VOL. 10, NO. 1 - 2013



geoexpro.com



EXPLORATION: The South China Sea Enigma

GEOCHEMISTRY The Dark Horse Upstream

# INDUSTRY ISSUES A Social Licence to Operate?

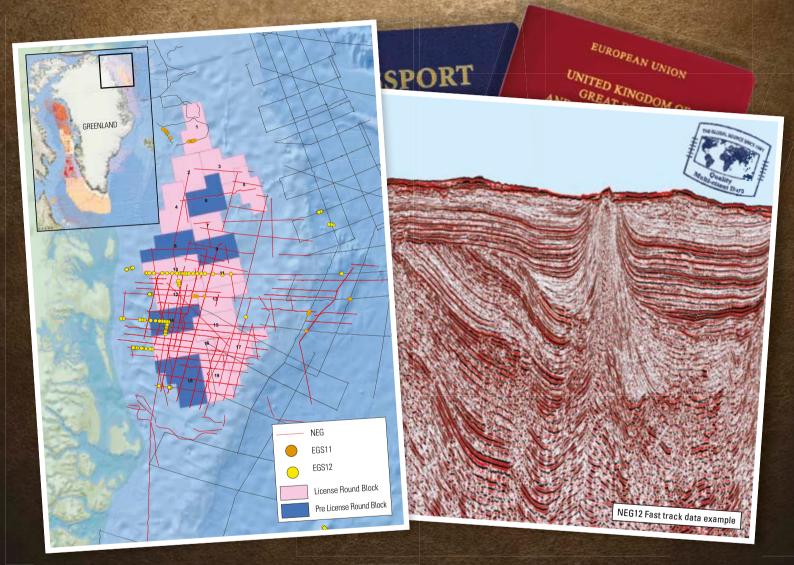
# RECENT ADVANCES IN TECHNOLOGY Broadband Seismic and Beyond

GEOLOGY

GEOPHYSICS

RESERVOIR MANAGEMENT

# TGS DELIVERS NORTHEAST GREENLAND



# AVAILABLE DATA FOR THE NORTHEAST GREENLAND LICENSING ROUND

- Aerogravity: 206,444 km
- Aeromagnetic: 314,946 km
- NEG 2D data\*: 8,470 km
- AWIRE11: 10,778 km
- EGS11\*\*: Sea floor sampling
- EGS12\*\*: Sea floor sampling

\* In cooperation with Fugro

\*\* In cooperation with VBPR



 Airborne and Marine Gravity compilation available



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# This edition of GEO ExPro Magazine focuses on South East Asia and Petroleum Geochemistry

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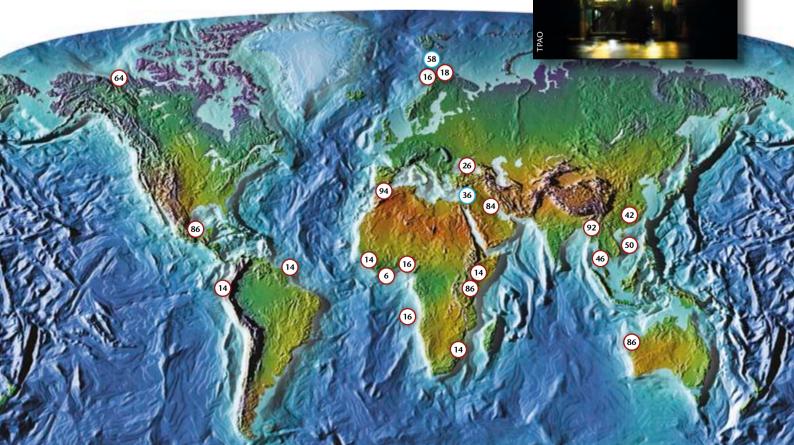
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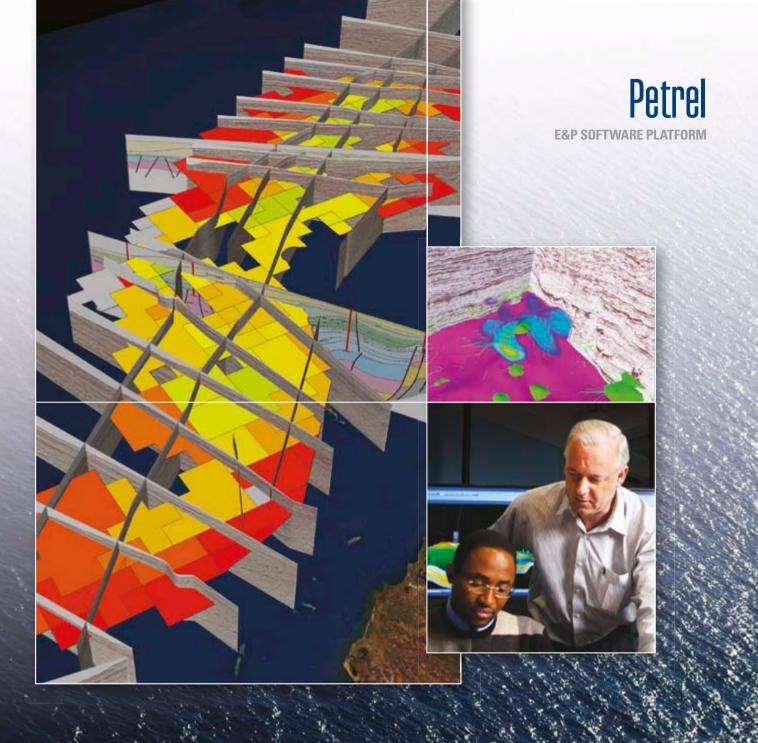
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After a major deep water gas discovery, interest in the Black Sea is increasing





# Drill Your Best Prospects Objectively Assess Economic Value and Risk Factors

In depth prospect evaluation enables decision makers to understand uncertainty in potential resource volumes and assess expected economic value. With the Petrel\* E&P software platform, exploration teams calculate play chance maps, simulate risked prospect volumes, and evaluate potential rewards—directly linked to data and interpretations.

With this critical insight, teams choose the best prospects with a clear understanding of their geological and economic chances of success.

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# Challenging the Industry

As discussed in our cover story, geochemistry is the unsung and underused star of hydrocarbon exploration, despite first being employed back in the 1930s. Yet the application of this science has a wide range of uses in exploration, from the basin scale, where it can improve the understanding of hydrocarbon generation, migration, and accumulation processes, to assessing the quality of oil in a recent discovery and enhancing field life by noting changes in composition of hydrocarbon fluids. In this edition of



The South China Sea holds significant hydrocarbon resources.

*GEO ExPro* we look at the methodologies involved and the science behind petroleum geochemistry. Several examples illustrate how timely application of this discipline can potentially save considerable time and substantially reduce the costs of projects.

South East Asia is an important area for the petroleum industry, producing about 1.8 MMbopd and 23 Bcfgpd, as well as large volumes of LNG. The South China Sea is at the epicentre of this region, with much of the supplies of hydrocarbons passing through it. It is also an important resource in its own right, with some accounts proposing potential oil reserves of as much as 213 Bbo, while the USGS is rather more conservative, suggesting that the area's main resource is gas, putting the discovered and undiscovered gas reserves at about 266 Tcf – all significant volumes. However, there is still relatively little known about the timings and mechanisms behind the genesis of this vast area, and particularly its complex tectonic history in Cenozoic times, a topic which we discuss further in this issue.

While much of South East Asia has been explored, it still contains unexplored frontier basins and regions which for either practical or political reasons – as in the case of Myanmar – have not been fully explored. When looking at these relatively untouched areas, it may also be time to consider our industry's 'social licence to operate'. Should oil and gas exploration ever be terminated – or not even begun – for environmental or social reasons? And do we individually hold any responsibility for the consequences of exploration?

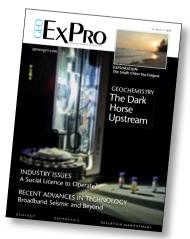
#### JANE WHALEY Editor in Chief



## THE DARK HORSE UPSTREAM

Geochemical analytical techniques like the Whole Oil Gas Chromatograph pictured on the cover are set to become a mandatory part of the petroleum exploration process. With the ability to identify minute differences in even very tiny oil samples, the GC can be used to assess the maturity, age, depositional and post-emplacement history of an oil as well as to correlate it to other oils or source rocks across a basin – and can do so for a bare fraction of the cost of even a single day of drilling.

*Inset:* The genesis of the South China Sea is a complex enigma which we are only just beginning to understand



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# Harper Basin Exposé

# Unexplored West African offshore basin holds great promise

The undrilled Harper Basin lies offshore Liberia between the Liberian-Sierra Leone Basin to the north, and the Ivorian/Tano Basin to the south-east. It covers approximately 20,000 km<sup>2</sup>, extending from shelf to basin floor and is an embayment formed between two transform ridges: Grand Cess to the north and Cape Palmas to the south. The geological structure and tectonic history of this basin is similar to that of adjacent ones. The Ivorian/Tano Basin is a proven oil producer that contains several large oil fields, including the Jubilee Field, while the Liberian Basin is still relatively early in the exploration cycle but has had several oil discoveries over the last five years. Hence the Harper Basin is considered to offer very good hydrocarbon prospectivity.

This Basin forms part of the West African Transform Margin and was initiated in the Mesozoic, during the opening of the central Atlantic and the break-up of Gondwanaland, with the development of an active rift system through the Aptian-Albian interval. The major phase of rifting ceased in the Mid Albian. A post-rift, drift phase from Upper Cretaceous to Recent times has resulted in general deepening of the basin. This has led to a major influx of sediment with the deposition of deepwater marine shales and large, turbiditic, sand-prone channel and fan-lobe systems, which extend from the midslope out to the basin floor.

The example 2D dip line shown here extends from the upper slope to the ultradeep and indicates the main features of the Harper Basin. Three main plays have been identified: syn-rift, Aptian-Albian structural traps, charged by early syn-rift lacustrine source rocks; Early post-rift, Late Albian-Cenomanian slope and basin floor fans, charged by either the syn-rift source or early, post-rift, marine shales; and Upper Cretaceous turbiditic channel systems, charged by Cenomanian-Turonian anoxic, deepwater, marine source rocks.

Interpretation of the existing 2D TGS dataset, combined with basin modelling studies, leads to a number of interesting conclusions. Syn-rift structural traps can be identified over much of the area, which offers multi-level prospectivity, and these form the primary target where the Upper Cretaceous overburden is thinner. Source rock maturity and expulsion post-dates the main tectonism in the basin, and seal presence is evident in West African Transform Margin analogues. Also, Cretaceous slope and basin floor fan systems demonstrating high amplitude character have been identified, some of which cover over 300 km<sup>2</sup>. Volumetric assessment of these features suggests field sizes over 1,000 MMbo in place could be present.

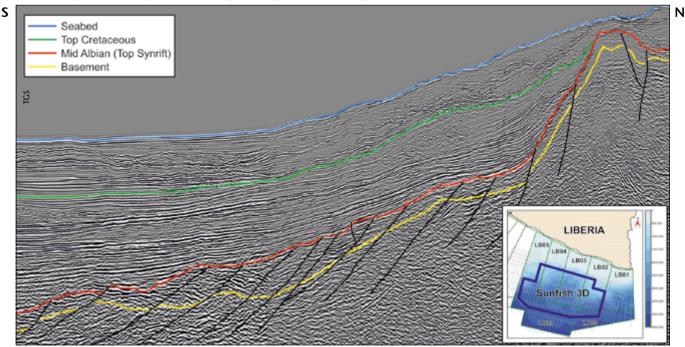
This area has not been licensed previously and the acreage will be included in the upcoming Liberia 2013 bid round, which will cover concession Blocks 1 to 5 and ultradeep Blocks 29 and 30.

The existing TGS 2D seismic regional data (approximately 5 km x 15 km grid) produced a large number of plays and leads and therefore a new multi-client 3D survey, called 'Sunfish', was initiated by TGS on 15 January, due to be completed by early July 2013. This acquisition of 7,800 km<sup>2</sup> is being undertaken by the *Polarcus Asima*, towing 12 streamers, and will be processed by TGS, with PSTM volumes available before the opening of the bid round and PSDM volumes following soon after. Sunfish is supported by industry pre-funding and additional opportunities to pre-fund the project are still available.

A more extensive description of the hydrocarbon prospectivity of the Harper Basin will be published in the next edition of the GeoExpro App Edition in March 2013.

PETER CONN, TGS, Geological Products and Services

Composite 2D dip line (from Harper Basin including TGS's regional and ultradeep seismic)



# Lebanon is ready. Are you?

3D MULTI-CLIEN SEISMIC



The Lebanese government has now authorised its much-anticipated first offshore oil and natural gas licensing round. Pre-qualification began on February 1st, 2013 with bids invited from May 2nd onward.

Spectrum have acquired a 3D Multi-Client seismic survey in a highly prospective area offshore south-west Lebanon. This survey provides valuable 3D seismic data to assist exploration efforts in a strategic area of the Levantine Basin. The survey covers over 3,080 square kilometres.

Final products are available now.





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LEBANON

# Connecting Operators and Geologists

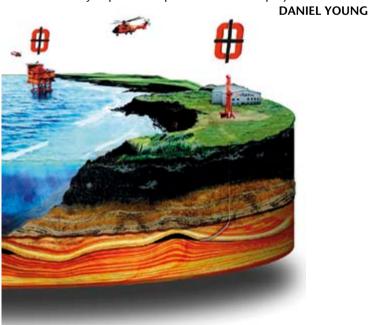
# New website puts competence and experience at the forefront of the recruitment process

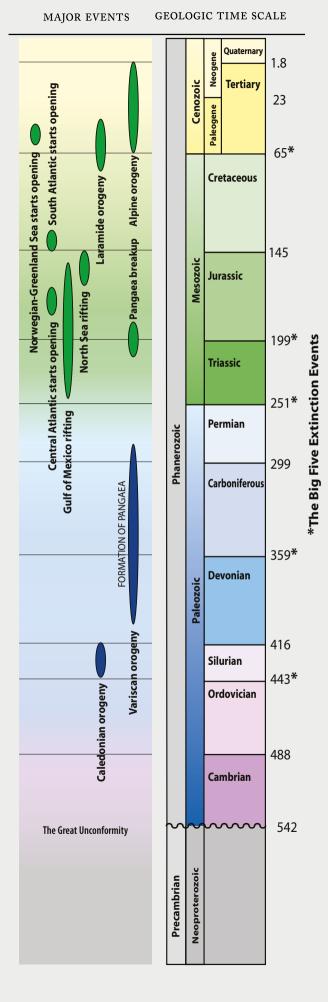
GeoPlacer.com is a recently launched website that connects competence-assessed wellsite and operations geologists with clients, which officially opened online registration for operators at PETEX 2012 in London. Since its unveiling in August of last year, the website has seen an influx of registrations by experienced geological personnel from all over the world. It now has a fully populated database of CVs from these geologists, who are ready to work with GeoPlacer.com's expanding network of operators around the globe.

For operators, registration with GeoPlacer.com will provide a range of tools to help operations geologists plan projects and assess the resources required. For example, the GeoPlacer planner offers a visual timeline of a registered operator's past, current and future resource requirements, which is linked to the database of experienced, highly qualified geologists, offering operators access to people with the various skill sets required for each and every well. Operators can gain access to exactly the right geologist for their project, simply by searching the database on years of experience, well types, region and a wide range of competences.

As the website continues to welcome new consultants to its database, the number of geologists using the website's search feature to find work opportunities is increasing each week. In fact, the total knowledge of all the registered consultants on GeoPlacer.com amounts to over eleven thousand years of relevant geological work experience. The market's strong demand for wellsite geologists has increased the need for operators to plan for projects further in advance than ever before. Included in the consultant profiles is a helpful planner to facilitate this demand and to allow consultants to schedule work for where and when it suits them.

The launch of the website coincides with a nationwide advertising campaign in various publications. This will be one of the many methods used by GeoPlacer.com as it looks to expand in the global market and enhance the ability of consultants and operators to find the most suitably experienced personnel for their projects.







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# Getting the Message Right

Understanding – and avoiding – the hidden costs of content management systems for oil industry websites

'Join the Conversation', followed by a plethora of social media tools (Twitter, YouTube, Facebook) is a headline seen on more than one major oil or gas company's website – but before Twitter and her friends showed up, company blogs were once Top-of-The-Pops 'social media'. Yet blogs are anything but passé. Instead, entire websites are now built out of traditional leading open source blogging softwares, like WordPress, 'Joomlal' and Drupal, just so companies can continually update and add more content, online.

## The Latest Trend in Online Marketing: Easy Content Updates

Blogging softwares give companies an easy-to-use Content Management System (CMS) for creating or updating website content. (After all, a blog is just an online website where non-HTMLcoders can quickly and easily write and share content.)

CMS platforms for managing website content are attractive for a number of reasons.

Firstly, a CMS lets you keep content accurate, current, fresh and relevant to online readers in an attempt to build your organisation's credibility with readers and major search engines. Seemingly, with only basic word processing skills, it is easy to write content (words, pictures and videos) directly onto a website and publish at a time convenient to you and your team, without acquiring the special skills of a web developer.

Another advantage is that leading blogging softwares have already mastered 'ease-of-use', so it should be faster to train staff on managing software that is widely considered easy to learn. And these same softwares may also decrease your expenses when building a new website. Free softwares like WordPress are customisable and more easily integrated. They are also typically less expensive than custommade Content Management softwares and can be more stable. Managed by a large community of active developers, there is a wealth of support available.



...because open source matters

Popular blogging softwares like these are now used to build entire websites

In addition, particularly in high profile industries, there are many critics keen to feed upon an organisation's 'bad news' stories. A CMS-built website lets companies mitigate the risk of online criticism. By consistently listening and thoughtfully replying with good information (also known as Content Marketing) many organisations are encouraging fascination with their brand and attracting allies online.

## **Circumventing the Hidden Costs**

But as it is with trying anything new, there are certain problems you could face after switching to a CMS website. Here are five steps to avoiding common errors while maximising benefit when using such a system.

- 1. Establish parameters for creating website content. Inconsistent writing style is a danger of CMS-driven websites. A Website Best Practices Guide will ensure you do not lose the credibility you are working hard to achieve with a CMS. Important things to include in this guide are message guidelines, publication frequency and stylistic preferences.
- 2. Train staff to be Online-Writers. Online readers have unique expectations: from how they read to how they search. In order to meet your target audience's expectations, document

your approach to writing online, then train and practise it.

- 3. Avoid solipsism. The same rules apply online as in good conversation. Be others-centred in your content. Focus on topics that interest your target audience or you will lose key opportunities to make your audience think well of you.
- 4. Employ a keyword strategy. Each article must be indexed with search terms or it won't be easy to find topics on your site, let alone on the Internet. Search terms must be listed for each post to help search engines see your content.
- 5. And finally, stick to a content plan and a pre-set frequency. If your last update was Dec 2010, readers think you lack either the resources or the level of care to manage your online presence – it is as distressing as a store with dirty floors. Having a Content Strategy and an Editorial Calendar helps to ensure you'll be creating an asset of searchable, well-organised, target-market-relevant content to attract readers to your website.

In brief: Content Management Systems are a powerful tool for oil and gas websites – take full advantage of them!

ALYSHA DOMINICO Tangible Words

# Polarcus

1

11

OLARCUS ASIMA



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8 SX134

# Another Turbulent Year A look back – and a look ahead



THINA MARGARETHE SALTVELT, PH.D

Brent oil prices averaged US\$ 111.7 a barrel in 2012, the highest nominal value ever recorded, up US\$ 0.8 from the year before. Oil prices have fluctuated widely the last few years, and this trend continued in H1 2012. Oil prices reached a year high on 13 March at US\$ 126.22 a barrel as the political tension between the West and Iran over Iran's nuclear programme reached a climax with growing rhetoric and increasing threats of a military confrontation/Iran closing the Strait of Hormuz. In Q2 oil prices dived and reached the year low at US\$ 89.23 a barrel on 21 June. This drop was driven by several factors: increasing turbulence in the Euro zone and a flight to safety away from risky assets such as oil for financial players, and weaker growth prospects for large economies such as the US. In addition, Saudi Arabia, the world's largest oil exporter, was pumping oil at record levels and Iran and the West agreed to restart the negotiations on Iran's nuclear programme.

From July oil prices started to rise as the stress around the Euro zone eased and risk appetite returned to the market. Saudi Arabia cut production, the EU and US tightened their sanctions against Iran, and the EU started an oil embargo against Iranian oil. Brent oil prices fluctuated in the US\$ 97–117 pb range in H2 and traded between US\$ 105 and US\$ 117 in Q4.

For 2013 we think the oil balance will improve, but supply risks will remain high. The global oil balance is expected to soften on a more subdued demand recovery and a robust increase in supply from both OPEC, mainly Iraq, and non-OPEC countries, predominantly the US tight oil/shale oil and deepwater production and oil sand production in Canada. The world's capacity buffer should therefore build from an uncomfortably low level in 2012 to a more healthy level in 2013. Risks to supply have increased markedly after the Arab Spring, so oil prices are expected to stay volatile at high levels.

The main oil price drivers to look out for in 2013 include improvements in global economic conditions, especially in the US and China, and increasing living standards, population growth and urbanisation in Emerging Market economies, especially China, India and the Middle East. The recent boom in US and Canadian unconventionals production is anticipated to last and to remain the centre of gravity of non-OPEC supply growth together with OPEC NGLs, while deepwater production is moving back up on the agenda and is expected to take a growing share of offshore production going forward. Other drivers include the impressive growth in Iraqi oil, which is expected to continue in 2013, and the return of Libyan oil production, plus the 900 Mbopd Manifa project in Saudi Arabia which will come on stream in late 2013/early 2014. However, problems with oil production in Sudan/South Sudan, Syria and Yemen will continue in 2013. In addition Saudi Arabia needs to cut production to balance the market at a higher price.

On the pessimistic side, political risks, such as a military attack on Iran by Israel, cannot be ruled out, while the risk of the Arab Spring and Syrian turbulence spreading to Saudi Arabia or Iran can from time to time push up oil risk premiums. There may be demand surprises stemming from higher or lower than expected economic growth, especially in China in late 2013.

Also in 2013, look out for huge turnarounds in the gas market, with new pricing strategies in the EU and Japan based on gas and a move towards a more transparent global gas market, which will have growing influence as competition increases in all sectors and gas gets relatively cheaper compared to oil. Increasing competition from cheap coal and wind is also anticipated.

## ABBREVIATIONS

#### Numbers

(US 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 litreboe:barrels of oil equivalentbopd:barrels (bbls) of oil per daybcpd:bbls of condensate per daybwpd:bbls of water per day

#### Gas

MMscfg: million ft<sup>3</sup> gas MMscmg: million m<sup>3</sup> gas Tcfg: trillion cubic feet of gas

Ma: Million years ago

## LNG

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

#### NGL

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

# Reserves and resources P1 reserves:

Quantity of hydrocarbons believed recoverable with a 90% probability

#### P2 reserves:

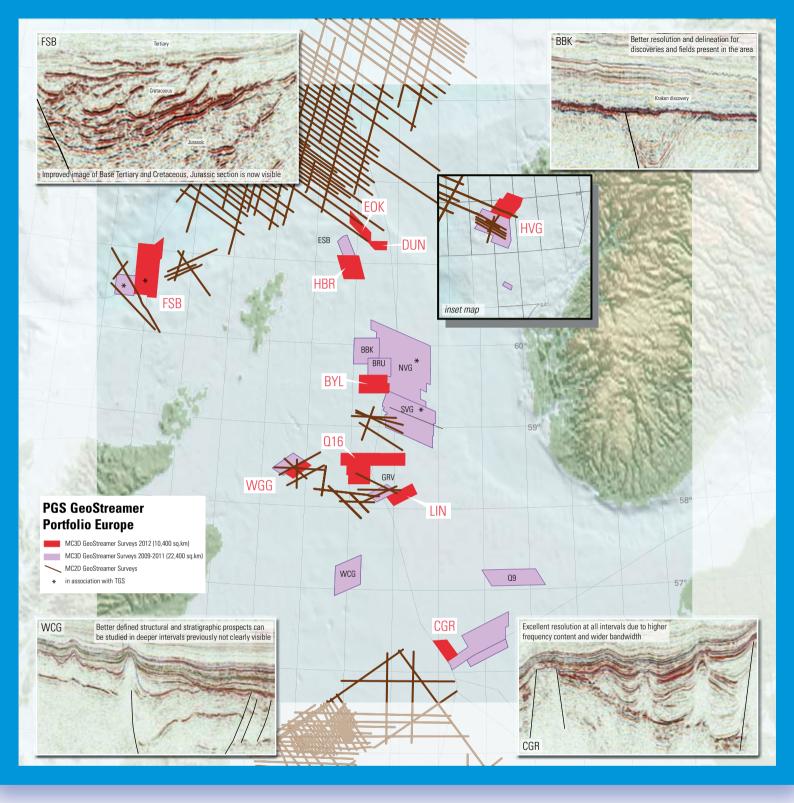
Quantity of hydrocarbons believed recoverable with a 50% probability

#### P3 reserves:

Quantity of hydrocarbons believed recoverable with a 10% probability

#### **Oilfield glossary:**

www.glossary.oilfield.slb.com



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mceurope@pgs.com

# **Africa Spearheads New Acreage Drive**

## Suriname

Staatsolie will formally open its 5th International Bidding Round on 28 January 2013. The industry will have the opportunity to bid on four blocks on the Demerara Plateau - Block 54, Block 55, Block 56 and Block 57 – where a 5,000 km 2D BroadSeis data set was processed by CGGVeritas in September 2012. The Bid Round will close on 26 July 2013.

