VOL. 8, NO. 2 – 2011

GEO ExPro

GEOSCIENCE & TECHNOLOGY EXPLAINED

Ida Tarbell and the Standard Oil Company Story

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EXPLORATION

New Zealand's Underexplored Potential

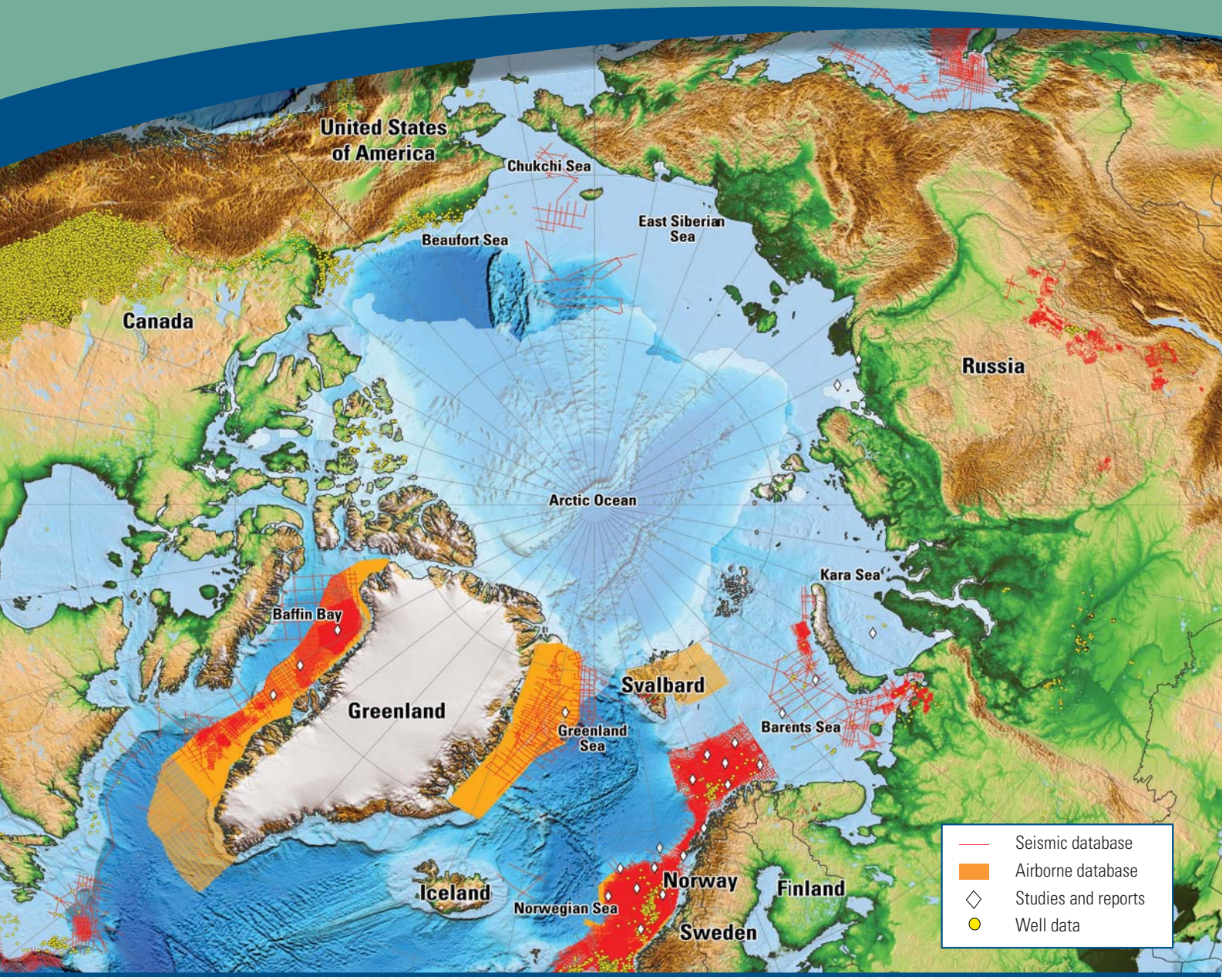
HISTORY OF OIL

Alaska: The Start of Something Big

TECHNOLOGY

Is Onshore Exploration Lagging Behind?

Explore the Arctic



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Eldad Weiss has grown his business from a niche provider of graphical imaging software to a global provider of E&P data management solutions.

The Canadian Atlantic basins extend over 3,000 km from southern Nova Scotia, around Newfoundland to northern Labrador and contain major oil and gas fields, but remain a true exploration frontier.

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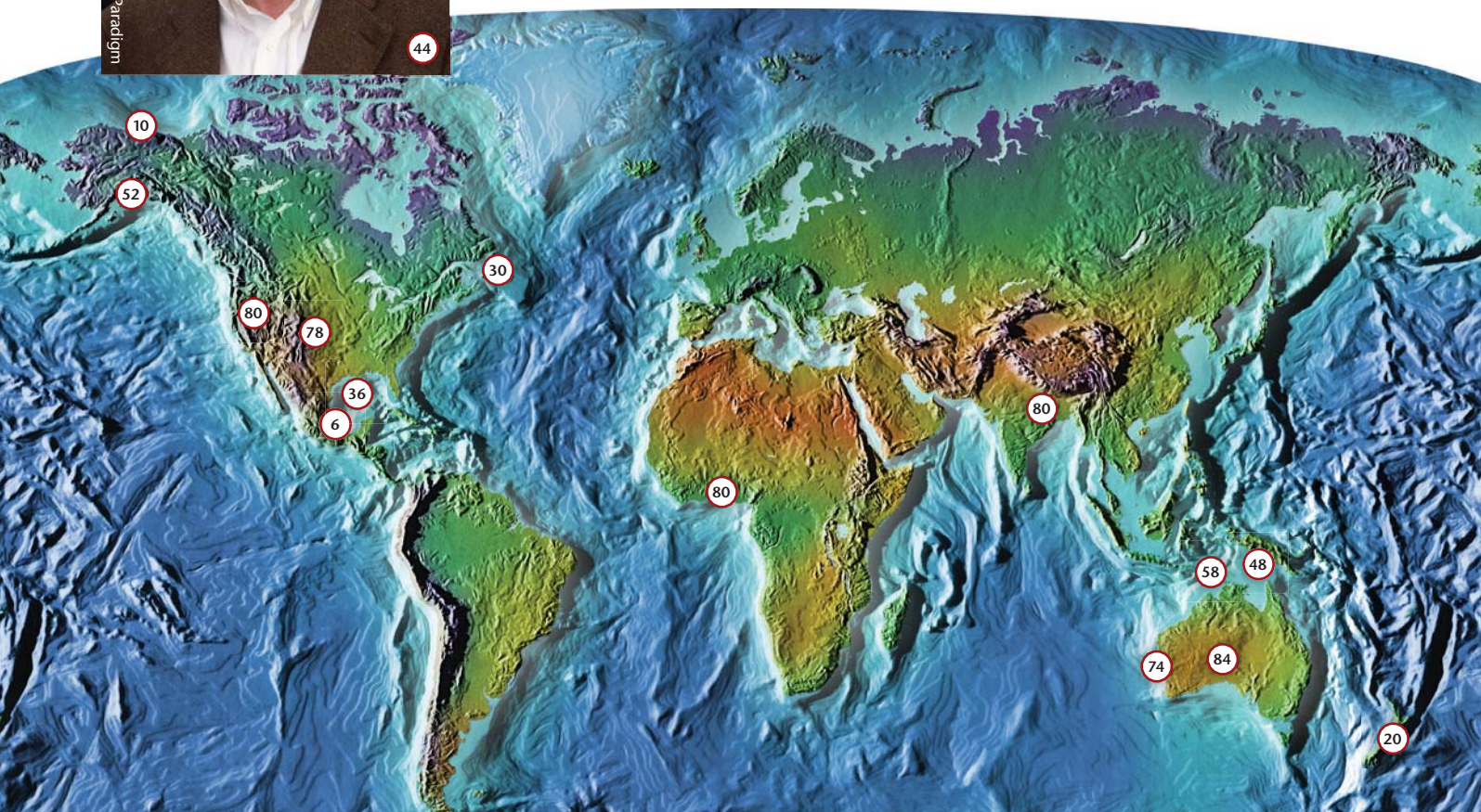

Exploration creativity

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Looking for Opportunities

The price of oil is soaring relentlessly upwards, in the wake of upheaval in the Middle East and worry about the security of oil supplies. At the centre of the upheavals is Libya, possessing the highest reserve volumes in Africa, although only producing about 1.65 million barrels of oil a day, well below the output of Nigeria and Angola.* Saudi Arabia has promised to meet any shortfall, but is also trying to satisfy OPEC while ensuring that domestic dissatisfaction in the Kingdom is minimised. And the opinion of experts is that this disturbance is not a short term phenomenon, but that the effects will be felt for a number of years to come. Some analysts have predicted that oil could rise as high as US $220 a barrel, which would have a huge impact throughout the world, but particularly in developing countries not blessed with large reserves of hydrocarbons.

Fuel prices are expected to continue rising

But, as with most things, one man's misfortune is another's opportunity. The knock-on effect of the global turmoil on the upstream oil and gas industry should mean greater concentration on finding new resources. Companies will have to 'think outside the box' and consider fresh frontier areas, deeper waters and yet more inhospitable terrain in order to keep the resource numbers up. Shale gas – a revolutionary idea to many only a few years ago – is now almost mainstream, at least in the USA and Canada. More and more countries are searching for that resource, with the first Asian shale gas discovery announced recently. Maybe price increases could result in opportunities for further research into the extraction of shale oil, or perhaps some of the frontier areas discussed in this edition of GeoExpro, like the 'underwater continent' of New Zealand, may yield results.

Technology will also need to keep pace, as exploring in these challenging environments for hard-to-win hydrocarbons will require all the ingenuity and inventiveness of our finest geophysicists, technologists and engineers.

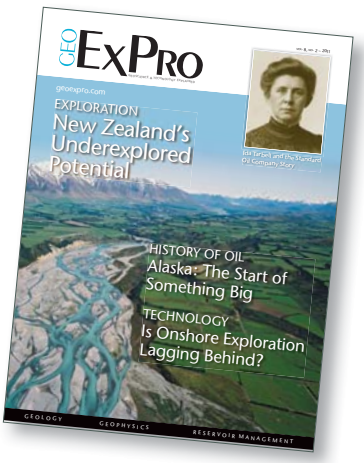
However, according to the latest Barclays Capital Original spending survey, there should be more money available to follow these ideas, as budgets for global E&P expenditure are forecast to increase by nearly 11% in 2011. In fact spending by some of the supermajors is anticipated to increase by 17% per annum, having remained almost unchanged since 2009. So maybe not all gloom and doom – at least not for everyone.

* *BP Statistical Review of World Energy 2010*

JANE WHALEY
Editor-in-Chief

UNDEVELOPED POTENTIAL

The vast offshore Canterbury Basin of New Zealand extends onshore beneath the Canterbury Plains to the foothills of the Southern Alps. The large braided systems of the Rakaia River, South Island, New Zealand are modern day analogues for many of the world's largest oil and gas fields.



Inset: Ida Tarbell was a revolutionary investigative journalist, responsible in no small part for the legal break-up 100 years ago of the Standard Oil Company's hold on the US oil industry.

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GEO ExPro is published bi-monthly for a base subscription rate of GBP 60 a year (6 issues). We encourage readers to alert us to news for possible publication and to submit articles for publication.

Cover Illustration:
Lloyd Homer, GNS Science
Inset: J.E. Purdy Co., Boston (Wikipedia)

Layout: Bookcraft Ltd.
Print: NXT Oslo Reklamebyrå

issn 1744-8743

Southern Gulf of Mexico

Can exploration in the Southern Gulf reverse Mexico's declining oil revenues?

The Mexican oil industry is now in its seventh consecutive year of decline. To energize the industry there, in 2008 the Mexican Congress approved reforms that will eventually allow some participation by private international firms for the first time since nationalization of the oil industry in 1935. The measures included several administrative changes, with the creation of a new advisory board to provide independent coordination of long-term energy strategy, and the establishment of a new hydrocarbons agency to regulate the sector. Pemex was allowed more autonomy, so it can form service contracts with private companies and be more flexible in its procurement mechanisms.

Since the 2008 reforms, Petroleos Mexicanos (Pemex) has expanded exploration programs in the Gulf of Mexico offshore Campeche, in the south-eastern Gulf of Mexico. These are beginning to yield significant results, with several major oil and gas discoveries. It has also started an ambitious exploration program in the deep Gulf of Mexico waters to replace production for the declining supergiant Cantarell Field. Discovered in the 1970s and at that time the world's third largest oil field, Cantarell now produces 70% less than its 2004 peak. Pemex has touted that its deep waters hold massive potential reserves (exceeding 30 Bbo) that will require new technology to explore and produce. It now has a new deepwater rig to explore that region – and there is plenty of room to drill. The Mexican deepwater portion of the Gulf of Mexico has been penetrated by less than 20 wells, in an area that Pemex estimates will hold 56% of their total potential remaining resources.

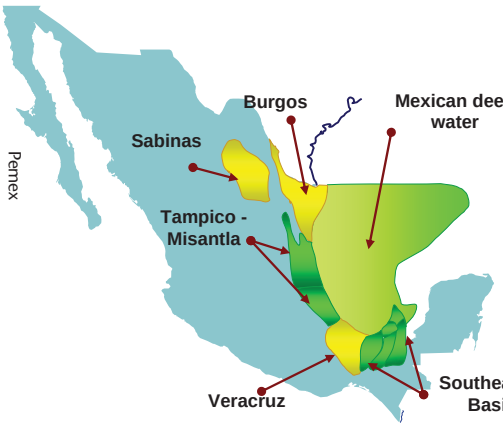
Since the start of their deepwater exploration campaign, fourteen new wells have been drilled, with eight of them finding hydrocarbons. The latest was the Labay well, which found more gas, close to the 2006 Lakach gas discovery. Antonio Escalera, exploration manager for Pemex, said "We have identified 2.4 Tcf of gas reserves and we believe the potential of the area could be as high as 15 Tcf of natural gas." A second well is planned at the Lakach find to evaluate the size of the field.

However, finding more gas will not fix Mexico's falling oil revenues and, thus far, the deepwater oil exploration has not paid off. Drilled in 831m water depth, the Leek well discovered condensate and gas in 2009 and has been the only bright spot in the search for oil. However, with the new deepwater rig, much more exploration of the area is planned. The first use will be on the Tulipau-1 prospect in 700m water depth and it will subsequently drill the Maximino prospect at a 2,900m water depth.

Pemex has also made a strategic shift to take a second look at its shallow waters.

Drilling a new trend in the shallow waters off Campeche led to the Tsimin Field discovery in 2008. More drilling has resulted in finding more reserves along the trend. The Xux discovery followed Tsimin and the two new fields are believed to hold 1.5 to 2.0 Bbo oil reserves, which would account for more than ten percent of Mexico's total proven oil reserves, which in January 2010 stood at 10.4 Bbo, according to the EIA. The crude for the two fields is light and very high quality, contrasting to the heavy oils pumped from the other big fields in the Gulf. With other prospects nearby, Pemex is optimistic that the trend may extend to the shoreline. Development is being fast tracked with the construction of two production platforms this year and oil is expected to start flowing at 150,000 bopd in about two years.

THOMAS SMITH



Six main geological basins are the current focus of exploration efforts by Pemex, with in particular a structured and strategic program to locate new reserves in the Southern Deepwater Gulf of Mexico.

ABBREVIATIONS

Numbers
(U.S. and scientific community)

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

Liquids

barrel = bbl = 159 litre

boe:	barrels of oil equivalent
bopd:	barrels (bbls) of oil per day
bcpd:	bbls of condensate per day
bwpd:	bbls of water per day

Gas

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

Ma: Million years ago

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

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

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

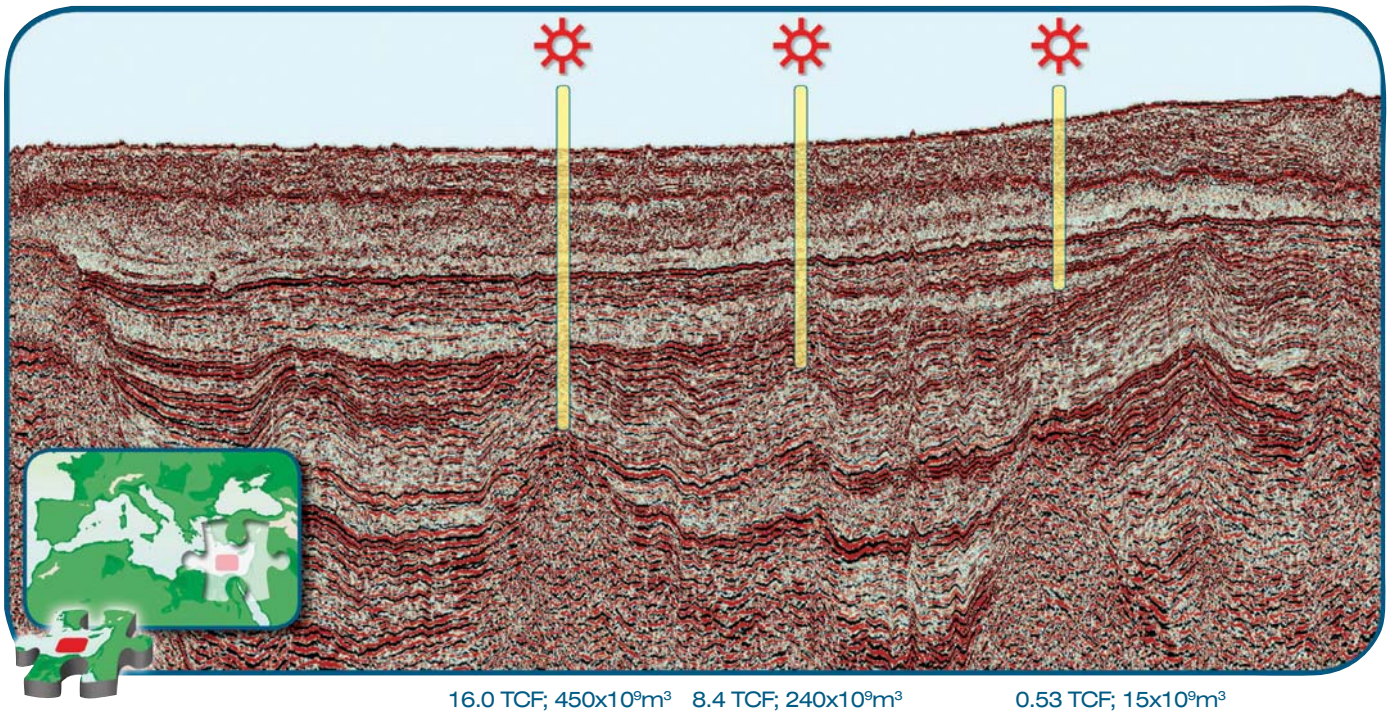
P2 reserves:
Quantity of hydrocarbons believed recoverable with a 50% probability

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

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

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

...three world class gas discoveries.



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

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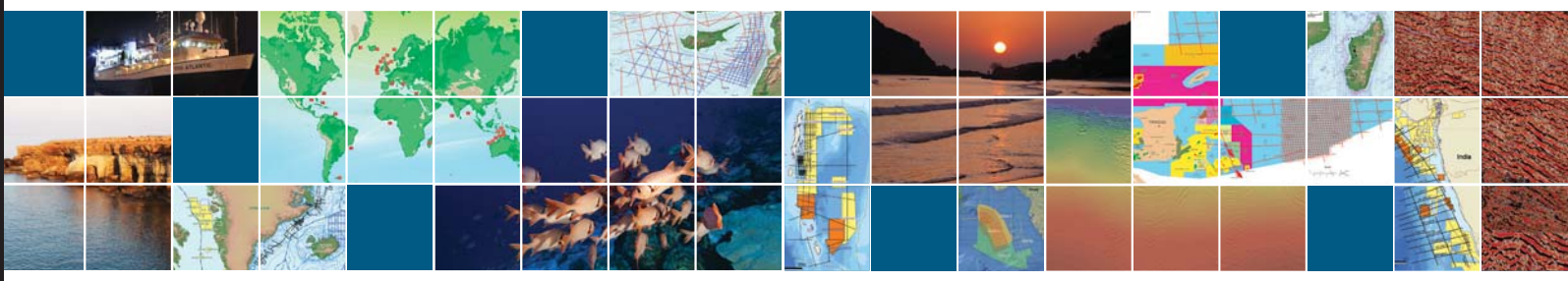

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First Arctic Technology Conference Exceeds Expectations

Recognizing the large, and largely unexplored, hydrocarbon resources lying within the Arctic Circle, the organizers of the Offshore Technology Conference (OTC) held their inaugural Arctic Technology Conference (ATC) in Houston. Over the course of three days in early February, the ATC brought together more than 1,200 attendees representing operating companies, service providers and consultants to discuss the potential and pitfalls in operating in the Arctic.

"I was pleasantly surprised by the number of attendees from around the world, as well as the amount of interest and momentum being created by this event," said Pierre-Alain Delaittre, Global Consultant with Total's Technology Specialists group and Chair of the Arctic Technology Conference program.

Setting the Stage

At the conference's opening plenary, Susan Cunningham, Chair of the OTC Board of Directors, reminded attendees of the size of the prize in the Arctic. She quoted a US Geological Survey study from 2008, which estimates that the Arctic region contains 90 Bb of oil, nearly 1,700 Tcf of natural gas and 44 Bb of natural gas liquids, the vast majority of which (84%) is expected to occur in offshore areas.

Exploiting these resources will require the industry to more effectively demonstrate the lasting economic benefit that it can provide local communities, according to Mark Shrimpton, Senior Associate with Stantec Consulting. He said that although last year's events in the Gulf of Mexico flared up negative attitudes toward the industry, these can be overcome with a sustainable development strategy that incorporates the economic aspirations of the local communities, something that has been done successfully in his province of Newfoundland.

"I appreciated his comments, as it reminded the audience that the development of fossil fuels is good news for local communities, provided that we conduct our activities in an environmentally sustainable way," said Delaittre. "This is true wherever the industry works, but there are special sensitivities in the Arctic."

Operator Opinions

In well-attended topical luncheons, some of the operators most heavily invested in Arctic E&P shared the technical, economic and political challenges that await companies in the Arctic, and how they are addressing them.

Susan Cunningham, Senior Vice-President of Exploration with Noble Energy and Chair of OTC, which organized the Arctic Technology Conference.

Michael Borrell, Senior Vice President of Eastern Europe for Total, reviewed his company's more than 40 years of operating experience in extreme-cold climates, and highlighted the progress of developing projects that push the envelope of what is technically feasible. Chief among these is the Shtokman gas field, located in the Russian zone of the Barents Sea and subject to harsh metocean conditions, ambient temperatures of -50°C and risks that the floating production unit (FPU) may get trapped in 2m thick ice every few years.

As with all of its Arctic developments, Total is partnering with other companies for Shtokman (Gazprom and Statoil), thus sharing the risks and rewards in developing the proposed 25 year, 149 Bbo (23.7 Bcm) per year project. It is also investing in an R&D program emphasizing health and safety, engineering and technology, the environment and standards harmonization.

David Lawrence, Executive Vice President, Exploration and Commercial for Shell Upstream Americas, stated that with an estimated 30 Bboe in Arctic Alaska alone, and "because the timeline to development will be measured in years and decades, the US needs to get moving." Lawrence listed several enablers for success in developing Arctic assets, including clear and concise regulations coupled with a supportive government, inclusive international cooperation, greater public involvement and early engagement from all stakeholders.

Technology was a major focus of the conference, both in the exhibit hall and in the technical sessions that featured more than 130 oral presentations on topics ranging from pipelines and vessels to exploration drilling, geohazards and ice management.

"The technological developments aimed at winterizing equipment and facilities have made significant progress and will continue to do so, but the areas in which I have seen significant progress include drilling and autonomous underwater vehicles," said Delaittre. "These will be vitally important in building subsea infrastructure in offshore Arctic fields."

Optimistic Outlook, Economic Reality

Delaittre was heartened to hear a sense of optimism regarding the industry's preparedness for Arctic exploration. "Globally, the different parties – geoscientists, drillers, developers and producers – feel ready to go from a technology standpoint," he said. "What seems to be putting the brakes on further development is economics. As with other technically challenging regions in our industry's past, the price of oil is governing the pace of development in the Arctic."

It is also generally accepted that many of these projects will be more expensive than projects in less harsh areas, due partly to shorter weather windows that limit offshore seismic shooting seasons, drilling activities and transportation and shipping routes.

However, it is equally accepted that further collaboration between all sectors of the Arctic exploration and production community is vital to overcoming hurdles. "While collaboration has always been important in our industry, the unique challenges confronting us in the Arctic will make the need for technical, financial and logistical cooperation even more important. I was encouraged to see new collaborative relationships beginning amongst attendees at the ATC, which is certainly an important function of any conference."

