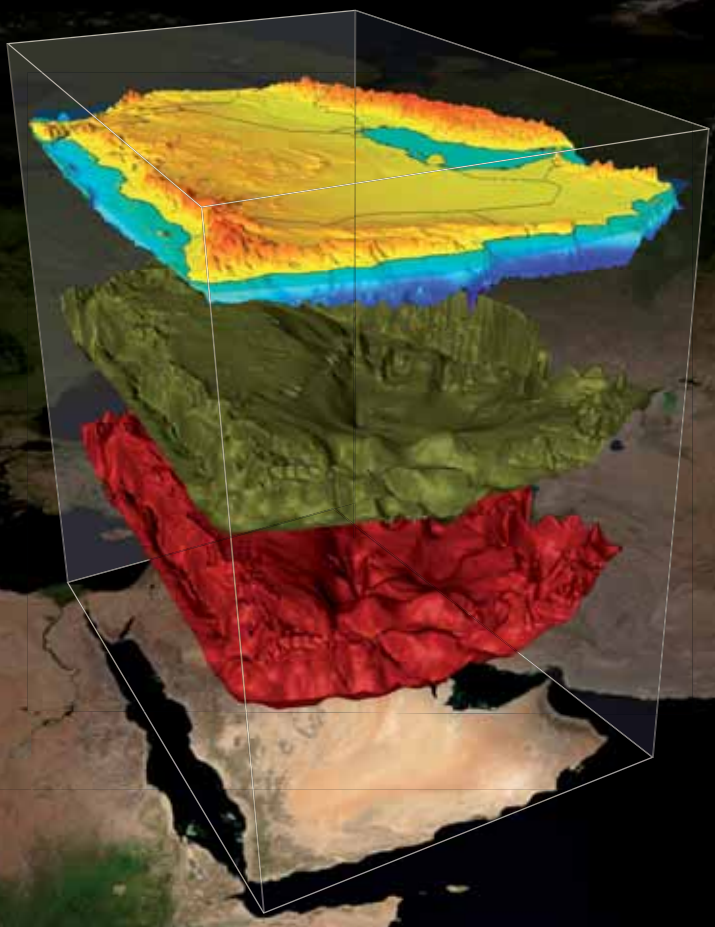
There is recognition across the international industry, both in the IOC and NOC community, that the AIPN Model Contracts have widespread acceptance and application in the day to day business of the industry. The intensive drafting process by the contract committees, made up of commercial and legal professionals, negotiate the content to find a balance between the multitude of ideas.

***What makes a good negotiator?***

The negotiator has to deliver an acceptable contract that achieves the objectives of the mandate. It is important to have a strong technical and legal foundation, and good drafting skills. Perhaps most important is the ability to listen and hear the counter-parties and to negotiate and draft a document that addresses their multifaceted needs while maintaining the integrity of the agreement.

***And what makes a good deal?***

Many of the hydrocarbon industry agreements are negotiated to last for years if not decades. A good agreement will cover the immediate responsibilities of the parties and at the same time address the mechanism for resolving future unknowns. Agreements can be living documents, evolving to meet new circumstances with the addendum and incorporation of new clauses, mutually agreed by the parties to address new circumstances. ■



# Exploration isn't two dimensional

The first commercially available 3D plate-scale exploration environment for the Middle East is here.

If you want a new insight into the Middle East subsurface, talk to Neftex. The Neftex 3D Exploration Cube provides the regional depth framework to help you evaluate opportunities rapidly and pinpoint resources more accurately. The resulting reduction in exploration risk will help save your exploration costs.

## A quick look at the Neftex 3D Exploration Cube:

- 236 sequence stratigraphically calibrated depth surfaces from basement to present-day topography and bathymetry
- Multiple formats available for you to load depth grids to the software platform of your choice, including XYZ, Zmap+,CPS-3
- Other formats are available on request

## Benefits

- Supporting faster, more integrated, new venture and appraisal activity
- Reducing exploration risk through improved visualisation of the subsurface
- Providing regional context for petroleum systems analysis and play fairway evaluation

To learn more about Middle East and other available Neftex 3D Cubes and how they can benefit your resource exploration, please contact us now.