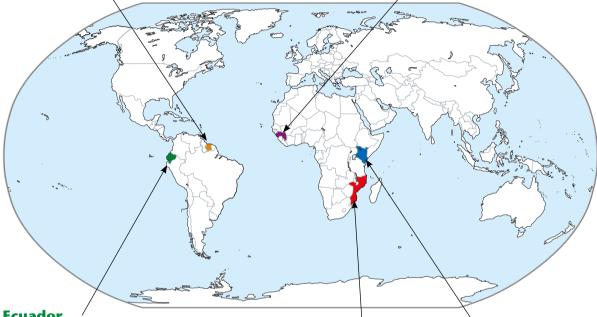
### Guinea

Guinea is working to put in place a new oil code by the middle of 2013 and will then invite companies to explore 21 offshore blocks, according to Guillaume Curtis, the country's deputy mines and geology minister. He cautioned that the ministry had not yet decided whether this would be done through an auction process or through company-by-company negotiations. In September 2011, Guinea adopted a new mining code that gives the state 15% of mining projects along with the option to purchase an additional 20%, bringing its total potential share in projects to 35%. Curtis declined to say whether the new oil code would be modelled along the same lines.

This new feature throws the spotlight on

countries around the world where key licensing

opportunities have recently been announced.



## **Ecuador**

On 28 November 2012, Ecuador put aside three blocks for staterun oil company Petroamazonas, which could decide to team up with other state companies to explore the areas, while 13 other blocks were put up for auction. Companies will have six months to present their bids, and contracts should be signed before the end of September 2013.

Oil Minister Wilson Pastor is confident these 16 blocks will attract investments worth around US\$ 1 billion in oil exploration projects from state-run and private companies. However, as the blocks are in south-eastern provinces, near the border with Peru and therefore distant from the northern Amazon regions where most of Ecuador's crude is extracted, he added, "I don't think we'll get interesting offers for the 13 blocks. It's very likely that only eight will receive offers." The minister indicated that preliminary studies show there are between 400 and 1,600 MMb of crude oil reserves in the area where the blocks are. The government may decide to put four more blocks in the area up for auction in the future. Six indigenous groups live in the area and have vowed to oppose oil exploration because they fear investors will spoil their homeland.

In a bid to increase state revenue from the key oil sector, Ecuadorean President Rafael Correa asked oil companies to sign lessprofitable service contracts in 2010, or leave the country. Ecuador has not attracted any investments in oil exploration projects since then. Pastor said oil companies that win the auction would also have to sign service contracts, but the deals would be different from the ones signed in 2010, so that companies can recover the investments they make in exploration.

## Kenya

According to Hudson Andambi, senior petroleum geologist at Kenya's Energy Ministry, there are plans to move away from direct negotiations and switch to bidding rounds to license the country's oil exploration blocks. Confident there will be no problem in attracting exploration companies, Andambi said Kenya planned to increase the signature bonus companies pay when they are granted new licences, which now stands at US\$ 300,000. The size of new exploration blocks Kenya leases in the future will also be minimised so more companies can explore. In a conference in New Delhi, the Energy Minister, Kiratu Murungi, said Kenya would demarcate and license six new blocks following the relinguishment of acreage by Anadarko and Tullow. The blocks are identified as L5, L7, L11A, L11B and L12 offshore and 10BB and 13T onshore. The timing of the round has yet to be clarified.

### Mozambigue

According to deputy minister of mineral resources Abdul Razak Noormahomed, Mozambique plans to auction up to 12 oil and gas blocks in the January-March period of 2013. The areas on offer are east of the existing blocks in the deepwater Rovuma Basin close to the Tanzanian border in the north-east, as well as in the Zambezi River Delta in the centre of the country. When evaluating future bids, Mozambique has said it was looking for companies not only with the necessary technical and financial skills and those interested in LNG, but players who would also help develop domestic gas-based industries.

# Strength in depth

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# Production Starts in Block 31

Production began at the end of January from the BP-operated Block 31 in Angola, one of the largest subsea developments in the world. The development will produce from four oil fields – Plutao, Saturno, Venus and Marte (PSVM) – which were discovered between 2002 and 2004 in water up to 2,000m deep, some 400 km north-west of Luanda. Initial production of around 70,000 bopd will come from three production wells in the Plutao field and is expected to ramp up to plateau rates of 150,000 bopd over the coming year as the Saturno, Venus and Marte fields come on stream in 2013 and 2014. Nineteen discoveries have been made on Block 31 to date, which covers an area of 5,349 km<sup>2</sup> in water depths which range from 1,500 to over 2,500m.

PSVM produces through a Floating Production, Storage and Offloading vessel (FPSO) which has 1.6 MMbo of storage capacity. It is the first FPSO in Angola's ultra-deep water. A total of 40 production, gas and water injection wells will be connected to the FPSO through 15 subsea manifolds and



A view from a helicopter of BP's Plutao, Saturno, Venus and Marte (PSVM) Floating Production, Storage and Offloading (FPSO) vessel

associated subsea equipment.

The International Monetary Fund recently stated that it expects Angola's oil production, which was 1.73 MMbopd last year, to grow more than 4% in 2013 to 1.8 MMbopd. Angola is Africa's second-largest oil producer after Nigeria. ■

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# **Pipeline Attacks in Nigeria**

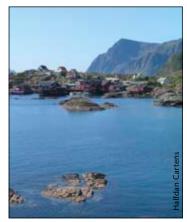
Attacks on pipelines have become commonplace in the oil-rich Niger Delta, and are symptomatic of the unrest in that volatile province. Previously the attacks were often the work of militants, who used explosives to blow up sections of the pipeline as a protest against foreign oil companies producing in the area.

But since a 2009 government-sponsored amnesty programme cut down on the militant strikes, the pipelines have been subject to an increase in attacks with a different motive. Less sophisticated, the attackers use hacksaws and blowtorches to siphon off the oil inside the pipeline, a process known as 'bunkering'. Although individually small scale, overall these thefts of crude have risen so that the International Energy Agency has estimated that they could cost Nigeria about \$7 billion a year. Bunkering has also spread out of the Niger Delta to other parts of southern Nigeria, and is reputed to be causing periodic shortages in the towns and cities of this impoverished yet resource-rich nation, where 70% of the population live below the poverty line.

Every year, thousands of people lose their lives as a result of accidents caused by these ruptured lines. And the environmental effect is devastating, as it is estimated that more oil is spilled annually from the delta's network of terminals, pipes, pumping stations and platforms than was lost into the Gulf of Mexico from the Macondo blow-out.

# **Lofoten Island Drilling Nearer?**

Exploration off the Lofoten Islands is strongly opposed by environmentalists



As discussed in *GEO ExPro* Vol. 9 No. 5, the seas around Norway's remote northern Lofoten Islands remain the largest unopened section of the Norwegian Atlantic Ocean, and environmentalists are strongly opposed to these pristine waters being licensed for hydrocarbon exploration. At the beginning of February, however, this possibility moved a step closer, when Norway's ruling Labour Party said it may support exploration, suggesting that the way forward would be an impact assessment study. This is contrary to their previous stance, as two years ago, after months of dispute, they struck a deal with

their smaller coalition partners to forbid oil exploration off the islands until the parliamentary term ends in 2013.

The Lofoten Islands, 200 km north of the Arctic Circle, have unique cold water reefs and are an important spawning ground for cod. They shelter killer and sperm whales and are a very popular destination for hikers, mountaineers and birdwatchers, and there are moves to make them a UNESCO World Heritage Site. But the area is also believed to hold at least 1.3 Bboe, and the Norwegians speculate that discoveries in this area could help boost their production, which is expected to fall to a 25-year low this year. ■

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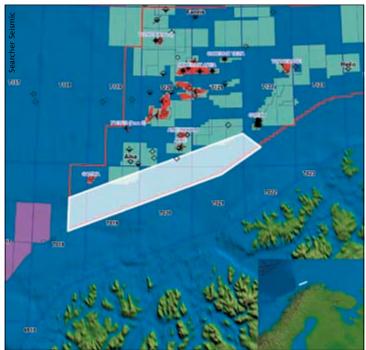
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# New Barents Sea Survey

The new multiclient survey lies close to a number of recent discoveries

One of the hottest areas in north-west Europe at the moment is the Barents Sea, where a number of major discoveries have been made in recent years, including the giant Skrugard and Havis finds, which have estimated combined reserves of between 400 and 600 MMbo. With annual licensing rounds and increasing infrastructure in the region, the need for additional information about the area is always strong, with industry demand for acreage in the Barents Sea at an all-time high.

Searcher Seismic, in partnership with Dolphin Geophysical, have recently announced that they are about to undertake a non-exclusive 3D high resolution survey, which will cover 2,880 km<sup>2</sup> of the Troms area in the southern Barents Sea, about 100 km from the coast. This acreage recently opened for exploration and is located immediately adjacent to proven oil and gas fields. Interpretation suggests that the survey, which is known as Rødspurv, covers an area which is thought to be charged from the north by the Mesozoic rocks located down dip of the Troms-Finnmark fault complex, with potential reservoirs being Permian and Carboniferous clastics.



# **Reservoir Monitoring**

The transition from technology development to commercialisation is a very critical phase of any technology innovation company. A main shareholder securing this transition as well as giving valuable input for further development is crucial for long-term success.

Norwegian company OCTIO specialises in the permanent and semi-permanent monitoring of reservoirs, drilling and injection wells using high vector fidelity seismic MEMS sensors with interface to EM, chemical, biological and oceanographic sensors. Having developed its systems over a number of years, it has now joined forces with Statoil Technology Invest, which has become a major shareholder. Statoil is considered one of the world's leading oil companies with regard to enhanced oil recovery (EOR) and is continuously seeking solutions to improve this further, combined with a high focus on reducing risk and cost of operation.

Reservoir monitoring system on the seabed



# Fully Integrated Geoscience Group

From the beginning of February 2013, all the geoscience divisions of Fugro will be incorporated into their new home in CGG, creating a fully integrated Geoscience group which the company believes holds a leading position in the fast growing high-end integrated geology and geophysics and reservoir market. Over 2,500 ex-Fugro employees have been incorporated into this new group. The agreement with Fugro which led to this also includes strategic partnerships, such as the creation of a joint venture company, Seabed Geosolutions, owned 60%/40% by Fugro and CGG, which will focus on the rapidly growing seabed acquisition market, and a marketing and selling multi-client agreement for CGG to sell Fugro's existing 3D data, which remains owned by Fugro.

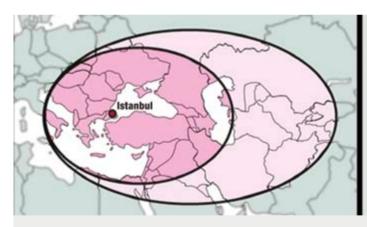
As part of this development the company has decided to shorten and simplify its brand name from CGGVeritas to CGG, capitalising on the heritage of this long-established company.

# A World of Experience

Task Geoscience is a geological consultancy specialising in the interpretation of wireline and LWD borehole image data, core description and multidisciplinary data integration. Our expert staff have experience in a wide-range of geological environments from worldwide settings.

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#### **First Announcement**

Following last year's highly successful inaugural event, AAPG Europe is proud to announce that APPEX Regional is returning to Istanbul in 2013. The specialised acquisition and divestiture conference will examine the latest E&P developments in Eastern Europe, the Black Sea, Caspian Sea, East Mediterranean, Middle East and the Former Soviet Union. APPEX is a gateway for anyone looking to buy or sell prospects in a friendly environment.

# Save the date for your diary, 5-7 November 2013



"Participating in APPEX was really a pleasure for me. I had opportunities to listen to relevant presentations and meet a lot of experts." — Przemyslaw Karcz, Senior Geologist, Polish Geological Institute

"Thanks for the excellent organization and for hosting us in Istanbul." — Gundogan Coskun, Senior E&P Geophysicist, TransAtlantic Petroleum

"It was thoroughly enjoyable and useful and all the delegates I spoke to about it said the same. Looking forward to next year's event already!" — Angus Warren, Principal, Warren Business Consulting

"The 10 minutes presentation for the exhibitors in combination with the relevant sessions at the Conference is a good opportunity for exhibitors to present prospects to the participants."

- Mesut ATALAY, General Manager, Yerbil Petroleum Ltd.

The next APPEX Regional event will be held on the 5-7 November 2013 in Istanbul; further details will be announced soon. For all enquires please email Europe@aapg.org or call AAPG Europe on +44 (0) 207 434 1399



Most E&P professionals are familiar with aspects of geochemical analysis. But why is a science that could save exploration and production companies millions of dollars and months of drilling time not an industry standard?

HUNTER C. EDEN AND DAVID MUNGO, StratoChem Services



In 2008, Petrohawk of Houston made the now historic Texas Eagle Ford shale discovery after consulting geochemical data from a nearly forgotten 50-year-old wellbore. The basic 1950s geochemistry confirmed sufficient organic content and maturity in the unusual formation and Petrohawk moved ahead, finding a field it is now estimated will produce between 3 and 4.8 Bbo. As petroleum exploration and production becomes ever more complex, more companies are finding that geochemistry makes the difference for success.

At heart, petroleum geochemistry is the application of chemical analysis to determine the presence and properties of hydrocarbons trapped in geological formations or the potential to generate such hydrocarbons. But like most simple definitions, this leaves much unsaid.

While geophysics has long been considered the go-to tool of upstream geoscience, geochemistry has become increasingly important as hydrocarbons become more difficult to discover and recover, requiring ever more precise forms of analysis to differentiate between a viable prospect and a dry hole in the making.

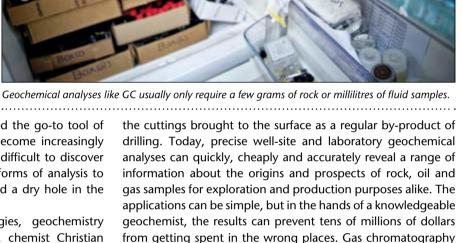
Like many game-changing technologies, geochemistry is not a new science. As early as 1838, chemist Christian Friedrich Schonbein proposed that chemistry might be used to further geological understanding, but it was not until the early twentieth-century work of Alfred E. Treibs in Germany and Victor Goldschmidt in Switzerland that the geochemistry and organic geochemistry we now use for hydrocarbon exploration came into their own as a scientific discipline.

Nonetheless, technological limitations and imprecise understanding of the organic chemistry of hydrocarbons kept the discipline largely out of use until later in the twentieth century. "When things did not work out correctly or dry holes were drilled, the geochemical data were often blamed," explains Dr. Henry Halpern, a former geochemical consultant at Saudi Aramco with over thirty years' experience in the field. Indeed, only recently has geochemistry gone from relative obscurity to become a vital part of the exploration process.

### The Missing Piece

What makes geochemistry so valuable is its capacity to tease out highly specific information about the characteristics of a petroleum system from just a few rock, oil or gas samples. Like a missing puzzle piece, the various applications of geochemistry allow explorationists to fill in the holes that inevitably appear in even the highest quality geological and geophysical data. The best-established geochemical services revolve around the chemical analysis of source rocks for the presence of hydrocarbons.

For decades, geochemists have been able to tell explorationists whether they have a viable source rock with sufficient organic charge, and, if so, its maturity and type, simply by analysing



A basic chemical analysis used for everything from drug testing to cosmetics quality control, GC can parse out the components of an oil sample with great accuracy. The resulting chromatogram – a peaked graph showing the unique pattern of molecular abundances making up any given oil – serves as a fingerprint which a geochemist can use to identify and compare to other oils. By comparing the presence and ratios of various components, multiple oils can be correlated to their respective sources.

### **Major Savings**

(GC) is a typical example.

The possible applications are vast, and all for a tiny fraction of the cost of a day's drilling. Beyond the characterisation of oils for the purpose of connecting them to their sources in exploration, the technique can be used in a reservoir continuity study which assesses GCs of samples from multiple wells suspected of accessing the same reservoir. If a comparison of two chromatograms shows significant differences in the ratios of certain components, the wells from which the oils derive are probably not in communication, perhaps due to unseen geological features creating reservoir compartments. If part of a field's productivity is declining and the production company is considering well injection or downdip waterflooding, a reservoir continuity study will establish the option's viability for repressurising the entire system long before injection even begins.

"Without the geochemistry... we would have moved ahead and started injection only to find out in three to five



years' time the waterflood wasn't working and would have had to abandon our investment," said one reservoir geologist working for an upstream company in North America. The geochemical continuity study costs far less than any other reservoir engineering tests in direct expenditures, and yet even bigger savings come from the opportunity costs avoided. The geochemical method of reservoir continuity determination requires only а representative oil sample from each zone - no wells need be shut down to assess continuity. By a similar process of comparing oil signatures, GC can also be used to allocate and monitor production in wells with multiple pay-zones without costly stops to production.

On the inorganic side of conventional

geochemistry are techniques that investigate rocks' elemental and mineralogical compositions to clarify questions about formation boundaries – known as chemostratigraphy. X-ray Diffraction (XRD) is the most common mineralogical assessment technique, while Inductively Coupled Plasma Mass Spectrometry (ICP-MS) is the standard for chemostratigraphic analyses. Moreover, recent advances in X-ray technology combine a gamma ray source with a sensor that detects the resulting fluorescence into a compact handheld device. While this so-called 'XRF gun' has a slightly more limited range of elemental detection than the ICP-MS, it requires no sample preparation (decreasing the per sample cost by a power of ten) and allows for rapid screens of entire wells in



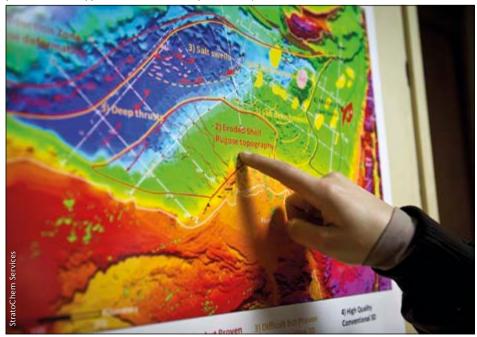
Geochemical analysis of oil and gas can be used to characterise wells and basins, revealing information that is very difficult to determine using other methods.

just days, providing a lithological picture more complex than the basic mud log. Lower costs mean more data can be obtained for the same price such that the XRF can be perfectly adequate for generating the elemental ratios used in stratigraphic analyses. Additionally, the new XRF is non-destructive, so samples can be used for further analysis. (See page 74 for further information about this technique)

### **Beyond the Basics**

By linking a GC with other instruments, geochemists can glean even greater information from rock, oil and gas samples. For rock samples, the hydrocarbons inside can be extracted either

Spectrum Geophysical recently began offering their clients a new basin model study of the offshore Levantine basin that employs, for the first time, a full spread of geochemical analyses to more accurately predict the best approaches to the basin's petroleum systems.



by a solvent or – for samples that require utmost precision –by a closedsystem thermal extractor (a device similar to a pyrolyzer). The extracted hydrocarbons can now be run through the same instruments (i.e., the GC) as oil samples to compare oil and source profiles, allowing explorationists or development geologists to correlate oil and source rocks that may be geographically quite distant.

Rock extracts and oil samples can also be analysed in further detail by combining the GC with mass spectrometry (GC-MS). This instrument measures the abundances of various organic compounds called biomarkers to reveal details about the original organic material that produced the hydrocarbons, the depositional environment, the source rock lithology, and the age and maturity of the oil. Dr. Halpern

# PES

# The 12th PESGB/HGS Conference on African E&P



# Africa: Success in Rift, Sag and Passive Margin Settings

Wembley Stadium, London. September 11th-12th 2013

This annual conference, alternating between London and Houston has established itself as the primary technical E & P conference on Africa, with an attendance regularly exceeding 400. There will be about 25 high quality talks plus a large poster session covering E & P in all regions of Africa. Keynote presentations already confirmed include:

Origin of Palaeozoic Sag Basins - Mike Daly (BP) Cretaceous Fan Fairway of West Africa - Paul Dailly (Kosmos) and Robin Sutherland (Tullow) Exploring giant turbiditic reservoirs offshore Mozambique - the ENI experience - F. Fonnesu African Rifts and Source Rocks - Alain Huc Pre-Salt Seismic Imaging - Jay Thorseth (BP)

Details of sponsorship opportunities and display booths are available from Rebecca Dibley at PESGB office: Email: rebecca@pesgb.org.uk or Tel: +44(0)20 7408 2000

Main Conference on 11th-12th. Additional events on Tuesday 10th include a course 'Petroleum Basins of Sub-Saharan Africa' by D. Macgregor, stadium tours, an evening talk and an icebreaker reception. For details see website www.pesgb.org.uk

Registration will open on 1 April 2013 – Early Bird rates will be available



Basins image courtesy of the Exploration Fabric of Africa project compiled in memory of Ed Purdy, a former contributor to many African conferences VAT Registration Number 539 2064 43 – Registered Charity Number 1085619

**PES** GB

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explains: "Certain biomarkers...are useful for oil-source and oil-oil correlations and can lead to new discoveries by mapping distribution and migration pathways." The same principles hold true for gas analyses using a combination of GC and isotope ratio MS technology that examine the isotopes of natural gas to assess maturity and origin of gases.

Geochemistry also yields useful data in unconventional plays. "I have used geochemical data... as an aid in understanding and high-grading unconventional oil plays," says Dr. Douglas Waples, an award-winning geochemist who has taught and published extensively (including several geochemistry textbooks), now working as a consultant for companies around the world. "A newly developed kinetics technique provides the best way to map the level of hydrocarbon generation in the source rock, since the mean activation energy derived from the kinetic analysis can be calibrated accurately to the Transformation Ratio (TR) for each source rock."

The kinetics technique to which Waples refers is a personal speciality. Source rock kinetics has long been a part of the geochemical arsenal; by heating a rock sample at several different rates and mathematically analysing the rate of pyrolysis, kinetic parameters can be obtained that can be used to predict hydrocarbon generation in basin modelling studies. In the past, the costs associated with kinetics meant that analysis of many samples was an impractical, prohibitively expensive, timeconsuming process. Waples, however, realised that the laws of thermodynamics permit one to estimate one of the kinetic parameters (the A factor) more accurately than the pyrolysis experiments could. Once the A factor had been determined, there was no need for different heating rates. This has the effective result that twenty times more data can now be generated at the same cost, in the same time, as the old method. The large amount of additional data in turn allows kinetic parameters to be employed for other very valuable purposes: distinguishing different organofacies, and as a new indicator of thermal history that is directly linked to hydrocarbon generation.

### **Integrating Data**

Perhaps the most powerful application of geochemistry is when a range of geochemical inputs taken from oil and gas information as well as source rock kinetics are combined with existing seismic and geological information to create a full basin model with precise migration pathways and source rock and reservoir locations. Waples tells of one instance when this combination of geochemical data was crucial to a company's decision-making. "In one study the kinetic data indicated that the source rock at the studied location was too immature to have sourced the discovered hydrocarbons, which had previously been assumed to have been locally generated. Biomarker analysis of stained and unstained samples confirmed that the hydrocarbon stains were indeed significantly more mature than the unstained host rock, and thus indicated migration of significant distance from the kitchen." The company pivoted away from an exploration plan of unconventional fraccing to one geared more toward a conventional play.

Combining geochemical data with a company's geological and geophysical data through the use of powerful software allows explorationists to see where there is an actual hydrocarbon 'charge' in the structures indicated by their seismic. "A good charge model is the first requirement for successful exploration. It is the driving force behind the subsequent activities which focus on risk reduction of reservoir and structure or trap," explains Neil Hodgson, New Ventures Manager with Spectrum Geophysical.

Seeing the value added by geochemistry, Spectrum has recently begun selling an integrated study to clients prospecting in the Eastern Mediterranean offshore basin. This combines the available geochemical rock, oil and gas data with 35,000 km of 2D seismic to produce a comprehensive model of the petroleum systems in the Levantine basin. "The contribution isn't limited [to charge], as integrated geochemical data can allow the volume of expelled, migrated and reservoired hydrocarbons to be estimated, with key implications on the phase and quality

Medium pressure liquid chromatography (MPLC) is a technique for the separation of oil samples into their component parts based on the shapes of the molecules. Analysis of these components enables a deeper understanding of the oil's characteristics and the geological factors that led to its generation.