TED MOON

Game Changer for Alaska's North Slope

Great Bear Petroleum recently leased over 2,000 km^2 south of the Prudhoe Bay field to test what could become one of the world's largest continuous oil and gas plays.

In October, 2010, as part of Alaska's yearly leasing program, Great Bear Petroleum bid on 105 tracts in the North Slope Areawide lease sale. They won all 105 tracts for a little over eight million dollars, covering a broad area located directly south of the existing Kuparuk and Prudhoe Bay oil fields. In doing so, Great Bear has become one of the state's largest lease holders at 500,000 acres (2,000 km^2), the most any one company can own under Alaska's leasing regulations.

"My phone literally rang off the hook," says Ed Duncan, COO of Great Bear Petroleum of Austin, Texas, just after the lease sale. "People were telling me, 'why didn't I think of that'. The response from our industry colleagues has been tremendous and gratifying at the same time."

"We looked globally at source rocks for oil and gas development. The Brookian Foredeep of the North Alaska has some of the richest source rocks in the world and quickly became our focus," Ed Duncan continues. "The primary source rock in the onshore Gulf Coast is the Eagle Ford Shale (*GEO ExPro* Vol. 7, No. 4) that started out as a shale-gas play and has become a very hot oil play. New and still unfolding technology has made production from very tight shale formations possible. When we found out we had this technology already in place and being used on the North Slope, we had the confidence that we could address the operational challenges."

"Our leasing was targeted based on a solid understanding of source rock distribution, thermal maturity and operational achievability."

"Exploration on the North Slope had gotten very myopic over the last twenty-five years, concentrating on and around the existing fields on conventional plays," says Mr. Duncan. "I worked at BP looking at new ventures and then in the late 1990s consulted on the exploration of unconventional plays. I had also worked the North Slope of Alaska and studied the organic shales that were the sources for much of the oil found along the Barrow high. Some of these organic shales, like the Shublik Formation, have very similar lithologic characteristics to that of the Eagle Ford Shale. We mapped all the optimally stressed shales located at drillable depths and leased accordingly."

Attractive Targets and Lease Terms

In fact, the United States Geological Survey covers most of what Great Bear used to stake their play. The USGS has published data which identified four marine petroleum source rock units on Alaska's North Slope; the Middle to Upper Triassic Shublik Formation, a basal condensed section in the Jurassic to Lower Cretaceous Kingak Shale, the Cretaceous pebble shale (HRZ), and Hue Shale units.

Along with four very juicy looking shale targets, Mr. Duncan cited Alaska's yearly areawide leasing key in obtaining their strategic holdings.

"In response to the industry's request for more frequent sales," says Kevin Banks, Director of Alaska's Division of Oil and Gas, "the state implemented an annual areawide leasing program, with the first held on the North Slope in June, 1998. Now we offer yearly lease sales on the North Slope, Foothills, Beaufort Sea, and Cook Inlet areas."

"We were very pleased by the October Sale results," says Kevin. "We have seen bidding for tight sand plays but this is the first real non-conventional play for the North Slope. It has us looking at new unit regulations and a general re-examination of how to manage the state's oil and gas lands."

"We are planning to start drilling late this year with production tests in 2012," says Ed Duncan. "The shale gas play here is extensive and we think the oil play will be larger than the Eagle Ford in Texas. Our model calls for thousands of production wells over the next 20 plus years with a sustainable plateau oil production rate in excess of 100,000 bopd."

THOMAS SMITH

Great Bear's objectives include world class source rocks like the pebble shale unit (lower photo) and the Shublik Formation (upper photo).

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According to David Hill, Vice President of Encana's Natural Gas Economy Operations, natural gas is "cleaner, safer, more affordable, more stable and more plentiful than conventional vehicle fuels. So we have decided to move all the company cars and trucks, a total of 1,600 vehicles, onto natural gas. At present the United States imports 40% of its petroleum, despite the plentiful availability of natural gas. In fact, latest calculations suggest that there is over 100 years of supply of natural gas in North America at current production rates, so why aren't more of us using it to power our vehicles?"

Compressed natural gas (CNG) is 20 to 40% more affordable than conventional gasoline in most regions of the U.S. It is also more environmentally friendly, as carbon dioxide emissions are about 30% lower, and levels of nitrogen oxides and particulates emissions are also very low.

"We believe that natural gas is a safer alternative," adds Hill. "Natural gas vehicles – NGVs – have an excellent safety record and are built to stringent standards. As well as that, natural gas is lighter than air and quickly disperses into the atmosphere in the event of a leak or accident."

The company is even converting its drilling rigs to use natural gas, creating large fuel savings and lower emissions. Hill says "Encana has ten drilling rigs running on natural gas in its U.S. operations and is evaluating converting additional rigs in the near future. There are also tremendous environmental and public health benefits to converting the larger vehicles to run on natural gas – converting one refuse truck from diesel to natural gas is equivalent to removing 325 cars from the road."

At the moment there are about 1,000 natural gas vehicle filling stations in the United States servicing about 110,000 natural gas vehicles.

JANE WHALEY

Encana

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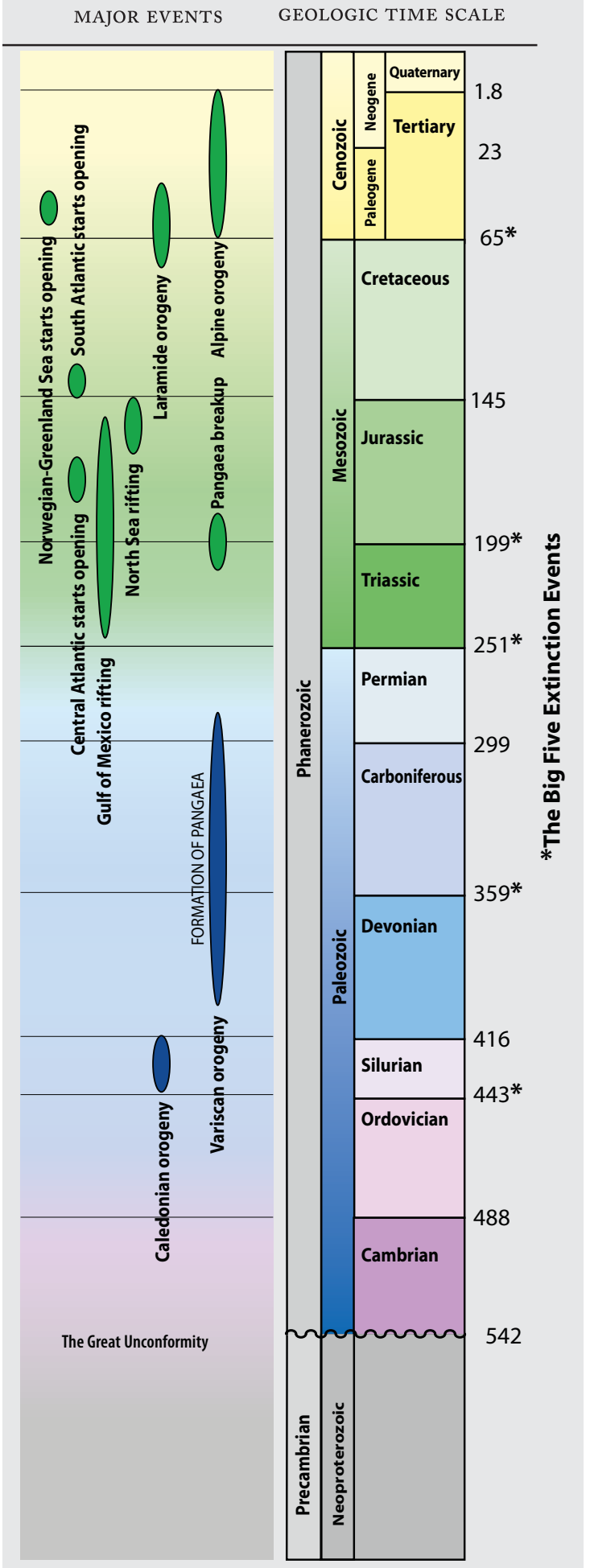

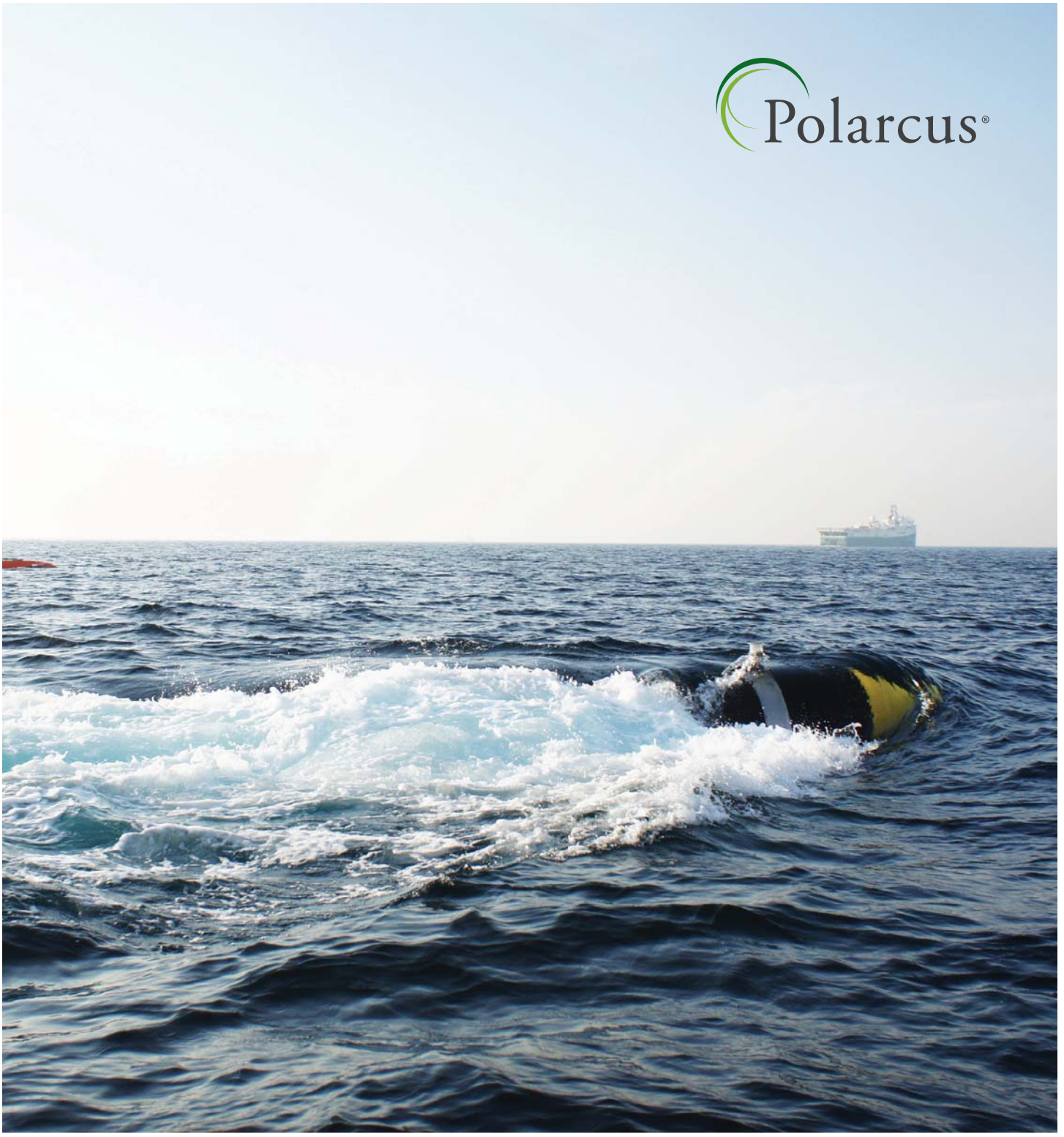

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Shudders Through the Market

Growing political unrest in North Africa and the Middle East – the world's oil oasis – has sent shudders through the oil market, lifting oil prices sharply.

The oil market is worried that the unrest that started in Tunisia and Egypt will spread to the large oil-producing countries in the region and stop the production and transport of oil to the world market. The Middle East alone accounts for around 30% of the world's aggregate oil production and North Africa for around 5%. Oil is the most important commodity in the world and a dramatic cut in oil exports from this region would therefore sharply impact oil prices and economic growth globally.

And the worries are not unfounded. Part of the Libyan oil production has come to a halt and oil companies are closing their offices and evacuating their staff. Libya accounts for some 2% of the world's aggregate oil production, or 1.6 MMbpd, and is an important supplier of oil to, for example, Italy, Germany, France and Spain. OPEC has promised to boost production to replace the loss of oil production arising from the unrest in Libya. Saudi Arabia is the only OPEC member with a significant production buffer. On previous occasions the country has shown its willingness to step up production if the supply of oil becomes dangerously low, as was the case during the Gulf war in 1990-91, the oil strike in Venezuela in 2002 and the US invasion of Iraq in 2003. With its current production buffer, Saudi Arabia can push an additional approximately 3.5 MMbpd into the market.

wikimedia commons

Political unrest in Libya and other parts of North Africa and the Middle East could have major implications for the global oil market and the world economy.

Although Saudi Arabia has historically been a safe oil supplier with substantial capacity, we are nevertheless still slightly worried about the overall reliability of deliveries and supply capacity to the oil market. There is thus a high risk that the spiral of rioting that forced the leaders of Egypt and Tunisia to relinquish power may spread to other large oil-producing countries in North Africa and the Middle East such as Algeria and Iran. If the political unrest spreads and causes stoppage to production in other large oil-producing countries in the region, the Saudi Arabian buffer capacity could quickly come under heavy pressure. But not even Saudi Arabia is safe from a possible revolt against the regime in power. The kingdom is the world's biggest exporter of oil, accounting for around 12% of the world's oil production. A significant cut in Saudi Arabian oil production could have serious consequences for the oil market.

Oil Market Squeeze

Even if the unrest does not spread to the other large oil-producing countries in North Africa or the Middle East, the uncertainty arising from the recent turbulence could make oil companies more reluctant to launch new projects in the area until the political situation has stabilised. Moreover, it will take time before new regimes are in place in Tunisia and Egypt. Given uncertainty over the new governments' framework conditions for the oil sector in the respective countries, oil companies may choose to take a cautious stance on new projects in the region for a while. They will then have to search for new opportunities in calmer parts of the world, with, for example, shale oil in the US, oil sands in Canada and deepwater production moving higher up on the agenda. A lack of investment in sufficient production capacity to meet the increased demand for oil going forward could in the worst-case scenario give rise to an oil market squeeze in the medium term and boost oil prices.

Hence, the political unrest in North Africa and the Middle East may result in higher oil prices in the short as well as the medium term. Higher crude oil prices do not only push the prices of petrol, diesel, fuel oil and aircraft fuel higher, but they will also feed through to the production costs of goods and services. Higher oil prices could act as an extra tax on the consumer and put global economic growth to the test. In addition, unreliable production and supply conditions could cause the major oil consumers to hoard oil for reserve purposes. This may bolster the demand for oil with a resultant tightening of the supply/demand balance in the market.

Growing political unrest with lower oil production or exports from North Africa and the Middle East could have major implications for the global oil market and the world economy.

THINA MARGARETHE SALTVEDT Ph. D
NORDEA MARKETS

A global view on shale oil resources

Over the next few decades the global production of oil will decline, so it's good to know that vast resources of shale oil are still largely untapped in the world's fine-grained sediments.

But what is the size of potential shale oil resources worldwide? And how could it impact on your future exploration activities?

As an industry first, Neftex have created a commercially available diagrammatic report that evaluates the nature, distribution and quantity of shale oil across the globe.

It will provide you with informed insights into this underexplored resource from a global perspective and help define its potential.

This report is based on a unique and robust global database of published geochemistry data, which we've collated, processed and interpreted. Please contact us for further details.

To learn more about Neftex, a leading provider of global geoscience products and services, visit us online www.neftex.com

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For more information contact: reports@neftex.com

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Tel: +44 (0)1235 442699 www.neftex.com

Double Naming Ceremony

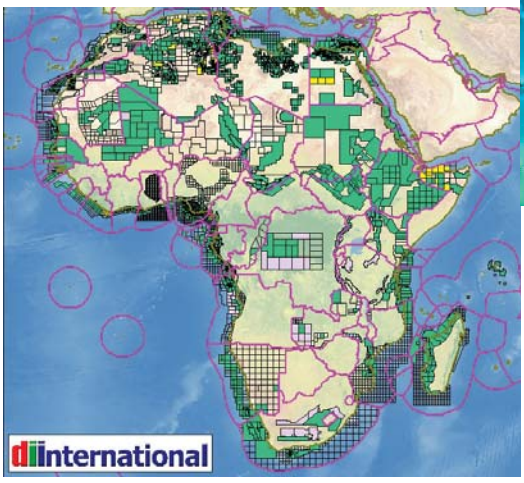
There was a double celebration in Dubai on 16 February 2011, when seismic company Polarcus held a double naming ceremony to welcome two new vessels to its fleet. The **Polarcus Samur**, a girl's name which means swift in Arabic, is a purpose-built seismic vessel of the ULSTEIN SX133 design, with an overall length of 84.2m and a beam of 17m, which can deploy up to eight streamers. **Polarcus Alima** is slightly larger, at over 90m length, and is a sister ship to the Polarcus Asima, currently working off the Falkland Islands. She is capable of deploying 12 9,000m long streamers. The name Alima, meaning wise, reflects the vessels' low environmental footprint and other features designed to safeguard the environment in the harshest of operating conditions. Both ships are 'arctic-ready' with an ICE-1A class notation, double hull, and an advanced ballast water treatment system that eliminates the risk of introducing invasive species into fragile ecosystems such as those found in the Arctic.

New West Africa Scouting Service

Drilling Info International launched a new West Africa Activity Scouting Region at APPEX 2011. The new service covers the countries of the Atlantic Margin between Mauritania and Namibia. It is designed to provide accurate and up-to-date information in a concise and easy to use format and supplements the company's North Africa Service, which was launched in April 2010.

Drilling Info's VP for Africa, John Balch, stated "This a very exciting time for oil exploration in Western Africa. In the near future we expect to see the first exploration wells in the ultra deep waters off Angola, Congo, Gabon and even Namibia, all targeting geological similarities to Brazil's prestigious subsalt plays. In the northern margin of the Gulf of Guinea region recent successes by Tullow Oil and Anadarko have significantly de-risked the Upper Cretaceous turbidite sands play, which extends over 1,200 km, six countries and multiple sub-basins."

Exploration in Western Africa has benefited from an influx of new players in recent years and there has been a flurry of activity, especially in the deep water areas. New seismic data has extended the knowledge base into the deeper waters of the South Atlantic, where the availability of deepwater drilling units from the Gulf of Mexico has enabled drilling programmes to be brought forward.



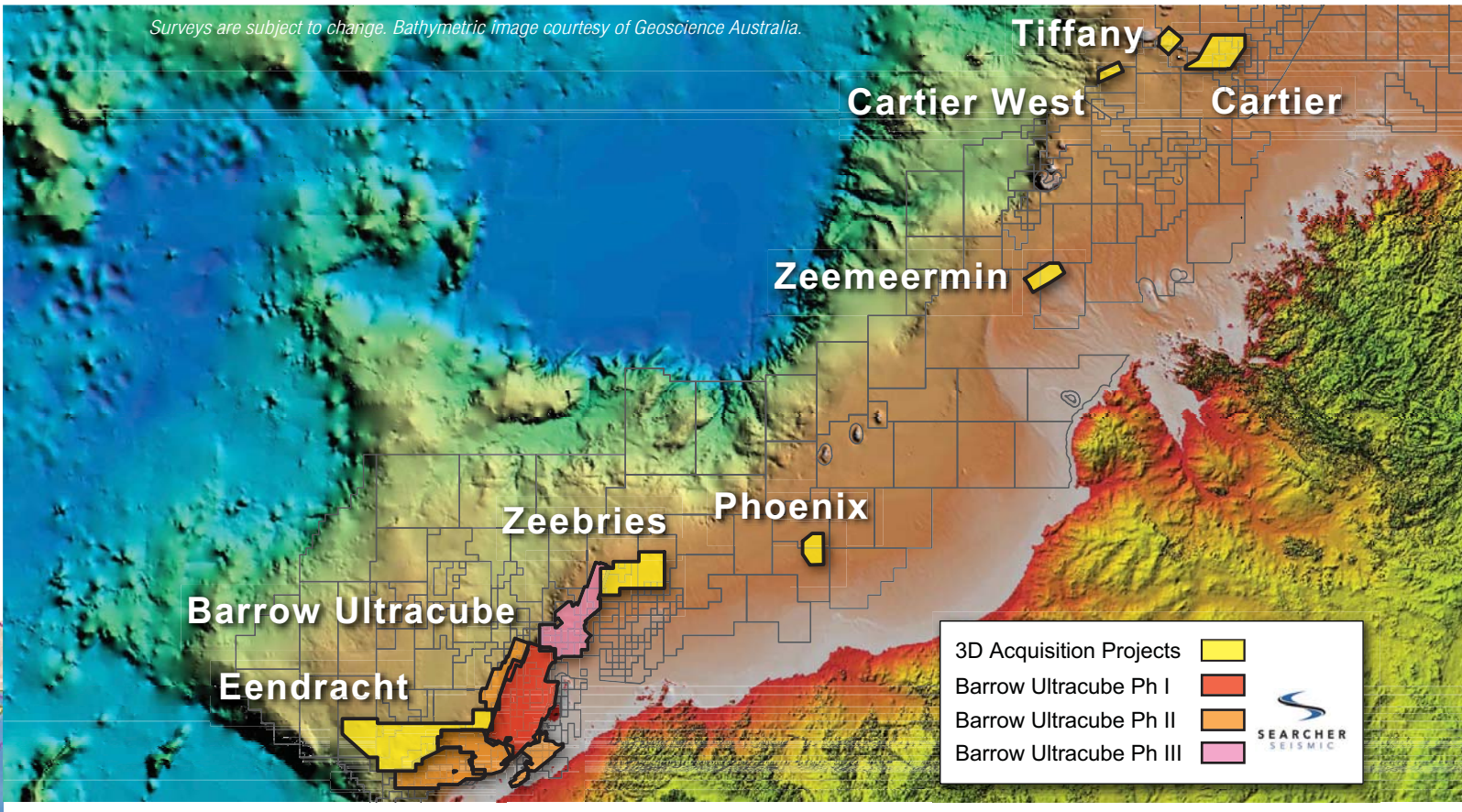
Building a Depositional Framework

Integrating well and seismic data within a sequence stratigraphic, depositional framework is the aim of a recently announced partnership, designed to help oil companies develop their knowledge of the depositional and stratigraphic architecture of a field. The collaboration between dGB, provider of open source seismic interpretation software to the oil and gas industry, and Surface and Subsurface Resources (SSR), specialists in the stratigraphic interpretation of wireline log data, will allow companies to construct a complete depositional framework for an area, with improved high resolution seismic-steered well correlation of sequence stratigraphic surfaces gained through well data and wireline logs.

This is achieved through the integration of two of dGB's most advanced software modules, Horizon Cube and Sequence Stratigraphic Interpretation System, with SSR's Depositional Trend Analysis tool, a high resolution, near-synchronous, stratigraphic correlation framework which has been successfully applied in many basins around the word.

Netherlands-based dGB's seismic product OpendTect is the only available open source seismic interpretation platform in the oil & gas industry today and is offered at no cost under the GNU GPL license. It provides sophisticated interactive attribute analysis, allowing the visualization and interpretation of multi-volume seismic data.

NEW **NORTH WEST SHELF**...



...NON-EXCLUSIVE **3D SEISMIC SURVEYS**

Fugro is adding several new 3D projects to the existing data library over the North West Shelf.

Zeebries - currently acquiring ~3800 km^2 in the Carnarvon Basin.

Phoenix - recent acquisition of ~1100 km^2 in the Canning Basin.

Eendracht - recent acquisition of ~8000 km^2 in the Carnarvon Basin.

Cartier & Cartier West - recent acquisition of ~2770 km^2 and ~520 km^2 in the Timor Sea.

Tiffany - recent acquisition of ~730 km^2 in the Timor Sea.

Zeemeermin - recent acquisition of ~1160 km^2 in the Browse Basin.

Barrow Ultracube - a joint project between Fugro and Searcher that consists of three phases and involves the reprocessing, integrating and phase matching of existing 3D surveys in the Carnarvon Basin.