**Neftex**

For more information contact: enquiries@neftex.com
Call + 44 (0) 1235 442 699 or visit www.neftex.com/3dcube

[photo credit: NASA]

# The Energy Challenge

There is no reason to believe that we will be able to cut $CO_2$ emissions in quantities that will limit the global temperature increase to 2°C within 2050.

More than 80% of the energy consumed comes from fossil fuels. As a direct result of this we produce more than 30 gigatons of $CO_2$ each year. It is also well known that the Intergovernmental Panel on Climate Change (IPCC) advocates a reduction to 14 gigatons within 40 years to avoid an average temperature increase in excess of 2°C. To put this into perspective, if we continue the current big spending trend, the $CO_2$ emissions will reach 57 gigatons within 2050.

Can it happen? Are we able to cut emissions of such gigantic proportions? Well, judge for yourself.

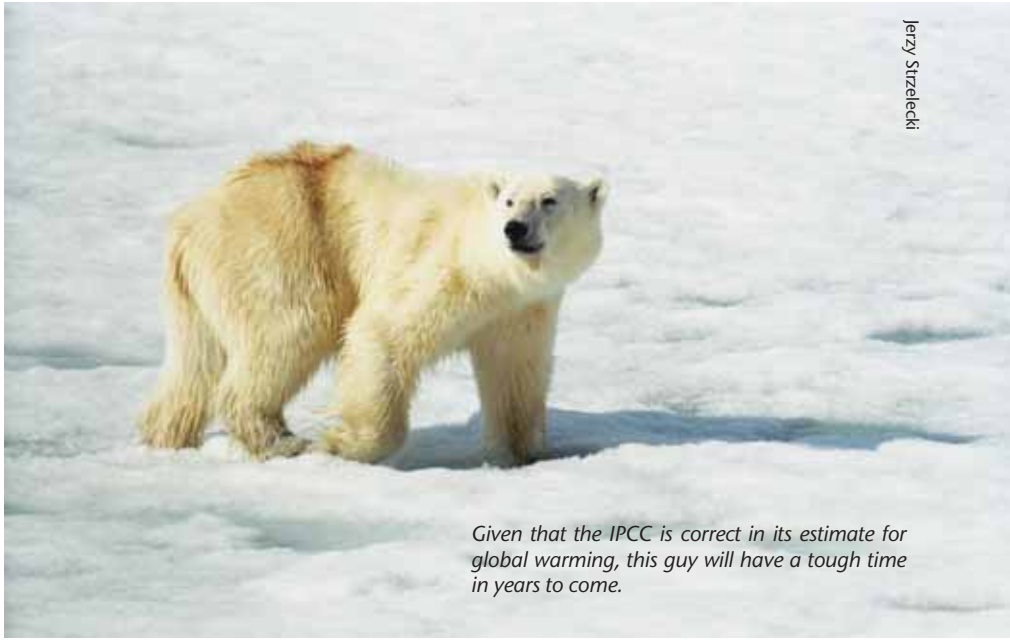
According to IEA, what it takes is that *every year* up to 2050 we build 35 coal-fired and 20 gas-fired power plants with CCS (carbon capture and storage), 30 nuclear plants, 12,000 onshore and 3,600 wind turbines, 45 geothermal power plants, and so on. Knowing that, as an example, we have not yet built even one gas-fired power plant with CCS, it sounds a little bit optimistic to envisage a new one every second year from now. Worse, it will not happen before a) the technology is proven, and b) somebody pays for it. The former is likely within short time, the latter is not. The building of nuclear plants also needs to be speeded up. The US alone will need to build 1,000 one-gigawatt nuclear reactors by 2050, i.e. 25 each year.

The IEA also says that we need to build 3,000 CCS-plants by 2050; that amounts to 75 per year. As of now the current rate is 0 per year. And the discussion about leakage of $CO_2$ from the reservoirs has just started. There should be no doubt that environmentalists will gather momentum in proportion to the number of projects that are launched.

More food for thought: China is installing more wind turbines than any other country. But, as David Biello, associate editor at *Scientific American* says, "wind energy still only generates a tiny fraction of China's electricity. Indeed, even with aggressive government backing and green energy mandates, such "new energy" – including wind, solar, nuclear power plants, and biomass – accounts for less than 3% of China's electricity production, compared to more than 70% provided by coal".

Alas, fossil fuels need to be part of our energy future, and we will use more of it than the IPCC appreciates. We can only hope that the IPCC calculations are wrong.