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of the hydrocarbons and post-charge biodegradation... All of these parameters are essential to the understanding of the development scheme for oil and gas, and the estimation of the value of any resource."

But given the obvious utility of geochemistry, why has it only begun to see wider use recently?

#### The Industry Dark Horse

The recent rise of geochemistry is part of the larger economic story of the explosive growth of the oil and gas service sector. Consistently high oil prices combined with technological breakthroughs in liquid natural gas and unconventional shales have created huge demand for exploration, fuelling the growth of exploration service companies. The Canadian Imperial Bank of Commerce calculates the petroleum



Careful preparation of samples, including extraction of unwanted organic matter, mud additives or well-site contaminants, is often necessary to achieve the most accurate possible geochemical analyses.

service industry's annualised growth rate to have reached nearly 10% over the past five years. True, in hard financial terms, even the revenue from top service sector players like Schlumberger, Halliburton, Baker-Hughes and Weatherford makes up a bare fraction of the whole multi-trillion dollar petroleum industry – and geochemistry forms just a sliver of that fraction.

.....

But that sliver shows signs of growing faster than the pie. Even as industry economics have created new demand for geochemistry, advances in the science continue to create new possibilities. "With the advent of better and better means of analysis and greatly reduced levels of detection limits, all analytical data are better today than even five years ago," says Halpern.

But past misunderstandings of geochemistry have led some companies to remain wary of the discipline. "In earlier times at some companies, geochemistry was done by explorationists who were really not familiar with interpreting data or asking for the right services," Halpern explains. "When these projects that had made use of geochemistry turned out unsuccessful, it resulted in a lack of trust [that] may have persisted at many companies because the 'old timers' remembered a bad experience."

Simple bureaucracy can often be the biggest obstacle to making full use of geochemical services. In many cases, the approval of crucial services gets obstructed by a manager or government official unwilling to spend a few thousand dollars on geochemical sample analyses that could only theoretically save the company money. Such well-intended scrimping can be costly. "[I've seen companies ignore geochemical data] due to economic constraints or strategic conflicts or being risk averse," said a petroleum geoscientist with a major North American exploration company who requested to remain anonymous. "The data pointed in the right direction, but action was not taken. By the time the

data was realised to be of enormous value, it was too late to capitalise on it."

Still, Halpern and his fellow geochemists remain convinced that geochemistry is a discipline on the rise. "I find that most companies realise there is a need for geochemical data nowadays," he affirms. Hodgson, too, sees a central role for geochemistry: "[I]ntegrated geochemistry can be considered... the keystone of exploration: at the heart of – and gluing together – the raft of activities in the exploration/value creation process." And exploration companies like Petrohawk in Texas seem to agree.

Once the dark horse of the geosciences, geochemistry is surging forward throughout the upstream sector. From basic source rock characterisation and oil GC correlations to full basin modelling studies, gas isotope analysis and one-run kinetics data, explorationists who once mistrusted geochemistry now increasingly depend on it to make the right exploration decisions without blowing their budgets. As projects get more complicated and costly, geochemistry may just be the horse that keeps the whole race going.

# About Stratochem...

StratoChem Services, the largest independent geochemical testing company in the Middle East and North Africa, was founded in 1989 by two experienced Egyptian geoscientists, Mohamed Said and Tarek El-Azhary. The pair met as geology students at Cairo University, but remained close friends after graduation.

After years of worldwide experience working in the petroleum industry, Said and El-Azhary realised the oil and gas sector in their home country consistently spent a great deal of money on exploration projects that utilised incomplete information.

Knowing that even simple geochemical analyses could

reveal previously undiscovered resources, the pair decided to provide the missing services themselves. Started with just personal savings, a small lab in Cairo, and a mechanical engineer, StratoChem has grown into a world-class provider of petroleum analysis and interpretation with over 70 employees.

StratoChem now serves upstream companies in North America, Europe, Africa, and the Middle East, offering a broad capacity for rock, oil, and gas analysis that includes everything from basic TOC and oil GC, to mud gas isotope logging, one-run personalised kinetics, and full, 3D basin modelling.

# The Black Sea Hots Up

Interest in this underexplored area has increased recently, spurred on by Romania's first deepwater discovery. We look at the results and implications of recent drilling in the Black Sea

## **KEN WHITE**

**TPAO** 

The Black Sea, which straddles south-eastern Europe and Asia Minor, has long been considered prospective for oil and gas, although this optimism is based mostly on limited drilling and modest success in shallow waters. The industry was further alerted to this potential by a major study undertaken by Purvin and Gertz in 2011, which predicted the development of a Romanian offshore industry on the basis of the potential existence of a 600 Bcm offshore resource.

A number of factors explain the general lack of exploration to date: the littoral countries have traditionally been well supplied with reasonably priced oil and gas by major producers, Turkey and Russia; the lack of technology in the countries bordering the Black Sea has limited the scope for exploration; and, until very recently, terms and conditions offered to private investors in the upstream petroleum industry were poor.

It is less than two years since the *Leiv Eiriksson* D/S moved out through the Bosphorus after a US\$ 200 million three-well venture for TPAO and partners off the Turkish coast; a giant find in the extensive deepwater regions, where exploration has been sporadic, had once again proved elusive. That all changed, however, in February 2012 when ExxonMobil and Romania's OMV Petrom announced the results of Domino-1, Romania's first deepwater wildcat, in the Neptun East block. Located in 930m of water, Domino-1, drilled using the *Deepwater Champion* D/S, encountered over 70m of net gas pay. At the time OMV chief executive Gerhard Roiss declared the discovery had established an in-place resource of around 3 Tcf, making it the biggest gas find in the company's history. It is understood that while ExxonMobil has plans for additional drilling in 2013, and has recently secured some additional adjoining acreage, the find is also the subject of talks with Bulgaria, as part of the field apparently lies in disputed waters.

Such a resource is not considered large by global standards, but its significance lies in the fact that it is considered to be the precursor to finds at five nearby structures, something that should help ensure strong industry interest in Romania's 30-block bid round, split evenly onshore and offshore, that is planned to be held in April 2013. With the emergence of shale gas in Europe, where there is increasing evidence of a more united approach on energy, there is a growing belief that the exploration and development of significant gas reserves in the Black Sea would reduce the short-term imperative to supply gas from the Caspian to south-eastern Europe. Not surprisingly, just a few months after the Romanian find, elevated levels of activity have become apparent throughout the Black Sea region, particularly in deepwater, with much of the available deepwater acreage in the western Black Sea already taken.

The drillship Deepwater Champion passing through the Bosphorus enroute to the Black Sea in March 2011

# Norway APA 2012 Over 300,000km of Marine Gravity and Magnetic Data Available

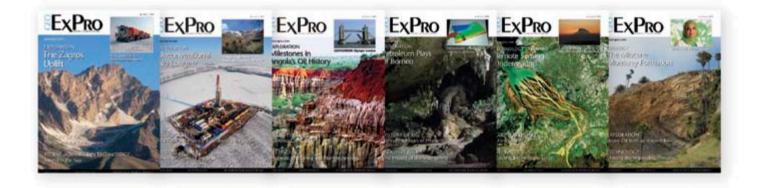
The Ministry of Petroleum and Energy has announced the acreage offered in APA 2012, comprising of 51 production licenses; 34 in the North Sea, 14 in the Norwegian Sea and 3 in the Barents Sea. ARKeX can give you the data you need to aid your next phase of exploration work.

ARKeX brokers multi-client gravity and magnetic data on behalf of major seismic companies and offers a broad range of data that stretches over the Norwegian continental shelf and beyond.

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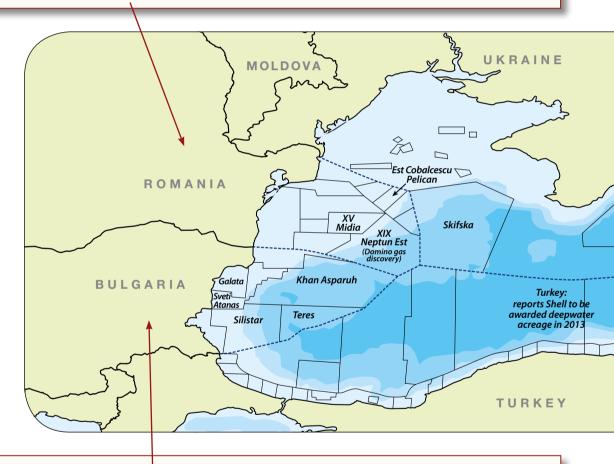
### **Romania: High Level of Interest**

Although the deepwater Domino discovery was the real gamechanger for Romania, most exploration since then has been in shallow water. Recent developments include Sterling Resource's drilling in early October 2012 of the loana gas prospect in Block XV Midia. Located on the western edge of a large 150 km<sup>2</sup> structure, the well targeted the Mid Pontian sandstone formation, and gas saturation in both this and in a shallower secondary objective were encountered, but reservoir development was poorer than expected, so further investigation will be required. A second well tested the Eugenia oil prospect in the more northerly Block XIII Pelican permit and preliminary analysis indicates hydrocarbons in Late Cretaceous sandstones, with further interest evident within an Eocene limestone section. A third, shallower but high-risk objective was a large Oligocene slump or fan structure as outlined by seismic. Although drilled downdip to enable exploration of the deeper main objectives, 100m of good quality sandstones with some minor gas shows were encountered, so the Oligocene, a new play in the area, remains an interesting prospect.

Sterling Resources has also recently mapped prospects in the

shallow water part of the Midia block while a new oil structure, Irina, has also been mapped in the Pelican block on trend with Eugenia. Sterling has also evaluated the Anca, Maria and Nadia prospects in water depths of 100–120m that are believed to be in similar formations to the deepwater Domino discovery 35 km to the south-east.

The general level of interest in the Romanian offshore has been demonstrated by the relatively high number of deals. Sterling, for example, sold its stake - the portion of the Midia concession containing Anca and Maria - to ExxonMobil and OMV, and separately secured a 50% operating interest in the 1,000 km<sup>2</sup> shallow water Block XXV Luceafarul, west of and adjacent to the Midia Block. This contains an existing gas discovery and multiple exploration plays. Similarly, Beach Energy farmed into the shallow water Est Cobalcescu Block operated by Melrose Resources in mid September 2012. The block has an average water depth of less than 100m and is close to the ExxonMobil deepwater block in which the partnership commenced a 6,000 km<sup>2</sup> 3D seismic survey at the end of 2012.



### **Bulgaria: Energy Independence?**

Interest in Bulgaria has been rising since March 2012, when the industry was invited to tender for the deepwater (up to 2,000m) 14,220 km<sup>2</sup> Block 1-21 Khan Asparuh permit, which was eventually offered in July 2012 to a consortium led by Total. It is understood that two wells are to be drilled during the initial five-year exploration phase to test a structure thought to have between 700 and 1,400 Bcf potential.

Melrose Resources declared in July 2012 that 3D seismic data acquired over the central area of the offshore shelf Galata permit in 2011 had confirmed the presence of seven structures in the area with a total combined unrisked P50 prospective resource estimate of 125 Bcf. The highest ranked prospect, Kamchia, has an estimated P50 of 27 Bcf and a 40% chance of success. Preparations are underway to drill this in April 2013 as part of a multi-well programme that possibly includes two exploration wells in Romania. This was followed late August by the award to Black Sea Energy EOOD of the 1,319 km<sup>2</sup> shallow water Block 1-19 Sveti Atanas, located south of the Melrose production acreage.

The authorities opened a tender for the 4,032 km<sup>2</sup> deepwater Block 1-22 Teres in the Black Sea exclusive economic zone near neighbouring Turkey in December 2012; the bid deadline is May 2013. This adjoins the Silistar block that was awarded to Lederbel BG but is being contested as the tender process has identified 'substantial irregularities and indications of fraud'. A new tender for the acreage is planned once the investigation is concluded.

At present, production from the Melrose Resources fields off northeastern Bulgaria accounts for 10–15% of the country's domestic needs and the Bulgarians hope that the result of this increase in drilling will be gas supply independence in a few years.

### **Ukraine: Another Domino?**

A long-running border dispute with Romania was resolved in 2009, allowing companies to look more closely at this country. Until recently, the only area in the Ukrainian Black Sea under a PSA was the Prykerchenska Block, which lies in water depths between 700m and 2,100m and which has been the subject of an extended legal dispute. This was finally advanced in May 2012 with the grant of a licence to Vanco for an initial eight-year term, requiring a large but unspecified amount of 3D seismic to be acquired and the drilling of six deepwater wells.

Then in August a consortium of ExxonMobil, Shell, OMV

#### **Russia: Black Sea Core Region**

Rosneft, which is owned by the Russian government, has stated that the Black Sea is one of its core regions in its drive for increased resource potential. The company signed a strategic cooperation agreement with Eni in April 2012, whereby the two companies will form a joint venture for the development of the deepwater Zapadno-Chernomoskaya block. Rosneft says the tract hosts multiple prospects and estimates the three largest to

have combined reserves of 3.5 Bbo Drilling is expected in 2015–16.

Petrom and Nadra Ukrainy won the right to sign a PSA for the

16,698 km<sup>2</sup> Skifska area, pledging to invest US\$ 400 million in the

initial exploration phase together with a signature bonus of US\$

325 million. Lying adjacent and geologically similar to the Domino

discovery, there are high expectations that the Skifska field could

produce up to 4 Bcm of gas annually from the end of the decade.

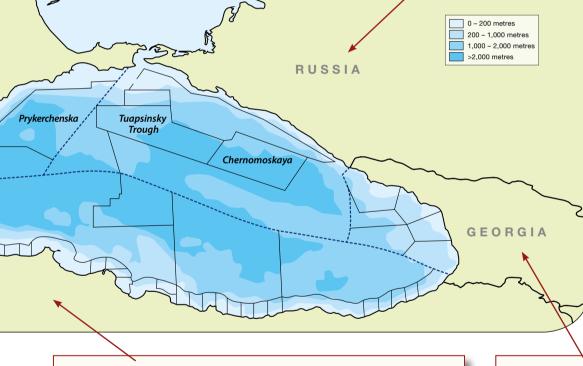
Analysts see the exploration projects as a game-changing shift for

Ukraine, whose energy inefficient economy is being squeezed by

high fuel import prices, and whose price disputes with Moscow have

twice since 2006 triggered supply disruptions to Europe.

At about the same time Rosneft signed a deal with ExxonMobil creating a joint venture to explore the 11,200 km<sup>2</sup> Tuapsinsky Trough acreage in the waters off the Krasnodar region. Seismic acquisition is complete and interpretation of the data underway with the drilling of the first exploration well planned for 2014–15.



#### **Turkey: Deepwater Available**

Turkey holds the largest Black Sea acreage and TPAO, the national oil company, believes that the sector holds reserves of 10 Bb of oil and 53 Tcf of gas. The company announced it will invest US\$ 4 billion in the Black Sea over the period 2011–13 while the ministry has announced it is aiming for commercial production in either 2015 or 2016. Although there is plenty of available acreage, so far this investment has yielded little in the way of commercial reserves, and concerns that the Black Sea's prospectivity may be overrated have affected investment levels. At the present time TPAO has all the deep and ultra-deepwater licences and, following the exit of Petrobras and ExxonMobil, no international players are involved.

Shell chief executive Peter Voser has indicated his company, now conducting a shale gas exploration programme in the south-east of the country, is assessing oil exploration and production opportunities in the Black Sea with TPAO; media sources indicate the award of ultra-deepwater acreage to Shell is imminent.

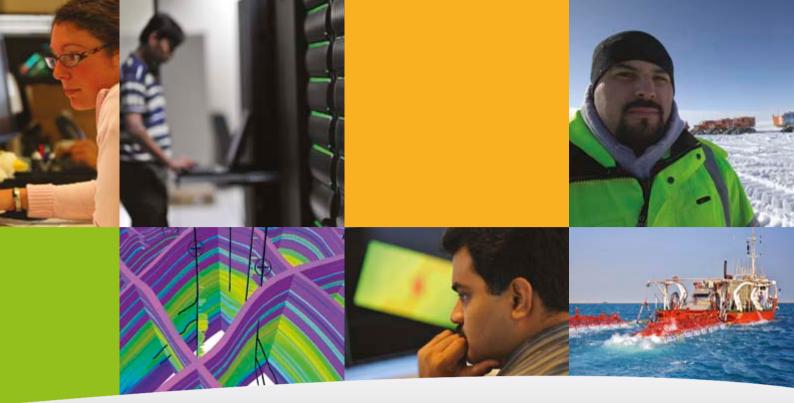
#### **Georgia: Limited Prospects**

Offshore acreage is limited and Georgia has attracted little industry interest since Anadarko withdrew from exploring the Rioni Basin on the Black Sea shelf in 2009. The deepwater remains virtually unexplored and while little is known about offshore reserves, they are likely to be modest.



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# **Real-Time Jata**

Real-time information has been used for guite some time in the E&P industry to help improve the safety and efficiency of well construction. The benefits are well documented and today many companies share standards and create their own best practices, but it was not always that way.

In the year 2000 several industry leaders came together with a shared purpose - to bring commonalities to the way that real-time systems worked, simplifying interoperability and ultimately, enabling a broader, richer set of technologies. Those companies included Baker Hughes, BP, Chevron, ExxonMobil, NorskHydro, Halliburton, Schlumberger, Shell and Statoil.

## **Standardised Approach**

Each company was developing or utilising real-time systems, but

BARRY MCKAY. HALLIBURTON

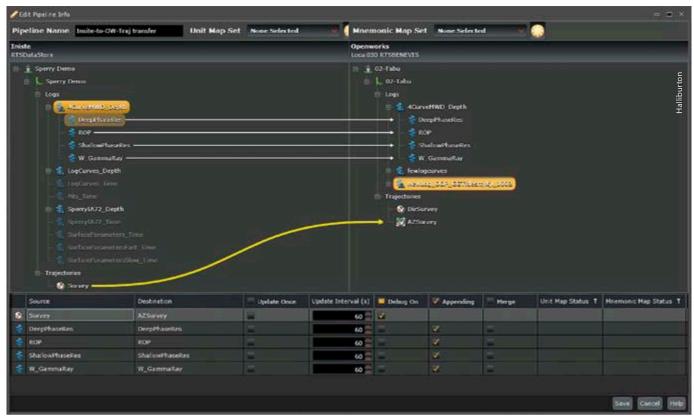
Real-time information improves the safety and efficiency of well construction. Halliburton looks at how WITSML is used for data delivery with both its customers and internal workflows

> their solutions were propriety to their own needs. They realised there was a need for a common language to communicate well site information and soon after, Wellsite Information Transfer Standard Markup Language (WITSML) was conceived. Their primary reasons for creating a standardised approach to exchanging drilling information were:

- to facilitate energy companies to leverage their investment in highly instrumented fields and to enable new capabilities for automation and optimisation that would otherwise be impossible or difficult to achieve;
- to reduce the cost of information exchange between software applications within an operating company and between operating companies, joint ventures, partners, contractors, and regulatory authorities;



\_\_\_\_\_ Real-time in action: the bustle of collaboration within a real-time centre with all the expertise and software tools required to optimise and monitor operations.



DecisionSpace WITSML – a next generation product integrating all of Halliburton's WITSML capabilities into a single system.

- .....
- to reduce the cost of replacing or substituting software which results in improved functionality.

The group decided they needed an organisation to help facilitate the development of this standard and turned to Energistics. Energistics serves as the facilitator, custodian and advocate for the development and adoption of technical open data exchange standards in the upstream industry.

#### Landmark Lead the Way

Landmark, a Halliburton business line, was a founding member in the development of the WITSML standard and continues to lead and develop innovative software solutions that incorporate WITSML. One of the first of such software tools was OpenWire<sup>®</sup>, which integrated WITSML data into the OpenWorks<sup>®</sup> geosciences project data management system. It enabled Landmark's interpretation and geological software to utilise data collected in real-time as both offset wells, and also in near real-time workflows.

The first version of this product was introduced based on the early work around the WITSML standard. It has undergone several upgrades and changes and now supports OpenWorks and EDM<sup>™</sup> drilling engineering-based workflows.

Landmark developed the first WITSML server in the early 2000s. Soon after, Halliburton's Sperry Drilling business line introduced the server to allow real-time data to be drawn out of their databases for use in WITSML client-enabled workflows.

Today, Landmark offers at least seven technical applications and processes that utilise WITSML processes and solutions. The company continues to develop and support the use of WITSML and is in the process of unifying all of its WITSML technology into a single tool that supports any of its technical databases and integration workflows. This product is based on the latest version of WITSML, 1.4.1, which provides important improvements in cross-company collaboration; and while Halliburton is also active in the other Energistics-based data standards, such as PRODML and RESQML, it is WITSML that defines Halliburton as a leader in the use of data standards.

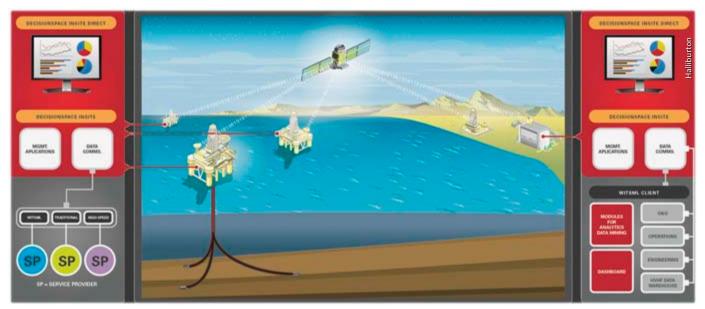
### Plug and Play

One of the primary benefits of using WITSML is to allow operating companies and other consumers of real-time data to do a job with Schlumberger today and Halliburton tomorrow, while allowing the data flow to remain the same. This 'plug-and-play' approach to data transfer allows a user to have best practices for data use and data management without having to rely on proprietary solutions.

By making this an open standard, the knowledge base entry point can be lowered, which it allows for simpler operations when dealing with multiple wells and multiple service providers simultaneously.

The energy industry as a whole is facing a multitude of challenges: an increase in overall operations, more data and an aging workforce with limited replacement resources. Having a data standard that is simple to use means that years of experience are not required; anyone with a basic understanding of drilling operations can use a WITSML system for understanding the well data collected.

By freeing the most highly trained employees to spend less time finding and mining data, they are able to analyse the new data easier and more quickly to get a better and more complete picture of what's happening beneath the Earth for current and future operations.



Global reach – real-time data collection and transfer systems are becoming a necessity for optimising operations, whether offshore in deepwater or on land in remote locations. WITSML binds these locations together so a single user can understand the data globally.

.....

### **Customers Benefit**

The first use of WITSML with customers is with real-time data: to determine what exactly is going on at the rig, making sure the right data is available to the right person at the right time – which is essential in most operations. Additionally, internal Halliburton services use the data that is collected in real-time to understand how effectively and efficiently the services provided are performing to ensure a high level of service quality.

Because all of the data is aggregated from multiple sources and service providers, it allows a customer to see a complete picture of the operation, activity or drilling environment. Operators can literally 'see' what the well is doing, and can not only make decisions in real-time, but can also make decisions about planning for future operations, based on current operations. A second use is to apply real-time data acquired during the drilling and logging of a previous well in the planning and development of the next well or field.

By combining historical or planned information with real-time acquired data a host of workflows can be enabled – improved reporting, real-time geosteering, drilling engineering in realtime, and so on. All of these processes utilise designed wells or drilling situations in concert with the data collected in real-time.

## Using WITSML Internally at Halliburton

In addition to simply using WITSML, Landmark has developed more than 15 data objects for internal purposes, most recently to solve a data flow issue between three fracturing service product lines within Pinnacle, Halliburton's fracture diagnostic and reservoir monitoring technology.

The challenge Landmark faced was to improve the effectiveness and reduce the uncertainty of stimulations. Microseismic data is the only direct measurement of fracture dimensions away from the wellbore. Being able to visualise in real-time how the formation responds to stimulations in the context of basin scale geoscience environment enables us to understand the attributes of a fracture and what changes to

make to the current or next stimulation stage. Understanding how the reservoir responds and what adjustments to make can ultimately improve production through maximising stimulation reservoir volume and also minimise treatment costs.

For example, a DecisionSpace<sup>®</sup> stimulation program was developed whereby new objects were created that worked within the WITSML system to share microseismic data from Pinnacle, treatment data from fraccing services, and geological data from the OpenWorks database. These systems use the new objects to talk to each other, using existing WITSML servers and WITSML clients.

Within Energistics, a new Microseismic group has recently been formed to address this same problem and Halliburton works closely with this work group to ensure that their learnings from this fracturing data communications process are captured in the open version of a microseismic data exchange process.

In addition to WITSML, Halliburton continues to use any communication protocols, including proprietary ones, in support of its services and workflows. Processes for geosteering, effective hole cleaning and efficient drilling are among them. New technologies and solutions are constantly under exploration, to encourage maximum information sharing, thereby promoting safe and efficient operations.