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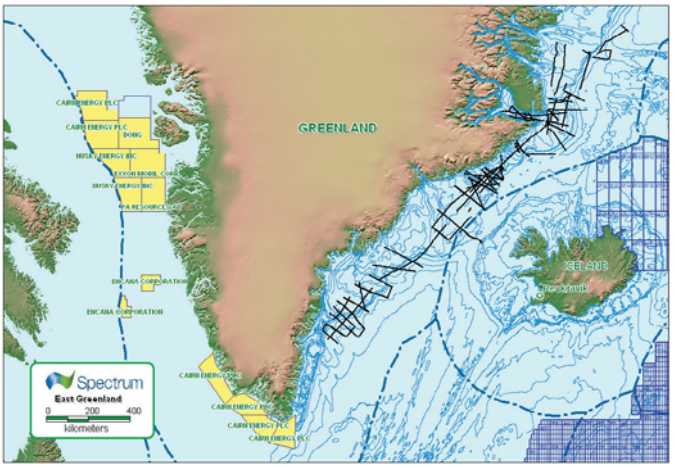
www.fugromcs.com.au

East Greenland Collaboration

Seismic companies Spectrum and Petroleum Geo Services (PGS) have collaborated to use their combined experience in seismic processing in order to elucidate the petroleum potential of an important frontier region. They recently completed reprocessing 7,357 km of vintage 2D seismic data obtained offshore the south-east coast of Greenland in the 1980s. The survey area included the southern part of the East Greenland rift basin, which the US Geological survey estimates contains undiscovered reserves of 31,400 MMboe.

Using contemporary techniques perfected for sub-basalt imaging in the UK Atlantic Margin and offshore India West Coast, the two companies were able to improve definition, particularly of the pre-Tertiary basalt sedimentary section. This is considered very important, as East Greenland forms the conjugate margin to the Norwegian continental shelf, Faroe-Shetland Islands and Rockall Basins, so it is considered that successful plays found in those area may well be present in East Greenland, which to date has only been explored with regional seismic and a few Ocean Drilling Program wells.

The reprocessed data is available from both Spectrum and PGS.



The PGS/Spectrum reprocessed lines are shown in black

North Sudan Seeks New Explorers

After the January referendum in Sudan resulted in a clear decision to split the country, the President, Omer Hassan Al-Bashir, has issued an edict to the Ministry of Oil to ensure oil exploration in North Sudan is stepped up. About 75% of the country's daily production of 500 Mbo comes from the southern half of the country, although since the peace treaty signed in 2005, the proceeds have been split equally between the north and the south. However, the decision to separate into two countries, which will come into force in July this year, means that the northern part of Sudan will lose billions of dollars in oil revenues. As a result, the President is proposing that the scope of oil exploration is widened in an effort to encourage new investors to the north. The two sides are currently negotiating a new oil-sharing deal, because even though most of the oil is in the south, the main markets are to the north of Sudan, and South Sudan will need to use the existing pipeline infrastructure and refineries in the north to export its oil.

Alliance for Arctic Exploration

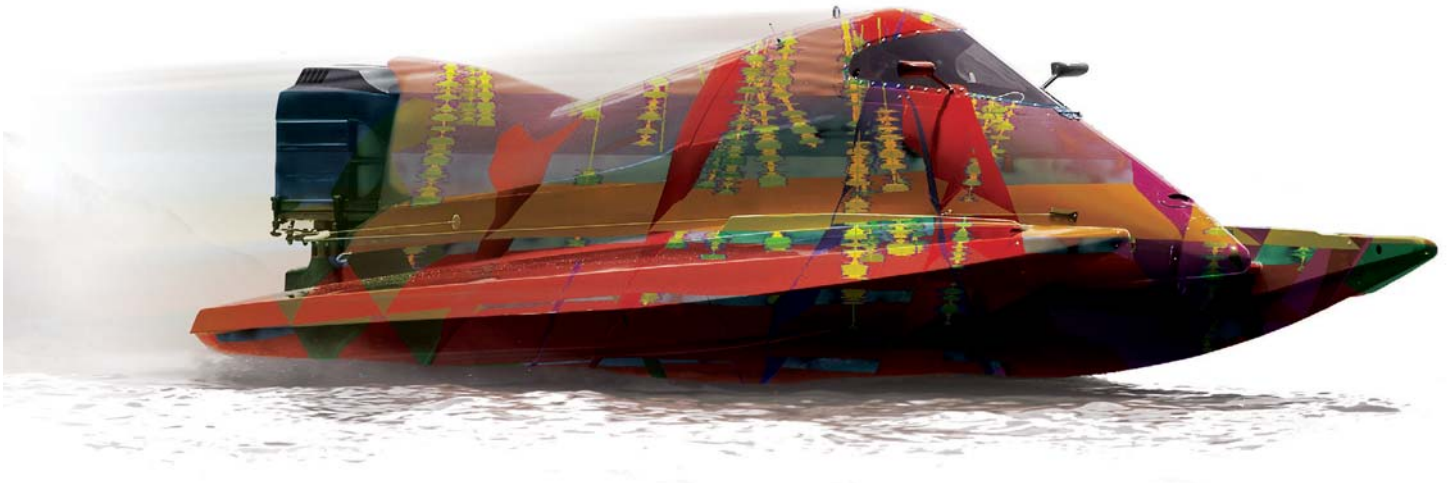
The Princess, one of several ice-class vessels in the CGGVeritas fleet

CGGVeritas

CGGVeritas, a leading geophysical services company, recently formed an alliance with Moscow based JSC Geotech Holding to create a joint venture in order to undertake exploration in Russian and CIS Arctic waters. The collaboration, which was announced February 25, 2011, will provide marine seismic data acquisition and processing services for the oil and gas clients operating locally in Russia and CIS. CGGVeritas will make available one 2D ice class vessel and one 3D ice class vessel to the joint venture, and the arrangement will allow them entry into the vital Russian and CIS offshore market.

Geotech Holding is a major Russian oilfield service company and one of the largest onshore seismic service providers in the world, employing over 12,000 people. Among other services, it offers 2D and 3D seismic surveys, seismic data processing and interpretation, geological modeling; well logging and vertical seismic profiling; and wildcat, exploration, and development drilling. The Company leads the field in some of the most promising regions for hydrocarbon potential, such as Timano-Pechora petroleum province and West and East Siberia.

Want sealed frameworks from geological and geophysical data in minutes, not weeks? **Speed Up**



DecisionSpace® Desktop software automatically generates accurate sealed frameworks in about a minute.

As geoscientists interpret data, Landmark's new unified DecisionSpace® Desktop software automatically constructs fault networks, seals horizons against the fault network and generates a sealed framework. When geologists make picks or geophysicists interpret sections, watch live updates ripple through the framework and then create accurate, report-quality maps instantly. What once took hours, or even days, now takes just a minute.
So speed up your cycle time. Get better answers faster. Visit us in Booth 619.

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THE SUBMERGED CONTINENT OF NEW ZEALAND:

View south along the north Taranaki coast in the vicinity of Tongaporutu river mouth, showing magnificently exposed deep-water sand-rich strata of the Mount Messenger Formation, laterally equivalent deposits to producing petroleum reservoirs in subsurface Taranaki Peninsula.

Lloyd Homer, GNS Science

Are There Continent-Scale Resources Offshore?

CHRIS URUSKI, MIKE ISAAC, RAY WOOD AND PETER KING, GNS SCIENCE

New Zealand has produced petroleum for nearly 100 years since oil first flowed from the Moturoa field in Taranaki Basin. Discovery of the Kapuni gas field in 1959, the giant Maui gas field in 1969 and the McKee oil field in 1979 cemented Taranaki as the focus of exploration. The discovery and development of the Pohokura and Kupe gas fields and the Tui and Maari oil fields followed within the last decade. A total of around 2 Bboe has been discovered in Taranaki, and petroleum is New Zealand's fourth highest export earner.

Production is so far limited to only a small fraction of the 1.5 million square kilometres of sedimentary basins that underlie New Zealand's territory. Oil and gas exploration of onshore and nearshore areas away from Taranaki has been sporadic, but at least three basins, the East Coast, Canterbury and Great South, have been shown to contain effective petroleum systems .

Rises in the price of oil and the growing awareness of the extent of sedimentary basins within New Zealand's territory have increased industry interest in frontier areas, all of which are relatively unexplored and in many cases undrilled. Attention is now being paid to deepwater Taranaki, offshore Canterbury, Great South Basin, onshore east coast of the North Island, and the Raukumara Basin. At least some of this activity is the result of reconnaissance seismic surveys ▶

The islands of New Zealand are the emergent parts of an extensive, mainly submerged continental landmass; New Zealand territory covers almost 6 million km², 20% of it underlain by sedimentary basins.

in five frontier basins conducted by the Crown Minerals division of the Ministry of Economic Development.

Taranaki Basin: Where It All Began

More than 400 wells have been drilled in the onshore and shelf parts of the Taranaki Basin, covering about 100,000 km^2 of the western North Island and adjacent area offshore. Taranaki initially formed as an Early Cretaceous to Paleogene intraplate rift basin, during fragmentation of the Gondwana continental margin. The basin was structurally overprinted in the Neogene as a result of the development of the modern convergent plate boundary through New Zealand. Some depocenters contain more than 9,000m of basin fill. Exploration targets include structures and stratigraphic traps formed by rift-related processes and compressional inversion structures. Source rocks known to have generated hydrocarbons in commercial quantities are mainly Late Cretaceous and Paleogene coal-bearing rocks and marine shales but, in two areas, geochemistry indicates a mid Cretaceous or older source. Proven reservoirs include Paleocene and Eocene terrestrial, paralic and near-shore sandstones, Late Eocene to Pliocene turbidites, fractured Oligocene limestone, Miocene volcaniclastics, and Pliocene shelf sands.

In global terms, the basin is considered a far-from-mature province. The recent discovery of the large Pohukura gas field (2000), the discovery of oil in a new play in Tui (2003), with a world record production payback time of only 3 months, and the likely upgrading of the size of the gas resource at Mangahewa, are just a few of the indications that the basin may yet hold surprises. Some of the current challenges and opportunities for exploration include evaluation of reservoir quality for tight gas plays, improvement of seismic imaging in areas covered by volcaniclastics, unravelling migration pathways from petroleum kitchens, and exploration of Cretaceous deep reservoir potential.

Tempting Explorers for 100 Years

The East Coast Basin covers about 130,000 km^2 of the east coast of North Island and the adjacent Hikurangi margin. Over 300 oil and gas seeps, both onshore and offshore, have spurred exploration interest since the late nineteenth century. More than 40 wells have been drilled onshore, including a sub-commercial dry gas discovery. Only three wells have been drilled in the extensive offshore region and all had good gas shows. The oil and gas seeps are testimony to the area's source and migration potential; the challenge is to find good quality reservoirs.

Most wells have targeted compressional anticlinal traps formed inboard of the modern plate margin. Recent research suggests that exploration may have to be turned on its head; it appears that turbidite sands are likely to be better developed along synclinal axes than across anticlinal crests. En-echelon large-scale thrust ridges formed by syn-depositional tectonics along the Neogene convergent margin are inferred to have formed barriers to downslope sediment transport, with intervening piggy-back basins instead acting as conduits for coarse-grained turbidite flows. Good quality reservoirs may be preferentially developed in synclines, and traps may be developed either stratigraphically by lateral facies change or structurally by basin inversion. Seismic amplitude anomalies and interpreted gas chimneys on the flanks of these basins support their consideration as exploration targets.

This play was unknowingly explored by the historic Waingaromia-1 well, spudded in 1884. Rain prevented transport of the rig to the planned drill site on top of a hill near an oil seep. The hole was drilled in the valley instead and found oil at about 300m. The well produced 20 to 50 bopd until associated gas caught fire and destroyed the rig. Modern work has shown that Waingaromia-1 was drilled into a stratigraphic trap within a syncline.

*Thick, little-deformed Cretaceous and Paleogene rocks of the **Raukumara Basin** were deposited in a passive margin setting. Early Miocene convergence resulted in emplacement of thrust sheets, yet the overall structure of the basin remains remarkably simple.*

Raukumara and Pegasus Basins

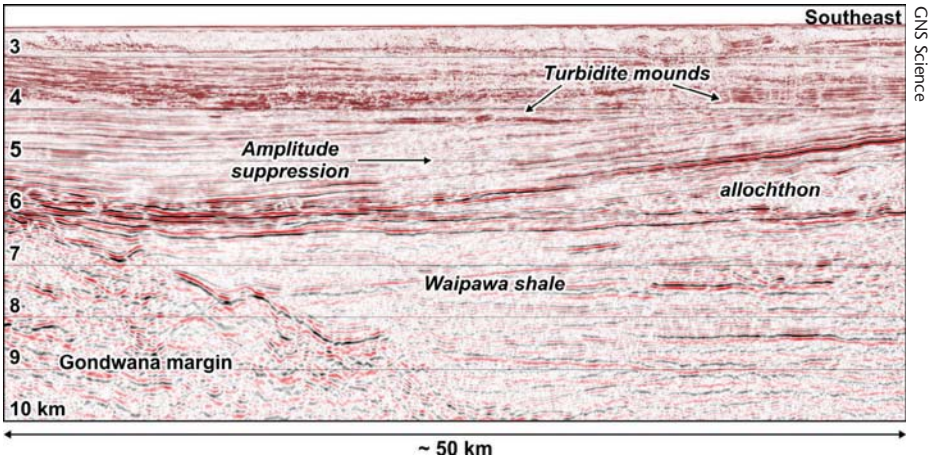
The deepwater Raukumara Basin lies north of the East Coast Basin and west of deformed rocks associated with the modern plate boundary. Pegasus Basin, north of the Chatham Rise and east of the East Coast Basin, lies entirely on the Pacific plate. Neither basin has been greatly affected by Neogene tectonics along the plate boundary. They have not seen any drilling activity, but seismic amplitude anomalies are strong indicators that both basins have active petroleum systems.

Raukumara Basin initially formed as a passive sedimentary wedge across the fossil Gondwana subduction margin. In the Early Miocene its eastern margin was uplifted, folding the basin into a large syncline. In-place Cretaceous and Paleogene rocks are overlain by thrust sheets emplaced in the Early Miocene. Younger Neogene turbidite successions flowed along the axis of this basin. Crown Minerals collected seismic data across much of the basin in 2007 and in 2010 Petrobras was awarded an exploration permit over an area of 12,330 km^2 .

Recently, the first reconnaissance 2D seismic survey across the Pegasus Basin revealed more than 10,000m of sedimentary fill, with more than 6,000 m deposited in the Neogene. This basin originated along the Gondwana subduction margin and contains a fossilised subduction system separated by 100 km and 100 million years from the present-day subduction margin. Large structures have been mapped and there are direct hydrocarbon indicators throughout the basin.

Canterbury Basin: Taranaki's Twin?

Canterbury Basin covers at least 360,000 km^2 east of the South Island, extending from the foothills of the Southern Alps to the Bounty Trough offshore. Eight onshore and five offshore wells have been drilled. ▶



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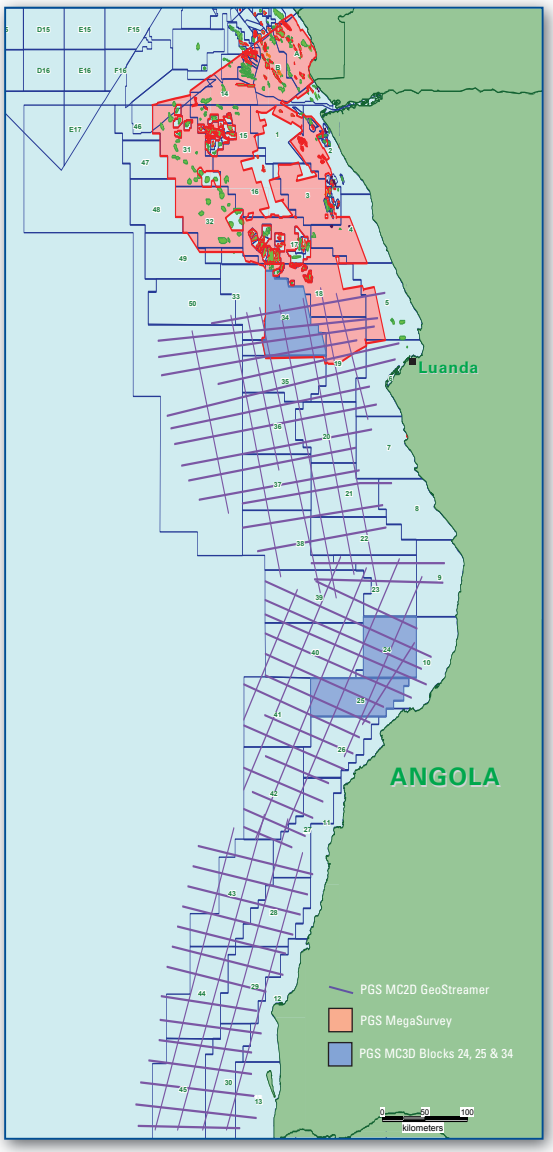
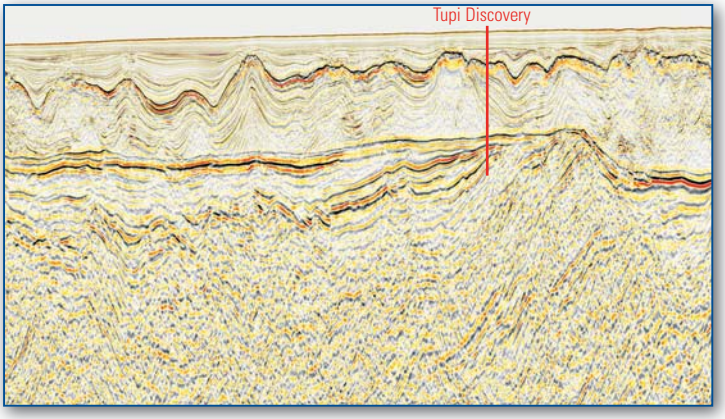
GeoStreamer® Southern Angola MC2D

In 2011, PGS in association with Sonangol, acquired a 12,700 km 2D GeoStreamer regional grid to address the potential of the Kwanza, Benguela & Namibe Basins.



Angola - MegaSurvey, MC3Ds and GeoStreamer Regional Grid



Santos Basin Brazil - Pre-Salt **(PGS GeoStreamer Line)**

Pre-Salt tilted fault blocks - Benguela Basin (PGS MC3D line in Southern Angola)

The unexplored Pre-Salt section of the offshore basins of Angola holds tremendous potential for hydrocarbons. It has great similarities with the Pre-Salt on the Brazilian margin, which abutted Angola prior to the opening of the South Atlantic.

PGS has successfully used its unique GeoStreamer technology in Brazil to clearly image the Pre-Salt over areas including Tupi.

GeoStreamer improves resolution in difficult geological settings such as the Pre-Salt. We are now bringing our experience and technology to address the Pre-Salt of Angola.

PGS GeoStreamer - A Clearer Image

Sonangol

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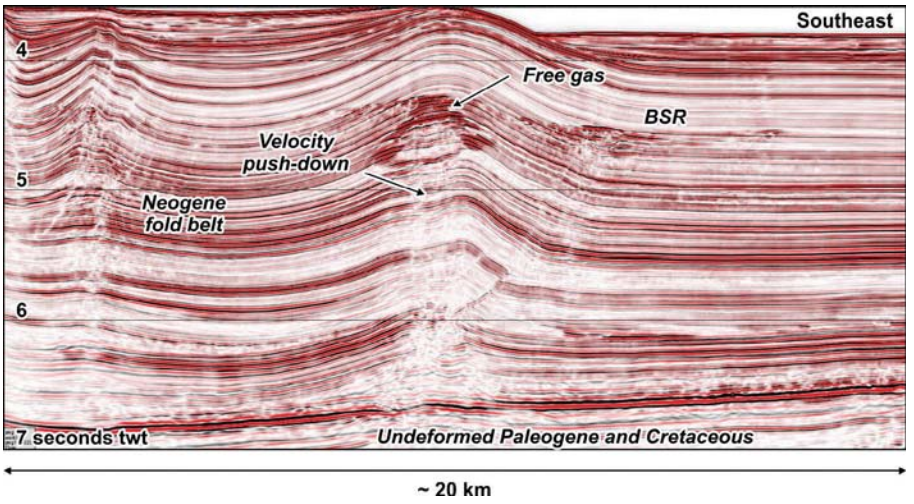

*The little-known **Pegasus Basin** due east of Wellington was mapped for the first time in 2010. Seismic surveys show direct hydrocarbon indicators associated with large, gentle folds; in places a bottom-simulating reflector inferred to represent gas hydrates forms a seal.*

Galleon-1, a sub-commercial gas discovery, produced 10 MMcfgpd and 2,300 cfpd of condensate, while Cutter-1 discovered a 56m gross hydrocarbon column in poor quality sandstones. Several companies have interests in exploration permits, including Anadarko, Origin Energy, AWE and NZOG.

Late Cretaceous and Paleogene geology and tectonic history are similar to those of Taranaki Basin. Canterbury Basin has up to 6,000m of Cretaceous to Recent basin-fill, thickest in Cretaceous rift basins. The most widespread source rocks are Late Cretaceous to Paleocene alluvial to coastal plain coaly rocks, but biomarker and isotope geochemistry of oil shows from the wells indicate that mid-Cretaceous paralic coaly rocks in syn-rift depocenters may be most petroleum-generative. The most promising reservoir rocks are terrestrial sandstones of the Cretaceous syn-rift succession, and Late Cretaceous to Miocene fluvial, estuarine, shallow marine and deep-water sandstones and limestones.

In the deeper continental slope waters, Anadarko and Origin have committed to drill the giant Carrack-Caravel prospect. The prospect lies within the petroleum kitchen that sourced the Galleon discovery. At basement level, Carrack and Caravel are two separate culminations on a large closure; Caravel to the north encloses 58–78 km^2 at top Cretaceous level, and Carrack encloses 200–220 km^2. Both structures exhibit strong AVO anomalies.

Extensive fields of pock marks at the head of the deep-water Bounty Trough, as seen on the sea floor on swath bathymetry and within shallow sediment horizons on 3D seismic data, could indicate an underlying active petroleum system.

Great South Basin

The Great South Basin is a large Cretaceous, and possibly older, rift basin to the south of the Canterbury Basin. It lies almost entirely offshore in water depths averaging 750m. It was first explored by Hunt International Petroleum Company, and eight wells were drilled from 1974 to 1984. Four had oil and gas shows and one, Kawau-1A, was a sub-commercial gas-condensate discovery with an estimated 461 Bcfg. Source rocks are coal-bearing Cretaceous units, with significant oil potential. The Kawau reservoir is Late Cretaceous transgressive sandstone and recent work suggests that Late Cretaceous and Paleogene turbidites sands may also be present.

***Great South Basin** syn-rift and post-rift sediments are draped over structural highs, some formed of open folded Triassic-Jurassic marine and non-marine sandstones and mudstones.*

OMV, PTTEP and Mitsui are partners in three permits, and Greymouth Petroleum has another. The OMV joint venture acquired more than 20,000 km of 2D seismic data and reprocessed older data. Exxon Mobil has recently relinquished acreage in the basin, after evidently targeting a specific play type, but leaves a legacy of newly-acquired high-quality seismic 2D and 3D data that is now open file.

Numerous large prospects are present in the basin. The Greymouth permit lies across the basin margin where plays may include pinch-out traps.

Deepwater Taranaki – Stepping Out

North-west of the Taranaki shelf edge is the deepwater extension of the basin. Anadarko, Hyundai HYSCO, AWE, Global Resource Holdings and RCT hold a permit over 32,830 km^2 of the basin.

There has been no drilling in the deepwater Taranaki Basin but seismic line ties to wells near the shelf edge allow extrapolation of the Late Cretaceous to Neogene stratigraphy into the basin. In the deepwater province an additional, extensive, thick deltaic succession is interpreted to underlie Late Cretaceous coal measures drilled closer to shore. The delta overlies a rift basin interpreted to be Jurassic and Early Cretaceous in age. North-west trending Mesozoic rift structures and orthogonal Cretaceous and Paleogene rifts associated with fragmentation of Gondwana form large basement highs, across which reservoir facies are draped. Potential reservoirs are of Cretaceous to Neogene age, with Miocene channels and turbidites particularly attractive. Some of the play types are correlatives of fairways in the nearshore part of the basin, but others are unique to the deepwater province.

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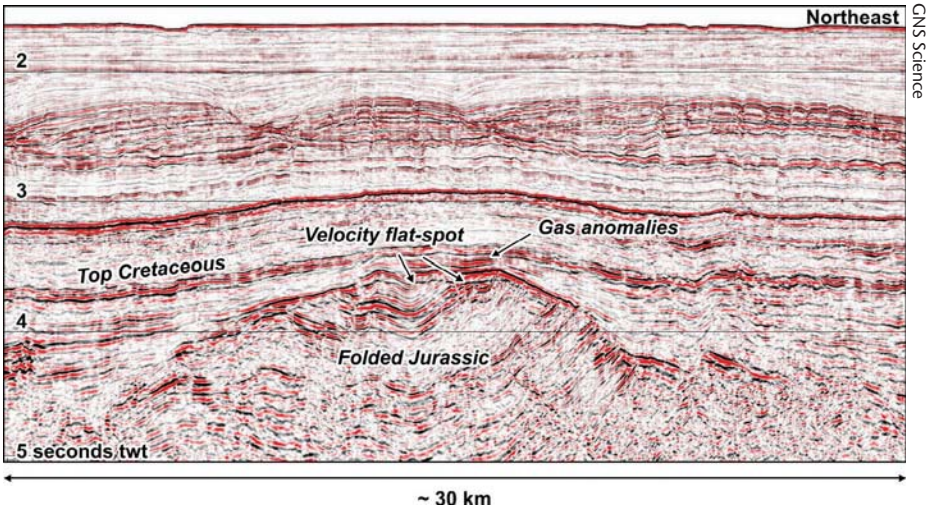


Mount Taranaki, a dormant andesite volcano 2,518 m high, towers over the Taranaki peninsula, home to New Zealand's producing oil and gas fields, some of which lie between the volcano and the coastline seen in the distance.