**HALFDAN CARSTENS**



Jerzy Strzelecki

*Given that the IPCC is correct in its estimate for global warming, this guy will have a tough time in years to come.*

## 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.

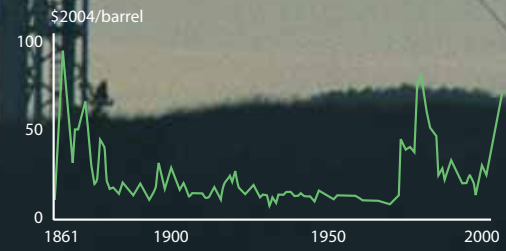
### Numbers
Million = 1 x $10^6$
Billion = 1 x $10^9$
Trillion = 1 x $10^{12}$

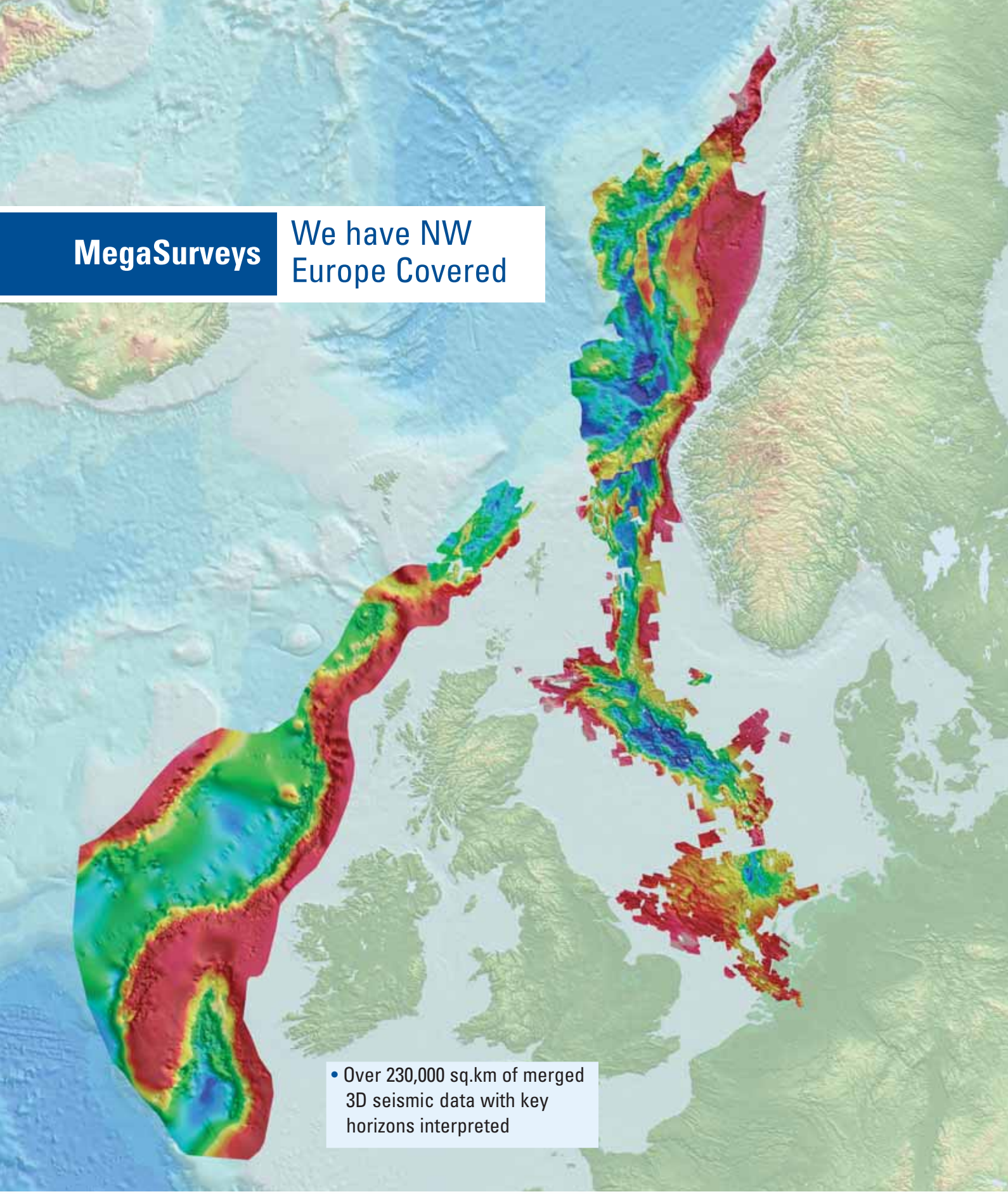
### Supergiant field
Recoverable reserves > 5 billion barrels (800 million $Sm^3$) of oil equivalents