## **Future Looks Strong**

The future of the WITSML standard is strong; of the thousands of wells Halliburton works on every year, about half of them deliver data in WITSML. The vast majority of contracts in place for Halliburton specify that data must be delivered in WITSML, and contracts have been won based on WITSML-enabled solutions.

Adoption of WITSML and other Energistics standards are anticipated to increase and ultimately become universally adopted, as operators determine that data is a critical aspect of well construction and can have a profound effect on the company's return on investment for drilling and completion operations.

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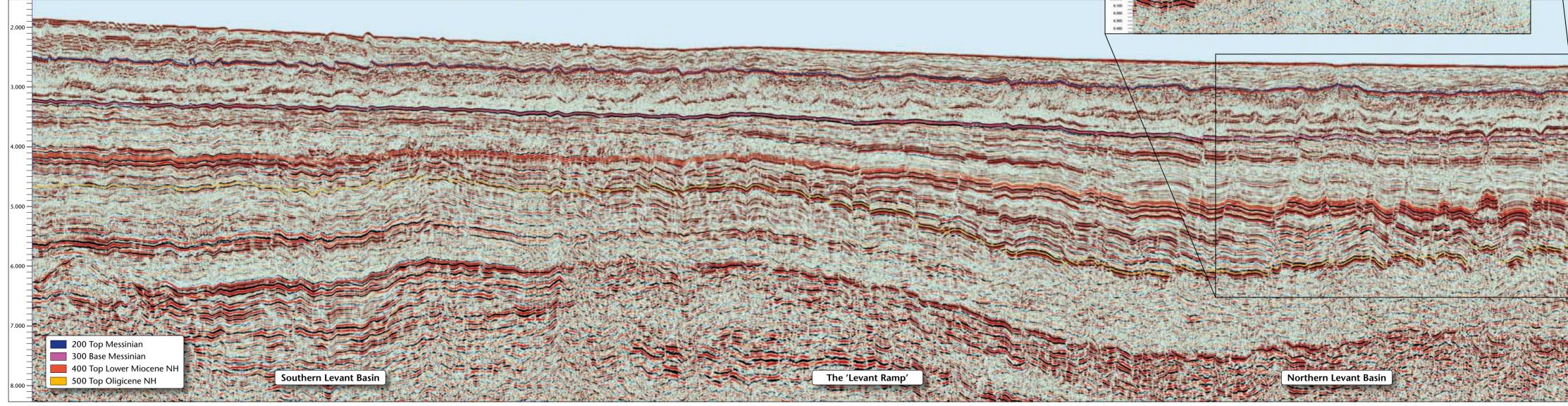
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# Power Up! Selecting a 3D Dataset for the 2013 Licence Round **Offshore Lebanon**

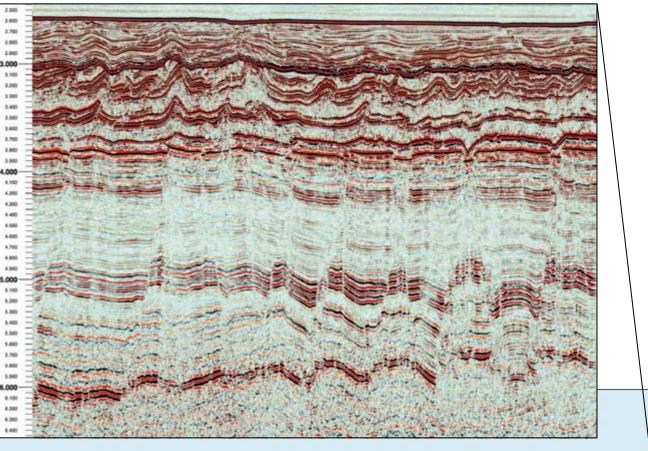
The understanding of the Miocene play fairways in the Eastern Mediterranean can now be significantly enhanced by combining integrated reservoir distribution and hydrocarbon charge models based on regional 2D seismic with 3D seismic data available offshore Lebanon.

The seismic section below (TWT, Sec) is a 210 km PSDM 2D line running from south to north through the Levant Basin (for location see map on page 39). The Southern Levant Basin has seen over 30 Tcf of gas discoveries in the Early Miocene sequence (yellow to orange) since 2009.

The seismic line to the right is an example of the 3D fast-track volume from offshore Southern Lebanon, acquired by Spectrum in 2012. These 3D data give clarity on reservoir architecture and provide the definitive data for mapping structures, defining the timing of structure formation and identifying additional play systems.







# Lebanon Offshore: Promising Play Fairways and Structures

With the opening of the first Lebanese Offshore Round coming up, it is time for companies to assemble a 'bidding dataset' to support their evaluation of this prospective and unexplored area.

#### NEIL HODGSON, Spectrum

The end of 2012 brought with it the exciting announcement from the Lebanese Petroleum Authority that their first Offshore Licensing Round will open in May 2013. Now that the clock is really ticking, counting down towards the bid submission period, it is time to assemble a 'bidding dataset' to support the evaluation of blocks in the round. For some companies this will first take the form of acquiring a 2D seismic grid across the entire Lebanese offshore – particularly useful if the dataset is extended over the major gas discoveries to the south. And for companies further advanced in evaluation, it is time to upgrade from regional 2D seismic data to evaluating the available multi-client 3D datasets.

#### **Prospectivity Revealed**

In the Eastern Mediterranean, an Early Miocene structural lineament separates the Southern and Northern Levant Basins. This lineament, referred to as the 'Levant Ramp' (Taylor, 2011), runs close to the southern Lebanese border, and separates two discreet sub-basins. To the

south is the biogenic gas-prone, thinreservoired, complex-structured and rather well-explored Southern Levant Basin. To the north is the thermogenic oil- and gas-prone Northern Levant Basin offshore Lebanon, with thick reservoirs and numerous large structures which are unexplored. It is curious that for each play element (reservoir, charge and trap) the Northern Levant Basin is lower risk or more oil-prone than the Southern Levant Basin.

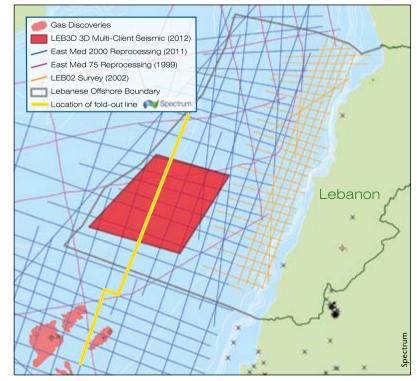
Our play fairway understanding was developed using well data and a 2D seismic grid that extends across the whole Levant Basin (Hodgson, 2012). However, the acquisition of the new 3D seismic volume allows the fine detail of this play fairway in the Northern Levant Basin to be examined for the first time. Fortunately, offshore Lebanese waters are blessed with numerous 3D datasets, giving about 65% coverage of the offshore area, most of good quality. Inevitably the underlying geology makes some of these datasets more prospective than others. The turbidite sandstone reservoirs of the Early Miocene can be traced south and west back to their provenance in the Nile Delta. This Early Miocene seismic sequence is relatively thin in the Southern Levant Basin discoveries (thickness ca. 100– 300m), yet can be observed on the seismic data to dramatically thicken across the Levant Ramp to the north (thickness ca. 500–1000m). Here, the high clastic content is evident from the seismic response. Whilst lateral reservoir quality variations might be significant in the Syrian Arc synform-constrained channelways to the south, this is not expected within the large turbidite fans prograding into the Northern Levant Basin.

#### **Structures Clearly Imaged**

Structurally, the Southern and Northern Levant Basins appear very different. The plays to the south of the Levant Ramp are shallower and comprise both inverted Syrian Arc half grabens and highly tectonised basement block drape structures. In the Late Miocene, when these complex compressional structures were forming in the south, across the Levant Ramp

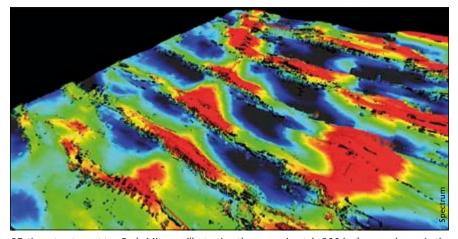
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Map showing the location of the foldout line on the previous page, together with available 2D and 3D data



to the north the structuration was dominantly extensional, generating the simple piano-key fault blocks characteristic of the Northern Levant Basin. These faults are superbly imaged with 3D seismic data and the fault-aliased mapping problems of 2D data are readily resolved, revealing simple three-way dip and one-way fault closed structures, with throws in excess of 400m.

Unsuspected from 2D data, the western half of the 3D dataset reveals an anticline running north-south formed by early Upper Miocene compression, cut by east-west faults and generating a number of interconnected structures with well-defined closures. Each structure is 20–60 km<sup>2</sup> with up to 400m of relief, whilst the



3D time structure at top Early Miocene illustrating the approximately 800 km<sup>2</sup> super-closure in the south-west of offshore Lebanon.

north-south anticline has a time super-closure of over 800 km<sup>2</sup>, which will increase in areal extent in the depth domain. To the south the structures are lower relief (up to 200m), including the large Hyperion structure visible on the 2D data (Hodgson, 2012) and now much more accurately mappable on the 3D data. To the east, more features can be found on the 3D data, including the large and surprisingly high relief (>1000m) Oceanus structure.

This dramatic structure unusually deforms the base salt and shows deformation structures within the salt. It manifests itself as a gas chimney in the post-salt section and an anomaly associated pockmark on the sea floor.

An unexpected benefit from the 3D seismic data is the identification of base salt structural closures, and a considerable thickness of turbidite sands just below the Messinian salt, creating a second play fairway to target in the area.

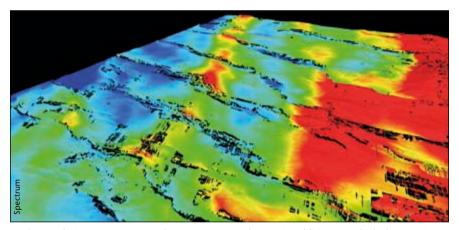
#### **High Chance of Success**

The hydrocarbon charge systems for the Northern and Southern Levant Basins are very different. The existence

of a mature oil source is demonstrated by the observation of multiple oil seeps on SAR and Landsat data above the pinch out of the eastern Mediterranean salt canopy along the Levant Basin margin. 3D basin modelling demonstrates that to the south of the Levant Ramp, the Oligocene is unlikely to be thermogenically oil-prone and indeed the majority of the hydrocarbons discovered are biogenic in origin. To the north of the Levant Ramp, in addition to a biogenic gas play, the Oligocene has been oil-generative since Messinian times, i.e. after the formation of the simple fault block structures in the Upper Miocene. Deeper sources in the Early Tertiary and Cretaceous will have been mature for oil and gas condensate over a longer period (Ali, 2012; Dupin, 2012; Dubille 2012).

Interpretation of the 3D data acquired by Spectrum in 2012 demonstrates that this area not only has the highest chance of success for generation and trapping of thermogenic hydrocarbons offshore Lebanon, especially in the large basin

centre anticline, but it also has large, simple structures and the most compelling reservoir case. Indeed the 3D data shows that structures in south-west Lebanon are less complex than those encountered in the recent gas discoveries to the south, and suggests strongly that the rapid commencement of drilling on the low risk Lebanese structures is soon to usher an age of hydrocarbon independence for the Lebanese nation.



3D base-salt time structure reveals numerous new closures in addition to a thick clastic unit just below the salt.

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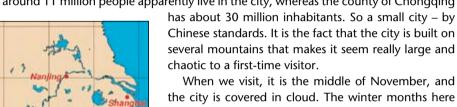


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#### **INGVILD CARSTENS**

Spectacular natural scenery, deep canyons, salt mining and dinosaurs – so much to see in the Chóngqìng area of south central China

Approaching Chóngqìng Airport from the air, you fly in over the valley alongside the city for what feels like forever. The whole place appears to be balancing on several mountains, and the forest of skyscrapers stretches into infinity. How big can this city be? It turns out that 'only' around 11 million people apparently live in the city, whereas the county of Chóngqìng



the city is covered in cloud. The winter months here are wet and cold, and Chóngqìng is wrapped in a fog that rarely lifts before springtime, but the summers are long and hot and humid – and still overcast. Hence the city's nickname – the Capital of Fog.

#### The Three Gorges

The city of Chóngqìng is situated in an area characterised by complex geological features. It lies in the middle of a transition zone between the Tibetan Plateau and the middle and lower reaches of the Yangtze River. The Yangtze, the third longest river in the world, and the Jialing River both run through the city and join forces here.



Along the

As a major inland port on the great Yangtze River, Chóngqìng has been an important city for centuries and was the wartime capital during WWII. It is one of the fastest growing cities in China.



A leisurely cruise through the Three Gorges and their offshoot smaller gorges takes several days and is one of the major tourist attractions in China.

The earth's crust has been pushed up, shaping the mountains that the city is built upon, and large amounts of faulting and movement over a long period of time have left the area fragmented and unstable. The surface rock appears stable, but underneath is a much softer layer, and below this is more stable rock, making the Chóngqìng area particularly prone to geological disasters. As a result, the city has been devastated throughout its history by flash floods, mudslides, slumps and collapses in the rainy season.

One of the great tourist attractions in the whole of China is a cruise along the Yangtze and through the Three Gorges, and Chóngqìng is the perfect starting point. These deep canyons, the result of millions of years of erosion by the Yangtze River, start a few kilometres east of the city and level out 200 km further east. The gorges are between 300 and less than 100m wide and the surrounding cliffs rise to a height of over 1,300m,

often jutting out over the river. As well as awe-inspiring scenery, there are a number cultural sites along the Gorges, such as Baidicheng (White Emperor City), known as the 'Poet City', after the many famous Chinese poets who have lived there. With interesting villages, temples and pagodas built into the rock, a cruise down the Three Gorges is a tranquil respite after the noise and bustle of Chinese cities.

The construction of the world's most powerful dam, the Three Gorges Dam, which was completed in July 2012, has had a significant effect on the Gorges. Designed to regulate the flooding of the Yangtze and to improve navigation, as well as to provide hydroelectricity, the dam, which is situated about 200 km downstream from Chóngqìng, has raised the water level considerably, reducing the visual impact of the Gorges. It has also drowned a number of archaeological and cultural sites, although some of them were excavated and moved before inundation. It is estimated that more than a million people have been relocated and over a hundred towns and villages submerged by the construction of the dam, which has created a 600 km long lake. There has also been significant environmental damage, with the endangerment and extinction of many plant and animal species.

#### On the Dinosaur Trail

If you drive a few hours west of Chóngqìng into the famous province of Sìchuãn, just across the border you will find the smaller city of Zigong, which is located in the Sìchuãn Basin. This area has a rich geological history, and is a part of the Global Geopark Network, which is under the UNESCO umbrella. Zigong Global Geopark consists of the dinosaur area, the well salt industry area, and the Qinglongshan area.

Inside the Dinosaur Museum at Zigong, which has been described as 'the best dinosaur museum in the world'.



In 1972, a Chinese gas company working in the area stumbled upon Gasosaurus, which proved to be the first dinosaur of many to be found in the area. The dinosurs are found in the middle to late Jurassic Dashanpu Formation. This consists of four main horizons: the upper and lower Shaximiao Formations, which are the most productive regarding dinosaur fossils, and the Zhenchuchong and Ziliujing Formations, which remain relatively unexplored. Today, over 8,000 dinosaur fossils have been excavated from the Dashanpu Formation, predominantly sauropods, theropods and stegosaurians, making it one of the largest dinosaur fossil sites in the world.

In the Jurassic, the Dashanpu forest resembled nothing like the dinosaur quarry we see today. The area was covered in lush forest, and a large river probably fed a large lake. Over millions of years, dinosaur remains was swept down the river and into the lake, explaining the large number of specimens found in this area.

#### White Gold

For more than 2,000 years, predating the Han Dynasty (76–88 AD), salt has been produced in the Zigong area, making Sichuãn a wealthy province. The brine in the aquifers in the Zigong area has a salinity of over 50 grams per litre. To begin with, large pits were dug to extract the salt, but even before the Song Dynasty (960–1279) the locals were digging wells straight down into the earth with sophisticated drilling tools made of iron and bamboo. Once the well was completed, men (later replaced by buffalo) brought the brine to the surface, where it was transferred to the cooking units and evaporated, leaving pure salt behind. A by-product of the drilling process was natural gas, and with time, the Chinese developed tools to contain and utilise the gas in salt production, replacing wood as a heat source.

Over 400 years before the Europeans thought of it, the salt-producers of Zigong had invented the deep percussion drilling technique. This technique was refined over the years, and between the Ming and Qing Dynasties, in 1835, the salt-producing region of Zigong reached another milestone,

Brine 'cooking' at the Shenai well in Zigong to make pure salt



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#### **Hotpot and Brain Food**

In the freezing cold and wet temperatures of the Chóngqìng winter, the poor boatmen working the river used to warm themselves with a hot chilli and Sìchuãn pepper broth. The cheapest meat, including brains and intestines, were cooked in the broth, heating the working men from the inside out. Today, hotpot is the most popular dish from this province, and intestines are replaced by the most delicious vegetables, meats, fish, mushrooms and tofu. Tourists are recommended to try a less spicy version, and it can also be advisable to steer away from the preferred ingredients of the Chóngqìng locals.



drilling a well that was over 1,000m deep.

Due to the high salinity of the brine in the Zigong area, and the depth of the wells, Zigong became a commercial centre in the Sichuan province. In 1736, the Xiqing Guildhall was built as a meeting place for salt merchants, with rooms for travelling businessmen, which opened onto a large courtyard where a stage was built, and the merchants were entertained at night, after long days of work and negotiations. Today the building houses the Salt History Museum, and contains an impressive amount of artifacts from the entire history of salt production in the Zigong area.

> Nowadays, only four drilling rigs remain to be seen in Zigong, but the museum is working hard to protect and preserve them. Three of them are located in between large apartmentblocks in the city. This area is now also being developed into a museum, and in a few years it will be opening its doors to the public. If you want to experience one of the old saltproducing wells of Zigong, Shenhai well is the only one that is still in operation. Here, brine water is still being pumped up in the traditional way. The well produces about 4 tons of salt per day, and the men boil the water out of the brine on old cookers.

> If you are still hungry for some geotourism, the Changshan Range right outside Zigong city hosts two magnificent specimens of silicified wood. They were discovered in 1983 and are primitive conifers named Araucarioxylon. The larger specimen is 23.3m long with a diameter

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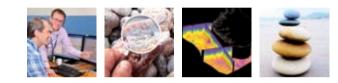
for plant growth.

**Zigong City** 

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of 1.3m. The trees indicate that when they were growing, the

climate in Zigong was subtropical or warm temperate, with

few variations, copious amounts of rain and shorter periods of

cold, dry season every year. This made for a suitable climate

Zigong is a very small city by Chinese standards, with less

than three million inhabitants. The Fuxi river, a tributary to the

Yangtze, flows through the city, and like Chóngging, Zigong is



very humid and plagued by fog. The ground the city is built on used to be a vast, inland sea, now the source of the riches of the region: salt, brine, coal and natural gas. Today these resources are still an important part of the Zigong economy.

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The city is also the original home to the Lantern Festival in China, and is known as the Lantern Town. The festival originated back in the Tang Dynasty (618–907), and grows in size every year. Today the festival has been copied from Beijing to Hong Kong, but if you want to experience the real thing, Zigong is still the place to get an authentic experience. ■

As one of the fastest growing cities in China, construction sites are popping up all over Chóngqìng. New housing areas are completed and bridges and



# Charles Hutchison

<sup>2</sup>hoto courtesy of Timothy Hutchison

#### A Geologist in Love with South-East Asia

One day in 1957, a young geologist was reading the *Times of London* in Trinidad where he worked for an oil company. The newspaper carried an advertisement which was to change his life path for good.

#### **RASOUL SORKHABI**

The young geologist was 24-yearold **Charles Hutchison**, and the advertisement was from the University of Malaya in Singapore for the position of an assistant lecturer in the newly established Department of Geology.

Charles applied for the position and soon received an offer, which he accepted, and the university urged him to start working as soon as possible. In those days, air travel was not a routine way of transportation, so Charles sailed on a ship for England and then on another ship to Singapore, an island on the southern tip of

Charles Hutchison as Professor Emeritus of the University of Malaya in Kuala Lumpur in 2004. the Malay Peninsula. The whole voyage took seven weeks. At the port in Singapore, Professor Charles Solomon Pichamuthu (1900–1990), a geologist from southern India who had established the Geology Department at Singapore, received the young Charles. The Malay Peninsula was to be his home for the rest of his life.

#### **Igneous Rock Specialist**

Charles Strachan Hutchison was born on 17 April 1933 in the town of Fraserburgh in Aberdeenshire, Scotland as the first child of his family; his only sibling was born ten years later. Charles went to schools in Fraserburgh, and then studied at the University of Aberdeen, graduating in 1955 with B.Sc. first class honours in geology. He then went to work in Fyzabad in Trinidad, before coming across that fateful advertisment.

Life in Singapore was enjoyable and work in the geology department was fun. Hutchison was only the second teaching member of staff in the Department, the other being Professor Pichamuthu, who had obtained his Ph.D. from the University of Glasgow and had, therefore, a liking for Scotland. Besides Pichamuthu and Hutchison, a secretary and a laboratory assistant were the only people working in the department. In the new environment, Hutchison soon developed his hobby of photography.

While a geology student in Scotland, Hutchison had been fascinated by the abundant igneous rocks of his homeland. He thus conducted research on the petrology and tectonics of igneous rocks in the Malay Peninsula. Rocks, no matter what type, are easily weathered in the hot and humid equatorial climate of South-East Asia, but rivers and mining quarries provided important opportunities for Hutchison to see into the basement.

His first paper was published in the prestigious *American Journal of Science* in 1961. He also wrote his doctorate thesis on 'Tectonic and petrological relations within three rock

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associations of orogenic zones in Malaysia', submitted in 1966 to the University of Malaya in Singapore.

#### **Growing Departments**

The late 1950s and early 1960s was a period of rapid change in the geopolitical situation in South-East Asia. Administered for decades as a British colony, Malaya became an independent state in 1957, followed by Sarawak and North Borneo (Sabah) in 1963, when all three formed the Federation of Malaysia. Singapore became a self-governing state in 1959, an independent state in 1963 (joining Malaysia), and finally an independent republic in 1965. Both Malaysia and Singapore still remain within the (formerly British) Commonwealth of Nations.

Due to political changes, the University of Malay was split into two universities: the campus on the Bukit Timah Road as the University of Malaya in Singapore, and the campus in Pantai Valley as the University of Malaya in Kuala Lumpur. In 1960, Hutchison, along with his colleagues, moved to Kuala Lumpur, while still retaining his doctoral candidacy in Singapore. In Kuala Lumpur, Hutchison played a leading role in founding the university's geology department, where he continued his research, teaching and writing. It was also in 1960 that Hutchison married his wife, Ann, formerly Chan Ah Eng, a Malaysian Chinese; the couple raised a daughter (Helene) and a son (Timothy), and the marriage lasted until her death many years later.

For some time, Hutchison became interested in the newly developed science of thermoluminescence dating, but igneous petrology, tectonics, and mineral resources of the Malay Peninsula remained his main research interests throughout his career. During the 1960s and 70s, the geology department at Kuala Lumpur witnessed stable growth – thanks in part to the leadership of Neville Seymour Haile (1928–2004), an Oxford geologist who had conducted pioneering work at the Geological Survey of Borneo and had joined the geology department at Kuala Lumpur in 1964.

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Charles Hutchison (far left) with university colleagues, friends and students in Penang, 1960. Standing second and third right are Professor C.S. Pichamuthu and his Indian wife.



#### **Prolific Author of Repute**

Hutchison was a founding member of the Geological Society of Malaysia in 1967, and served as its president during 1969–71. An early book that brought international repute to Hutchison was *The Geology of the Malay Peninsula* (*West Malaysia and Singapore*), co-edited by Hutchison and Derek J. Gobbert, who was a professor of palaeontology and stratigraphy at Kuala Lumpur from 1961 to 1968. This book (now a classic) was published in 1973 in the Regional Geology Series by Wiley-Interscience,



London, and was a successor to John Brooke Scrivenor's 1931 book *The Geology of Malaya*. Of the 11 chapters in the book, Hutchison wrote the chapters on volcanic activity, plutonic activity, and metamorphism.

In 1974, Hutchison published Laboratory Handbook of Petrographic Techniques, a massive work of over 500 pages. He was promoted to full professor of applied geology at Kuala Lumpur in 1977, and (upon N. S. Haile's retirement) served as head of the geology department from 1978 to 1982. Hutchison's second textbook, *Economic Deposits and Their Tectonic Settings*, came out in 1983.

Professor Hutchison retired from his university work at Kuala Lumpur in 1987 although he retained his university title until 1992. During this period, he mostly resided in the U.K. where his son was a university student. In addition, from 1988 to 1991, Hutchison was coordinator for an international project entitled 'Studies in East Asian Tectonics and Resources (SEATAR) Transects', and edited and contributed to a number of its reports.