The Late Cretaceous coal-bearing units that are present across the top of the deepwater delta sourced the oil and gas in the Tui, Maui, and Maari fields. The present-day oil expulsion window is modelled to include the base of the coaly facies and much of the underlying delta. Beyond the delta front the succession may include pro-delta turbidites that could have carried kerogen into deep water, similar to the Kutei and Sabah basins of Indonesia where hydrodynamic sorting aided preferential transport and deposition of oil-prone leafy kerogen. Seismic amplitude anomalies are strong indicators of an active petroleum system.

More Than Taranaki

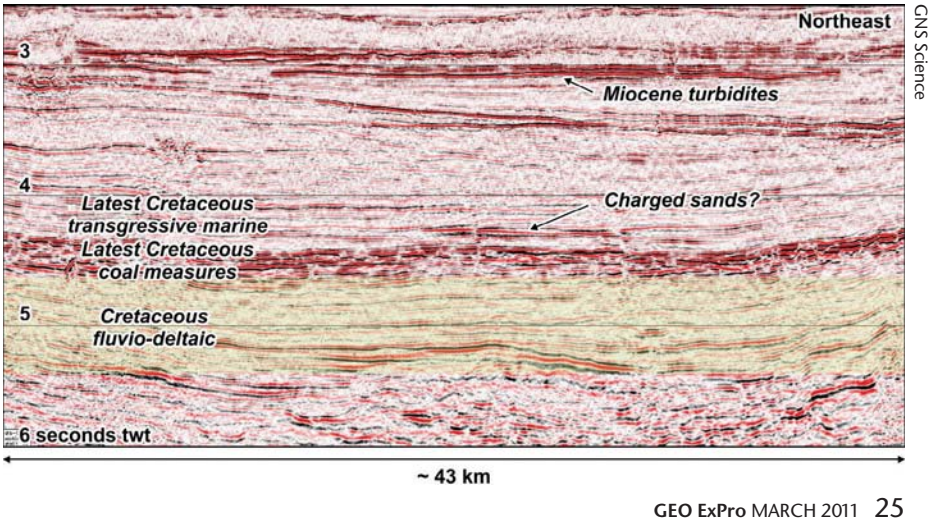
New Zealand's territory covers almost 6 million km^2, including about 1.5 million km^2 of prospective sedimentary basins. Taranaki remains the reference point for exploration, as it is the best known basin, but even it has proved to hold surprises.

Many basins originated along the active Mesozoic Gondwana margin. In some areas, Jurassic Murihiku rocks, formerly considered as basement, may be part of the basin fill and have source potential. Rift basins formed throughout much of the region during the breakup of Gondwana in the Cretaceous. After a long period dominated by intraplate rifting and subsidence in a passive margin setting, initiation of the modern plate boundary through New Zealand began in the mid Eocene. North-west New Zealand was affected by a major compressional event in late Paleogene time, while in the south there was rifting. Major Oligocene crustal downwarps are also recorded. The modern plate boundary propagated through the region in Early Miocene time.

Development of a regional tectonic and paleogeographic framework allows extrapolation of basin architecture and inference of petroleum systems development beyond Taranaki. Research on Taranaki reservoirs provides insights into the controls on reservoir distribution and secondary processes affecting porosity and permeability, with implications for similar depositional systems in other basins. Structural and plate motion history give insights on source rock distribution, reservoir provenance, burial history, regional heat flow, and the timing of hydrocarbon generation and structural trap formation.

Widespread understanding that New Zealand is a submerged continent with vast sedimentary basins has been a long time coming, but will undoubtedly shape thinking about the country's petroleum prospectivity in the future. Given the nature, extent and geological history of the basins, it is unlikely that the only commercial accumulations of oil and gas in New Zealand are in nearshore and onshore Taranaki. Exploration efforts in New Zealand's frontier basins may be rewarded by discoveries of significant petroleum resources.

GNS Science is New Zealand's premier provider of natural resources research and consultancy services. Open-file data and reports are available on the Crown Minerals website: (http://www.crownminerals.govt.nz/cms/petroleum/technical-data). ■



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*In eastern **Taranaki Basin** close to the shelf edge, wells have shown basement to be overlain by Late Cretaceous coal measures. In the deepwater province, however, the coal measures are underlain by a thick deltaic unit of older basin-fill rocks. The colored polygon is the modeled oil expulsion window.*

IDA TARBELL: Pioneering Oil Industry Journalist

Exactly a hundred years ago Standard Oil, which controlled the oil industry in the US, was forced to split into several companies, due largely to the pioneering work done by **Ida Tarbell.**

RASOUL SORKHABI, Ph.D.

J.E. Purdy Co., Boston (Wikipedia)

Ida Minerva Tarbell (5 November 1857 – 6 January 1944), a six-foot-tall, courageous American woman teacher, journalist, biographer, author, and lecturer. A pioneering "muckraker" (a term President Theodore Roosevelt coined in 1906, and today known as investigative journalist), her works are still regarded as important historical documents. This photo was taken in 1904 when her book The History of the Standard Oil Company *was published.*

In 1911 – now one hundred years ago – the US Supreme Court ordered the Standard Oil Company, an oil monopoly in the USA, to split into several independent companies with separate boards of management. This anti-trust regulation against a company that controlled 90% of oil production in the USA was partly influenced by the research work of a woman journalist, Ida Tarbell, author of *The History of Standard Oil Company*. Here we present the first of a three-part look at this fascinating chapter in the history of the oil industry. In this issue, we look at the life and work of Ida Tarbell and how she was led to write that masterpiece in the history of investigative journalism and the oil industry. In the next issue we will present a profile of John D. Rockefeller and how he created the Standard Oil Company. Finally, we will examine the structure of Standard Oil and what actually happened to its child companies.

In 2002 the US Postal Service issued a set of "Four Women in Journalism" stamps, including one of Ida Tarbell shown here.

Ida Minerva Tarbell was born in a family farmhouse in Erie County, Pennsylvania in 1857, two years before Edwin Drake discovered oil in the nearby Oil Creek, Titusville, which ushered in the modern oil industry in the USA (*GEO ExPro* Vol. 6, No. 3). In 1860 her father, Franklin Tarbell, moved the family to Rouseville, a village on Oil Creek, and started manufacturing wooden tanks for oil storage. With more oil discoveries in the region, his business grew, and shortly after he formed a local oil production and refining company. Meanwhile, his family had also grown: Ida now had three younger siblings. In 1870, the family moved to a new house in Titusville.

This was also the year John D. Rockefeller established the South Improvement Company (later Standard Oil.) His aim was to integrate the oil industry activities in the US under his umbrella enterprise in order to lessen the mushrooming competition from the numerous small companies, which was reducing oil prices. His ambitious and notorious scheme of buying, entering into partnership, or destroying uncooperative smaller companies eventually made Franklin Tarbell's company go out of business in 1872. Ida Tarbell, then a curious and studious young girl, witnessed this business brutality with a particular interest.

In fall of 1876, Ida entered the Allegheny College, Meadville, PA, the only female student in her class. In 1880, she graduated in biology. For the next two years she taught at a school in Portland, Ohio, and then joined the writing staff of *The Chautauqua*, a home study magazine at Chautauqua, New York. In 1890, the US Congress passed the Sherman Anti-trust Act, although the government was reluctant to enforce it. The following year, Tarbell went to Paris to study the biography of Madame Roland, a woman intellectual during the French Revolution, and also to work as a free-lance journalist for magazines back home.

Samuel McClure, who had founded the *McClure's Magazine* in 1884, was impressed by Tarbell's writings from Paris and commissioned her to write articles on Louis Pasteur and Napoleon Bonaparte. In 1894, Tarbell returned to Pennsylvania, and a year later, she published a series of articles on the biography of Abraham Lincoln in the *McClure's* which earned her a national reputation.

Taking on Standard

All these experiences prepared Tarbell to take on the task of writing *The History of the Standard Oil Company*, as a series of articles in the *McClure's*. "Don't do it, Ida," her father cautioned her, "They will ruin the magazine." But Tarbell went ahead, interviewing people and investigating all documents with help from an editor friend John M. Siddall. The Standard Oil heard of her investigations, and one of its senior managers Henry H. Rogers requested his friend Mark Twain (the famous novelist) ▶


Rasoul Sorkhabi

Ida Tarbell's family house in Titusville, Pennsylvania. The house is now owned by the Oil Region Alliance of Pennsylvania.

to introduce him to Tarbell. For months, Tarbell had access to Rogers for interviews, which Rogers hoped would make Tarbell's report "right" in the Standard. Their relations were cordial; especially since both were of the same generation who grew up on the Oil Creek. "I remember your father's tank shop [in Rouseville]," Rogers told Tarbell. But after Tarbell in one of her articles documented how Standard Oil obtained information from the railroads about the sale and shipments its competitors made and then ensured that the shipments did not reach their destinations, Rogers was furious and did not want to meet with her again.

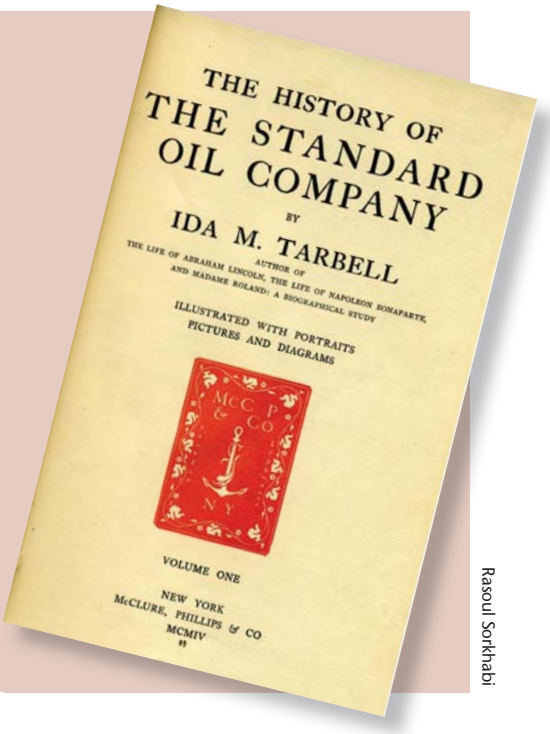
Tarbell's *The History of the Standard Oil Company*, both as articles in McClure's and in a 1904 book volume, was well received by the public, the media and by the political supporters of Theodore Roosevelt. He had been elected US President in 1903, and was called by some media the "trust-buster."

In 1905, Tarbell went to Kansas and Oklahoma to cover the recent oil discoveries. In 1906, she helped create *The American Magazine* (where she served until 1915 and was succeeded by John Siddall as editor). In the same year, Tarbell bought a house in Easton, Connecticut, where she would eventually pass away in 1944 (at age 86) during the turbulent years of World War II. Tarbell's house was declared a National Historic Landmark in 1993. In October 2000, Tarbell was listed among the National Women's Hall of Fame in New York, and the Pennsylvania State House declared November 4 as Ida Tarbell's Day in that state.

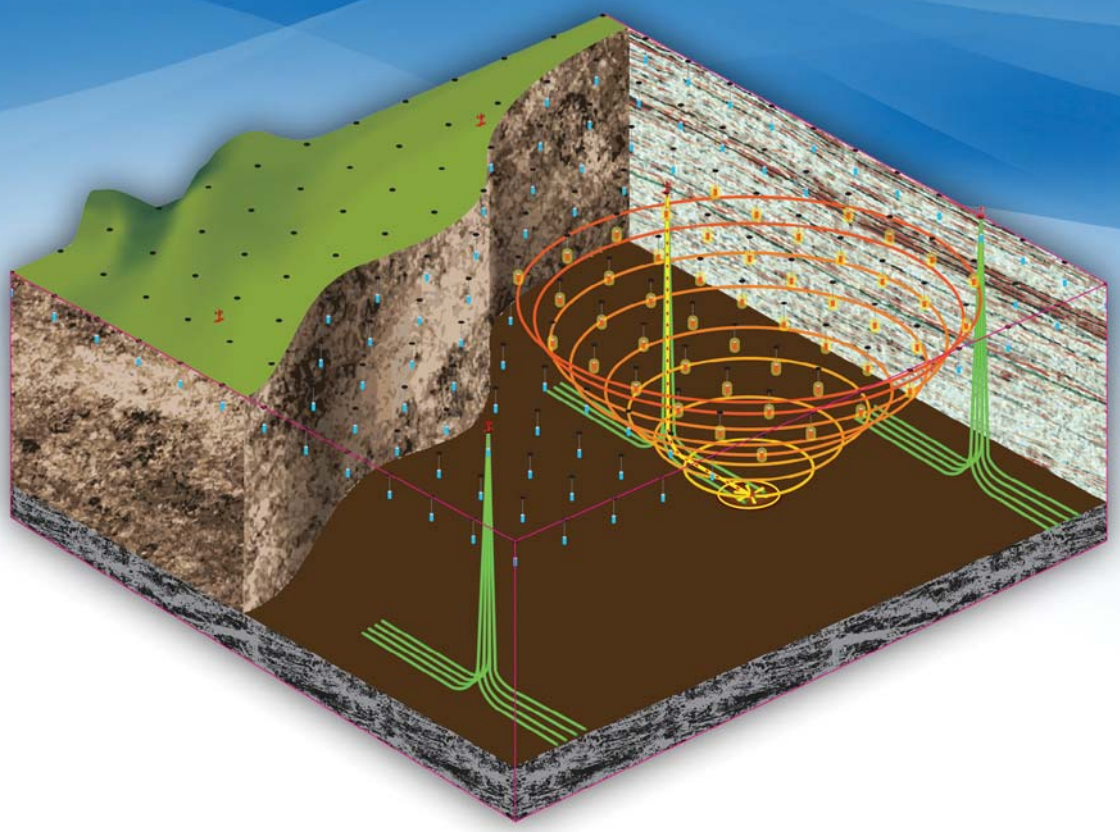
In her autobiography, *All In the Day's Work* (published in 1939), Tarbell remarked on the Standard Oil Company: "I never had an animus against their size and wealth, never objected to their corporate form. I was willing that they should combine and grow as big and rich as they could, but only by legitimate means. But they had never played fair, and that ruined their greatness for me."

This autobiography, as well as a more recent work, Kathleen Brady's *Ida Tarbell: Portrait of a Muckraker* (1984,) are informative sources for additional reading on Tarbell. However, Tarbell herself did not like the title "muckraker," and preferred that she is viewed as a historian journalist. ■

The History of the Standard Oil Company, published in two volumes in 1904, was first written as a series of twenty articles for *McClure's Magazine* from November 1902 to July 1903, and December 1903 to October 1904. Daniel Yergin, author of *The Prize*, regards it "the single most influential book on business ever published in the United States." In 1999, the *New York Times* listed this work as No. 5 of the top 100 works of the twentieth-century American journalism. Tarbell's *The History of the Standard Oil* is not only fun to read, not only a masterpiece of investigative journalism, but given the stature of the Standard Oil Company, it is also a historical review of the oil industry in the nineteenth century USA in 850 pages.



Rasoul Sorkhabi



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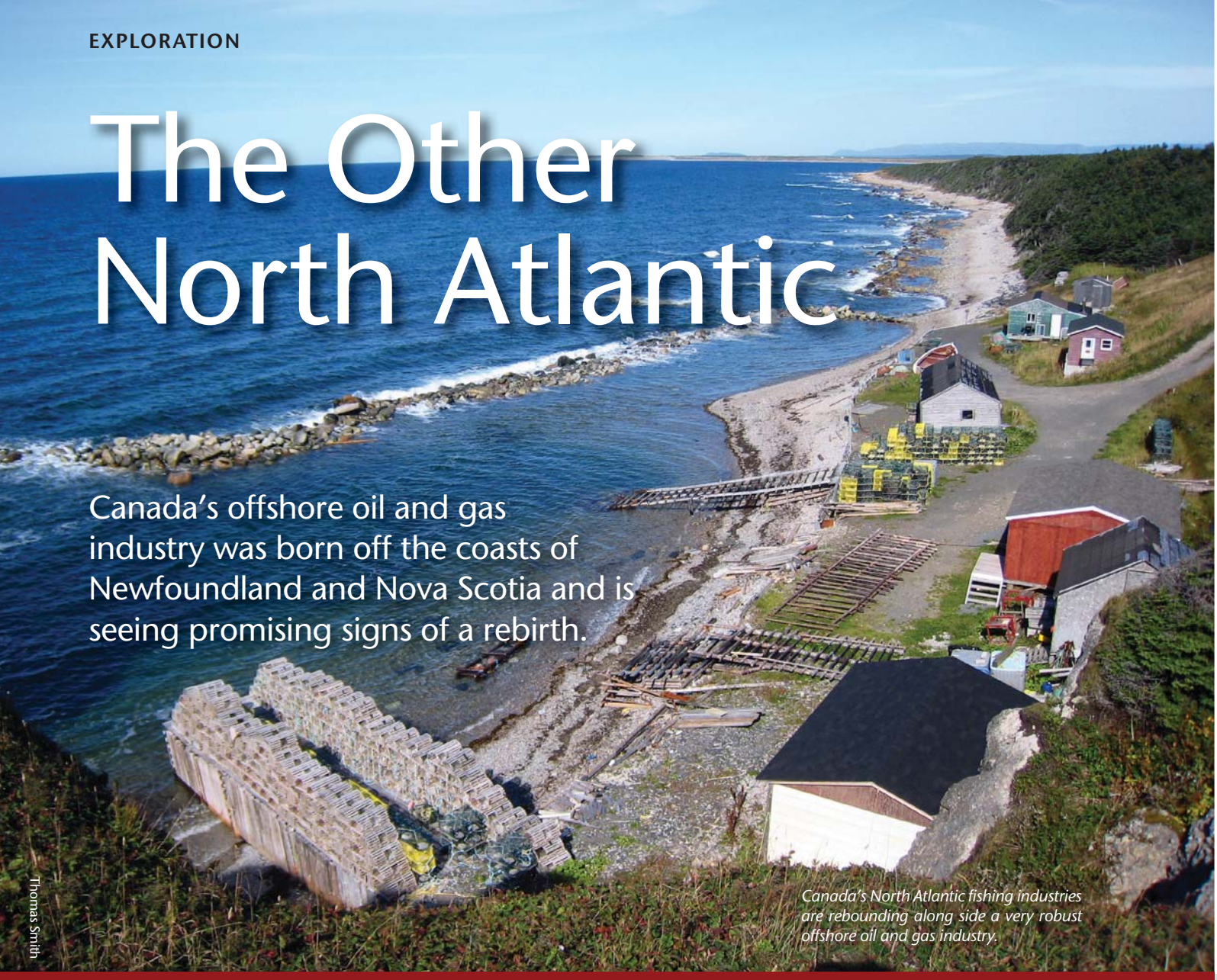
The Other North Atlantic

Canada's offshore oil and gas industry was born off the coasts of Newfoundland and Nova Scotia and is seeing promising signs of a rebirth.



Thomas Smith

Canada's North Atlantic fishing industries are rebounding along side a very robust offshore oil and gas industry.

THOMAS SMITH

Exploration drilling for oil and gas in the Northern Atlantic off of Newfoundland, Labrador and Nova Scotia began in the mid-1960s. It was not until 1979 that any significant fields were found and for those discoveries, development would be difficult and years off. The late 1990s would be the start of the region's oil and gas industry, which has slowly grown for two decades. Now, however, new discoveries and prospective frontier basins could lead to a successful future.

Painful Path to Production

Oil and gas exploration in the Canadian North Atlantic offshore area started with geophysical surveys in the late 1950s; the first shallow water wells were drilled the following decade. Wells were few and far between off Labrador and Newfoundland owing to the remoteness of the area and low oil prices until in 1973, dramatically increasing oil prices led to more exploratory drilling. Only small fields were found before 1979 when the Hibernia oil field was discovered off the Newfoundland coast. Between 1967 and 1978, 71 wells were drilled off Nova Scotia, resulting in four significant oil and gas discoveries. Again, it was not until 1979 that a major gas find would be announced by Mobil and Petro-Canada east of Sable Island. In fact, the Venture well found as much gas as had been found to date in the area. More drilling would confirm 15 additional discoveries, but development of these fields would prove to be difficult.

The Cohasset Field, discovered in 1973, and Panuke, discovered in 1986, became Canada's first commercial offshore development, known as COPAN. The project produced 44.5 MMb of 50° gravity oil from 1992 to 1999. The first major gas project off Nova Scotia occurred with the Sable Offshore Energy Project (SOEP). The initial discovery was made in 1979 but low gas prices delayed production until 1999. The development is located 225 km of the east coast and involves six gas fields containing 85 Bcm (3 Tcf) recoverable gas reserves. The Deep Panuke gas field was discovered in Jurassic carbonates beneath the Cohasset and Panuke fields in 1999 and is due to go into production this year.

At about the same time as the Sable gas project was getting under way, oil production started further north in the Grand Banks of Newfoundland at Hibernia. Discovered in 1979, 315 km south-east of St. John's, Newfoundland, many obstacles

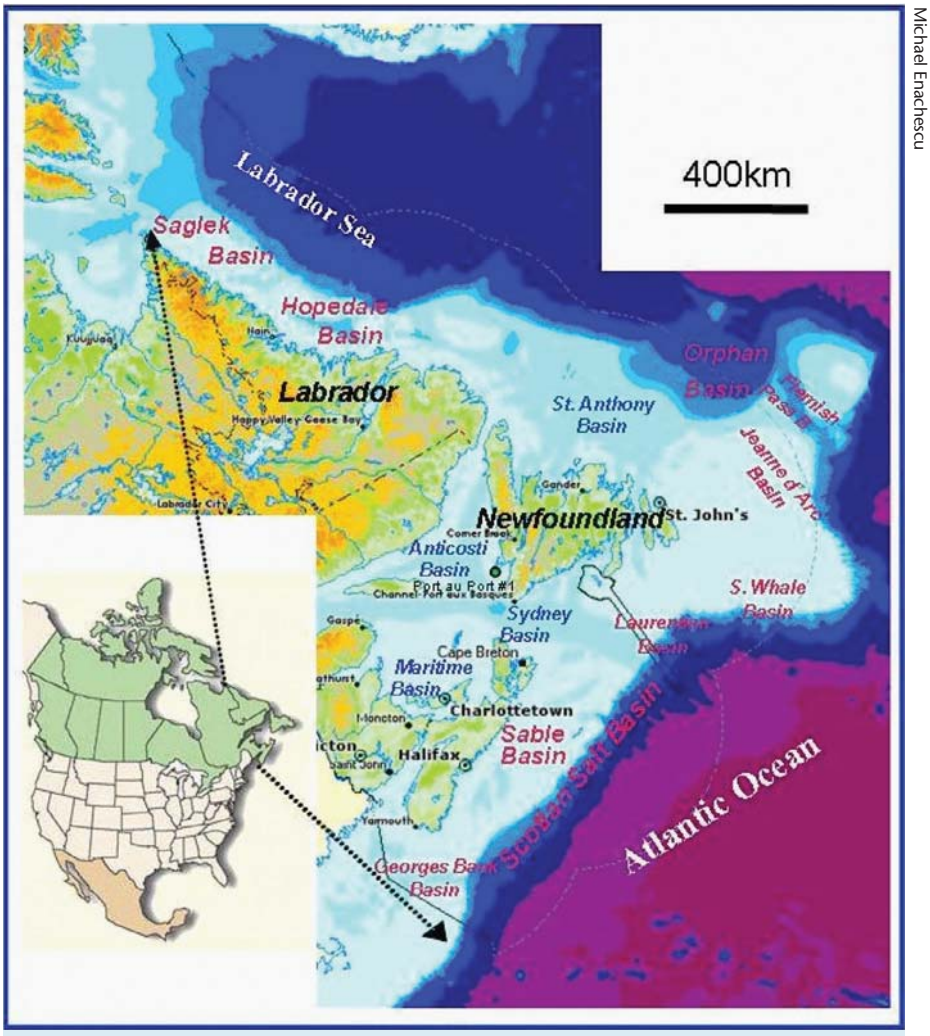
had to be cleared before development could take place. There was a jurisdictional dispute with the federal government and after that an agreement amenable to both the oil companies and governments was needed for development to move ahead.