### 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



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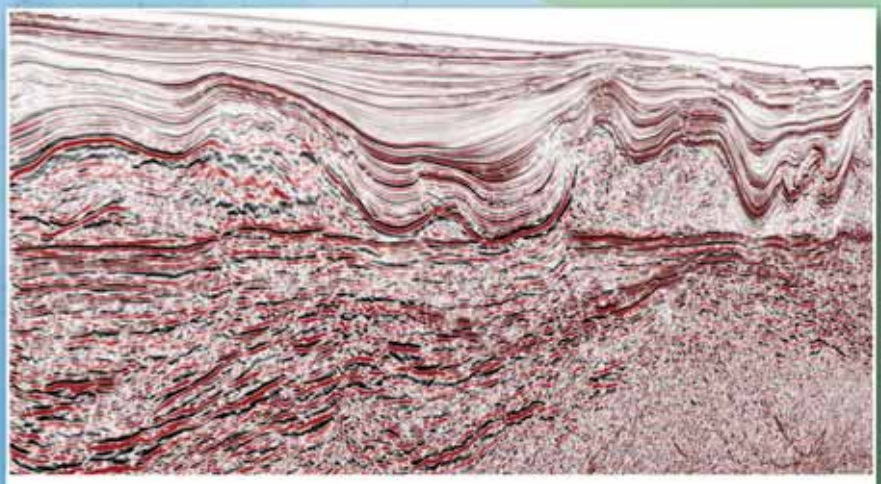
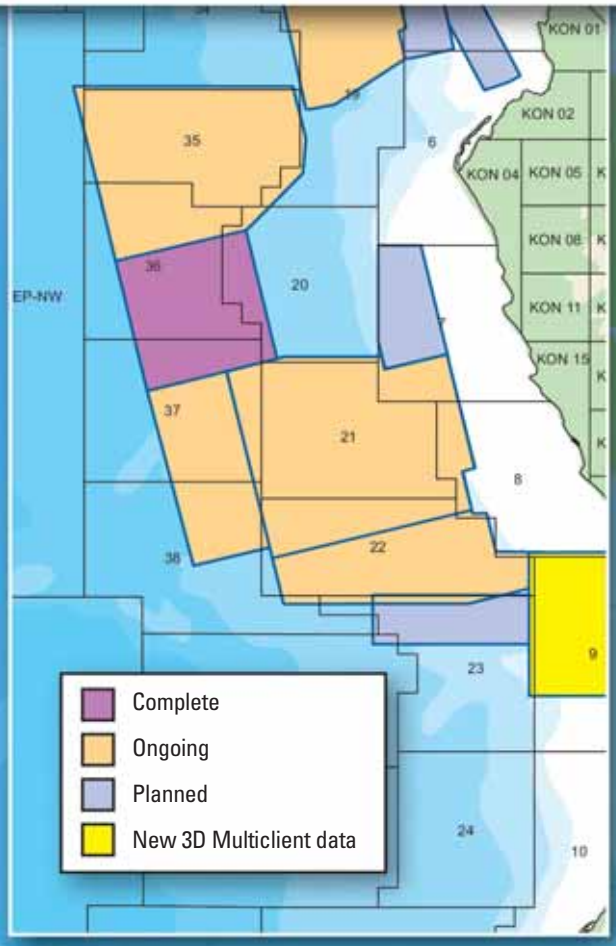
# Look East:

## Welcome to the **Kwanza Basin, Angola**



Anisotropic TTI Gaussian Beam PreSDM
(maximum frequency 40Hz)–using final velocity model




# Multiclient Services

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- 31,300 km$^2$ of 3D anisotropic TTI prestack depth migration
- 3D GSMP* general surface multiple prediction technology
- Petrel*-ready deliverables.

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