Hutchison published over 100 articles, but he is perhaps best known for his two books: *Geological Evolution of South-East Asia* (1989, dedicated to "the former professors of geology at the University of Malaya") and *South-East Asian Oil, Gas, Coal and Mineral Deposits* (1996, dedicated to his wife Ann), both published by the Oxford University Press. These two books synthesised the geology of South-East Asia and

are still useful and benchmark volumes in the field. A second edition of *The Geological Evolution of South-East Asia* was published by the Geological Society of Malaysia in 2007. In the preface to his book, Hutchison remarked: "I have always taught my students that every aspect of geology involves interpretation. From thin sections to hand specimens, to maps and thence to regions, there is an increasing order of interpretation. This book is, therefore, a personal interpretation of the region."

In 2005, Hutchison published *Geology of North-West Borneo*, which he dedicated to the geologists of The Geological Survey, Borneo Region (established in 1949 as the Geological Survey Department, British Territories in Borneo) who "through their pioneering work in a difficult nearly inaccessible terrain, made it one of the greatest in the world." In 2009, Hutchison and his renowned Malaysian colleague D.N.K. Tan edited the *Geology* 

# Understand the regional structure of the

#### of Peninsular Malaysia.

Hutchison was appointed Professor Emeritus at the University of Malaya in Kuala Lumpur in 2004, and from May 2009 until his death on 18 October 2011, served as Visiting Senior Research Fellow at his department.

#### Influential Teacher

A tall Scottish geologist from a land where geology was born, Hutchison had great devotion to his work, and was thus an influential teacher, author and a geologist equally comfortable in the field, in the laboratory and in the office. He trained several generations of Malaysian geologists, and made significant contributions to our knowledge of South-East Asian geology. And he lived long enough to see his great-grandchildren.

Hutchison was elected honorary fellow of the Geological Society of London, The Geological Society of Malaysia, the Institution of Mining

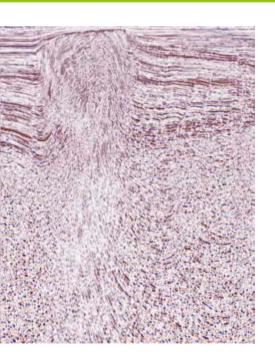
and Metallurgy of London, and the Mineralogical Society of America. In 1994, he received the American Association of Petroleum Geologists (AAPG)'s Special Commendation Award. In September 2012, the late Professor Hutchison was remembered at two Memorial Sessions held at AAPG's International Conference and Exhibition in Singapore, where he had started his love of South-East Asian geology 55 years before.



Author's note: I am grateful to Mr. Timothy Hutchison for kindly sharing with me information, photographs and the late Professor Hutchison's two unpublished autobiographical essays, which, I hope, will be published in the future as they chronicle the post-war development of geological activities in the Malay Peninsula. For a list of Professor Charles Hutchison's publications see my 'Memorial to Charles Strachan Hutchison (1933-2011, published in Geological Society of America Memorials, vol. 41, December 2012).

(ftp://rock.geosociety.org/pub/Memorials/v41/Hutchison-C.pdf)

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# South China Sea ENIGNA RASOUL SORKHABI, Ph.D.

The South China Sea, a marginal sea between Asia (the largest continent) and the Pacific (the largest ocean) covers an area of 3.5 million square kilometres and is surrounded by sedimentary basins, some of which have produced petroleum for decades. The oceanic and the stretched continental crusts underlying the South China Sea have experienced a complex tectonic history in Cenozoic times, which geologists are only beginning to unravel.

The South China Sea (SCS), which spans from Singapore and the Malacca Strait in the south to the Strait of Taiwan in the north, and from Borneo and the Philippines on the east to Vietnam and south-eastern China on the west, is one of the largest marginal seas in the world. Bordering eight countries, the SCS is important, among other things, for its international marine transportation and navigation, its rich marine biodiversity including fisheries, its impact on the monsoon climate of South East Asian countries, and its oil and gas resources. The SCS's numerous seamounts and islands are mainly coral reefs, atolls, shoals and sandbars, many of which are submerged at high tides and have no native inhabitants. They are usually clustered into geographical groups, notably the Spratly Islands and Reed Bank offshore the Philippines, Scarborough Seamounts along the central axis of the SCS, and Macclesfield Bank, and the Paracel and Pratas Islands in the north.

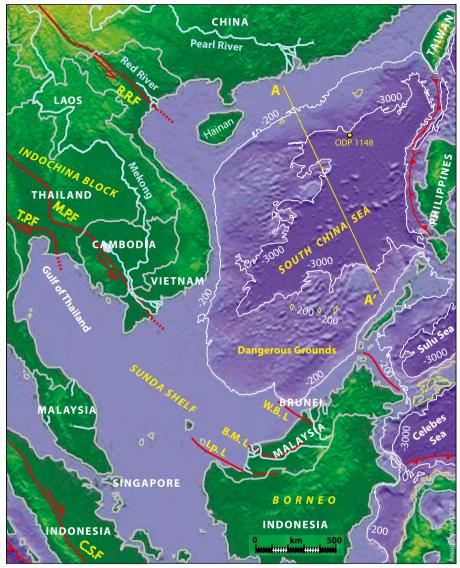
**Complex Geology and Data Secrecy** Geologically, South East Asia, including the SCS, is a mosaic of tectonic blocks located between the convergences of the Earth's largest tectonic plates: Eurasia, Indo-Australia and Pacific-Philippine Sea plates. It is apparent that understanding the tectonic and stratigraphic evolution of the region has critical relevance for the exploration of oil and gas resources in the numerous basins of the region. However, despite an increasing number of studies since the 1980s, our knowledge of the geology of the region still remains poor for a variety of reasons: the geology is complex; the data are fragmentary and sporadic; the geologic information is scattered in various local publications, and the crucial subsurface and offshore information acquired by national and international oil companies largely remains in secrecy.

The SCS is an oceanic basin surrounded by Sundaland on the west and southwest and a chain of volcanic islands on the east. Sundaland is the continental basement-basin complex of South East Asia, developed since Palaeozoic times. It consists of the onshore Indochina Block and the offshore Sunda Shelf, extending to a water depth of 200m. The Sunda Shelf is a stretched continental crust and encompasses the majority of explored petroleum basins in South East Asia. The continental slope, which ranges from 200 to 1,000m, is narrow and steep. The oceanic crust begins at water depths of 3,000-3,500m, and extends to water depths of over 5,000m.

Gravity inversion data as well as deep seismic surveys indicate that crustal thickness (depth to the Moho) of the SCS varies from 30 km in the Sunda Shelf through 18–12 km in the Dangerous Grounds to 11–7 km beneath the oceanic crust. Sediment thickness on the oceanic crust is 1–2 km, while that on the Sunda Shelf within deep grabens exceeds 12 km in places.

#### Patterns of Sea Floor Spreading

Examination of seafloor magnetic lineations indicates that the SCS oceanic basin opened between magnetic anomalies (polarity chrons) 11 and 5C, which respectively correspond to the geologic times 30 Ma and 16.6 Ma, according to the Gradstein et al. (2004) geologic time scale, or 32-16 Ma according to the older version. These data further show that the ocean basin opened in at least two major phases. During phase I, from 30 Ma to ~21 Ma, the seafloor spreading was north to south, with the spreading ridge striking east-west, and as a result the continental block containing the present North Palawan Island, Reed Bank, Macclesfield Bank and Paracel Islands was separated from the South China continental block to the north. At magnetic anomalies 7-6B (between



A map of the South China Sea and surrounding countries. The South China Sea oceanic crust almost follows the 3,000m bathymetry line. The oceanic floor is subducting beneath the Philippine Islands on the east. Major strike slip faults (shear zones) shown on the map are: Red River Fault (R.R.F., currently rightlateral, but left-lateral during Oligocene-Miocene times), Mae Ping Fault (M.P.F.) and Three Pagodas Fault (T.P.F.) in the Indochina Block, Central Sumatra Fault (C.S.F.) in Sumatra, and Lupar Line (Lp. L.), Bukit Mersing Line (B.M.L.), and West Baram Line (W.B.L.) in Borneo. The location of ODP-Leg 184 well 1148 and the structural cross-section below are also shown on the map.

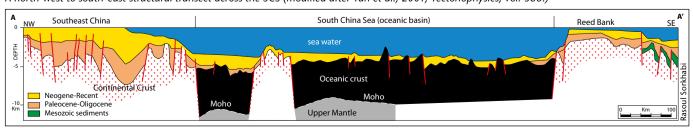
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24.9 and 21.75 Ma) the spreading ridge jumped to a north-east-south-west trend, with the seafloor spreading in a north-west-south-east direction, which eventually separated Reed Bank from Macclesfield Bank.

While this chronology of the opening

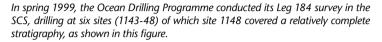
of the SCS is widely known, it is by no means a final scenario. S.K. Hsu and his Chinese colleagues (*Marine Geophysics Research*, 2004, Vol. 25) have identified even older magnetic anomalies dating back to C17 in the north-eastern corner of the SCS which puts the seafloor spreading

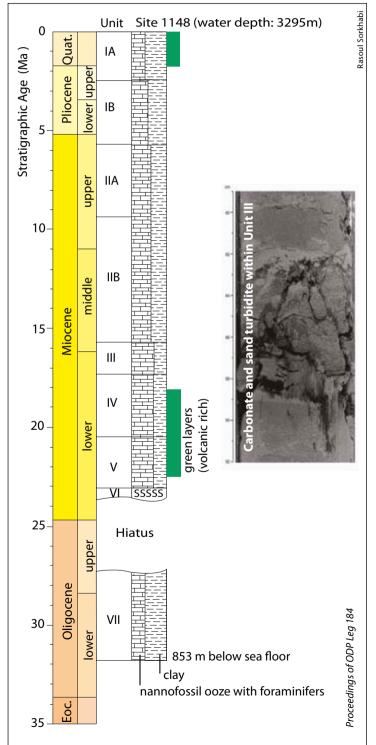
A north-west to south-east structural transect across the SCS (modified after Yan et al., 2001, Tectonophysics, vol. 388.)



#### South China Sea: What's in a Name?

European navigations and accounts of South East Asia. In Chinese records it has usually been referred to as 'Southern Sea' (Nân Hâi). The Vietnamese prefer to call it 'Eastern Sea' (Bien Dong) because of its location to the east of their country. In Malaysia, Indonesia, and many other countries,





The name South China Sea entered English through the early following the European maps, it has usually been called South China Sea. However, the sea portion within the Philippine territories has sometimes been specifically called Luzon Sea by the Philippines, and since 2011 officially 'West Philippine Sea' by the Philippine government to counter the Chinese claims to sea waters close to their western coasts.

> in that part at ~37 Ma. In any case, the interpretations of magnetic anomalies need to be corroborated by drilling data from the SCS floor.

The opening of the SCS within the larger framework of South East Asian geology has been a subject of debate among scientists for several decades, and a few models have been proposed, which are briefly discussed below.

#### Indian Indentation and South East Asian Extrusion

One popular tectonic model for the origin of the SCS was proposed by Paul Tapponnier and his French colleagues (Geology, 1982, Vol. 10). In an experiment involving indentation of a rigid block against a deformable plastic material, these researchers examined the effect of the collision of the Indian plate (a Precambrian shield) against the relatively 'soft body' of Asian continent, a basementsedimentary complex which was subjected to multiple phases of tectonic deformation in Palaeozoic and Mesozoic times. This idea was based on the Swiss geologist Emil Argand's interpretation in his La Techtonique de l'Asie (1924): that the collision of the rigid India with the plastic Asia during the 'Alpine [Himalayan] orogeny' caused not only north-south dipping folds and thrusts (in the direction of the collision) but also eastward 'flow' of rocks in eastern Asia.

The India-Asia collision took place at about 55–50 Ma, and since then the Indian plate has been pushing against Asia at a rate of about 5 cm per year, resulting in 2,500-2,000 km of continental deformation. Tapponnier and his colleagues, based on a comparison of their experimental results with a tectonic map of Asia, suggested that after the collision, between 50 and 20 Ma, the Indochina Block was extruded south-eastward (out of the way of the indenter) for 800 km along the then left-lateral Red River Fault, which spans from eastern Tibet to northern Vietnam. This tectonic escape and clockwise rotation of the Indochina Block was interpreted to be responsible for the opening of the SCS during this period. After 20 Ma, the extrusion tectonics shifted to other strike-slip faults in central Asia, thus terminating the seafloor spreading in the SCS and opening new extensional basins in continental Asia.

This elegant model has been elaborated on by many other researchers, and it indeed offers a useful perspective on the strike-slip motions and associated pull-apart basins in Central and South East Asia as a result of the Indian collision in Cenozoic times. Geochronological data from rocks along the Red River Fault suggest fault activity to be in the Oligocene-Early Miocene, and total movements on the fault have been estimated to be several hundreds of kilometres. Nevertheless, the direct relevance of the Red

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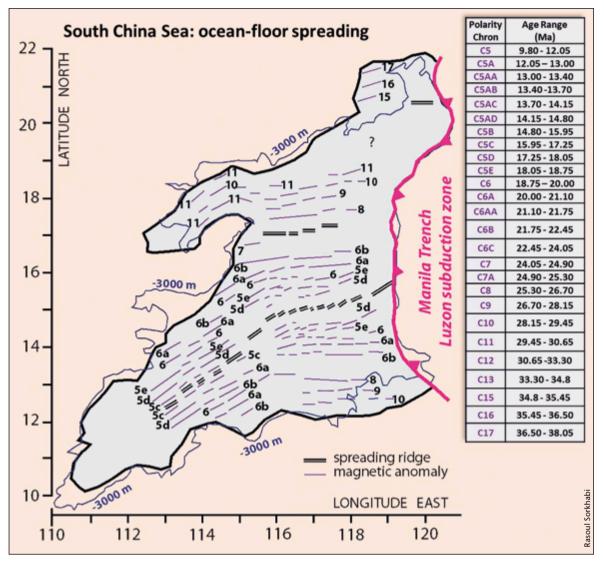
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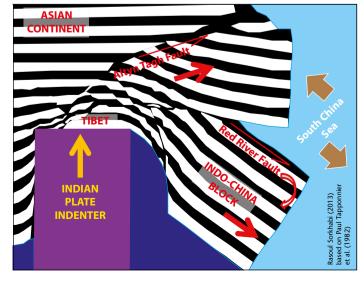
Patterns of the SCS seafloor spreading based on magnetic anomalies (polarity chrons). Data for C11 to C5 come from Briais et al, 1993 (Journal of Geophysical Research, vol. 98B); data for C17–15 (38–34 Ma) come from Hsu et al., 2004 (Marine Geophysics Research, vol. 25,). Polarity chrons are from the 2004 geologic timescale.

River fault activity for the opening of the SCS has also been questioned. For one thing, it is not clear how the Red River Fault extends offshore and is linked to the seafloor spreading structures. Moreover, magnetic lineations of the SCS show that the seafloor spreading began in the east to north-east (far from the Red River Fault) and then 'unzipped' in a west to south-west direction, thus creating a wedge-shaped sea with its maximum width in the north-east.

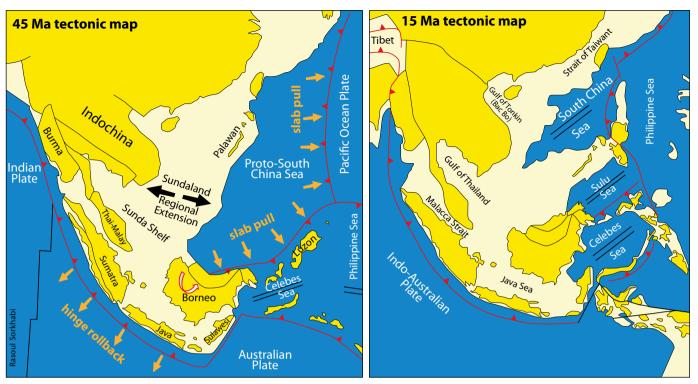
#### Subduction and Crustal Extension

Another influential model for the opening of the SCS involves crustal extension in response to ocean-plate subduction on the western Pacific side. The initial idea for this model was given in the early 1980s by B. Taylor and D.E. Hayes (*AGU Geophysical Monographs 27, part II*) and has been developed by Robert Hall and his research group at Royal Holloway University of London.

This model considers the existence of a Proto-South China Sea during the Eocene which started subducting beneath the Pacific Ocean and the continental crust of Borneo. Crucial A tectonic model for the opening of the SCS invoking the tectonic extrusion of the Indochina Block as a result of the India-Asia collision. This geologic model is based on the correlation of the regional geology with experiments on plasticine by Paul Tapponnier and his colleagues (Geology, 1982, vol. 10).







A tectonic model for the origin of the SCS based on the subduction-extension events as discussed by Robert Hall in his papers (Hall, 2002, Journal of Asian Earth Sciences, vol. 20; Hall, 2009, Petroleum Geoscience, vol. 15).

evidence for the Eocene-age Proto-South China Sea comes from the subduction complex and deepwater sediments of north-west Borneo (the Rajang-Crocker outcrops of Sarawak and Sabah). The pull of the eastward subducting slab is believed to have caused sufficient extension in the continental crust, which eventually led to the opening of a new oceanic basin – the SCS – during the Oligocene-Miocene.

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While this model provides a reasonable framework for the origin of the SCS, geologists have also attempted to incorporate certain valid aspects of the India indentation model for an integrative scenario. For example, lan Longley (1997, Geological Society of London Special Publication 126) has suggested that the widespread crustal extension of Sundaland in the Eocene was back-arc rifting induced by the Indian plate collision and contemporaneous oceanic subduction beneath the southern margin of Sundaland (Sunda arc). Tung-Yi Lee and Lawrence Lawver (1995, Tectonophysics, vol. 251) have argued that the extrusion of the Indochina Block induced the subduction of the pre-existing Proto-South China Sea, thus providing a mechanism for crustal extension in addition to the slab pull. Several geologists have extended the

strike-slip faults of extrusion tectonics in the Indochina Block to major faults in northwestern Borneo. For instance, Christopher Morley (2002, *Tectonophysics*, vol. 347) proposed a right-lateral transform system by linking the Red River Fault to the Lupar and West Baram Lines in Borneo, thus explaining the south-east movement of the Luconia carbonate platform from the Chinese margin in the north to the Borneo margin to the south.

#### **Further Enigmas**

Any model for the genesis of the SCS should also explain the cessation of its seafloor spreading at about 16 Ma. This was probably due to major plate reorganisations in the region which shifted tectonic stresses. There is no consensus among geologists on this issue either. One possible case, as discussed by Charles Hutchison (2004, Marine and Petroleum Geology, vol. 21) and Andrew Cullen (2010, Petroleum Geoscience, vol. 160) is the regional uplift of Borneo and the convergence of the Dangerous Grounds with North West Borneo (the so-called Sabah orogeny along the North West Borneo Trough) in the Middle Miocene, and the coeval Sulu seafloor spreading.

Reasons for the protracted controversy on the origin of the SCS are manifold:

the region contains a large number of tectonic blocks and structures about which we do not have sufficiently detailed information. The offshore extension of the onshore rock formations and structures is highly interpretive. Substantial uncertainties exist in the interpretation of palaeomagnetic data or the accuracy of geochronological data collected by obsolete techniques. And as data have been gathered piecemeal, they have revealed a more complex geologic history that any single model could account for.

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And food for further thought: mantle plumes are known to last for tens of millions of years and trigger crustal rifting and the development of ocean basins as they impinge the tectonic plates moving over them. Some Chinese geologists have invoked the role of a mantle plume for the opening of the SCS. A case in point is the Hainan Plume beneath Hainan Island where lavas have outpoured since the Late Miocene, the bulk of them flood basalts in the past 3 million years. The rise of this mantle plume is believed to be associated with the deep subduction of the Pacific and Philippine Sea slabs in the east. If indeed a Hainan hotspot has been operative, its relationship to the nearby SCS remains to be investigated.

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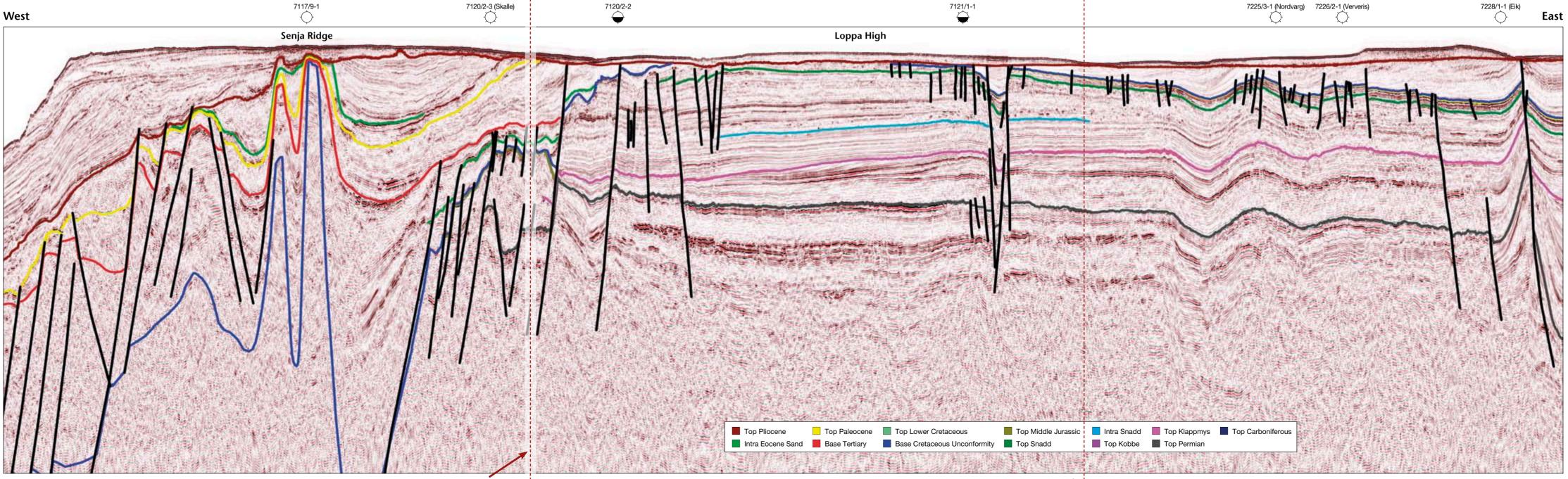
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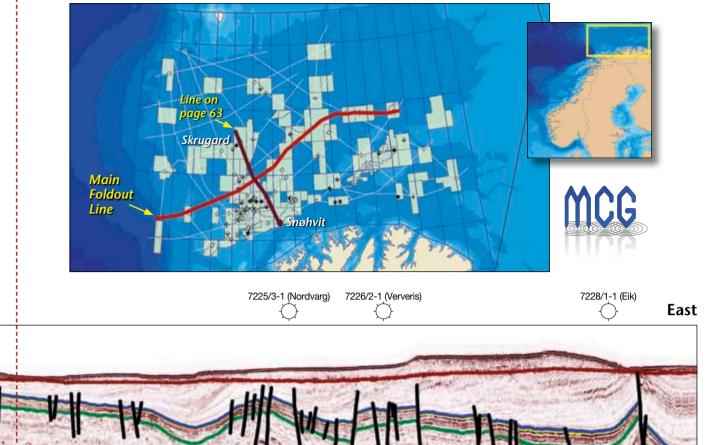
# **Barents Sea:** Complete Integration of Well Data and Seismic Data

Prograding Triassic sequences can be observed in the centre of this line, which connects the Bjarmeland Platform and the Tromsø Basin and Senja Ridge.

There is new and growing enthusiasm for hydrocarbon exploration in the Barents Sea after three recent discoveries. These are Skrugard and Havis, which both have substantial proven oil reserves, and Norvarg, a gas discovery. This enthusiasm has been further encouraged by the Norwegian government, which has announced 72 new blocks in the Barents Sea for the 22nd licensing round. Most of the announced blocks are in the Bjørnøya and Fingerdjupet Basins, leaving much of the Barents Sea still virtually unexplored and open.

MCG's recent BST (Barents Sea Tie) multiclient survey, covering 6,507 km, aims to shed further light on the prospectivity of this fascinating region, particularly though the integration of seismic with CSEM and well data.





# **A Powerful Integrated Tool**

#### Although considered primarily a frontier region, recent discoveries have put the Barents Sea firmly on the map **PETER ABRAHAMSON**, MultiClient Geophysical

Large parts of the Barents Sea can be regarded as frontier areas. These include the south-western area, covering the Tromsø, Bjørnøya and Fingerdjupet Basins, across the Nordkapp Basin and the Bjarmeland Platform and up to the completely unexplored border Grey Zone, which has now been divided into a Norwegian and a Russian part.