ExxonMobil Canada is the lead owner along with the five other companies that formed the Hibernia Management and Development Company (HMDC) to tackle this very technologically complex and investment-intensive project. The area of the discovery is not only one of the foggiest places on earth, but also noted for high waves, icebergs, sea ice and hurricanes. Building the world's first and only iceberg-resistant gravity-based structure (GBS) occurred in Bull Arm, located about 150 km from St. Johns, Newfoundland. Starting in 1990 and using owner capital and government grants, the entire dry dock and fabrication facility had to be built. It took six years to complete the massive GBS and first oil was achieved on November 17, 1997, four weeks ahead of schedule.

Three more fields, Terra Nova (2002), White Rose (2005), and North Amethyst (2010) have since been brought into production using floating production, storage and offloading (FPSO) systems. A fifth field, Hebron is slated to be developed using a stand-alone concrete GBS with oil flowing by 2017. The Jeanne d'Arc area had recoverable resources of 6 Tcf gas and three billion barrels of oil; over one billion barrels have already been produced. ▶

The Hibernia platform is one of the world's largest gravity based structures.

HMDC



Michael Enachescu

Mesozoic rifted basins (in magenta type) and Paleozoic basins (in blue type) off Canada's North Atlantic coast.

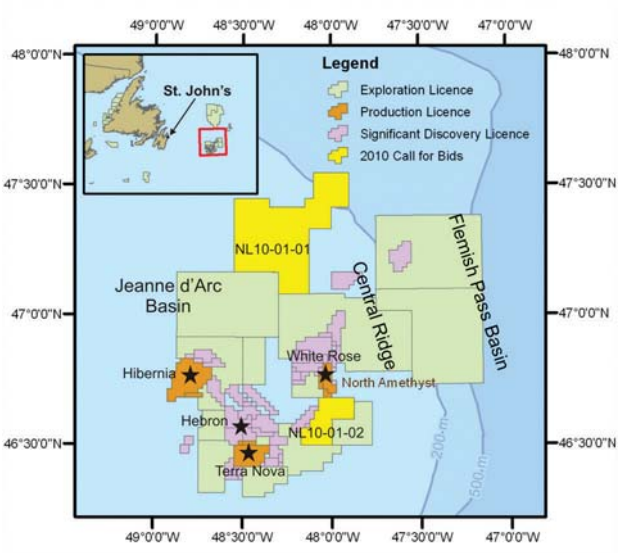
Mesozoic Rift Basins

The Pangean breakup began in Late Triassic time and continues today. The rift and drift phases have created new oceans and sedimentary basins have formed along both sides of the passive continental margins. Many of the world's major petroleum provinces are found in these basins. The North Sea basins, Brazil's offshore, Gulf of Mexico, central Africa offshore and eastern Canadian offshore are some of the existing petroleum provinces found around the Atlantic. Many of the rift basins are just beginning to be explored as is the case for the Canadian Atlantic basins.

The Canadian Atlantic basins are primarily extensional, resulting from repeated rifting and thermal subsidence episodes. This basin chain extends from offshore southern Nova Scotia to northern Labrador, a distance of over 3,000 km, in water depths from 10 to more than 4,000m. These Late Mesozoic basins are fault-bounded, contain thick successions of sediments, and are located above thinned continental crust. Structural styles and basin geometry varies considerably along the margin trend.

Common to the more prospective basins are fine sediments with high organic content. Where mature, these high quality Late Jurassic source rocks have generated large quantities of hydrocarbons. Significant discoveries have been found in five offshore basins, namely the Sable sub-basin off Nova Scotia, Jeanne d'Arc and Flemish Pass basins off Newfoundland, and the Hopedale and Saglek basins off Labrador. Large portions of these basins remain under explored and several other large, prospective Mesozoic basins remain frontiers for the oil and gas industry

Location of producing fields and leases off the Newfoundland coast.



Michael Enachescu

Twenty-seven wells have now been drilled off the Labrador coast, resulting in five significant gas discoveries with recoverable reserves of 4.2 Tcf. However, development could still be years off.

Let us look at the prospective basins on this margin, running from north to south.

Nova Scotia Basin

Underlying 900 km of Nova Scotia's offshore along the southern margin of Canada's Atlantic shelf and slope and up to 200 km wide, the **Scotian Basin** contains numerous sub-basins, separated by ridges or local highs, and by faults.

"The petroleum system here, in common with the other prospective Mesozoic basins, starts with widespread, high quality Late Jurassic source rocks," says **Dr. Michael Enachescu**, petroleum geoscientist for MGM Energy Corporation in Calgary and an Adjunct Professor for Memorial University in St. John's, Newfoundland, Canada. "Where mature, these source rocks have generated large quantities of hydrocarbons as is the case offshore Nova Scotia. To date, 6 Tcf gas and 75 MMbo have been discovered primarily on the shelf in an area known as the Sable Basin."

"Several slope fan plays have been drilled with only one announced success – the Annapolis G-24 well," says Dr. Enachescu. "Good source rocks were found by some of these wells but very little reservoir rock was encountered. More studies into the basin evolution and reservoir distribution of the deeper water sections are needed in this poorly understood area."

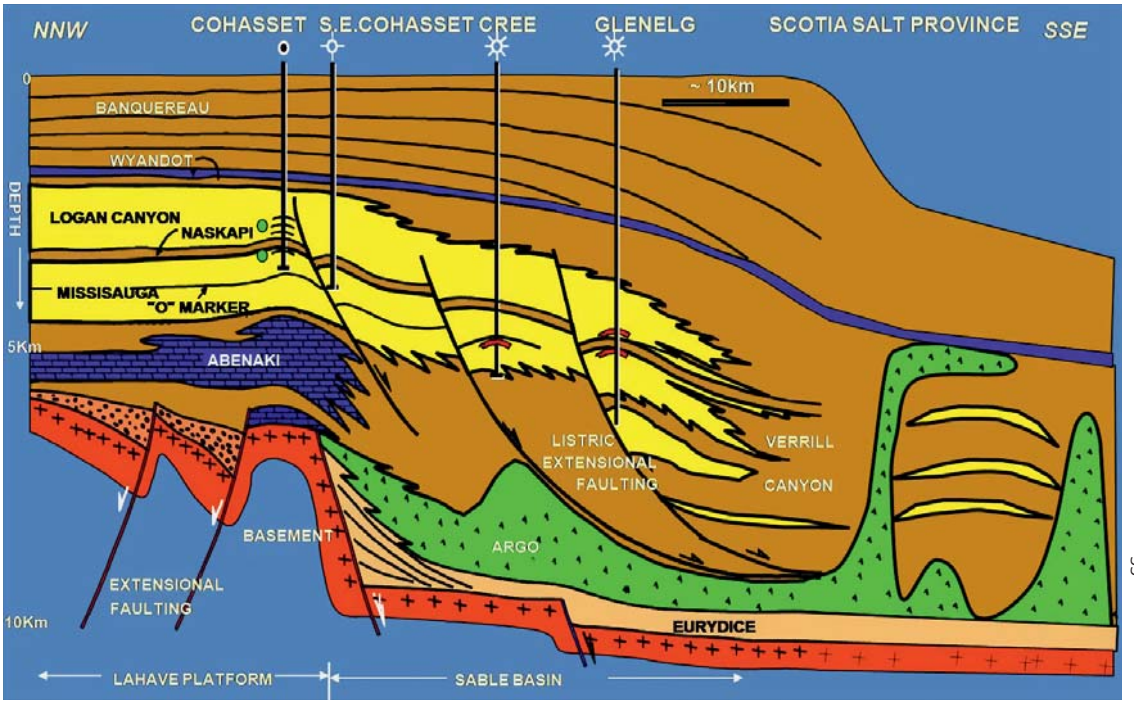
BEPCo Canada Company was the successful bidder for two deep water parcels located about 160 km south-west of Sable Island, and is preparing to drill a well in deep water about 200 km south of Halifax. This will be the first deep water well drilled off Nova Scotia since 2005. Still, this complex basin, the size of the Gulf of Mexico, remains little explored, with less than 200 exploration and development wells drilled to date.

Southern Grand Banks

"The **Laurentian** and **South Whale Basins** have a similar evolution with the Scotian Basin area during most of the Mesozoic era," says Dr. Enachescu. "These two rift basins have a strong imprint of salt tectonics that continues south off Nova Scotia and north into the Grand Banks."

The 60,000 km^2 Laurentian Basin had long been in a boundary dispute between France and Canada that is now settled. As a result, only one well had been drilled until 2010. That well, located in French territo-

The Scotian Basin cross-section showing structural elements and gas discoveries in the Late Jurassic deltaic sandstones. Deformed salt formations are shown in green and extend north into the Jeanne d'Arc Basin.



Hogg and Enachescu

rial waters, was a dry hole but reported to intersect several reservoir intervals. ConocoPhillips and BHP Billiton drilled the East Wolverine G-37 well on a deep prospect within this basin. A company spokesperson said that their expectations of success were low going into the project giving that it was a 'rank exploration well'. They are said to be still analyzing the data collected by the well, however they have dropped some licenses and only two of the smaller licenses remain.

"The South Whale Basin is the other prospective area in the southern end of the Grand Banks," says Dr. Enachescu. "Because of its shallow water depths and ice free environment, it was the first location drilled offshore Newfoundland. It is also the most prospective basin in the area and contains a nearly complete Mesozoic section. The other basins, namely Whale, Horseshoe, South Jeanne d'Arc and the southern Carson basins have undergone an erosional event during the Early Cretaceous Avalon Uplift. With erosion removing the Late Jurassic source rocks, the petroleum systems in these basins may have been destroyed."

This basin was tested by 14 wells through the 1980s, all unsuccessful. Another medium depth well was drilled in 2005 but abandoned without testing some Late Cretaceous strata and without reaching the Early Cretaceous reservoir sandstones. No other exploration activity for the area has been announced.

Grand Banks

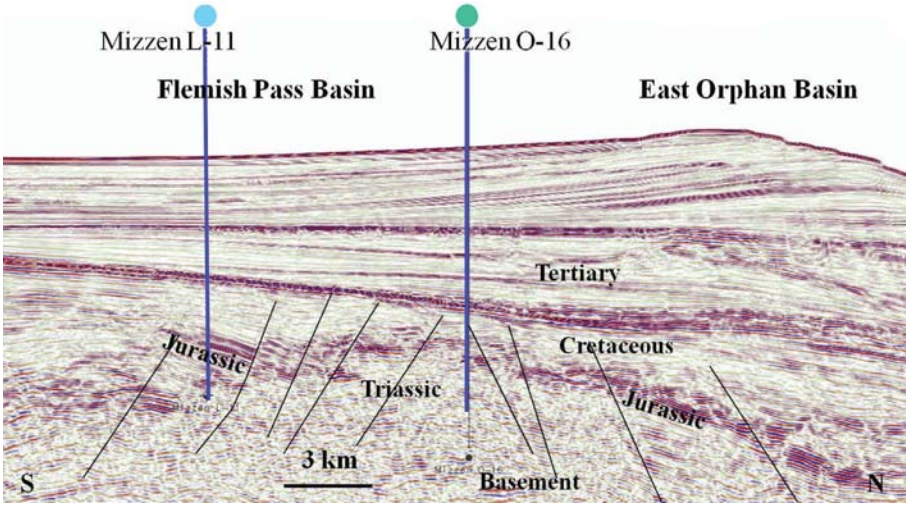
"The **Jeanne d'Arc Basin** has a proven petroleum system," says Dr. Enachescu. "Mature, Jurassic (Kimmeridgian) source rocks are a key element of the petroleum system for these Atlantic basins to be prospective. Based on mass-balance and hydrogen-index techniques, Fowler and McAlpine (1995) estimated that the Egret Member has generated 245 Bbo (39 Bcm) of oil in the Jeanne d'Arc Basin. This basin combines these rich source beds with excellent Late Jurassic to Mid-Cretaceous reservoir rocks and large structures. It remains relatively lightly explored in spite of the past successes, with only 62 exploratory wells having been drilled in the 14,000 km^2 half-graben basin. Past exploration has concentrated on the oil play but plans to bring the area's gas to market could change that."

Some recent developments could mean more exploration activity for the basin. According to a company spokesperson, Suncor Energy, operator of the Terra Nova field, "has numerous prospects on the table". It is drilling a sidetrack well on its Ballicatters prospect. No announcements have been made on the first well drilled last year, but it has said "it is our intention, based on the success of Ballicatters, to continue with further exploration." Statoil Canada is a new operator in the area and plans to drill on its Fiddlehead License in 2011/2012. It is also a partner in the Ballicatters wells. ▶

Dr. Enachescu has worked for the past 40 years as a researcher, explorationist, consultant and professor. He is a renowned authority on the geology of the Canadian East Coast and Arctic frontier basins.

Michael Enachescu

GSI/Michael Enachescu



Seismic line across the northern Flemish Pass Basin and into the East Orphan Basin showing the locations of the Mizzen L-11 and the O-16 discovery well.

Northern Grand Banks

North and east of the Jeanne d'Arc Basin are three very sparsely explored moderate to deep water basins. Only the **Flemish Pass Basin** has a discovery, made in 2009 at Mizzen O-16 by Statoil. It is planning a second well here in 2011/2012. A total of seven wells have been drilled in the basin.

Lying north of Flemish Pass is the East Orphan Basin. "A major focus of exploration in Atlantic Canada," says Dr. Enachescu. "The East Orphan Basin is set in water depths ranging between 1,500m and 3,500m and has the potential to become a major deep water producing area."

Published regional maps made from seismic surveys reveal at least six large structures that each could hold several billion barrels of oil. While only two wells have been drilled here, the first, in 2007, encountered good quality reservoirs and a second well was drilled in 2010 in 2,600m water depth (a record for offshore Canada). The operator, Chevron, is still evaluating data from the Lona O-55 well.

According to tectonic models, the **West Orphan Basin** is slightly younger and shallower than the **East Orphan Basin**. Only seven wells have been drilled here between 1974 and 1985 targeting Mesozoic reservoirs on basement highs. There is no current exploratory activity but much of the section and basin remain unexplored.

These three basins, East and West Orphan and Flemish Pass, comprise a vast exploration frontier of more than 200,000 km^2. With only 16 wells drilled to date, much work remains to fully evaluate these high potential petroleum systems.

Offshore Labrador

Encompassing a vast area of about 200,000 km^2, with good hydrocarbon potential, are two rift basins off the Labrador coast. The drilling of 27 wells during the 1970s and 1980s resulted in the discovery of five large gas fields. The two main basins are the **Hopedale** and **Saglek**, the northernmost of this chain of rift basins along Atlantic Canada and the least understood geologically. These two basins are slightly younger than the other rifted Atlantic Canada basins but there is new evidence of basins containing older, possibly Late Jurassic rocks in deeper water on the continental slope. While little interest has been shown in this area for some time, a new seismic survey was conducted in 2010 and four exploration licenses have been awarded in the past two years.

As Dr. Enachescu points out "Canada possesses petroleum resources second only to Saudi Arabia. Our East Coast is the only North American coastal area with oil and gas production outside the Gulf of Mexico. While sparsely drilled – approximately 500 wells in comparison to over 30,000 in the Gulf of Mexico – the Canadian Atlantic basins are located along a Late Jurassic source rock super-highway. These high quality source rocks have generated huge quantities of hydrocarbons in one of the world's most politically stable and democratic countries and close to the world's largest petroleum market. I have no doubts that current efforts to understand all the elements of this complex margin will generate new information and ideas and ultimately conduce to new oil and gas discoveries." ■

The Canadian North Atlantic is crossed by enormous icebergs and has some of the stormiest conditions anywhere. In exploring and developing the area's resources, the oil and gas industry has proven that they can overcome these most challenging conditions.

Larry Hicks

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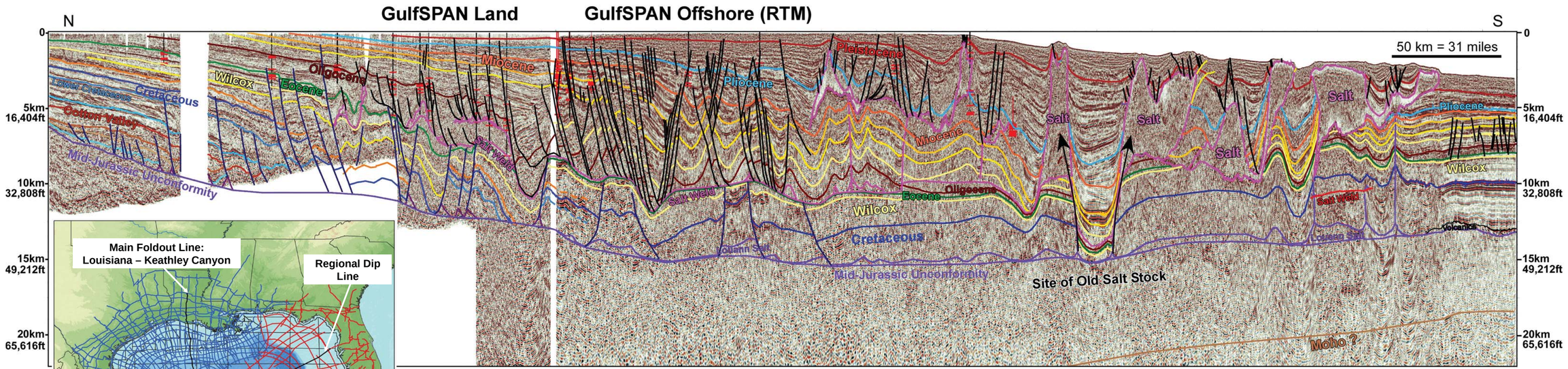
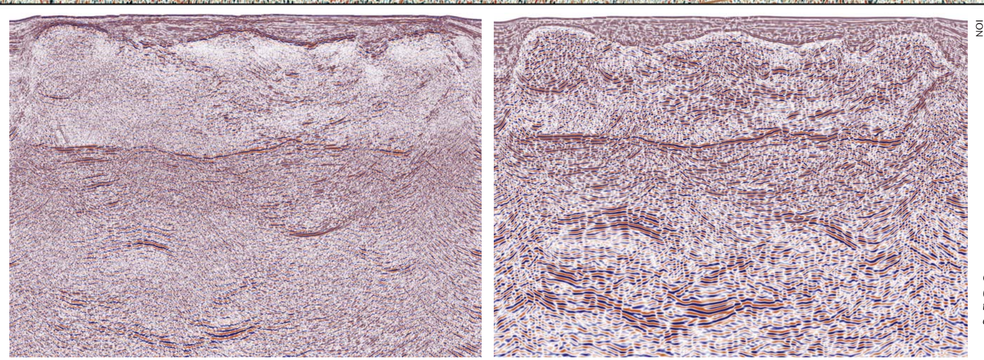
RTM re-processing gives a new look at the Gulf of Mexico Continental Margin



Regional GulfSPAN dip profile north to south from Central Louisiana to Keathley Canyon. This profile highlights the Cretaceous to Pleistocene prograding shelf margins and the interpretation of the deep water equivalent systems. The regional Eocene salt weld (pre-existing canopy) forms a major detachment surface accommodating Oligocene and Miocene expansion updip and the linked contraction to the south.

Inset base map shows the location of seismic profile and the complete GulfSPAN program. Red lines in the eastern Gulf of Mexico and onshore Florida are the recent continuation of this program to better understand the northern and eastern margins of the basin. Some of these lines have already been acquired and processed and some are in the planning stage.



Comparison of original Kirchhoff migration (left) and the reimaged RTM (right). Note the improved image of base salt and the coherent signal for the subsalt deeper strata. Improved deep imaging should provide new exploration targets.

A Unique Basin-Wide Dataset

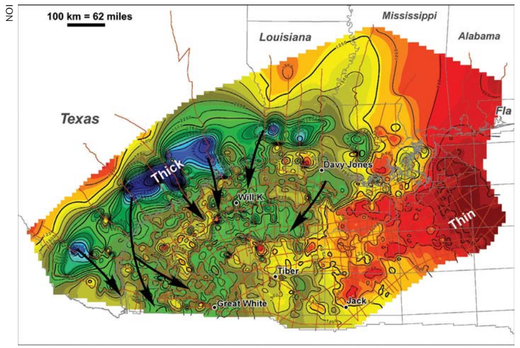
The GulfSPAN™ data illuminates the geology of the northern Gulf of Mexico Basin, all the way from onshore to deep water

BARBARA RADOVICH, BRIAN HORN, PETER NUTTALL, ADRIAN MCGRAIL; ION GEOPHYSICAL

ION's GX Technology is a leader in offering basin-wide regional, long-offset seismic data to the oil and gas industry. The GulfSPAN™ data, part of ION's world-wide BasinSPANS™ programs, is a unique dataset that does not exist on any other continental margin. It ties the northern Gulf of Mexico Basin west to east, from onshore to deep water. The 2011 era for basin-scale imaging in the northern Gulf of Mexico is highlighted by the recent release of the newly reimaged streamer/OBC PSDM (RTM) seismic data in the GulfSPAN project. The upcoming FloridaSPAN™ survey ties in existing GulfSPAN data, thereby extending the regional framework from West Texas through Alabama to Florida.

This regional PSDM dataset has been reprocessed utilizing ION GX Technology's Reverse Time Migration (RTM) methods and enhanced deep-imaging techniques, integrating gravity, magnetic and well data. The data have been re-interpreted with an improved well database. Additional well control for top and base salt aided the interpretation and guided the velocity model-building. This effort involved multiple processing iterations examining the effect of the salt velocities on imaging deep strata below the salt canopies. Ocean bottom cable (OBC) and streamer data were merged and reimaged to develop a basin-wide velocity model in order to produce a regionally consistent grid.

The seismic lines extend onshore and can be seen on the foldout to link prograding shelf margins in Cretaceous and Tertiary strata to their coeval basin floor sediments in deep water. Legacy (onshore) data were reprocessed to create a regional grid of PSDM data that tie the down-dip OBC and streamer data. Additional onshore surveys are currently in production, extending original dip lines tied to regional composite strike lines that follow the Jurassic, Cretaceous, Eocene, Oligocene and Miocene shelf margins.



Regional Wilcox isopach map from reinterpreted RTM data. The map identifies thick depositional trends (fairways) and the possible location of the deep water fan systems. Key wells (Will K, Davy Jones, Tiber, Jack and Great White) have been added to demonstrate their position relative to the Wilcox depositional system.

Regional Framework Re-interpreted

The original regional framework was re-interpreted, refining the horizon and fault interpretations and re-examining the linked (both extensional and compressional) fault and fold systems. These fold systems are developed in the western and east-central protraction areas and have undergone translation along multiple detachment surfaces since the Mesozoic Era. A regional Eocene to Oligocene salt canopy was loaded by Oligocene and Miocene prograding delta systems, creating a regional salt weld surface that is clearly delineated by the new GulfSPAN data.

Neogene contraction appears to have occurred in the central western Gulf of Mexico, resulting in the squeezing of pre-existing salt stocks and deflation of salt sheets. A number of additional salt weld surfaces are also imaged on the new data. Salt canopies are an indirect indicator of contraction related to up-dip extension. Deep synclines and expanded sections of younger sediments fill the depositional basins as the salt evacuates. Above the salt canopy condensed Mesozoic to Tertiary sediments have been drilled and demonstrate the existence of older salt stocks that rafted sediments into their present-day supra-salt position.

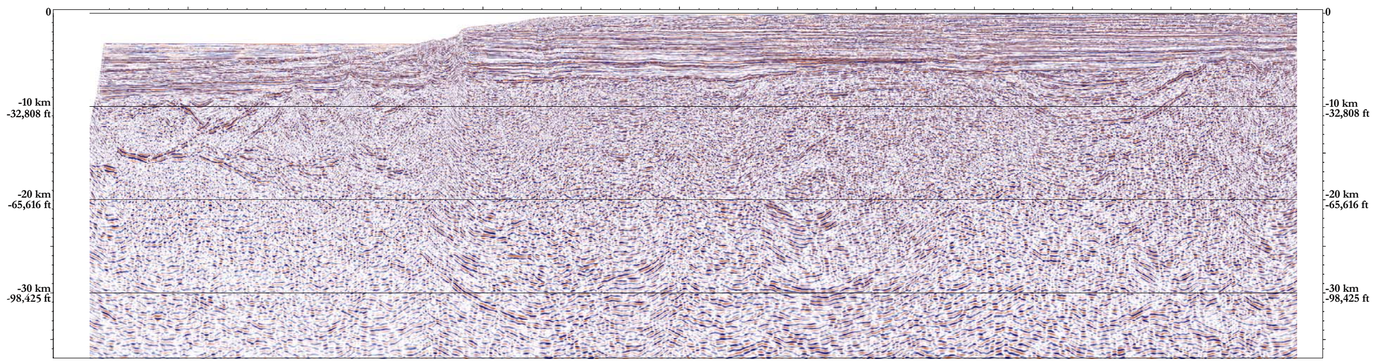
Regional isopach maps created from these data identify potential depositional fairways and structural timing of depositional events. These new insights will guide existing exploration play models and help identify new play fairways in the northern Gulf of Mexico.