More than 90 exploration wells have been drilled so far in the Norwegian part of the Barents Sea, mainly during the 1980s and the last decade. Most of these wells were classified as dry or with shows only, but they do verify the existence of a large petroleum system in the area. After 30 years of exploration in the Norwegian part of the Barents Sea, only one field is in production, the Snøhvit gas field, and one discovery, the Goliat oil field, is being developed. The three recent discoveries are therefore revitalising interest in the Barents Sea as a hydrocarbon province and putting a totally new focus on the whole region.

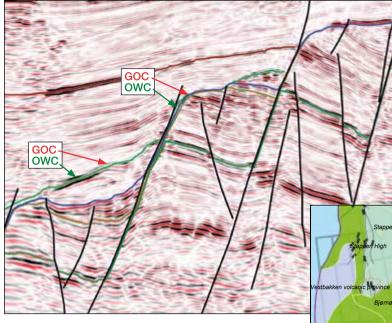
#### **Integrating Well Data**

By using the MCG BST (Barents Sea Tie) multiclient seismic data acquired over the whole Barents Sea, including the

Skrugard, Havis and Norvarg discoveries, we have a good tool to integrate almost all well data in the Barents Sea with a consistent, modern, high-quality seismic dataset. A total of 64 exploration wells and 11 IKU shallow wells have been tied into the MCG BST survey. Even upcoming wells that have a drilling location (such as Bønna, Darwin, Wisting, Appollo, etc.) have been included in this survey. The MCG BST seismic survey is a phase-matched and high-quality 'backbone' for all explorers in the Barents Sea, because it links all-important well data in the depth domain into the seismic time domain, where the mapping of drillable prospects is undertaken. The BST survey can also be used to consistently link other seismic datasets where prospects can be identified in detail.

This MCG dataset is a powerful tool to use in modern basin modelling. Proper modelling of source rock maturity and migration is fundamental to success in a highly competitive exploration game such as the Barents Sea. Recent geochemical studies indicate that there may be several alternative source rocks to the well-known Upper Jurassic Hekkingen Formation.

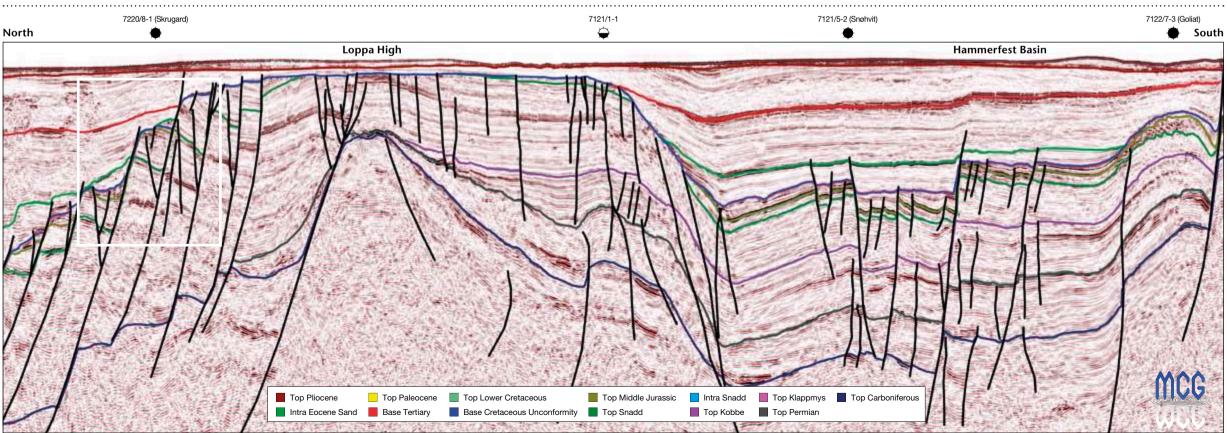
The main reservoir targets are in the early–middle Jurassic sandstones (the Stø, Nordmela and Tubåen Formations).



These are several hundred metres thick and have good porosity. This is the reservoir in the Skrugard and Havis discoveries. The Norvarg gas discovery has reservoirs in both the Jurassic and Triassic clastic formations.

A secondary target is the Lower Cretaceous Knurr Formation. A nice double flatspot in the Knurr Formation can be seen in the expanded line above. A similar double flatspot can also be observed in the Skrugard and Havis oil and gas discoveries.

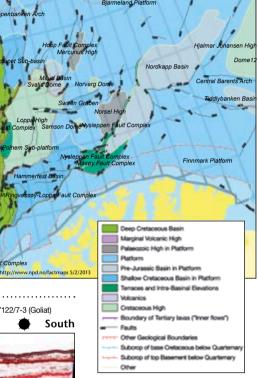




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The proven oil and gas contacts in the Skrugard well are shown in the Jurassic section. To the left of the well, the same double flatspots can be seen in the Lower Cretaceous Knurr Formation, that may contain more oil and gas.





This line connects the established oil and gas fields in the Hammerfest Basin (Goliat and Snøhvit) with the new oil and gas discovery, the Skrugard Field. The white box indicates the area shown in the expanded seismic image above.

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# Geochemical The Tuktoyaktuk Per Beaufort-Mackenzie and has a gas discussion orientation se demonstrated that detectable three and that these as a regioned to the second s

The Tuktoyaktuk Peninsula is located in the Beaufort-Mackenzie Basin area of Canada and has seen numerous oil and gas discoveries. Using multiple geochemical methods, an orientation survey on the peninsula demonstrated that oil and gas seeps are detectable through thick permafrost, and that these methods can be used as a regional exploration tool.

JOHN V. FONTANA, PG, and DAVID M. SENESHEN, PHD, CPG, Vista GeoScience

Located in Canada's farthest northern region, the hamlet of Tuktoyaktuk lies on the Tuktoyaktuk Peninsula at the tip of the Northwest Territories on the coast of the Beaufort Sea. Anglicised from an Inuvialuit word meaning 'resembling a caribou', Tuktoyaktuk, or Tuk as it is known, has a local population of around 1,000. There are about 1,350 pingos – unique, conical permafrost heave features – in the Tuktoyaktuk Peninsula area, the greatest concentration in the world. Tuktoyaktuk has more recently become known from the HistoryChannel.com series 'Ice Road Truckers', which features the winter ice road connecting Inuvik and Tuktoyaktuk along the Mackenzie River delta.

Arctic environments are challenging areas for oil and gas

exploration. Due to remoteness, extreme conditions, limited working seasons and sensitive environments, there are many restrictions and higher costs associated with exploration and development activities. This study area was located just south and east of Tuktoyaktuk. Tuk can only be accessed by the ice road in the winter, by boat or barge in the short summer when the sea ice melts off, and by limited-size aircraft with its one gravel runway and airport. Due to these additional costs and difficult conditions, any tools that are conducive to these sensitive environments can add value and important evaluation information to the exploration programme. Nearsurface geochemical exploration methods can be employed at relatively lower costs on a regional scale, have very minimal

Pingos, unique permafrost heave features that look like volcanic cones, dot the otherwise flat tundra landscape on the Tuktoyaktuk Peninsula. Pore water is expelled in front of the rising permafrost, and the resulting pressure causes the frozen ground to rise and an ice core to form. surface impact in these environments, and fewer permitting requirements, so they fit that category.

There are many unconnected discoveries and reserves in the region. A 1,220 km gas pipeline has long been proposed to link the Beaufort gas fields, via the Mackenzie River valley, to the North American energy grid in Alberta. Companies backing the pipeline – ConocoPhillips, Shell, ExxonMobil and Imperial – are asking the government to help underwrite the projected Canadian \$16.2 billion construction cost to help make it feasible. When construction on this project begins, exploration and drilling activity will likely boom again in the region.

#### Petroleum Microseepage

Identification of hydrocarbon micro-seepage anomalies using near-surface direct detection methods over oil and gas deposits in both terrestrial and subsea sediments has seen growing use by explorationists. Visible oil and gas seeps (macroseeps) were historically used to find oil and gas deposits. Searching for microseeps is simply a technological extension of those older methods using sensitive instruments, remote methods and analysis of soil, soil gas or water to detect non-visible trace amounts of oil and gas, or microseeps. Since the nearsurface environment determines which types of methods can be used to detect these anomalies, venturing into a new type of environment requires conducting orientation surveys, ideally over known deposits, to determine which method, or combination of methods, will work best in that environment. There was reasonable concern in this study that microseepage could not reach the near surface in areas with thick (100–600m) permafrost, and that this seepage would instead get trapped at the base of the permafrost.

In the arctic tundra environment, collection of free (interstitial) soil gas was not possible due to saturated and frozen soils. Half of the area is covered with small lakes, allowing lake sediments to be used as a matrix to test. The other sampling matrix available was soil from the frozen tundra. In another phase of the study, sediment collected from seismic shot hole borings was also used. Several geochemical analytical methods could be applied to these different matrix types.

#### Tuk and Mayogiak Orientation Survey

The geochemical orientation survey was designed to look for microseepage anomalies over the Tuk Tertiary oil field (estimated 10-25 MMbo), Tuk Cretaceous gas field (estimated 280 Bcfg) and the Mayogiak Devonian oil field (estimated 4 MMbo) in the Mackenzie Delta of the Northwest Territories, Canada. These fields had been drilled and explored by Esso in the 1970s and 1980s, but were left capped with casing in place with no available pipeline or transportation available for the crude oil or gas. Several years after the orientation survey was completed an additional well, the Tuk M-18, was drilled into the Cretaceous Kamik sands by Devon Energy and Petro-Canada. It has estimated reserves of 200-300 Bcfg and deliverability of 60-80 MMcfgpd. Since the fields were still under virgin pressure, the boundaries were well defined, and the area was clean and void of any producing infrastructure, pits, gas flares, etc., they were ideal candidates for testing the geochemical methodology as a regional exploration tool.

A helicopter was used to access the remote sampling locations



A power auger mounted on the side of the helicopter was used to collect frozen cores of the tundra. Helicopters are the only way to access the sensitive tundra environment during the summer months when the sun never sets.

in the summer season. For lake sediments, the helicopter was fitted with pontoons so it could land on the lakes allowing the use of a gravity core to collect lake sediments. A total of 85 lake sediment samples and 90 permafrost soil samples were collected at 500 to 1,000m spacing intervals along lines 2,000m apart over an area of 150 km<sup>2</sup>. Lake sediments were not collected over the Mayogiak field due to time constraints.

Frozen cores of the tundra soils were collected using a portable 8 horse power auger mounted to the gear racks on the helicopter. After drilling a metre through the upper tundra and frozen sediments, a modified split core barrel with a carbide cutting tipped shoe was used to cut an undisturbed frozen soil core to a depth of 1.5m. Lake sediments were collected using a 30 kg gravity core dropped from the pontoons of the helicopter and penetrated 0.3–1.0m into the lake bottom sediments. To maintain position, the pilot was not allowed to shut down on the lake, so it was rather exciting dropping a gravity core underneath the whipping blades!

A section of the lake sediments and soil cores was placed in a lined metal food-type can immediately upon removal from the core barrel. The remaining volume was filled with hydrocarbon-free prepared water and bactericide to prevent microbial degradation of the hydrocarbons. The can was then sealed on-site with a food canning machine. Back at the base The abundance of small shallow lakes allowed the collection of lake sediment samples on a grid of approximately 1–2 km spacing over the Tuk and Mayogiak fields. The general location of the productive oil and gas deposits is clearly indicated by the spatial distribution of pentane anomalies.

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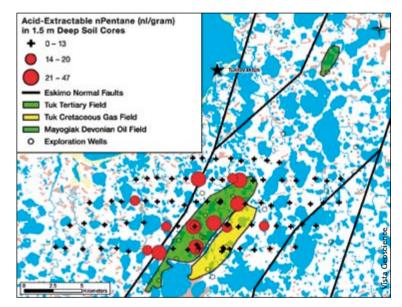
camp, a volume of fluid was displaced with a pure nitrogen headspace injected through a septa built into the lid of each can. The cans were frozen for storage and subsequent shipping.

#### **Direct Hydrocarbon Detection Methods**

There are a wide variety of geochemical methods that can be tested in an orientation survey. In this study, four direct hydrocarbon measurement methods were used to analyse the samples and determine which, if any, could detect surface expressions of the oil and gas fields through the thick permafrost. The purpose was to find the most effective method(s) that would then

be used to focus or complement higher cost methods such as seismic surveys, and subsequent drilling over onshore parts of the vast and remote Mackenzie Delta and Beaufort Basin areas.

The four methods included acid-extracted  $C_1 - C_6$ hvdrocarbons; canned thermally-extracted headspace C1-C6 hydrocarbons; disaggregated sediment headspace C1-C6 hydrocarbons; and solvent-extracted poly-aromatic (C<sub>6</sub>-C<sub>36</sub>) hydrocarbons. Analysis of the gaseous hydrocarbons (the first three methods) was done using Flame Ionisation Chromatography. Gas The heavier aromatic hydrocarbons



Headspace nPentane (ppb/v) in Lake Sediments

24 - 1018

1019 - 1447

1448 - 2091

Eskimo Normal Fa

Tuk Cretaceous Gas Field Mayogiak Devonian Oil Field

**Tuk Tertiary Field** 

Exploration Wells

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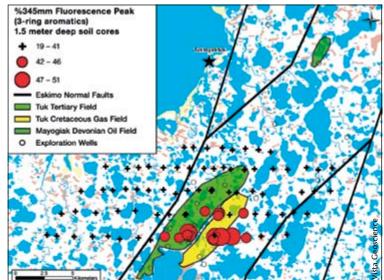
The distribution of pentane concentrations in acid-extracted gas from the 1.5m deep permafrost soil cores over the Tuk oil and gas fields identifies the general area of interest from a regional exploration perspective.

were extracted with organic solvents and the extracts were analys ed using a sensitive synchronous scanning fluorescence spectrometer.

To interpret the data, thresholds between background and anomalous hydrocarbon concentrations were determined using probability analysis to see anomalous breaks in the normal distributions. Discriminant analysis, which takes into account the multivariate or compositional nature of the hydrocarbons, was used to see how well each method could distinguish between anomalous and background conditions over and off the oil and gas fields.

Survey results found that hydrocarbons do migrate vertically through the thick permafrost and are detectable at the surface. Thermogenic ( $C_2$ - $C_6$ ) hydrocarbons are anomalous in lake sediments and soil cores over and adjacent to the oil and gas fields. Acid-extractable ( $C_2$ - $C_6$ ) hydrocarbons in soil cores and headspace ( $C_2$ - $C_6$ ) hydrocarbons in lake sediments provide good anomaly distribution and discrimination between background and productive areas. The

Frozen soil cores were collected over the Tuk oil and gas fields, but not over the smaller Mayogiak field. Synchronous scanning fluorescence spectrometry of these samples revealed that even the heavier aromatic hydrocarbons seeped up through the permafrost, possibly along faults, and are detectable.



#### Exploring The Mediterranean: New Concepts In An Ancient Seaway

A rich human history of civilisation, trade and war is deeply rooted in the complex ancient geology that underlies the Mediterranean region, having evolved through the convergence of the European and African plates and the closure of the Tethys Ocean. In more recent times, oil and gas exploration has found success in the diversity of resulting extensional and compressional tectonic regimes, with a procession of new plays being identified over decades of industry and academic activity. Despite intensive exploration, the region continues to deliver tangible success through its rich diversity of play types, as recent discoveries in the Eastern Mediterranean have testified.

This significant conference will assemble some of the best current thinking in Mediterranean petroleum geology, from the tectonics that underpin the basin, to the Messinian salinity event and its impact on exploration. From North Africa to the Adriatic, this conference will bring together the multiple cultures that surround this diverse region to reflect on a common geological framework and the petroleum systems that transcend political boundaries.

With its position to the west of 2.5 million sq. km of water, Barcelona will form the ideal backdrop to this timely event.

#### Themes will include:

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blender-extracted gas method showed the least amount of discrimination but still located the productive areas. Fluorescence of aromatic hydrocarbons is anomalous in soil cores over the southern part of the Tuk oil and gas fields, suggesting the ascent of heavier liquid hydrocarbons, possibly along the faults.

The orientation study over the Tuk and Mayogiak fields therefore shows that hydrocarbons present in lake sediments and soil cores provide statistically significant anomalies over the oil and gas fields, and offer useful indications of hydrocarbon accumulations at depth.

The surface expressions seen using these methods demonstrate that they can be used to aide regional exploration in similar environments and geologic settings. The information gained from these types of surveys can help focus where to conduct more expensive methods such as seismic surveys. These methods have also been applied successfully to



Frozen soil cores were collected in the tundra environment and were sealed in metal food-type cans on site for shipping and analysis.

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sediment samples collected from seismic shot hole borings in the same region enhancing the seismic data, and from soil cores and lake sediments collected in similar environments in the Alaskan Yukon Flats area.

Tuktoyaktuk has a local population of around 1,000, but during more active drilling booms, the population doubles, with workers residing in camps such as the one in the foreground here. Tuktoyaktuk has more recently become known from the HistoryChannel.com series 'Ice Road Truckers', which features the winter ice road connecting Inuvik and Tuktoyaktuk along the Mackenzie River delta.





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# The World in Our Hands?

Is the hydrocarbon industry's role simply to create wealth or to take a leadership role on corruption and the environment? Petex's forum delivered two explicit challenges to the industry.

#### **NIKKI JONES**



Hamish Wilson, Technical Director at leading environmental firm SLR Consulting, chaired the forum on 'Social Licence to Operate'.

The Petroleum Society of Great Britain's PETEX Conference, held in November last year, had one unusual draw – a debate on 'Obtaining a Social Licence to Operate, a Challenge for the Industry'. For an industry that is considered by many to extract resources with minimum involvement of local communities, and which has long been accused of indifference on all manner of local and global ills, the debate at such a venue represents an interesting development. In front of an audience of around 150, three oil executives and two key non-governmental organisations (NGOs) each made presentations and joined in discussions, chaired by Hamish Wilson, Technical Director at leading environmental firm SLR Consulting. Indicative of the subject's sensitivity, however, Chatham House rules were applied, preventing the identification of individual speakers with particular statements.

#### A Sobering Self-Assessment

The title of the debate perhaps indicates a level of sensitivity not often associated with the oil industry. Unlike the Corporate Social Responsibility (CSR) model that it seeks to replace, a social licence can only be granted by 'stakeholder' communities that accept and approve a corporation's activities. Whereas CSR can be seen as a tokenistic payment in kind from a corporation to a host community, a social licence acknowledges the prior rights of the host community and seeks their permission for each operation. In fact, the ultimate aim of a social licence is for the corporation to be 'adopted' by the local community and become part of the local identity – not a position commonly associated with the industry.

The event kicked off with the audience being asked to rate their own industry's level of social responsibility on a five-point scale. Soberingly, 12% of the 150-strong audience, drawn entirely from the industry, gave themselves the lowest grade; 28% voted for one notch above; and 30% gave themselves a fair-middling grade. Only 2% declared the industry's record 'excellent'. When asked whether an oil or gas exploration should ever be abandoned for either environmental or social reasons, an overwhelming 74% said 'yes'. Although undoubtedly a self-selected cohort, it appears that a social conscience is thriving in the industry.

#### A Clear Fault Line

The fault line between the industry and the NGO sector was clearly defined, with the oil majors expressing their support for 'soft law' initiatives such as multi-stewardship councils and voluntary agreements. The bigger problem, they stated, is what governments do with legitimate payments, which are

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not the responsibility of oil companies, even when it is clear that money will be either squandered or stolen. 'We have to be respectful of the rights of sovereign states to decide how they will use their money,' stated one executive, while another argued that governments would more effectively combat corruption if they concentrated on transparency within the Western banking system, closing down the safe havens for illicit funds.

Whilst agreeing this last point, the representative of the anti-corruption NGO countered that oil companies do have a moral responsibility when purchasing assets that have clearly been stolen as they effectively 'monetise' and launder such assets. Interestingly, the representative of the younger, non-major oil company did acknowledge the 'supply side' of corruption and identified positive examples of how her company is training staff at all levels to resist 'expediting payments'. She also argued that 'democratic accountability' was the best defence against corruption, giving the example of Ghana where officials have volunteered to publish their contracts with the oil company. In a marked progression from the statements of the oil majors, she stated that her company perceives strengthening 'democratic accountability' as part of its remit.

There was a tense moment as the representative of the anti-corruption NGO challenged the industry to commit to the combatting of corruption by withdrawing support for the American Petroleum Institute's attempts to derail section 1504 of the US's Dodd Frank legislation. The section requires

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President Barack Obama delivers remarks and signs the Dodd-Frank Wall Street Reform and Consumer Protection Act at the Ronald Reagan Building in Washington, July 21, 2010.



all extractive industries listed on US exchanges to report payments made to governments around the world. Clearly uncomfortable, there was no engagement from the executives on this issue, only evasive statements that companies 'need to follow the law' and 'build capacity' in host countries.

There was a clear consensus amongst the oil companies that their social licence comes from their role as 'wealth creators', with the executive of the more 'junior' oil company arguing most forcefully that their principle role is to be successful businesses, providing 'sustainable returns' to their shareholders. From this basis, they can 'maximise the developmental benefits of oil', she claimed, principally through the provision of jobs. She agreed with the executive of one of the majors that the stimulation of host economies through 'local content' – local procurement, employment and training – had a greater impact than tax revenues and is more valuable than traditional social responsibility programmes of providing schools and hospitals. The third executive took a markedly more passive approach, arguing that the role of the oil companies is simply to meet human needs, pointing out that the Millennium Development Goal on poverty reduction has been met three years ahead of target, with energy playing a large part in this. Unlike his two colleagues, he did not argue that his company has any 'developmental' intentions or obligations, and stated that governments' only role is to promote free markets.

#### A Direct Challenge on the Environment

A similar fault line between the oil industry and NGOs appeared over environmental issues, with the NGO representative asking, 'Are you just passive players meeting energy demands, or active?' An active strategy, he claimed, would make world heritage sites and areas where there would be a net loss of biodiversity 'no-go' areas, Strategic Environmental Assessments and waste management plans would be strengthened and oil companies would plan an 'exit strategy' from fossil fuels. He argued that turning all global deposits into commercially viable reserves will lead to a potential temperature rise of 6°, when the global target is a maximum of 2°. Although the use of gas will bring down the figure, the temperature rise is still calculated to be 3.5°. These figures, he explained, are derived from the 'Carbon Bubble', a report published in March 2012, and endorsed by the International Energy Agency (IEA).

He outlined a positive plan that, with 'a new mindset', would deliver energy with almost 100% renewables by 2050. Although not disputing that such an increase in green energy is possible, one oil executive argued that NGO estimates of overall consumption are optimistic. 'Hydrocarbons are not incompatible with a sustainable mix', stated the second oil major executive. However, the executives' obvious lack of explicit research or strategy, combined with a plea for 'trust' and support for the carbon market, highlighted the gulf







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between the two sectors. Even where there was agreement that water supplies are a significant area of sensitivity, the industry's response appears to be a reliance on the management of competition with other consumers, rather than the taking on of any leadership role. When asked directly whether his company would commit to improving Strategic Environmental Assessments (SEAs), the executive questioned was non-committal, stating only that there was 'a need to improve some processes', while a second commented that the environmental debate was not helped by mixing local issues with global warming.

#### Wealth Creators or Global Citizens?

In many ways the debate confirmed the well-established division between the two sectors that rests on widely divergent perceptions of corporate responsibility. While corporations argue that their 'social licence' comes from their wealth creation, NGOs urge them to act as global citizens, taking active responsibility for the 'collateral damage' of actual impoverishment, corruption, human rights abuses and environmental damage. However, any assumptions of predictability in the debate were mildly shaken by the arguments of the more 'junior' oil company who, while vehemently defending her company's primary aim of being a profitable business, indicated a more proactive approach to strengthening structures within host countries. When asked whether her company would ever pull out of a development if the social or environmental effects were bad, rather hesitantly she replied that they would, where those effects could not be managed. In comparison, the oil major executive stated that 'nowhere is off limits' and merely that the industry needs to 'keep reviewing its dependence on technology' and has a 'strong obligation to share lessons'.

This was a debate that clarified positions, and will perhaps prompt greater reflection on both sides. The industry was served with two specific challenges with which they can prove their commitment to corporate responsibility within a multi-agency framework – the withdrawal of support for the API's undermining of anti-corruption legislation and the strengthening of SEAs. Given the audience's assessment of their own industry and the desire expressed for greater morality, it appears that executives need to take note. For Petex, the session was a successful experiment that bears repeating.

#### Social and Environmental Responsibility

The PESGB will run a one day course in April entitled 'Social and Environmental Responsibility', aimed at making the next generation of industry leaders aware of the social and environmental responsibilities of the oil and gas industry.

Details at: www.pesgb.org.uk

# Unique and Fast Analysis in the Field

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Field-portable x-ray fluorescence (FPXRF) is a technique that is gaining momentum and acceptance in addressing applications in various fields in geology and mining. Thousands of these instruments are currently used in exploration and mining projects around the world. Now, for the first time, oil and gas companies are starting to benefit from the unique fast analysis capability that FPXRF offers.