A key component to ongoing exploration success is the quality of subsalt seismic images. Uplift from RTM over conventional Kirchhoff migrations give geoscientists a new look at many areas that were previously poorly imaged, particularly for deeper subsalt sediments. The deeper potential of previously explored areas may result in the identification of new plays and consequently in new discoveries.

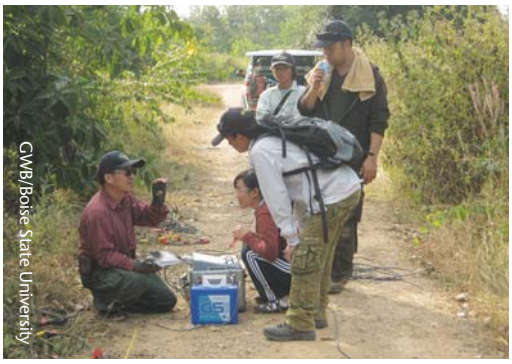
Similarly, preliminary imaging of the eastern part of the basin in Florida has illuminated potential in older Mesozoic strata, potential targets in the pre-salt section and a better understanding of crustal architecture in this area, as seen in the north-east to south-west regional dip line from the FloridaSPAN data.

Successful exploration strategies for the future will require a basin-wide perspective and a fundamental knowledge of how these various factors affect the development of the Gulf of Mexico petroleum systems.

Regional dip (200 miles x 25 miles, NE-SW) line from FloridaSPAN data. Acquisition using deep towed streamer has resulted in enhanced images of deep strata in both syn-rift and supra salt horizons. Initial interpretations suggest these data will reveal crustal structure in the Eastern Gulf of Mexico.



Making a Humanitarian Difference



A GWB project in Thailand.

The mission of 'Geoscientists *Without* Borders' is to connect young geoscientists, academia and the industry with projects that will benefit people and the environment around the world.

JANE WHALEY

David Ngobeni has been studying the effects of invasive trees on a vital water supply to a Children's Village in South Africa.

"The vision of Geoscientists *Without* Borders® is to apply geophysical technologies developed in the energy industry to projects in the developing world which would not normally have access to them," explains the SEG Foundation Program Manager of Geoscientists *Without* Borders. "Although the first goal is to apply geophysics to humanitarian purposes, in the process we create a bridge between academia and industry, and connect with the next generation of geoscientists, hopefully doing some good in the process. Many of our projects involve students from universities throughout the world,, working together and fostering co-operation."

Geoscientists Without Borders (GWB) originated in 2007 through the initiative of WesternGeco Chief Geoscientist Craig Beasley. Craig was President of the Society of Exploration Geophysicists (SEG) in 2004, at the time of the devastating tsunami in South-East Asia, and found the membership of the Society were coming to him and asking how they could help. Realising that geoscience could be used to undertake many humanitarian projects throughout the world, not just in the aftermath of natural disasters, he persuaded Schlumberger to kick-start the initiative with a donation of one million US dollars. The program continues to be funded by the SEG Foundation through donations from individuals, corporations, organizations and grants from other sources.

Transforming Lives

"We fund between two and four projects a year, and hope to fund even more in the future," the GWB Program Manager explains. "There is a great need, and also strong interest – each year we receive about 20 applications, from which we draw up a shortlist of maybe six. All are well deserving, and if we had more money, we could fund a greater number of them, so we would love to get more companies involved in sponsorship. Schlumberger, Santos, CGGVeritas, Global Geophysical Services and Geophysical Pursuit are major sponsors at the moment and we are very grateful to them."

"The main objective of GWB is to provide funding to projects that will benefit communities in need, where the application of geophysical science and information will improve poor conditions, or where dangerous conditions and hazards can be mitigated or removed using applied geoscience technology," she continues. "In the process, we hope to strengthen the global geophysical community through multidisciplinary partnerships and cooperation with other organizations active in engineering and geoscience throughout the world."

At the moment, GWB Borders has nine projects running in various parts of the world, ranging from schemes to address the rural water crisis in India and geophysical investigations into pollution caused by mining in Romania, to working on designs for earthquake and tsunami resistant buildings in Sumatra. Several students were able to showcase and explain their projects at the SEG conference in October last year, giving participants from developing countries the opportunity to travel to the US and to gain presentation experience, as well as giving them a look at recent technological developments in the geophysics industry.

Linking Students

David Ngobeni, a student at the University of Witwatersrand in South Africa, is part of a team studying the impact of non-indigenous tree species on groundwater. "We have used a variety of geophysical methods to map the hydrological conditions at a children's village, where over the last 30 years the water supply has gradually dried up. We think trees planted near the school are responsible for draining the aquifer, so we have used geophysical tools to map the groundwater conditions before and after the removal of these trees."

The project, which had a grant of US $88,000 from GWB, is the first time the effect of invasive trees on ground water has been documented in South Africa. "Not only will the results have broad applications throughout the country, but a more immediate effect will be felt by the children at the Village; if their water supply improves, the school will be able to continue and even expand," says David. "I have really enjoyed working on this project, particularly as it has involved co-operating with students from universities in the US and Canada."

Sudershan Gangrade is an engineering student who has been working on another water project in India. As he points out, "there are half a million people the state of Mahdar Pradesh alone without water, and at the moment we don't effectively harness the rain that does fall here. Our project is looking at the methods and community tools needed to aid water use management, to increase availability throughout the year. As well as participating in a very useful project, doing this has helped me determine my own future. I am studying as a research assistant in the US, after which I will return to India as an engineer to help my fellow countrymen."

As these examples illustrate, the program is amplying fulfilling one of its objectives, which is to energize students throughout the world and introduce them to the broad range of geosciences careers, while also strengthening university programs in geophysics and the geosciences. One project being undertaken in Thailand, for example, has managed to involve 15 institutions and 45 participants from seven different countries, with students using a wide range of geophysical methods to address the local geotechnical problems.

Geoscientists *Without* Borders has recently had a major boost through the creation of an endowment fund by Debra and Mark Gregg of Kiwi Energy, who have committed to provide matching funds for gifts of between $500 and $25,000. As they put it, "This humanitarian program is changing lives today. Universities are taking students to the field. Geophysical expertise is transferring from developed to developing nations. Disadvantaged communities are being assisted in many ways Best of all, this program showcases, in real life, the tremendous benefits that geophysical applications can bring to many global needs – not just oil and gas."

To learn more about GWB and its projects, take a look at the website (www.seg.org/gwb).

Charting a New Course in Seismic Imaging

Ted Moon

TED MOON

With his training in electrical engineering as a foundation, **Eldad Weiss**, Chief Executive Officer of Paradigm, has taken a methodical, logical approach to growing his business from a niche provider of graphical imaging software to a global provider of exploration and production (E&P) data management solutions.

Under the leadership of Eldad Weiss, Paradigm has grown to become the world's largest transnational technology company focused on developing and deploying software for all stages of the oil and gas industry's E&P processes. However, it may surprise some to know that Paradigm's beginnings in the 1980s were not tied strictly to the oil and gas industry, but instead to the larger arenas of image processing and the graphic arts. "We were a division of Scitex, a company that pioneered the development of technology advances for prepress software, which was the forbearer of the image- and page-editing software that is available nowadays," says Eldad. "Many major periodicals were using this software, and still are today, with the goal of creating better, sharper images."

Eldad was still at university studying electrical engineering when he went to work in the prepress industry, and he helped his company find other application areas for their technology. "We started in the textile- and rug-making arena, in which we were tasked with figuring out how to take a design created on paper and convert it digitally into something that could be woven into rugs," he says. "We also worked with the printed-circuit board industry, investigating how to create and optimize the process of making printed circuit boards for various electronics applications."

But it was mapping that opened the pathway into oil and gas. "We were providing technology – software, hardware and plotters – to help mapmakers print higher quality maps. We realized that it was a pretty natural transition to the exploration segment of the oil and gas industry, which at the time was challenged with producing higher-resolution, 2D seismic plots on paper," Eldad says.

Replacing Colored Pencils!

In 1984, Eldad and his group began supplying large drum plotters to the industry, and soon transitioned into supplying software to automate and computerize seismic plotting activities. "The first order of business was to mimic the manual process of producing seismic plots in the computers. In the 80s, much of this work was still done with paper and pencils, different colored pencils for each horizon you were interested in plotting," says Eldad. "In those days, you might be interested in picking up to 12 different horizons, which translated to 12 different pencils. Now, there are requirements for thousands of horizons! Clearly, the paper and pencil approach was not sustainable."

Eldad's company became the first to provide software that would plot seismic data graphically, but had to overcome both technical challenges and people's attitudes toward working with computers in this field. "You have to remember that this was the 80s, when computer-aided seismic interpretation was in its infancy," Eldad says. "We had to answer the question of why, given the high overhead costs of computers and technicians, people would even do this kind of work on a computer. This might sound strange given our current perspective, but it was a prevalent point of view back then."

Another obstacle involved how to interact with computer systems to manipulate the graphical data for optimal usage. "The concept of a mouse did not exist, so we brought trackballs in and figured out how to interface them with the computer, which was a first in this arena," Eldad says.

With these challenges effectively addressed and the software gaining greater industry acceptance, Eldad began to set his sights on broadening his company's exploration offerings. "We were not the domain experts in interpretation of the data, but rather in converting the industry's requirements into a computer-aided, graphical representation of the data that they could use to work more effectively.

"We realized that moving from strictly computer-aided graphical design to computer-aided exploration support was a logical and natural evolution for our company," he adds.

Adding a New Dimension

During this time period, many of the operators using Eldad's services were in the early stages of transitioning from 2D seismic mapping to 3D, which presented formidable challenges.

"We were one of handful of start-ups at the time who were trying to answer the fundamental question of how best to interpret 3D data sets," Eldad says. "Because there were not true 3D seismic data sets available to work with, we used data from the University of Houston's Seismic Acoustic Laboratory [SAL] Model, which recorded seismic on objects submerged in a large swimming pool in an attempt to mimic what true 3D seismic data might look like."

With this data as a starting point, Eldad and his colleagues worked to develop better interpretation solutions. Measurement concepts evolved from in-line to cross-line and then to various integrations between the two. Eventually, the concept of the time slice, which was not even a consideration in 2D seismic, was developed.

Eldad next set his sights on moving from interpreting in a time domain – the typical recording realm for seismic data – to depth. "Depth is a more natural interpretation realm to work in, and so we pioneered the concept of giving the interpreter the flexibility to do their work in both time and depth through our flagship product called GeoDepth," he says.

Acquiring Expertise

By this stage, the company, which had branched off from its parent under the name Paradigm, aimed to increase its footprint to include seismic processing, further interpretation, petrophysical analysis and drilling software.

"We were aiming to turn Paradigm from a niche provider of time-to-depth conversion and depth migration into a full solution company, which was accomplished through the methodical process of acquiring and integrating companies with key technological offerings," says Eldad. "Personally, I have found this process to be very rewarding and exciting."

Successfully integrating any new company into an existing organization presents unique challenges, but Eldad is proud of the way Paradigm has accomplished this as seamlessly as possible. "We integrate new companies in a way which respects their people's work ability, history and contribution."

This strategy includes the concept of maintaining people at their existing locations, rather than relocating them or shuttering their R&D centers. "We want our new employees to maintain their excitement and enthusiasm for their products, but at the same time, get them thinking about how this benefits the entire Paradigm organization," says Eldad. "We've done very well with this approach, which is evident from the fact that many of these folks are still with us."

Most recently, Paradigm acquired French software provider EDS, which developed the SKUA modeling software. SKUA, an acronym for Subsurface Knowledge Unified Approach, is a technology platform that provides fully 3D structural, stratigraphic and reservoir models with multi-resolution capabilities. "As an engineer, I was quite impressed with the ▶

quality of the SKUA solution, and I think it has high potential to improve the industry's performance. While the product came out in 2008, it really took us until late 2010 to develop it into the full offering that it is today," Eldad says.

This time period to develop a technology into a fully realized product, a process that Eldad calls "productization," is not unique to SKUA, and in fact most of Paradigm's products go through the same methodical and rigorous process. "There is a big difference between announcing that you have a great new technology and actually making it a useful product that can help an operator achieve their goals," says Eldad. "Only by testing a product on a massive scale can you identify issues and then work to solve them to optimise the product. It requires a thorough evaluation process that factors in scale, security, performance assurance and data quality. I feel that our ability to productize a technology has been a major benefit for the companies we bring in."

Industry Challenges Persist

While seismic processing providers have made significant strides in helping operators make better drilling, completion and production decisions, Eldad believes significant work remains in several key areas.

"An ongoing frustration for me is that even today, some software offerings provide solutions for the general interpreter that do not take them much farther than the traditional 'paper and pencil' approach," he says. "The industry should examine how to truly create a – and please mind the pun – working paradigm for how seismic data is interpreted."

Eldad acknowledges that much progress has been made, but adds that the industry is still fundamentally mimicking many of the procedures developed in the 1980s, rather than rethinking them, even though the underlying computing environment has changed so dramatically.

"In my opinion, the technologies currently at our disposal are ahead of the workflows, procedures and application software that have been developed," he says. "We have invested in our new Paradigm 2011 release and in our fundamental integration software to enable new workflows. But providing a technology is one thing. We really need industry leaders and management to encourage their people to take advantage of new processes and workflows."

Shifting to new workflows will require moving from the traditional interpretation task of manually picking a line and creating maps to a search-engine approach, in which the interpreter makes their decision based on the best interpretation available from the computer. "Advances in our software solutions should be able to provide multiple models and scenarios to the interpreter, such that their job will become selecting the right scenario, rather than the mundane task of picking and creating a scenario."

Data management is another area that requires some fundamental changes, according to Eldad. "Advances in data storage and computing technology have given us the ability to access vast amounts of data, but this requires some fundamental rethinking. Having all this access blurs the lines of what constitutes project data, an individual's data and corporate data."

Proper data management also means assuring that security safeguards are in place – a complex undertaking in a large-scale, collaborative project with multiple service providers and operators involved – and developing better user interfaces and analysis methods that identify unsafe drilling and production events early to mitigate their impact.

And what lies ahead for Eldad and Paradigm? "We will keep looking to develop and acquire interesting technologies that continue transitioning geoscience from a work of art to a full engineering process that presents various scenarios, evaluates the risks of each scenario and allows an informed engineering decision to be made. I've enjoyed using my engineering background to contribute to this transition." ■

Eldad Weiss and the Paradigm team at NAPE this year.

Paradigm

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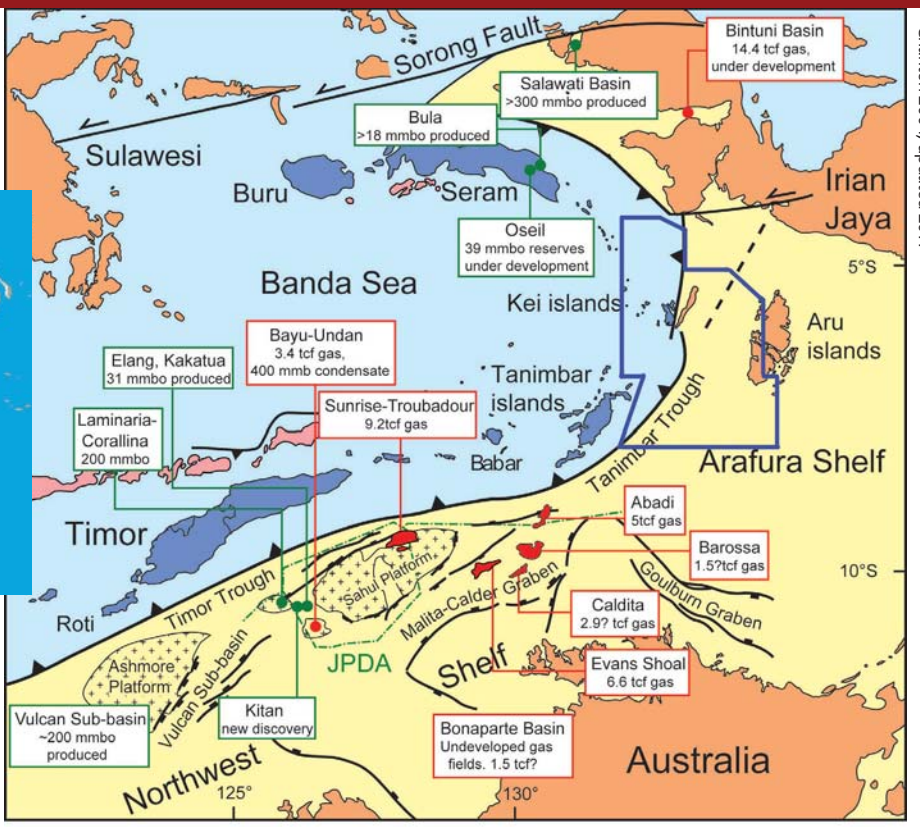
INDONESIA: The Eastern Frontier

New light has been shed on the petroleum potential of the Northern Arafura Shelf area in Eastern Indonesia.

GLYN ROBERTS AND TROND CHRISTOFFERSEN, SPEC PARTNERS LTD;
CHARLES RAMSDEN, FAR CAPE PTE LTD.



Charlton 2004, updated 2011

Structural elements of the NW Arafura Shelf region, showing the approximate survey area.

The Northern Arafura shelf area is frontier in nature but is on trend with a number of large fields, the largest of which are the multi-Tcf Abadi and Tangguh gas fields. It is relatively unexplored, with the two dry wells (Koba-1 in '84 and Barakan-1 in '95) drilled offshore on highs in and around the Aru Ridge, and only one on land (Kai Basar -1 in '96) which was drilled on the island and encountered thick Mesozoic rocks. The new data was acquired under the jurisdiction of the Indonesian Ministry of Energy and Mineral Resources (MIGAS). Its eastern and south-eastern portion covers part of the **Arafura Shelf and Basin** whilst its west and north-western portion covers the **Tanimbar** and **Aru Troughs** and the eastern part of the **Banda Arc** collision zone.

Known Petroleum Systems

The major discoveries in the region lie both to the north and south-west of the survey area. The Jurassic Plover sandstone petroleum system is proved to the north in the Tangguh field in the Bintuni Basin and to the south-west in the Abadi field, and also further westwards in fields such as Sunrise, Evans Shoal, Troubadour and Bayu Undan. In this petroleum system, the gas/condensate fields are thought to be charged from equivalent-aged deeper-lying Early-Middle Jurassic Plover formation source rocks.

Jurassic clastics have been sampled on the islands of Tanimbar and Kai (Charlton, 2004, 2008) and it has been suggested by

a number of authors that reservoir quality sandstones could be present over a large area along the Jurassic shelf margin, which is expected to run northwards from the Bonaparte Basin/Sahul Platform, through the survey area to New Guinea and the Bintuni Basin/Tangguh area.

The Jurassic reservoirs are expected to occur both on the western margin of the Arafura Shelf (west of the island of Aru and the Aru Ridge, where the Mesozioc section thickens rapidly) and in the western part of the survey area. The seismic data off Tanimbar and around the Kei Islands show them to be buried below a Neogene-aged melange, which is associated with collision tectonics forming the eastern margin of the islands. This situation is similar to that seen off the northern coast of Seram Island and off the southern coast of East Timor.

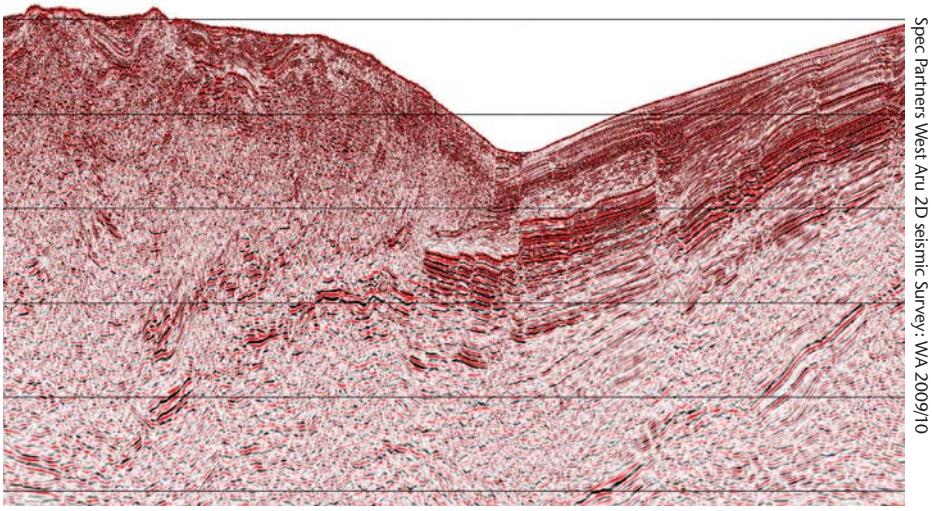
Reservoirs of probable Cretaceous age are also seen to the west and south-west of Aru, where the Jurassic soles out as it rises from west to east. Here a number of four-way dip closures, ranging in size from 25 to 250 km^2, have been mapped from the new seismic data.

In addition to this, the presence of deeply buried Early Cretaceous source rocks cannot be discounted, with Barber *et al* (2003), suggesting that these could be present along the flanks of the Tanimbar Trough. They also suggest that these could possess similar attributes to the excellent quality Echuca Shoals Formation source rocks, which have sourced oil discoveries in the Bonaparte Basin, for example in the Elang Field in the Australia – East Timor Joint Petroleum Development Area (JPDA).

It is interesting to note that Cornee *et al* (1997) report encountering black laminated marlstones and shales of Early to Late Cretaceous age in samples dredged from the eastern side of Kai Besar Island, which is on the northern margin of the survey area. The oldest of these were dated as Late Albian, which sits above the Echuca Shoals Formation.

Oil and gas seeps are evident on some of the islands of the Banda Forearc, such as Timor, Kei Besar and Seram. However, to date, the only established petroleum producing province in this collision complex is on the island of Seram. Results from an onshore well drilled on the island of Kai Besar (Kai Besar 1) have been reported (Widodo 2006) to show the presence of mature source rocks of Mid-Late Jurassic Plover Formation and Late Cretaceous Ekmai Formation with potential reservoir rocks at several levels.

Charlton (2004) proposed that the tectonism in the outer island arc has involved the inversion of graben basins which were filled with Permian to Jurassic sediment and that these could have potential for hydrocarbon trapping. In 2001 Charlton also reported that rock fragments of Triassic and Jurassic age, including Jurassic coals, have been ejected from mud volcanoes on Tanimbar Island.



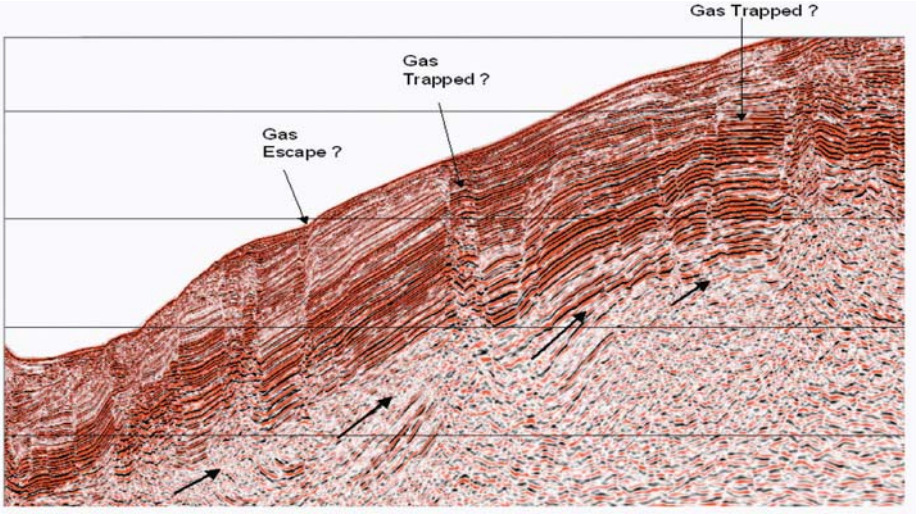
Spec Partners West Aru 2D seismic Survey: WA 2009/10

West to east section through the sag basin showing Mesozoic development below the melange. Section width 55 km. Timing lines every 1 second

Potential in Paleozoic?

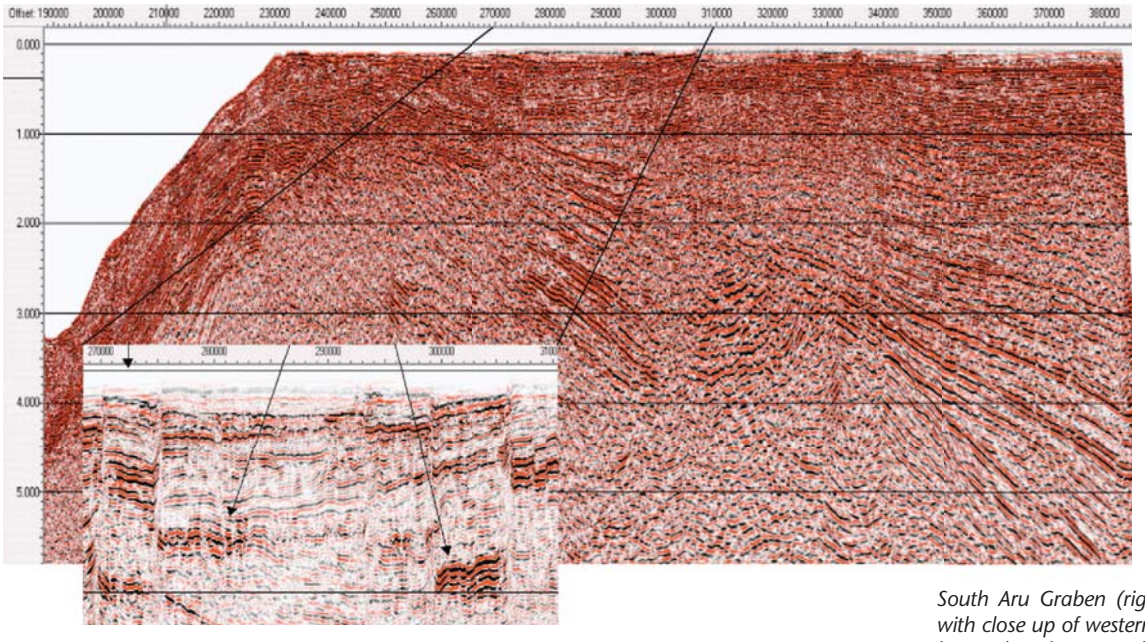
In addition to the Mesozoic petroleum system, we see thick Paleozoic sediments on the Arafura Shelf. These are particularly well developed south of the island of Aru in the South Aru Graben (Livsey *et al* 1992) which is possibly filled with several thousand metres of Cambro-Ordovician to late Devonian/Early Permian sediments. The Graben is characterised by a thin (< 1 sec TWT) cover of often faulted Cretaceous and younger sediments, unconformably overlying rocks of Paleozoic age which demonstrate a very high (> 5000 m/s from 1 sec TWT) stacking velocity (Adhyaksawan *et al* 2010). The Graben attains a depth greater than 10,000m in the easternmost part of the survey area. Its petroleum generating potential is evidenced by the presence of gas chimneys and bright reflections, interpreted as possible gas sands. This Paleozoic petroleum system is believed by a number of authors to be analogous to that seen in parts of the Bonaparte Basin and Goulburn Graben.

A number of authors have reported on the nature and petroleum potential ▶



Spec Partners West Aru 2D seismic Survey: WA 2009/10

Example of a Mesozoic Platform play on approximately west-east line. Arrows indicate possible HC migration and areas where gas may have escaped or been trapped. Section width 45 km.



Spec Partners West Aru 2D seismic Survey: WA 2009/10

South Aru Graben (right hand half of section) with close up of western part with the amplitude lowered to show gas chimneys and possible gas sands (arrowed). Main section width 190 kms.

of the undrilled Northern (Australian) Arafura Basin and contrasted it to that of the Goulburn Graben to its south, which contains a number of unsuccessful wells. The contention is that since the platform area to the north is less deformed than the Goulburn Graben, this area could be less risky as far as the timing and expulsion of hydrocarbons is concerned; and since the Paleozoic rocks are not so deeply buried, the reservoirs in the north could have improved qualities.

The petroleum potential of the Arufura Shelf is borne out by the recognition (on the Australian side to the north of the Goulburn Graben) of seeps both on satellite altimeter data and on sub-bottom profiles from a marine seepage survey; and by amplitude brightening on seismic data (Kennard *et al* 2007). The primary source rocks are thought to be near the base of the Cambrian but other source rocks could occur in the Devonian to Permian section. With the platform running north/north-eastwards from the Goulburn Graben to New Guinea, a similar scenario could be expected in the south and south-eastern part of our survey area.

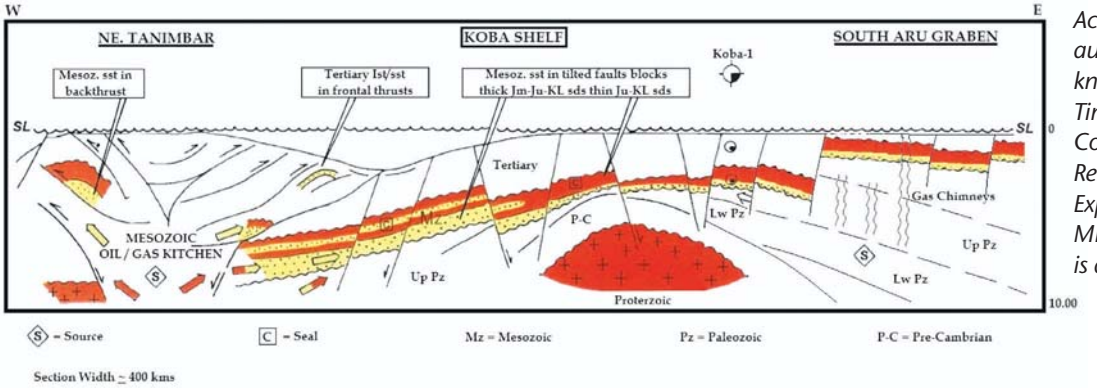
Multi Tcf Potential

The new long offset data has allowed us to recognise a number of different plays in the survey area, which are defined by their relationship to the main structural/stratigraphic provinces outlined briefly above and summarised on the cross section.

In conclusion, it is interesting to note that there are a number of potential petroleum systems in the area, rather than just the Cenozoic one which is generally the case in the Far East (USGS 2010), and that the geology has much in common with that of the North West Shelf of Australia. Discoveries could well be in the multi-Tcf range and include oil as well as gas.

We can also note that the long offset data, together with the use of Pre-Stack Time Migration, has been particularly good in assisting the imaging of the data below the Melange, which was formed by uplift and collision tectonics in this part of the Banda Arc and which runs along the eastern margin of the Tanimbar and Kei Islands. It is also useful in helping extract primary data from multiples on the shelf, thus illuminating the data within the underlying Paleozoic grabens such as the South Aru Graben. It will also be valuable in future work which may involve AVO analysis.

This data is being used to assess the petroleum potential of the area, which is currently unlicensed. It will be used by the authorities to help them decide the number and size of the exploration blocks to be put up in the next bid round, which could be announced as early as May of this year.



Schematic cross Section of Tanimbar Basin to South Aru Graben, summarising the main plays; Tertiary structures within the Melange (East of Tanimbar and Kei Islands); Cretaceous closures both Sub-Melange and on the Platform Margin west and south-west of Aru; Jurassic closures both Sub-Melange and in the Aru Trough; and Palaeozoic (South Aru Graben)
Width: 400 km; Depth: 10km

Modified from Pertamina BPPKA, 1996

Acknowledgement: The authors would like to acknowledge assistance from Tim Charlton, Jean-Jaques Cornee, Ian Longley, David Remus; Staff at Seabird Exploration; Staff at Horizon; MIGAS. A full set of references is available from the authors.

Alaska: The Start of Something Big

An oil discovery in the Moose Range wilderness on Alaska's Kenai Peninsula would bring a momentous change to the territory and have oil exploration implications far to the north.

THOMAS SMITH

The discovery in Moose Range was the boost Alaska Territory woefully needed at a time when mining was down and oil companies were pulling out. This is a story of what a few men accomplished, before and after the Swanson River oil find, to secure the prominence they were confident would be achieved. Without their efforts and that first oil discovery, Alaska's recent history could look much different. Their knowledge and insights helped to shape this great land and its oil industry.

Alaska's big hope for recognition and new prosperity eventually became oil, but until 1957, 165 consecutive unsuccessful exploratory oil wells had been drilled. The territory's only oil field produced between 1902 and 1933 in Katalla, located along the Gulf of Alaska. Seeps had long been found along the west side of the Cook Inlet yet drilling for that big discovery remained illusive.

John (Jack) Roderick noted in his book,

Thomas Smith

Denali, North America's highest peak stands watch over the 'great land' of Alaska.

Modified from Alaska Div. of Oil and Gas

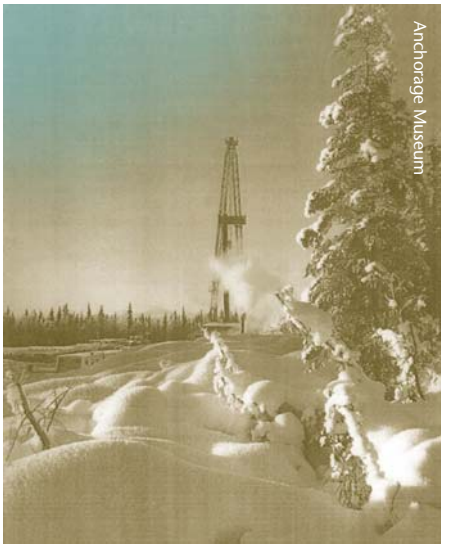
The two major oil producing areas are in Cook Inlet, south of Anchorage, and Prudhoe Bay adjacent to the Beaufort Sea.

Crude Dreams, "Alaska radiated opportunity and adventure when I first arrived in 1954… I reveled in Alaska's openness to newcomers and its absorption with self-determination." At that time Phillips Petroleum had almost completed drilling its Icy Bay well on the Gulf of Alaska while several companies were filing for leases on the Kenai and Alaska peninsulas. "The little guys were competing in the oil game" around the state.

By 1955, over 5 million acres (20,000 km^2) of oil and leases were held. The Mineral Leasing Act of 1920 and various amendments allowed just about anyone to file for leases at 25 cents per acre and hold up to 100,000 acres (400 km^2).

Also by 1955, statehood advocates had been hard at work. The idea of statehood was nothing new as the first bill for Alaska statehood was introduced in 1916. New ones were introduced nearly every year thereafter. But not until the Alaska Statehood Committee was formed in 1949 and the dashing and articulate publisher of the *Anchorage Daily News*, **Robert Atwood**, was appointed to head it did the prospects for statehood look good.

Yet Atwood banker, Elmer Rasmuson, and some serious Anchorage businessmen ▶



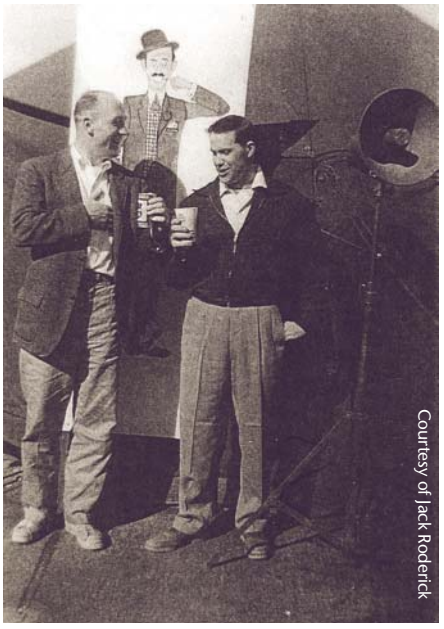
Anchorage Museum

The 1957 discovery of oil at Swanson River on Alaska's Kenai Peninsula would ensure statehood and a very successful oil industry.

knew it might take something special, and saw oil development as a way to promote statehood. Their group, informally called 'The Spit and Argue Club', filed for leases on the Kenai Peninsula with the aid of **Locke Jacobs**, self-taught oil-leasing "man in the know". The group tried to interest oil companies in drilling to no avail.

Atwood recalled those times to John Strohmeyer, author of *Extreme Conditions: Big Oil and the Transformation of Alaska*, "We pleaded with the oil companies to at least drill a hole… We tried to impress on them that what motivated our group was not the fast buck. We were interested in developing Alaska."

In 1954 the Richfield oil company applied to lease over 50,000 acres (200 km^2) on the Kenai Peninsula over a large topographic high and worked out a deal with Jacobs' leaseholder group. At first, a representative from the group offered to assign some of its leases at no cost to Richfield for a commitment to drill a well anywhere in Alaska within two years. Richfield did not accept the free acreage deal but would pay two dollars per acre with a five percent override for some of the acreage. About that same time Union Oil had filed for nearly 200,000 acres (800 km^2) west of Richfield's holdings. After the deal with Richfield, Jacobs worked through the night to file an additional 100,000 acres (400 km^2) around Richfield's Swanson River holdings.



Courtesy of Jack Roderick

Men like Jack Roderick (left) and Locke Jacobs were instrumental in keeping oil on the front burner before and after the Swanson River discovery. Both men were self-taught. Jack would start the Alaska Scouting Service to report on oil drilling and leasing activity around the state. He later became important in the politics of the area and was elected Mayor of Anchorage Borough from 1972–1975. Locke Jacobs was Alaska's leasing man. He knew where to file and who was filing for leases, putting together the lease deals that would eventually lead to the Swanson River oil discovery.

THE STORY OF ALASKA

The first Alaskans arrived about 20,000 years ago, probably from Asia via the Bering Land Bridge, and kept going south. The first actual residents arrived about 10,000 years ago and are the ancestors of today's native population. European settlement from Russia began with explorer Vitus Bering in 1741, when a government was established in the south-eastern town of Sitka. The name **Alaska** came from native Aleut word for **'Great Land'**.

Thomas Smith

Gold brought more people to Alaska than the ongoing fur trade and salmon canning industries combined.

Alaska became a U.S. property in 1867 with the signing of a treaty with Russia. William Seward, Secretary of State under President Abraham Lincoln, negotiated the deal for $7.2 million, or about two cents per acre. He was often ridiculed about the purchase, commonly known as Seward's Folly or Seward's Icebox.

The first Alaskan gold discovery occurred at nearly the same time as it was discovered in California, 1848. The gold fever culminated with the 1896 strike in Canada and the Klondike gold rush was on, bringing 80,000 people to the area. Alaska became a territory in 1912. With the influx of people, the government built telegraph lines, trails, roads, and finished the Alaska railroad in 1923.

By the 1930s, about a third of the population of the larger towns such as Fairbanks was employed mining gold. Gold was raised from $21 to $35 an ounce in 1933 and became an even more important source of employment and income for the territory. World War II put a stop to the mining but did highlight Alaska's strategic importance as an overland connection to the 'lower 48' with the building of the Alaska Canada Military Highway.

The Strike

Richfield sent two geologists, **Ray Arnett** and **Bill Bishop**, to check out the newly acquired lease area. They used hydrophone soundings around lakes (dynamite had been banned in the protected Moose Range) to map an anticline, using just 33 seismic test points. Bishop is said to have mapped out an anticline structure that extended from the Richfield leases onto the Anchorage leasing groups to the south.

Bishop picked a drill site near the Swanson River next to a hemlock tree that is rather rare in this area. Legend has it that he kicked the ground with his boots and said "drill here". Those boots have since been bronzed and are on display at the Anchorage Museum.

The drill site was located in nearly total wilderness near the Swanson River in the Moose Range, now in the two million-acre (8,000 km^2) Kenai National Wildlife Refuge. A 32 km road needed to be constructed to get into the drill site. To save surveying time and money, Bishop threw unrolling toilet paper tubes out a plane to mark the road path. The new road was punched through very quickly and drilling started in April, 1957. Richfield hit oil at a depth of 11,140 feet (3,395m) and announced the strike on July 23, sending headlines reaching to the nation's capital. This discovery would have major implications for future statehood and the oil industry.

A few weeks after the discovery, Chevron purchased a half interest in Richfield's leases and became operator of the

field. Only a year later, Union Oil would hit gas on the Kenai Peninsula and more than 100 oil companies would hold leases totaling over 18 million acres (73,000 km^2) in Alaska. In 1959, Union Oil and Marathon would find the Kenai Gas Field, Cook Inlet's largest field.

Statehood and Alaska's First Lease Sale

On January 3, 1959, President Eisenhower signed the official declaration making Alaska the 49th state. However, negotiations made before this date would have far reaching implications for Alaska's prosperity and that of a budding oil industry.

Since the 18th century, Congress had given new states part of the public domain land to help finance schools, hospitals, and other services. By the standards set after the Civil War, Alaska was expected to receive 30 million acres (120,000 km^2). As negotiations with Congress progressed, the final bill gave Alaska 104 million acres (421,000 km^2), an area about the size of California. The state would have 25 years to make its selections.

It would not take Alaskans long to select acreage in the Cook Inlet area. The new state held its first oil and gas lease sale in 1959, covering 77,000 acres (311 km^2) and netting the state $4 million in revenue.

More Than Statehood

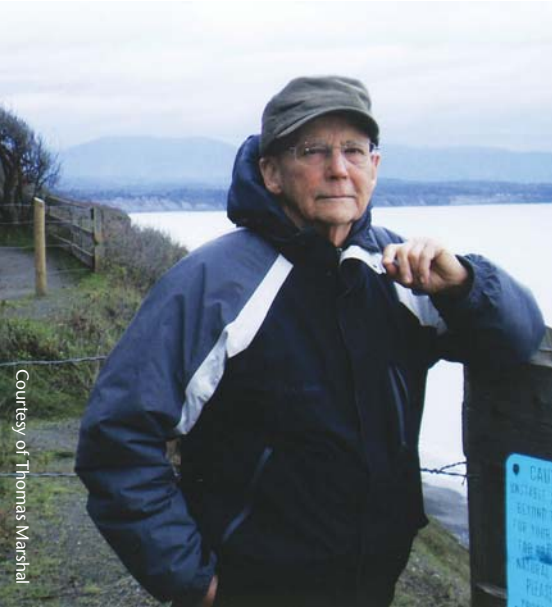
While the discovery of Swanson River Field helped convince the U. S. Congress to grant statehood, it also brought an influx of new and talented people to the land. The discovery caught the eye of a young petroleum geologist living in Casper, Wyoming. He already had connections in Alaska through his grandfather who was in the Canadian Mounted Police and frequently went into the Territory. So, shortly after oil was discovered in Alaska, **Thomas R. Marshall, Jr**. was heading north to homestead in the Matanuska-Susitna Valley north of Anchorage.

In 1960, Tom obtained a job as land selection officer for the state, but with his petroleum background was also helping with oil industry regulatory functions. "We had a two-man office, me and a petroleum engineer," recalls Tom. "The young state needed money to operate so the petroleum section stayed small. We witnessed discovery tests, helped operators fill out permit applications, and made sure all followed the requirements for casing, abandonment, monthly reporting, and so on."

"State land selections remained the top priority," says Tom. "Once given title to the land, we could dispose of it and get money. Areas with timber, agricultural possibilities, and known sedimentary basins were easy because they had multiple assets the state could exploit. Land on Alaska's North Slope was another matter – to most living here it was just a frozen waste land. We also had a governor that did not want to 'play into the oil companys' pockets', so selecting land on the slope was rather contentious."

Questionnaires to aid land selections were sent to seven oil companies; four responded. They all wanted a full four million acres (16,000 km^2) selected about 160 km south of the coast line, along the same latitude as the Umiat Oil Field, discovered by the Navy in 1946, in the National Petroleum Reserve-A (NPRA). However, Tom's geologic experience in Wyoming offered him a very different picture of the area's potential.

"I knew it would take something big to be economic," says Tom. "The Cretaceous oils in Wyoming were waxy and wells completed in those horizons had a rapidly declining productivity. Completions in the ▶


Courtesy of Thomas Marshal

In 1958, Tom Marshall came to Alaska following his dream to homestead in the north land. Little did Tom know he would make a critical land selection that would transform Alaska into a major oil producer.

Madison limestones were much better and we had a direct analog on the Slope, the Lisburne limestone. At that time, the Barrow Arch had been mapped to follow the north coast of Alaska from Barrow eastwards. I believed that the rise of deeper formations upon the arch would bring potential reservoirs into drillable depths near the coast."

A recon trip north with government officials from the Bureau of Land Management (BLM) and the National Parks Service would cement Tom's resolve on North Slope land selections. "Flying over the Prudhoe Bay area, there was talk about the central caribou herd and protecting this area," says Tom. "That is when I knew we had to act. I pushed hard for the 1.5 millions acres (6,100 km^2) along the coast."

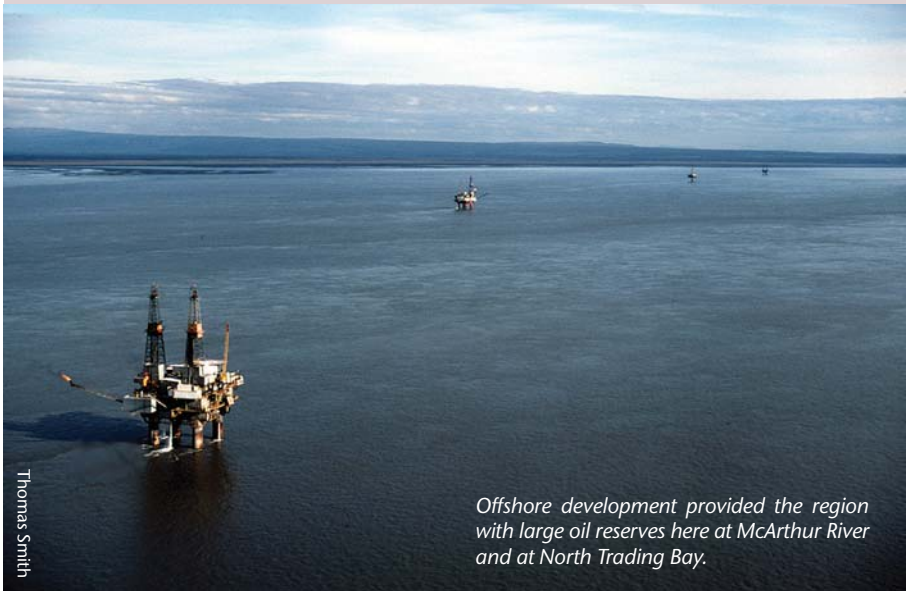
The oil companies were still lobbying for the foothills acreage. The coast was riddled with lakes and rivers and the state owned all these submerged lands. This presented the BLM with a problem; they had to survey these features, a nearly impossible task. It turned out to be the break Tom needed; he argued that if this land was selected by the state, the coastal survey would not be needed. In 1964, the governor agreed to the plan and approved the selection.

The rest is history. North America's largest oil field would be discovered in 1968, in an area that just might have been closed to oil exploration if not for being state selected. Innovative geologists Tom Marshall and Bill Bishop, oil scout Jack Roderick, landman Locke Jacobs, and businessman Robert Atwood did much more than just their jobs; they all possessed a forward looking vision that has helped transform that remote wilderness territory into a modern Alaska. ■

COOK INLET BASIN

Exploration of the Cook Inlet Basin state lease brought a steady string of new finds.

The first discovery of the west side of Cook Inlet, gas at Beluga River, would be discovered in 1962. This was followed in 1963 by the first offshore oil discovery at Middle Ground Shoal. Chevron's oil refinery began operations that same year on the Kenai Peninsula. Three offshore fields would be discovered in 1965, Granite Point, Trading Bay, and the area's largest oil field McArthur River with estimated reserves of 1.5 Bbo. Exploration drilling would peak in 1966. Between 1964 and 1968, 14 offshore platforms were installed. The Steelhead platform would be installed in 1986 and the final was Osprey in 2000. The last commercial gas discoveries would occur in 1979 and the last major oil finds would be in 1991. Production peaked in 1970 at 82 MMbo per year. Over 1.3 Bbo have been produced from the basin.


Thomas Smith

Offshore development provided the region with large oil reserves here at McArthur River and at North Trading Bay.

Gas that was discovered across Cook Inlet from the Swanson River Field supplies much of Anchorage's electricity.