#### What is Field Portable XRF?

XRF is a surface analysis technique in which a sample is bombarded with highenergy primary x-rays or gammas. This causes the sample to emit characteristic 'secondary' (or fluorescent) x-rays, which are detected and plotted based on energy and intensity. The energy of a detected secondary x-ray is unique for each element, and the corresponding intensities are converted to concentrations and reported as percentages (%) or parts per million (ppm). XRF is a mature and dependable technology, and FPXRF devices host this capability in a small handheld 1.5 kg pistol package.

This type of instrument has a number

Field-portable XRF is a new technique which can be used to accelerate decisions in oil and gas exploration and production

#### ALIREZA SOMARIN, PhD, PGeo

of salient features. As well as being light and portable, it is safe and userfriendly, with geologists and technicians requiring only a few hours training. It can analyse any type of geological sample, from cores to cliff faces, in realtime on-site, taking between 30 seconds and a few minutes depending the accuracy and precision on requirements. Up to 25 elements can be measured simultaneously from uranium (U) to magnesium (Mg), including the light elements such as aluminium (Al), phosphorus (P), silicon (Si) and sulphur (S). Calibration factors can be adjusted by users to match their specific sample matrix type, with some instruments able to do this task internally by built-in type standardisation.

The handheld device uses a Li-ion battery, which lasts about eight hours,

and a few models have built-in GPS, which records the coordinates for each sample that is analysed. Some of these devices can also be paired with external GPS/GIS devices in order to make geochemical maps in real time.

#### FPXRF in Oil and Gas E&P

FPXRF can analyse a variety of sample types which are common in the oil and gas upstream exploration and production industry, including drill cuttings, oil and gas cores, outcrops, and piston-cored sediments. The geochemical data from these analyses can easily be used in mud logging for the identification of oil and gas formations, as well as in chemostratigraphy and geosteering.

Although FPXRF cannot analyse hydrocarbons, they can be used to characterise

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# 20th Africa Oil Week

#### 25<sup>th</sup> - 29<sup>th</sup> November 2013

Cape Town International Convention Centre - South Africa

**15<sup>th</sup> Scramble For Africa: Strategy Briefing** 25<sup>th</sup> November 2013

**10<sup>th</sup> Africa Independents Forum** 26<sup>th</sup> November 2013

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Join us, as we will celebrate our **20<sup>th</sup> Africa Oil Week/Africa Upstream 2013** in Cape Town (25<sup>th</sup>-29<sup>th</sup> November, 2013), where we shall again host the world's leading meeting on Africa for corporate deal-making, Roadshows and senior-level networking across the oil/gas industry in and on Africa, and designed to build the African Continent's economic future.

Over 1,000 Delegates from Six Continents are attended in 2012, with 90 Presentations made during the Week, and with numerous Ministers/ Government Delegations in attendance and many State Firms/National Oil Companies and State Officials on the Program, plus with a record number of Exhibitions.

The Global Pacific & Partners' famous **Africa Oil Week** is the landmark Conference occasion for Africa, a meeting with a global reputation, and one of the top world-class Conferences held annually in the international industry Calendar. For our 2013 Conference we recommend early bookings/confirmations for all Sponsors and Exhibition slots, and for your earliest registration/s as delegates to the different events held across the Africa Oil Week during 2013 much expanded event, which will have a more intensive Program.

Our 2013 Conference will be hosted at the **Cape Town International Convention Centre**, with an Auditorium for 1500 delegates, and added space for Corporate Showcase/s and Exhibition opportunities.

For upcoming information and updates in due course, visit: www.petro21.com

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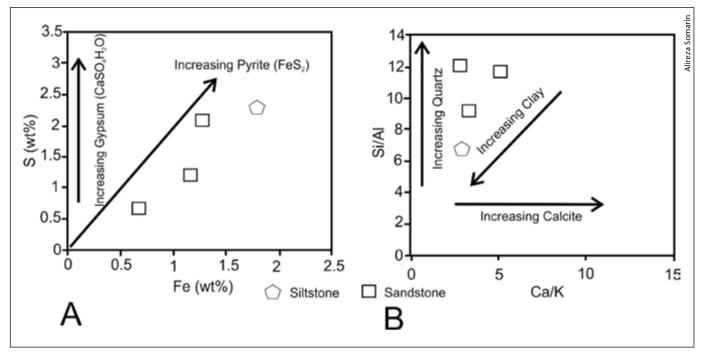
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A) Fe-S diagram for identification of sulfide and sulfate in the sample. B) Ca/K – Si/Al diagram for identification of calcite, clay and quartz in the sample.

reservoir properties that influence porosity (cements), permeability (clays, cement type), fracture population (Si content), and productivity (e.g. Si, Mg content). FPXRF is used on-site to determine elemental composition of a sample in real time and then the mineralogy of the sample can be inferred from its chemical composition. The mineralogy is

subsequently used to infer physical properties of the rock unit. Such application in oil and gas E&P can be shown as:

#### Elemental composition $\rightarrow$ Mineralogy $\rightarrow$ Physical properties of host rock $\rightarrow$ Process decisions in the field

Bulk chemistry is used to infer sample mineralogy and thus identify silicates, aluminosilicates (e.g. clay and feldspar), carbonates, and sulfides. For example, a lower Si/Al ratio indicates greater alumino-silicate content in a rock unit because these minerals have high Al content.

Elemental diagrams can also be used to infer mineralogy. The Fe-S diagram (above) shows that, in this example, the host mineral for sulphur is pyrite (FeS<sub>2</sub>) rather than gypsum (CaSO<sub>4</sub>H<sub>2</sub>O). Si/Al is a basic indicator of the abundance of quartz (SiO<sub>2</sub>) versus alumino-silicates such as clays and feldspars. The combination of Si/Al and Ca/K ratios can show the relative amount of clay, quartz, and feldspar in the gas/oil

Bringing the lab to the sample: the Thermo Scientific Niton FXL field x-ray lab can operate virtually anywhere on-site

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formation. For example, high Ca/K indicates the presence of calcite (CaCO<sub>3</sub>) cement and high Si/Al shows increased quartz (SiO<sub>2</sub>) in the sandstone. Ca/Mg ratios can provide a quantitative determination of the dolomite content of the carbonate rock.



As light elements such as Al, Si and Mg are very important in lithological investigations, sample preparation might be necessary. Some companies (such as Thermo Fisher Scientific) offer field portable sample preparation tools which are specified for oil and gas exploration and mining.

A number of properties of the reservoir rock can be characterised using portable XRF, including productivity, which can be defined by analysing redox sensitive elements such as V, Cr, Ni, Mo, Mn and Fe to detect oxic/ anoxic boundary in rocks. These and other trace elements can also be used for chemo-stratigraphic correlations. Aluminium content can be used as an indicator of clays in the rock ground mass and thus permeability, while Si content can be an indicator of fracture population and fracture potential. Porosity and cement type can also be identified using portable XRF.

#### Fast and Reliable Data

In conclusion, FPXRF analysers can provide fast and reliable geochemical data at the drill site, in the field, and in the core lab. This allows geologists to predict where the oil and gas is in the rock formation and what factors affect the porosity, and to predict the volume of oil and gas present. It also allows them to determine how the permeability of the rock can affect the flow of oil and gas from the rock to the well bore, and how a rock formation can be engineered to produce more by fracturing and well treatments. This can help operators to maximise the potential of each well and avoid waste related to ineffective fracture treatments.

#### About the Author

Alireza Somarin has a PhD from the University of New England, Australia, and was a post-doc at Lakehead University, Canada. He has taught various geology courses in several countries, including Canada, for more than 13 years and has published over 70 articles, including books, journal/conference papers, research reports, and short course volumes. He is an experienced geologist in the field of portable XRF and its application in metal exploration/mining as well as oil and gas exploration and production.



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Lasse and Martin start a new series on one of the hottest topics in the industry:

# Broadband Seismic Technology and Beyond

### PART I: THE DRIVE FOR BETTER BANDWIDTH AND RESOLUTION

### LASSE AMUNDSEN, Statoil and MARTIN LANDRØ, NTNU Trondheim

Once a new technology rolls over you, if you're not part of the steamroller, you're part of the road. One such new technology is broadband seismic. Want to be part of the steamroller or the road? In a series of articles, we give you an introduction to what broadband seismic has to offer.

"Technology presumes there's just one right way to do things and there never is." Robert M. Pirsig (1928–), American writer and philosopher The world's largest pipe organ was built between May 1929 and December 1932 by the Midmer-Losh Organ Company of Merrick, Long Island, New York. It weighs 150 tons, boasts seven manuals and has 1,439 stop keys, 1,255 speaking stops, 455 ranks, and 33,112 pipes! The most impressive stop on the organ would have to be the 16 ft Ophicleide, which is the world's loudest stop. This stop has six times the volume of the loudest train whistle.

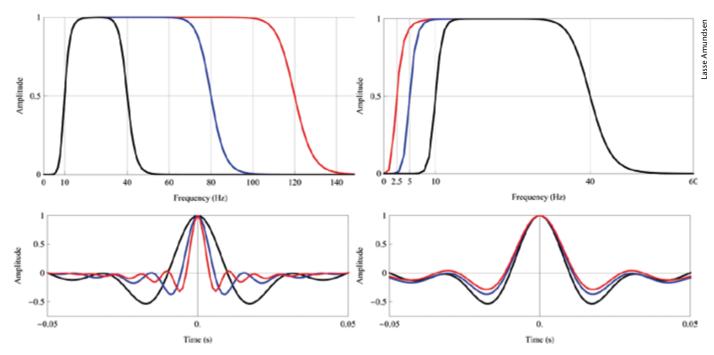


Figure 1: Temporal resolution. Left: Resolution increases with the maximum frequency. The number of octaves is 2,3 and 4 for the black, blue and red spectra, respectively. Right: Resolution is relatively insensitive to the minimum frequency. The number of octaves are 2,3 and 4, but the resolution is the same. A key learning is that side lobe reduction is obtained by adding low frequencies.

Most people think of broadband with regard to telecommunications, in which a wide band of frequencies is available to transmit information. This large number of frequencies means that information can be multiplexed and sent on many different frequencies or channels within the band concurrently, allowing more information to be transmitted in a given amount of time (much as more lanes on a highway allow more cars to travel on it at the same time).

In seismic exploration broadband refers to a wider band of frequencies being recorded than in conventional seismic exploration. In the marine case the conventional acquisition system is said to give a useable bandwidth of typically between 8–80 Hz, whereas broadband seismic systems are claimed to give useable frequencies from as low as 2.5 Hz up to 200 Hz or more for shallow targets. On land, marine vibrators today can produce signal frequencies down to 1.5 Hz.

The seismic acquisition system consists of the source system and the receiver system. But in the following discussion we are not going to discuss the technologies behind land or marine acquisition systems; instead, we will give an introduction to resolution and the benefits of hunting in particular for the low frequencies. In the articles that follow this one, we will present the seismic vendor's new broadband solutions – a combination of leading equipment, unique acquisition techniques and proprietary data processing technology. With reference to the quote at the start of this article, it is fair to state that there is not one right way to do things. Each of the vendor's solutions has unique capabilities.

### **Organ Pipes**

Did you know that organ pipes have gone through a technology development similar to that for broadband seismic? The frequency f of an organ pipe is  $f = v/\lambda$ , where v is the speed of sound in air (340 m/s) and  $\lambda$  is the wavelength. Let L be the length of the pipe. The longest possible wavelength equals 2L and 4L for open and closed pipes respectively. The maximum wavelength thus is  $\lambda = 4L$ , and the corresponding minimum frequency equals f=v/4L.

One of the biggest organs in the world is the Boardwalk Hall Auditorium organ in Atlantic City. It is equipped with 33,112 pipes, and the biggest pipe has a length of 64 ft. This is an open pipe so the corresponding lowest frequency is around 8 Hz. A closed pipe of the same length would give a lower frequency of 4 Hz.

But the story does not stop at 4 Hz.

The lowest produced note is obtained by combining a stopped 64 ft and stopped  $42\frac{2}{3}$  ft pipe to produce a resultant 256 ft pipe which gives 2 Hz! This is far below the threshold of the human ear, which is approximately 16 Hz. So what is the point in this focus on low frequencies for organ pipes? Can we feel the low frequencies directly on our body, or is it a combination of hearing and body feeling?

Anyhow, there is a strong similarity between the design of big organ pipes and today's developments in broadband seismic. As geophysicists, we would be thrilled if our marine seismic system produced frequencies truly from 2 Hz and upwards. We would want to activate all the pipes of the organ in Atlantic City, and especially the big pipes! The low frequencies are of particular interest for deep imaging, inversion and high-end interpretation.

#### **Temporal Resolution**

Improving bandwidth and resolution has been a priority since the early days of the seismic method – to see thinner beds, to image smaller faults, and to detect lateral changes in lithology. Although sometimes used synonymously, the terms bandwidth and resolution actually represent different concepts. Bandwidth describes simply the breadth of frequencies comprising a spectrum. This is often expressed in terms of octaves.

Commonly referred to in music, an octave is the interval between one frequency and another with half or double its frequency. As an example, the frequency range from f1 to f2>f1 represents one octave if f2=2f1. The range from 4 to 8 Hz represents one octave of bandwidth, as do ranges 8–16Hz, and 16–32Hz. Also, the range from f1 to f0 < f1 represents one octave if f0=f1/2.

In a classic empirical study, Kallweit and Wood (1982) found a useful relationship between bandwidth and resolution. For a zero-phase wavelet with at least two octaves of bandwidth, they showed that the temporal resolution  $T_{R}$ in the noise-free case could be expressed as  $T_R = \frac{1}{(1.5 \text{ FMAX})}$ , where FMAX is the maximum frequency in the wavelet. Other definitions are possible, but for two octaves or more of bandwidth the clue is that one can approximately relate temporal resolution to the highest, and only the highest, frequency of a wavelet. This leads to some very useful and guite accurate predictions. Examples are that wavelet breadth is  $T_B = \frac{1}{(0.7 \text{ FMAX})}$  and peak-to-trough is  $T_{PT} = \frac{1}{(1.4 \text{ FMAX})}$ .

Figure 1 demonstrates the expected improvement in resolution associated with increasing FMAX. We see that when the maximum frequency value is increased while holding the minimum frequency FMIN fixed, sharper temporal wavelets are obtained. Meanwhile, the right side of the figure shows three more temporal wavelets where the FMIN value is changed while holding FMAX fixed. We see that the main lobe shows hardly any change while the side lobes diminish as FMIN is lowered. Thus, filling in the low frequencies gives wavelets with less pronounced side lobe amplitudes. It is attractive because it is smoother, and

with less side lobe energy in the wavelet it is unlikely that a small-amplitude event will be lost amid the side lobes from neighbouring, large-amplitude reflections.

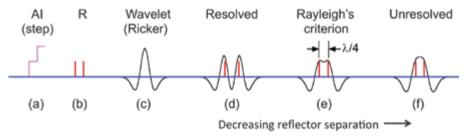
### **Resolution and Wavelength**

The classic definition of resolution, given by the famous geophysicist Bob Sheriff, is the ability to distinguish two features from one another.

The seismic method is limited in its ability to resolve or separate small features that are very close together in the subsurface. The definition of 'small' is governed generally by the seismic wavelength,  $\lambda = v/f$ . Geophysicists can do little about a rock's velocity, but they can change the wavelength by working hard to change the frequency. Reducing the wavelength by increasing the frequency helps to improve both temporal/vertical and spatial/horizontal resolution. Resolution thus comes in two flavours. The temporal resolution refers to the seismic method's ability to distinguish two close seismic events corresponding to different depth levels, and the spatial resolution is concerned with the ability to distinguish and recognise two laterally displaced features as two distinct adjacent events.

Figure 2 depicts two similar layers separated by interfaces. The measurable seismic signals that they produce may show as separate, distinguishable signals when they are well separated – a condition we call 'resolved'. When the interfaces are close together, however, their effects on the seismic signals merge and it is difficult or maybe impossible to tell that two rather than just one interface is present – this condition we call 'unresolved'. The problem of resolution is to determine how to separate resolved from unresolved domains.

Figure 2: Different limits of vertical resolution (d-f, after Kallweit and Wood, 1982; Zeng, 2009) for a step-wise acoustic impedance (AI) profile (a) giving rise to two reflection events R of same polarity (b). Resolution can be increased by increasing the high-frequency content of the seismic wavelet.



The yardstick for seismic resolution is the dominant wavelength  $\lambda$ . A much used definition of 'resolvable limit' is the Rayleigh limit of resolution: the bed thickness must be a quarter of the dominant wavelength. This resolution limit is in agreement with conventional wisdom for seismic data that are recorded in the presence of noise and the consequent broadening of the seismic wavelet during its subsurface journey. The dominant wavelength generally increases with depth because the velocity increases and the higher frequencies are more attenuated than lower frequencies.

The  $\lambda/4$  limit is by many considered the geophysical principle regarding the limiting resolution we can expect in determining how thin we can resolve bedding layers from seismic. However, we might be able to go beyond this limitation by focusing in on frequency's ability to tune in on the layer thickness. For reflectors separated by less than  $\lambda/4$  thickness, the amplitude of the composite reflection depends directly on the thickness of the reflecting layer. This composite amplitude variation can be used for estimating the thickness of arbitrary thin beds.

The stepwise AI profile in Figure 2 represents a somewhat uncommon model for reservoir geophysics. The model of greater interest is the wedge model (*see section below*), which gives reflections of equal amplitude but opposite polarity. In this case  $\lambda/4$  is known as the tuning thickness that corresponds to the maximum composite amplitude.

### Missing Low-Hertz Hurts Interpretation

Wedge modelling is often used to understand the vertical (thin bed) resolution limits of seismic. The wedge model is a high AI layer embedded in a low AI surrounding. As used in Figure 3, it consists of 11 traces, and thickens from 1 ms on the left to 51 ms on the right. Each trace (not shown) contains two reflectivity spikes of equal amplitude but opposite sign. The top spike is located at the top of the wedge. The bottom spike is located at the bottom of the wedge. To investigate the effect of low frequencies in the wavelet, we filter the model traces with impedance wavelets of 2.5–50 Hz



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### Deborah Yedlin, Tuesday, May 7

Herald Business columnist Deborah Yedlin began her career working as an investment banker in 1987, working in New York for Goldman Sachs. Upon completing her MBA in Finance, Deborah continued working in corporate finance, first in Toronto and then in Calgary. Deborah's career in business journalism began in 1996 and has included positions with the Financial Post and the Globe and Mail. Deborah has held her current position as business columnist for the Calgary Herald since April 2007. She is also a weekly business commentator for CBC radio.

In addition to her professional obligations, Deborah is active in the Calgary community, sitting as a director on a number of not-for-profit boards.

Deborah was born and raised in Edmonton, holds an undergraduate degree from the University of Alberta, an MBA from Queen's University and recently completed the Institute of Corporate Directors program through the Haskayne School of Business.

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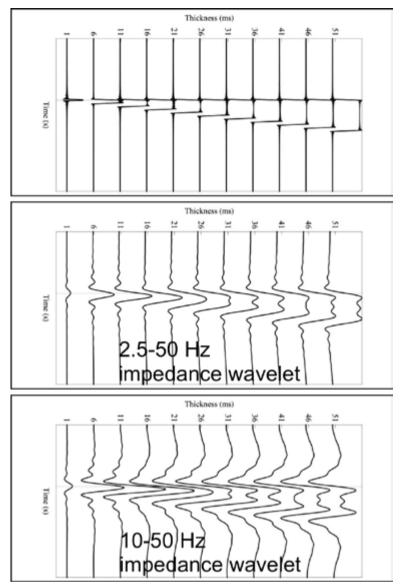


Figure 3: Wedge model (top) and its resolution. Observe that low frequencies in the wavelet reduce significantly the side-lobe effects, improving interpretability.

and 10–50 Hz. Note the side-lobe reduction and improved interpretability of the wedge when low frequencies are filled in. This example is a key result showing the benefit of low frequencies as it nicely illustrates the value for seismic interpretation.

### **Spatial Resolution**

Equally as important as temporal resolution is the issue of spatial resolution. The most common way to discuss spatial resolution is in the context of Fresnel zones. However, that discussion typically deals with resolution before seismic migration – the noble mathematical art of transforming seismic data into a 'true' image of the subsurface. We are interested in resolution after migration. To this end, we follow the method proposed by Berkhout (1984) for quantifying spatial resolution, via the use of the post-migration 'spatial wavelet'. The spatial wavelet is simply the migrated point diffractor's response after bandlimiting the temporal spectrum.

The two key parameters dictating the nature of the spatial wavelet are the temporal bandwidth and the spatial aperture. Figure 4 (top) shows three spatial wavelets for a single point diffractor in a constant-velocity medium. The temporal bandwidths are varied in the same way as in Figure 1, i.e. the maximum frequency value is varied while holding the minimum frequency fixed. As expected, the larger FMAX values yield sharper spatial wavelets. Thus, better temporal resolution also leads to better spatial resolution.

Figure 4 (bottom) shows three more spatial wavelets for the same medium. This time the FMIN value is changed while holding FMAX fixed. Again, the trends are the same as in the temporal case. In other words, the main lobe shows hardly any change while the side lobes diminish as FMIN is lowered. The side lobes are difficult to see in the figure, but a closer

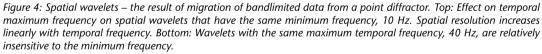
look would reveal that the side lobes diminish with lower FMIN.

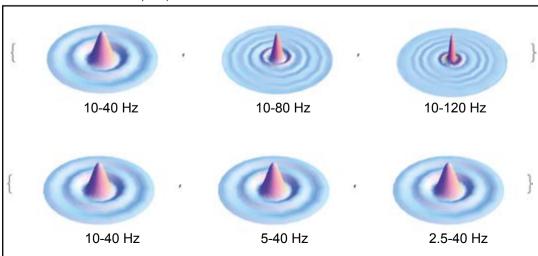
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Perched at the head of the Persian Gulf, Kuwait City has been an important trading post for centuries, but the discovery of oil has brought both immense riches and major trauma

### **ELEANOR ARCHER**

Kuwait City, a gleaming metropolis of designer shopping malls, hotels and restaurants, has evolved dramatically in the last couple of decades. As the capital of the state of Kuwait, it is the heart, limbs and brain of the country, home to 85% of the country's population and containing Kuwait's parliament, most governmental offices and the majority of Kuwait's corporate and bank headquarters.

### Ships, Commerce and Oil

Kuwait takes its name from 'kūt' meaning 'fortress built near water', possibly referring to an earlier fort and military outpost built in 1672 by the Bani Khalid tribe, situated where the city now stands. The area attracted Arab nomads, migrating east in the hot weather, and provided a natural harbour for a port, particularly since the water is relatively deep. Under the rule of the Al-Sabah, from 1756, Kuwait progressively developed as a centre of

trade and commerce, soon becoming a central part of the trade in frankincense from Oman, textiles from China, and Indian spices, all destined for the lucrative European markets. It had one of the largest sea fleets in the Persian Gulf region. Dhows, large wooden ships made from teak wood imported from India and made waterproof with shark oil, became a distinctive part of Kuwait's maritime fleet, and were particularly important in the western Indian Ocean, as their sails took advantage of the monsoon winds. Today, Kuwait still has one of the largest shipping industries in the Persian Gulf region.

The country also had a flourishing pearl industry, employing approximately 15,000 men in 700 boats at the beginning of the twentieth century. Today, annual pearl diving festivals are still held to remind new generations of their past, with young divers trained to



Dhows in Kuwait port in 1911

search for pearls, supported only by a rope around their waist and a friend ready to pull them out when they tug on it. This event is purely ceremonial, as the advent of Japanese artificially-cultured pearl farming in the 1930s caused the Kuwaiti pearling industry to collapse.

Kuwait did not suffer under the financial dip of the declining pearl trade for too long, however, as large oil reserves were discovered soon after by the US-British Kuwait Oil Company. Geological exploration started in Kuwait in 1935, and by 1937, oil shows had been found 42 km from the city, in the Burgan area. In February 1938, at a depth of 1,120 m, the drill hit a high-pressure sand zone in the Middle Cretaceous Burgan Formation, and oil and gas erupted to the surface (see *GEO ExPro*, Vol. 9, No. 1). Subsequent drilling proved the Burgan



anticline structure to be one of the largest oil fields in the Middle East. By 1952, the country had become the largest exporter of oil in the Persian Gulf region.



### **Regional Tensions**

In 1961 Kuwait became independent, joining the Arab League, and ending the British protectorate, which it had entered into in 1899 to help it withstand the Ottoman empire to the north. By the 1970s the government had nationalised the Kuwait Oil Company so that Kuwait became one of the richest countries in the Arabian Peninsula.

Unfortunately, tensions mounted between Kuwait and Iraq in 1990, when Iraq claimed that Kuwait was stealing oil near the border by slant drilling into Iraq's Rumaila field. In August 1990, Iraqi forces invaded Kuwait and seized the city, before annexing the emirate. The Emir of Kuwait, Jaber Al-Ahmad Al-Jaber Al-Sabah, fled into the Saudi desert, while his half-brother, Sheikh Fahad Al-Ahmed Al-Jaber Al-Sabah, was shot, killed and rolled over by a tank by Iraqi forces as he attempted to defend Dasman Palace, the Emiri residence in Kuwait City. More than 1,000 Kuwaiti civilians were killed, and around half of the population, including more than 400,000 Kuwaitis and several thousand foreign nationals, fled the country.

A United States-led coalition of thirty-four nations became involved in 1991, fighting to remove the Iraqi presence from Kuwait City and the state, in what was called 'Operation Desert Storm'. They succeeded in February 1991, but as the Iraqi forces retreated, they set fire to Kuwaiti oil wells, causing about 5 to 6 million barrels of oil to be lost. Oil and soot accumulation affected the entire Persian Gulf, with oil lakes covering about 5% of the land area of Kuwait. The fires took more than nine months for Kuwait to extinguish fully and it was two years before oil output reached pre-invasion level..

### **Extensive Restoration**

The effects of the war on the landscape of the city can still be seen today. During the occupation, the city was extensively damaged and many buildings had to be destroyed after it, including the Kuwait National Museum. Extensive restoration, however, created the city of today, and some of its best features survived the destruction. One of the most prominent landmarks in the country is the Kuwait Towers, built in 1977. A blend of Islamic architecture and modern design, the Towers are the ultimate symbol of Kuwait, looking out over the city, with one eye glancing back to Arabic tradition, and one eye on the blue waters of the Persian Gulf, which have carried, and will continue to carry, the trade that funds this prosperous city.

.....

The Kuwait Towers, a unique blend of traditional minaret and modern architecture, are a symbol of modern Kuwait. Built in 1977 as part of a water distribution project, they also hold a rotating restaurant



# Australia: Expand LNG projects?

Chevron has made two deepwater gas discoveries in the Carnarvon Basin off Western Australia that the company believes have the potential to drive expansions of its Gorgon and Wheatstone LNG projects in the same region. The discoveries are Pinhoe-1, located in 932m of water in the 3,627 km<sup>2</sup> WA-383-P, which local manufacturing, productivity issues and weather-related delays. While encouraging, it could be some time before these latest deepwater finds are absorbed into the infrastructure as output from the first of four LNG trains, due onstream in 2014, is already sold.

encountered around 60m of net gas pay, and Arnhem-1, located in 1,208m of water in the 3,782 km<sup>2</sup> WA-364-P, that confirmed 45.5m of net gas pay. According to Melody Meyer, Chevron Asia Pacific Exploration and Production Company president, "These discoveries in the Exmouth area are significant as they are located farther out from other discoveries in the greater Gorgon and Wheatstone development in the Carnarvon Basin and indicates development potential in the broader region."

Along with a number of other operators off Western Australia, Chevron has had to deal with huge cost blowouts on major LNG projects. In December 2012 the company revealed that costs for the flagship Gorgon project had increased from US\$ 37 billion to US\$ 52 billion. The increases are blamed on the high dollar, union demands, high-cost A tanker loading liquefied natural gas at the Karratha gas plant loading terminal, Western Australia



# Mexico: Biggest Onshore Find in Decade

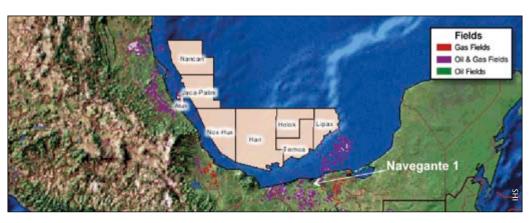
Pemex says it has found oil reserves of up to 500 MMb in southern Mexico with its Navegante-1 wildcat, a Sureste Basin discovery that outgoing President Felipe Calderon hailed as the 'biggest find' of petroleum on land in the past decade.

Located around 20 km from Villahermosa, the capital of the southern state of Tabasco, the well was drilled to a total depth of 6,911m. Tested in the Upper Jurassic between 6,584m and TD, the well flowed 1,770 b/d of 45° API oil and 7.3 MMcfg/d. Future plans include the drilling of two appraisal wells and seismic

when Pemex revealed that its oil production had dipped to its lowest level in three months, with crude falling to 2.54 MMbopd. It will be down to Pemex to provide most of the financing for development, even though the Federal government takes a significant share of its revenue, as there remains a constitutional ban on private companies holding exploration and production concessions. However, the inauguration of a new president on 1 December 2012 could lead to reform, but the issue is very politically sensitive.

acquisition that will help determine if the reservoir extends southwards as far as the Antonio Bermudez complex, located in the Tabasco-Chiapas region of southern Mexico, which has between 700 and 1,000 MMboe reserves and is the largest crude producer in southern Mexico.

The significance of the discovery was underlined



**KEN WHITE** 

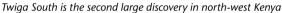
# Kenya: Discovery in Block 13T

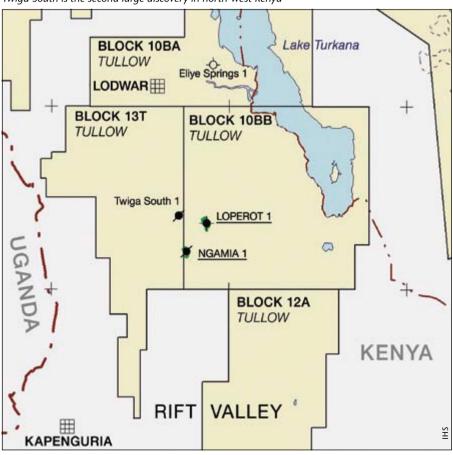
Only the second prospect to be tested in the onshore north-west Kenyan Lokichar Trough as part of Tullow Oil's multi-well drilling campaign in Kenya and Ethiopia, the Twiga South-1 wildcat is the first oil discovery in the 8,429 km<sup>2</sup> Block 13T in Kenya. Further up dip potential exists that Tullow plans to appraise but the result has derisked a number of other similar features on the western margin of the basin.

Drilled in late 2012 to a total depth of 3,250m, the well found three sandstone reservoir zones, which are analogous to the untested Ngamia-1 discovery around 22 km south-west in Block 10BB, and found good quality 30° API oil. It is understood that five tests are planned. In addition to the 30m of net oil pay, the well penetrated a thick section of tight fractured rock below 2,272m which had extensive hydrocarbon shows over a gross interval of 796m. This tight fractured rock section is a new play-type for the region that will require further evaluation to understand its extent and any productive potential. Tullow has a 50% operated interest in the Twiga South-1 well, with Africa Oil holding the remaining 50% interest.

Following completion of the testing programme, the Weatherford '804' rig will move back to flow test Ngamia-1, which has 100m of net pay in a gross oil-bearing interval of 775m in the Upper Lokhone/Auwerwer Sandstone. The well also found an additional 43m of potential oil pay over a gross interval of 175m in the Lower Lokhone Sandstone.

The government remains cautiously optimistic that a commercial discovery has been made and that Kenya is on the road to being an oil producer.





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# Thirteen Years in the Life of a Super-Major

### *Private Empire: ExxonMobil and American Power,* winner of the Financial Times Book of the Year 2012

In a rare, candid interview with a Wall Street oil analyst, Lee Raymond, CEO of ExxonMobil from 1999 to 2005, was asked what was the one issue that kept him awake at night. His reply was 'reserve replacement'. Steve Coll's detailed roll through the corporation's last 13 years is the story of the quest, common to all super majors, to satisfy shareholders by replacing stocks annually. For ExxonMobil, that is a billion barrels a year. As Coll explains, it is like asking the airline industry to fly higher and faster year-on-year, a drive that has led Exxon into danger spots the world over - Aceh in Sumatra, Nigeria, Chad, Equatorial Guinea, the Arctic and Iraq.

## Corporate Culture with a 'Military Flavour'

It has also led ExxonMobil, the world's most profitable corporation, to develop a unique corporate culture. Headquartered in Dallas, not Manhattan, Lee 'Iron Ass' Raymond promoted a pro-Christian, pro-marriage, insular and arrogant corporate ethos. From defying the Securities Exchange Commission on reserve reporting to appealing every claim for punitive damages made against the company, to choosing when and where to call on - or dispense with - the 'advocacy' services of the US government. Exxon has stood alone. doing what it does best, contributing an extraordinary \$493 billion net cash flow to the US between 1999 and 2011. Whatever the revelation – tortured bodies within its compound in Aceh, a drunk captain in charge of the Exxon Valdez, an extraordinary set of payments to the Equatorial Guinean ruling family – Exxon has marched on, apparently impervious.

In 2010 the corporation faced its

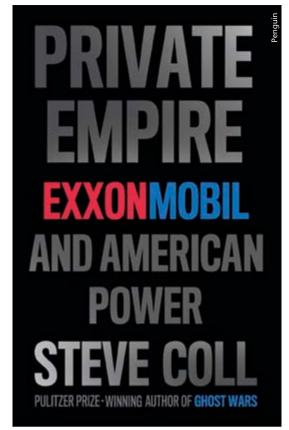
biggest threat: it was set to replace only an astonishingly low 45% of its oil and gas reserves, a rate that, as Coll points out, would lead to liquidation if it continued. As with all the super-majors, Exxon had missed the one boom that came with watertight contracts and stable government – the US 'shale revolution'. Fixated on the industry's own measure

of efficiency – Return on Capital Employed (ROCE) – a measure first adopted by Raymond and foisted on Exxon's competitors, the boards of the super-majors had kept their eyes firmly focused on the mega-reserves of the Arctic, Saudi Arabia, Kurdistan and Brazil, while neglecting home territory.

In 2010, CEO Rex Tillerson, who followed Raymond as CEO, finally moved to buy the successful shale company XTO for a staggering \$41 billion, bumping its reserve replacement back up to a healthy 209%. It was an acquisition made at the top of the market, which has been followed by a slump in US oil and gas prices, leading Tillerson to recently comment, "We are all losing our shirts over shale gas." Should Steve Coll feel like writing a sequel in ten years' time, it will be sure to make interesting reading.

### The Climate Change Challenge

With Tillerson as CEO, Exxon has moved – incrementally, and without admitting any previous wrong-doing – to improve its corporate image, most notably on climate change. Exxon has slid subtly from a position of absolute denial to one of 'insurance'. From having financed scientists and lawyers whose purpose



was to obstruct opponents as well as pressure groups, academics and front organisations - including one set up specifically to demand investigations into Greenpeace's tax affairs – Exxon has surprised the US public and government by recently advocating a straightforward carbon tax. As Coll speculates, this may simply be a reflection of Exxon's confidence that such a tax will never happen in the US and is therefore a surefire bet. But, as the author explains, it also reflects the industry's awareness of the travails of the tobacco industry, and the genuine fear that one day Big Oil may be similarly accused of deliberately withholding or manipulating evidence.

For anybody who wants to understand how the industry thinks and functions, Coll's book is a highly readable though confusingly structured encyclopaedia. It is full of insights and nitty-gritty detail, told with much drama but enough broad-brush strokes to give a clear and convincing narrative of an iconic corporation in challenging times.

### **NIKKI JONES**

Private Empire: ExxonMobil and American Power by Steve Coll. Penguin Press HC, 2012





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**PES** GB Stoneley Lecture Series The PESGB are proud to announce the next lecture and date to continue our Stoneley Lecture Series in memory of Professor Robert Stoneley.



### Geology and Me Hugh Dennis

"Comedian and geology enthusiast"

Tuesday 12 March 2013 Central Hall, Westminster, London

PESGB is pleased to announce that the speaker for the next Stoneley Lecture on 12th March 2013 will be well known comedian, actor and presenter Hugh Dennis.

While best known for Mock the Week, The Now Show and Outnumbered, Hugh is passionate about the outdoors and recently presented a BBC TV series entitled The Great British Countryside which examined the relationship of geology to the landscape and the industrial past. He says he is never happier than when at the top of a hill in the rain, looking at the landscape stretching away to the horizon.

Please put this date in your diary, and as the Stoneley Lecture is very much a public event, please invite your friends, family and work colleagues to attend.

Petroleum Exploration Society of Great Britain, 5th Floor, 9 Berkeley Street, London, W1J 8DW Tel: +44 (0)20 7408 2000 Fax: +44 (0)20 7408 2050 Web: www.peseb.org.uk & Email: peseb@peseb.org.uk

# Leading a Global Organisation

As President of the American Association of Petroleum Geologists (AAPG) **Ted Beaumont** is in a good position to review the industry in 2012 and to take a look ahead to 2013

## What do you think were the most exciting developments in the industry in 2012?

To me, the most exciting development is realising the economic impact that unconventional plays are having on US energy supply and the economy. Since April, I have been hearing that the US could potentially be energy independent in 10 years or so. Statements like that would have seemed ludicrous just five years ago. When I started in the industry in 1976, I remember hearing the president of a major US oil company say that he believed that the US had very little oil and gas left to find and develop. So it is remarkable to me, 37 years later, to hear knowledgeable people say that the US could be energy independent in just a few years.

### Any big surprises – good or bad?

I am kind of surprised by the strong negative reaction the public has had to hydraulic fracturing of reservoirs despite the overwhelming evidence that it can be performed in an environmentally safe manner. Hydraulic fracture stimulation is the key to unlocking reservoirs that are otherwise uneconomic. Obviously, we in the industry need to do a better job talking to the public about the actual mechanics of hydraulic fracturing, as well as reminding them about the enormous energy potential that we have thanks directly to that technology.

### What were the strongest areas for exploration in 2012?

My view is very parochial since I have spent my entire career exploring US basins. Here, the unconventional play dominates exploration. The strongest areas for exploration are those that have oil or wet gas unconventional reservoirs. Specifically, they are the Bakken Formation in the Williston Basin of North Dakota and Montana; the Eagle Ford Shale of south Texas; and the tight oil plays in the Permian Basin of west Texas.

## Any thoughts on 2013? Where do you expect expansion and where retrenchment?

It will be interesting to see where unconventional plays develop in non-US basins like the Vaca Muerta Formation in the Neuquen Basin of Argentina. Unfortunately, that play is currently plaqued by politics. The La Luna Shale in Colombia's Middle Magdalena Basin could see some drilling next year and the Llanos Basin has seen a lot of activity due to favourable terms from Colombia's government. It has an abundance of small but attractive conventional targets. In the UK, the organically rich Bowland Shale in the Bowland Basin, east of Blackpool, has attracted some attention. One recent shallow well here discovered gas but further development has been delayed by a couple of minor tremors and concerns that they were caused by hydraulic fracture stimulation. Maybe 2013 will see some new wells in the Bowland. The Arctic has incredible potential for conventional large fields but also has unconventional environmental problems. It is an expensive place to operate and is faced with daunting technological challenges. Eventually, the industry will overcome the challenges.

## How are you enjoying being President of AAPG?

I am having a fabulous time. It has been gratifying to travel outside the US and see how much AAPG is growing. This probably is due in part to our efforts as an association to provide the scientific support that can help professionals to better explore for or develop energy resources wherever they are found, and also in part to the growing demand for energy in all parts of the world. Counting the US, AAPG has offices in five different countries and 40% of our



Ted Beaumont is an independent consulting geologist. He has been active in the AAPG since joining it in 1974, and in 1992 he was awarded the AAPG Distinguished Service Award and AAPG Certificate of Merit.

members live outside the US. In the near future AAPG may need to consider a name change to more accurately reflect the make-up of its membership.

### What is the most exciting thing to have happened to you in your Presidency?

Meeting student members from all over Indonesia and Malaysia who were attending the AAPG International Conference and Exposition in Singapore. Some of them wore shirts with AAPG patches and their name embroidered over the pocket. I could look into their eyes and sense their enthusiasm about their future careers in the petroleum industry. It made me realise how big AAPG has become and how much our profession is changing. And by the way, I think the influx of these younger geologists will result in a significant, positive dynamic for the industry. The next generation of geologists strikes me as being very intelligent, very committed and very passionate about their careers. And I've seen this excitement among geologists from all corners of the world. It is a global professional organisation that I am very humbled and honoured to lead this year.

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## Burma: Bid Rounds Both Onshore and Offshore

### A long established petroleum country moves back into the limelight

### SHANKAR KRISHNAN DrillingInfo

Myanmar, or Burma as it was previously known, is a south-east Asian country covering a total land area of approximately 678,500 km<sup>2</sup> flanked by India and Bangladesh to the west, Thailand to the east and China to the north.

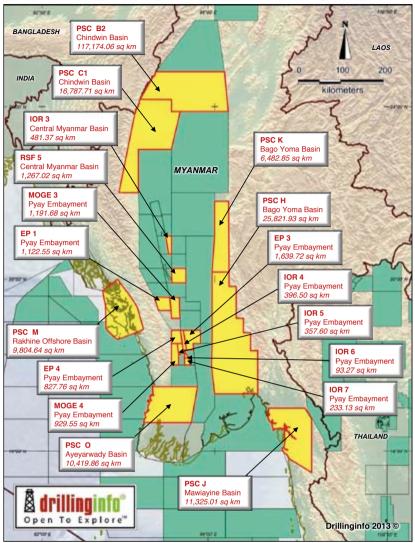
Oil and gas production in the country dates back hundreds of years, with the first onshore hydrocarbon discoveries made in the late 19th century. The modern petroleum industry was established during Britain's colonial administration of the country. The national oil company Myanma Oil and Gas Enterprise (MOGE) was established in 1985 and is responsible for issuing oil and gas licences in Myanmar. The country is tentatively emerging from its previous authoritative regime to one that is attempting to embrace transparency and the democratic ideal, although the new government remains militarybacked, with an ex-general as president.

### **Onshore Blocks Available**

After a successful bid round that opened on 8 July 2011 and which led to the award of 10 PSCs announced on 23 August 2011, the 2013 bid round announcement sees 18 onshore blocks up for bidding. The list, which was announced on 17

January 2013, includes the 16,828 km<sup>2</sup> PSC C1 that had been relinquished by then operator China National Offshore Oil Corp (CNOOC) in August 2012. It also includes two blocks, PSC O in the Ayeyarwady Delta and MOGE 4 in the Pyay Embayment, which have been pre-awarded, the latter to Nobel Oil.

The offshore offering, however, has already been postponed twice to an indefinite date in 2013 and the latest news is that MOGE is preparing for the release of offshore blocks without committing to any timeframe. Some operators have relinquished areas of low prospectivity, and MOGE has also been targeting those who had not fulfilled their commitments in the offshore areas through 2012, probably in anticipation of the release of these as part of the 2013 offshore bid round, in addition to offering frontier areas in the Bay of Bengal. The International Tribunal for the Law of the Sea had issued its verdict on the dispute over the territorial water boundaries between Myanmar and Bangladesh on 14 March 2012, paving the way for potentially more deepwater frontier offshore areas to be announced as part of the 2013 offshore bid round. The



A total of 18 blocks are available onshore Myanmar

offshore situation is being watched by the larger players in the industry as these blocks offer higher return on investments albeit with greater risks involved.

### **Potential Boom?**

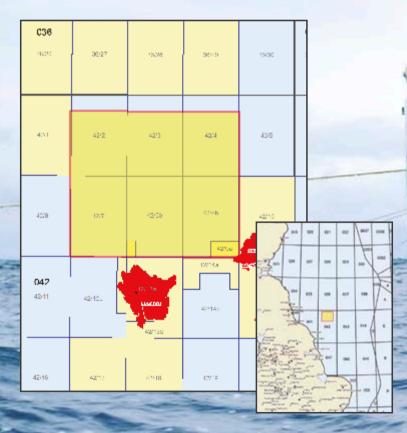
With the official lifting of Myanmar's ban on international trade and investments in May 2012, the prospect of a boom in foreign involvement in the once isolated and impoverished country is gaining momentum. In 2012, farm-in activity was noted to be picking up in the offshore areas, with French giant Total teaming up with Japanese partner JX Nippon to farm-in to the 5,373 km<sup>2</sup> offshore Block M-11 located in the Moattama Basin. Australian operator Woodside farmed-in to two blocks in 2012, deepwater AD-7 located in the Bengal Basin and Block A-6 situated in the Rakhine Basin. It may be construed that the country is taking positive steps to veer sharply from its past 'modus operandi', but the disadvantages of operating in Myanmar include high political risk, low transparency rules and procedures – and rife corruption.

## UK Q42 North Breagh Multi-Client 3D Data

Polarcus has acquired 1,295 sq. km of high density broadband 3D multi-client seismic data to the north of the Breagh field in the UK Southern North Sea. This Polarcus RightPlan<sup>™</sup> survey combines the ultra-quiet Sentinel<sup>®</sup> solid streamers towed at depth with GXT's WiBand<sup>™</sup> processing technology. Final data products will be available in Q2 2013.

For further information contact:

John Balch john.balch@polarcus.com +44 7554 444822 Elwyn Jones elwyn.jones@geopartnersltd.com +44 1342 870761





### CONVERSION FACTORS

Crude oil 1 m<sup>3</sup> = 6.29 barrels 1 barrel = 0.159 m<sup>3</sup> 1 tonne = 7.49 barrels

Natural gas 1 m<sup>3</sup> = 35.3 ft<sup>3</sup> 1 ft<sup>3</sup> = 0.028 m<sup>3</sup>

#### Energy

1000 m<sup>3</sup> gas = 1 m<sup>3</sup> o.e 1 tonne NGL = 1.9 m<sup>3</sup> o.e.

### Numbers

 $\begin{aligned} \text{Million} &= 1 \times 10^6\\ \text{Billion} &= 1 \times 10^9\\ \text{Trillion} &= 1 \times 10^{12} \end{aligned}$ 

### Supergiant field

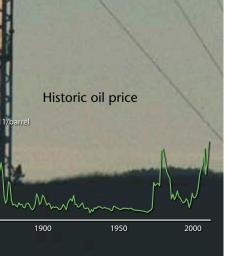
Recoverable reserves > 5 billion barrels (800 million Sm<sup>3</sup>) of oil equivalents

### Giant field

Recoverable reserves > 500 million barrels (80 million Sm<sup>3</sup>) of oil equivalents

#### Major field

Recoverable reserves > 100 million barrels (16 million Sm<sup>3</sup>) of oil equivalents



1861

## Highly Dependent on Oil Revenues

Algeria, recently in the news because of a terrorist attack, is one of Africa's leading oil and gas producing countries.



Algeria, with a current population of 36 million, has been an oil producing country since 1958. This was made possible by two commercial discoveries in 1956, Edjelleh and Hassi Messaoud, the latter being Algeria's largest oilfield, producing more than 400,000 bopd. The main areas of exploration for oil and gas are in the east, on the border of Tunisia and Libya, and the central area – where large gas discoveries have been made.

Algeria's production in 2011 was 1.7 MMbo and 7.5 Bcfg per day and the country consumed an average of 345 Mbpd in the same year.

Although Algeria is one of the major oil and gas producing countries of Africa, it is still considered to be relatively under-explored. Oil reserves totalled 12 Bbo at the end of 2011, according to the *BP Statistical Review of World Energy*, while gas reserves reached 159 Tcf (4.5 Tcm). With respect to oil reserves, Algeria ranks as fourth in Africa, behind Libya (47 Bbo), Sudan and Angola. With respect to gas, it ranks second, with Nigeria in the lead.

The country achieved political independence in 1962 after more than a century of colonial rule by France. Algeria's struggle for independence is said to be one of the most bitter in Africa's colonial history.

Algeria has experienced a significant economic upturn in recent years, in large part aided by strong oil and natural gas export revenues. The hydrocarbons sector is thus the backbone of the economy, accounting for roughly 60% of budget revenues, 30% of the gross domestic product, and more than 95% of export earnings. The country's other natural resources come from the mining industry and include iron ore, phosphates, uranium and lead.

According to BP, **In Amenas** is one of the largest wet gas projects in the country and involves the development and production of natural gas and gas liquids from wet gas fields in the Illizi Basin of south-eastern Algeria. It is a gas and condensate development project centred on four fields located in eastern Algeria some 1,200 km from the coast towards the Libyan border. The project came on stream in 2006.

The Algerian national oil company is Sonatrach (Entreprise Nationale Sonatrach) and it plays a key role in both upstream and downstream oil and gas industries. It is responsible for exploration and production, transport, refining, processing, marketing and distribution. Through its subsidiaries, the company has a domestic monopoly on oil production, refining and transportation.

### HALFDAN CARSTENS

The In Amenas gas compression plant in Algeria started operations in 2006. About 35 Bcf (9 Bcm) of gas are being produced per year from Ordovician sedimentary rocks in the Illizi Basin. BP, Statoil and Sonatrach have a joint operatorship of the field.



"Significant discoveries in Mozambique and Tanzania"

### "Successful presalt well offshore Angola"

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