Thomas Smith

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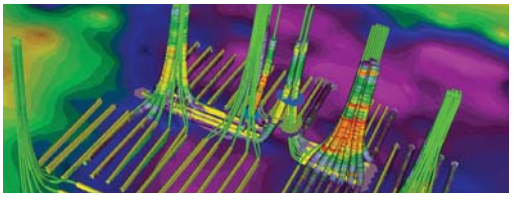
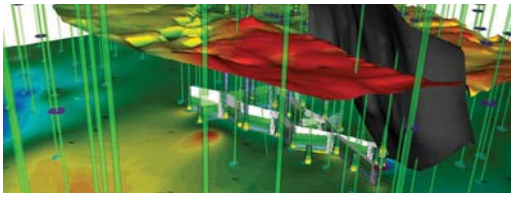
[1] Welling & Company Geological & Geophysical Software Study, 2009



Directional Well Module



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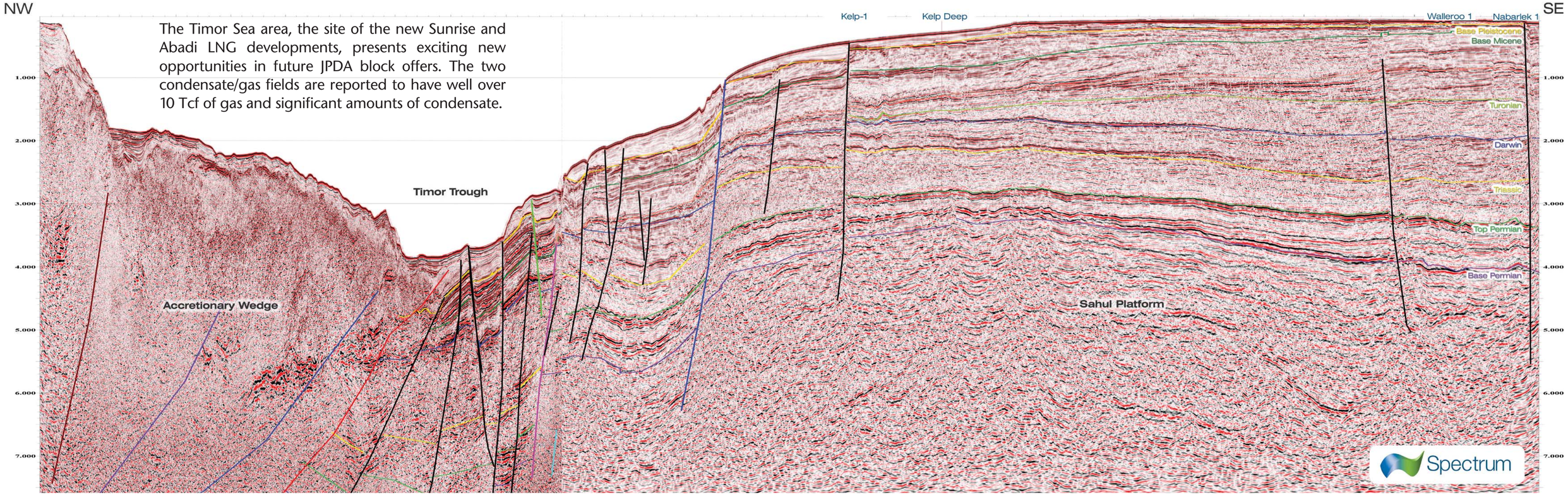
JOINT PETROLEUM DEVELOPMENT AREA TIMOR SEA

Exploration opportunities in the prolific Bonaparte Basin of the Timor Sea

The Timor Sea area, the site of the new Sunrise and Abadi LNG developments, presents exciting new opportunities in future JPDA block offers. The two condensate/gas fields are reported to have well over 10 Tcf of gas and significant amounts of condensate.



Treaty Brings Fresh Enthusiasm

SWEE GUAN LEE, PETRO ANALYST OIL AND GAS CONSULTANTS;
MARTIN BAWDEN, SPECTRUM

The signing of a boundary dispute treaty between Australia and East Timor in 2005 has resulted in a resurgence in exploration vigour, both in the JPDA as well as in sovereign East Timor territory.

The history of exploration in the northern Bonaparte Basin of Northern Australia and the Joint Petroleum Development Area (JPDA) started back in the late 1960s. Early explorers were quickly rewarded with successes such as the Sunrise and Troubadour gas discoveries in 1974. Gas economics back in the 1970s were unfavourable for the fields to be developed and these gas discoveries quickly faded from the headlines. It was not until the oil discoveries such as **Jabiru-Challis** in 1983 that the spotlight was put back on the area. In the JPDA, the stimulus from the Jabiru discovery in the Vulcan sub-basin spurred on the exploration effort which resulted in more discoveries in quick succession at **Elang, Kakatua, Laminaria** and **Corallina** in 1994 and **Bayu-Undan** in 1995.

Politically, the uncertainties in the late 1970s through to the 1990s over the international boundary issues between Australia and Timor stymied much of the enthusiasm to explore in the unresolved areas. The signing of the *Timor Gap Treaty* in 1989 and the establishment of the *Zone of Cooperation* allowed exploration activity to resume in these areas. The ratification of the Timor Sea Treaty between Australia and East Timor in 2005 finally brought about a certain calm and the area has experienced a fresh resurgence in exploration vigour, both in the JPDA as well as on sovereign East Timor territory.

"Northern Endeavour", the worlds largest FPSO at the Laminaria/Corallina field in the Vulcan sub basin

Developments in the JPDA

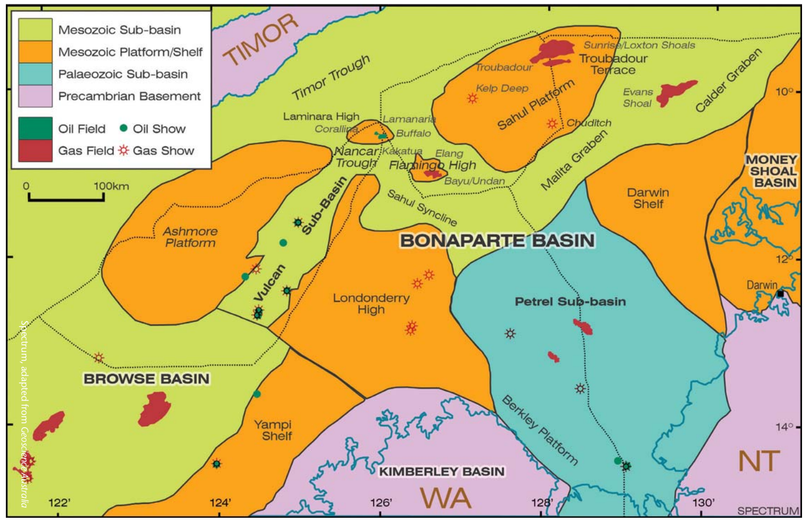
Several oil and gas developments have now been completed in the JPDA. The greater "Northern Australia" area now boasts some of the finest innovations in the oil industry, such as Australia's first subsea and FPSO development at Jabiru and the world's largest FPSO at Laminaria.

The Bayu-Undan gas/condensate field is wholly within the JPDA. The field was developed in 2003, initially as a condensate stripping project. Later in 2004/05, a platform complex was put in place to produce and supply gas to the Darwin LNG plant at Wickham Point. Gas is piped onshore through a 500 km, 26-inch line. The Darwin LNG plant now produces 3.2 million tonnes per annum of LNG which is exported to Japan.

With abundant discovered gas resource, this area could soon see multiple FLNG (floating LNG plant) developments taking place. As a development concept, FLNG is ideally suited to the remoteness that characterises this prolific oil and gas province.

The Bonaparte Basin has over 15 km of sediments and it can be roughly divided into two principal depocentres; a southern Palaeozoic and a northern Mesozoic depocentre. The majority of the hydrocarbons in the Bonaparte Basin are found in the northern Mesozoic basin.

Prior to the Mesozoic extension the Bonaparte Basin underwent two extensional episodes in the Palaeozoic and a compression event in the late Triassic. Significant amounts of gas have been found in the older Palaeozoic reservoirs.



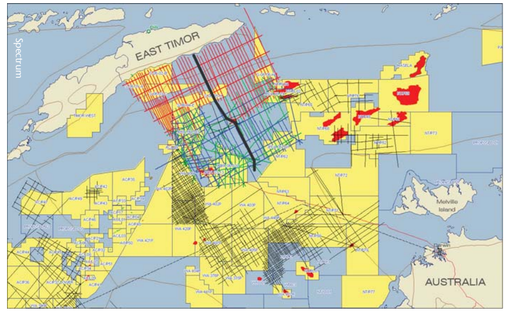
The Bonaparte Basin and its structural elements

The late Triassic compression resulted in widespread uplift and erosion, which produced inversion structures and anticlines as seen in the Petrel sub-basin. By the early to middle Jurassic, these uplifted areas had succumbed to erosion and collapse, and widespread fluvio-deltaic conditions prevailed in the Northern Australian margin. It was during this period that 'redbeds' and fluvio-deltaic clastics were laid down in mega-delta systems. These Jurassic fluvio-deltaic Plover sands are the main reservoirs for some of the large oil and gas fields found in this area.

Licence Rounds

The Australian government conducts an annual acreage release for offshore areas within Australian territory. Invitations to bid for the gazetted acreage are announced in the media including public releases on the Geoscience (Government of Australia) website. Bids are evaluated and awarded based the size of the committed work programmes, including wells, 2D and 3D seismic surveys and other geological and geophysical activities.

Within the JPDA, petroleum licences are administered by the Timor Sea Designate Authority (TSDA) a body comprising administrators from Australia and East Timor. In 2005, East Timor awarded five blocks in its first licence round. It is rumoured that the next round is not too far away.



The Northern Bonaparte Basin, the JPDA and the sovereign territory of East Timor are very well served with excellent seismic coverage of modern multi-client data as well as state-of-the-art reprocessed vintage seismic data. The acquisition of the Perth-based Australia Seismic Brokers (ASB) by Spectrum in April 2010 has enabled this global multi-client seismic services company to assemble a very comprehensive seismic database in this region. The position of the long foldout line on pages 58 – 60 is shown in black.

Marine Seismic Sources

PART VII: FISH ARE BIG TALKERS

Don't tell fish stories where the people know you; but particularly, don't tell them where they know the fish.

Mark Twain

Drawing by Birgitte Reisæter Amundsen (10)

MARTIN LANDRØ AND LASSE AMUNDSEN

Lasse Amundsen is Chief Scientist Exploration Technology at Statoil. He is adjunct professor at the Norwegian University of Science and Technology (NTNU) and at the University of Houston, Texas.

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

Of the 31,900 species of fish living today we know that more than 1,000 make sounds, ranging in frequency from 50 to 8,000 Hz. For most fishes, the sonic mechanism is a muscle that vibrates its swim bladder not unlike our vocal cord. For many other species, the sonic mechanism remains a mystery.

Sound Production

Like us, fish produce sound both unintentionally and intentionally. Unintentional sounds from fish come all the time, resulting from hydrodynamic patterns during swimming and feeding. These sounds can provide information to other fishes. In fact, the fishing industry has recognized predatory fishes' ability to take advantage of unintentional sounds to find prey and have designed fishing lures that emit low frequency sounds that mimic those produced by injured prey fish.

Intentional sounds are created to stay in touch with the shoal, to warn other fish of danger, to attract, communicate with and stimulate mates, and to scare intruders away from eggs and young.

The sounds that fish make are usually simpler than the calls of marine mammals. Fish sounds have been describes as grunts, scrapes, knocks, clicks, squeaks, groans, rumbles and drumming. Nearly all the fish species produce their sounds using their teeth, their swim bladder or a combination of both.

Some fish are capable of making very loud sounds. One of the noisiest is the oyster toadfish – a bottom dwelling fish found along the east coast of North America from the West Indies to Cape Cod. The toadfish is thought to make two types of calls; a grunting sound when it is aggressive or frightened, and a loud foghorn-like call heard underwater for great distances to attract a female during the spawning season.

Many fish take advantage of the noises other species make. We know that some sharks use sound to help them locate prey, while some smaller fish can detect the sounds larger predators make in their hunting. Furthermore, it is believed that a few fish species, including herrings and American shads, can detect the ultrasonic echolocation sound produced by hunting dolphins from a distance of up to 200m.

Cod You Believe It?

The cod is believed to speak mostly on special occasions. We do not hear much from them, but if aggressive or while spawning they are very vocal, producing a number of sounds via the swim bladder. These are mainly short-duration low-frequency pulses, described as grunts or bops, with frequen-

Volker Steger/Science Photo Library

The oyster toadfish doesn't need good looks to attract a mate – just a nice voice. To generate the foghorn sound, the toadfish contracts its sonic muscle against its swim bladder thousands of times a minute. At nearly three times the average wing beat of a hummingbird, toadfish have the fastest known muscle of any vertebrate.

cies in the range 50-500 Hz. In the spawning season the male makes pulsed, low-frequency sounds to scare away other fish. In contrast the cod's courting and spawning sounds consist of long series of pulses given with increasing frequency. During the spawning act the sound resembles continuous low-frequency sound – not unlike the sound from a Harley Davidson motorbike! Lately, it has been speculated that they use the continuous low-frequency sound to synchronize the fertilisation process.

Larger Arctic cod caught during the spawning season offshore Norway are commonly called *'skrei'*, probably from the norse word *'skrida'*,to wander. The skrei undergo seasonal wanderings, inhabiting the Barents Sea in the summer and autumn and migrating every December to January southwards to their spawning grounds between Finnmark and western Norway. The most important of these grounds are in Lofoten and Vesterålen.

Herring-made Bubble Screens

The sound production of Pacific and Atlantic herring is poorly understood. Recently it has been shown that the herring produce distinctive bursts of pulses, termed fast repetitive tick (FRT) sounds. These trains of broadband pulses, 1.7–22 kHz, last for a period of 0.6 to 7.6s. The function of these sounds is unknown, but social mediation appears likely. It is conceivable that killer whales use the distinctive herring sounds as foraging cues.

In Norwegian waters in the late autumn billions of herring migrate from open oceanic waters into deep fjords to spend the winter season waiting for spring to approach. In February, they migrate southwards to their spawning grounds, and then out to open waters again. Flocks of killer whales follow the herring to feed on their favourite prey. Often the whales dive to over a hundred meters to drive herring up to shallower waters, forcing the fish into tight groups while preventing them from escaping to deeper, darker and safer water. During this process the whales emit echolocation clicks, click bursts, and whistles, some of which may help to tighten the herring school or coordinate whale movements. At the right moment individual whales swim into the herd of fish and perform tail slaps that produce thud-like sounds. Apparently stunned by the tail slap, many fish turn belly-up, remain motionless, and become an easy catch.

Attacks from killer whales have been documented in Vestfjorden, in northern Norway, using multibeam sonar and echosounder. It was observed that herring schools were forced from large depths up to the surface by killer whales and saithe, after which the herrings expelled gas from their swim bladder via the anus as a consequence of the rapid change in depth, thereby producing a curtain of tiny bubbles around the school. The bubbles may confuse and deflect both visually and acoustically oriented killer whales due to increased scattering of light, reduced range of vision, and confounding effects of the reflection energy of bubbles and fish. ▶

A Norwegian killer whale herding herring.

Under cover of their bubble curtain, the herring have a chance of escaping.

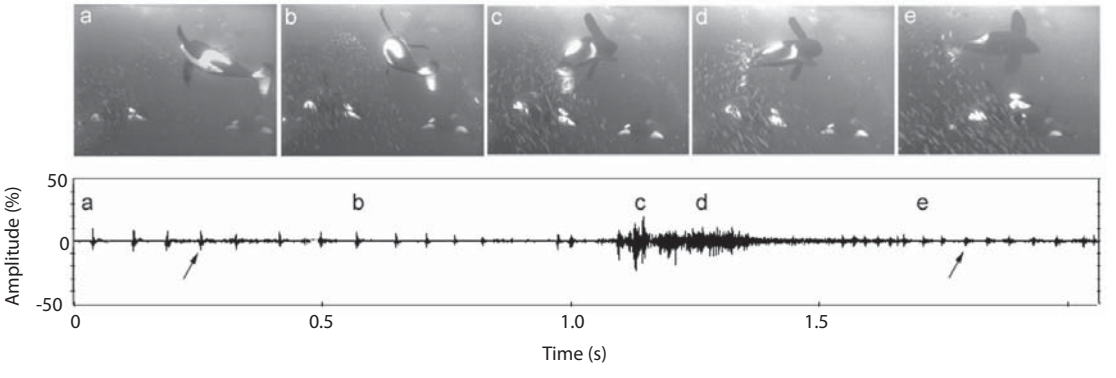
Killer Whale's Tail Slap

The Norwegian killer whales debilitate prey by slapping their tails into herring schools. It has been suggested that the thud-like sound produced by the tail slaps is caused by cavitation.

Single pulses measured from such tail slaps have waveforms and spectral characteristics very similar to those from the clicks of pistol shrimps, which are known to be produced by cavitations (see *GEO ExPro* Vol. 8, No. 1). The pistol shrimps produce broadband sounds with frequencies beyond 200 kHz and with a peak frequency in the range of 2–5 kHz. The source level is between 183–191 dB (p-p) re 1μPa @ 1m. The sound of killer whale tail slaps contain frequencies beyond 150 kHz, with peak frequencies below 10 kHz. The fact that the source levels of tail slaps are 186 dB (p-p) suggests similarity between the sound production mechanism of killer whale tail slaps, snapping shrimp, and a cavitating propeller.

Man-made Bubble Screens

Underwater bubbles inhibit sound transmission through water due to density contrast and concomitant reflection and absorption of sound waves. Therefore, it is not only herrings that exploit bubble curtains. Man-made bubble curtain systems that produce bubbles in a deliberate arrangement in water to attenuate unwanted wave trains, like water layer reverberations, were tested in the 1950s. In the 1970s it was proposed that a bubble screen above the source towed behind a submarine acquiring seismic below ice would reduce the effect of seismic scattering from the ice layer that was dis-



Killer whale tail slap extracted from video recordings (top) and the corresponding sound track (bottom). The letters of the video frames correspond to the times illustrated in the sound track. The clicks before and after the underwater tail slap are killer whale echolocation clicks (arrows).

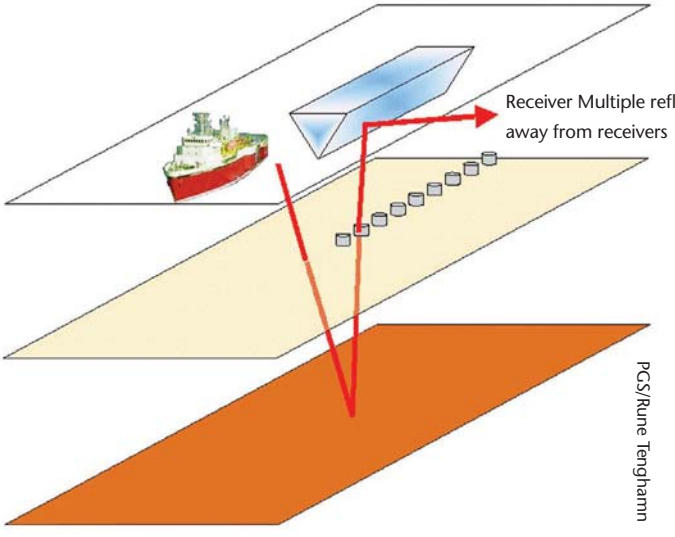
Adapted with permission from Simon et al., 2005, Journal of Experimental Biology *208, 2459-2466*

turbing reflections from the sub seabed. In the late 1990s, in the shallow waters of western Hong Kong a bubble screen was used to reduce the sound of pile driving in hump-backed dolphin habitat. Although the bubble curtain did not eliminate all behavioral dolphin responses to the loud noise, the experiment and its application during construction represented a success as the broadband pulse levels were lowered by 3–5 dB at a range of a kilometer.

Fisheries and Seismic

The potential impacts of seismic activities on fisheries can be divided into two types: acoustic disturbance of fish, and conflicts of interest over use of the same areas. Therefore, seismic acquisition is regulated in a manner to cause as little inconvenience as possible to the fishing industry, and to avoid the spawning periods.

In the next issue we will focus on the sensitivity of fish hearing.



PGS/Rune Tenghamn

By placing a bubble curtain at the bounce point of the multiple on the air-water interface, the idea is to suppress multiples in seismic acquisition. In 2002, ExxonMobil and PGS conducted an offshore field test which established that the curtain could have sufficient reflectivity to redirect upcoming acoustic energy away from the seismic sensors so that it would not be recorded as multiples.

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http://www.acoustics.org/press/151st/Miller.html ■

Why Are Onshore Exploration Technologies Lagging Behind?

While much of the offshore throughout the world has been explored with the benefit of modern technology, the prohibitive cost of land 3D seismic means that many onshore areas remain relatively unexplored.

DAVID BAMFORD

'Man-hauling' cables hugely increases the cost of onshore seismic acquisition

The starting point of exploration thinking is an understanding of the impact of plate tectonics through geological history. Thus mining companies that have successfully explored for minerals onshore along the West African Transform Margin seek analogue deposits onshore in South America where the two regions were juxtaposed before the opening of the South Atlantic. In the same way, the new frontier of offshore East Africa gas is rooted in the perception that a Late Jurassic basin may have opened as Madagascar moved away from Africa.

Large Areas of Onshore Unexplored

If a map of global bathymetry and topography is overlain with one showing where some 200,000 exploration wells have been drilled in the last 40 to 50 years, one notes that much of the offshore has been explored, while surprisingly large expanses of the onshore – the north-eastern USA, East Siberia, much of mid-continent Africa, and so on – remain underexplored.

Offshore, due to the relatively inexpensive nature of marine 3D seismic data, at least as far as multi-client surveys are con-

cerned, it is possible both to reconnoitre and explore a huge area with 'surgical' precision. For example, most of the deep water Gulf of Mexico and deep water Angola is covered from 'corner to corner' with such 3D – many versions of it in the former case.

Generally speaking, this is not possible onshore due to the prohibitive cost of land (and transition zone) 3D seismic data, and explorers have to recourse to a more traditional 'focussing' approach, in which a range of technologies – including the boot on the human foot – come into play. The steps towards focussing in on an area in this way can be characterised as: is there any evidence of the components of a viable petroleum system in the region under study; is there any evidence at all of actual hydrocarbons, such as seeps that can be sampled; and can suitable, preferably large, structures be envisaged? Only after these steps have been taken can we ask if 2D, or preferably 3D, seismic will delineate prospects.

Surprising as it might be to modern geoscientists, our predecessors in countries such as Iran, Iraq, Kuwait, Saudi Arabia, Russia and the onshore USA did actually get out in the field. In fact they spent most of their time there; they hit rocks with hammers, they plane-tabled, they drew cross sections, and yes, they knew a seep when they saw one and sampled it. They didn't spend their life looking at computer screens!

Extensive field work can still answer significant questions during the reconnaissance phase of exploration. Can we identify potential source, reservoir and seal rocks? Are there any active seeps? Following sound principles of structural geology including section balancing, can trapping structures be envisaged at depth?

And technology, of course, has its place.

Direct Hydrocarbon Detection

A key step in screening a brand new basin is determining whether a respectable source rock exists and if so, whether it has matured and hydrocarbons have migrated away from it. Early in onshore exploration, such investigations inevitably focussed on visible seeps – *macroseeps* – that could be sampled and analysed.

In the final 20 years of the last century, this form of **direct hydrocarbon detection** moved offshore, adopting both 'high' technology (satellite SAR)and 'low' (looking for seeps out of an airplane window in sun glint, wearing expensive sun-glasses). This worked well, because any remotely sensed seeps or seep-related anomalies or phenomena could be sampled and fingerprinted with geochemistry. In the early 1990s, ▶

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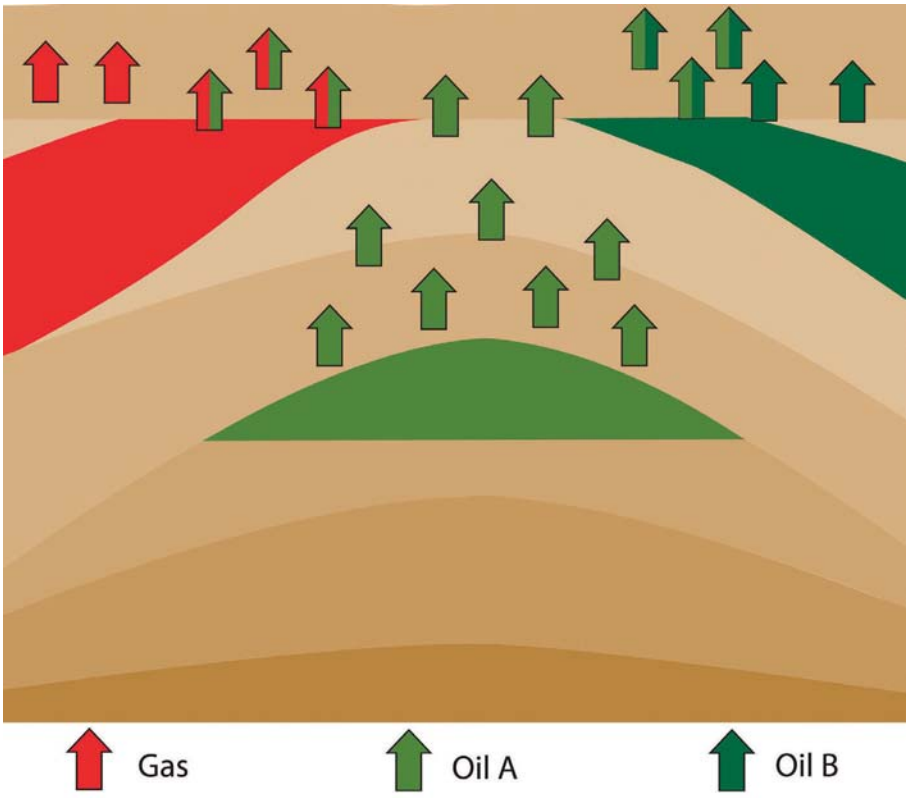
An early version of a full tensor gravimeter.



W. L. Gore & Associates, Inc

Vertical migration can be the result of diffusion of dissolved gases, movement in ascending water, continuous gas flow, transport in buoyant microbubbles.

BP ran a study in the Gulf of Mexico where they ground-truthed over 40 surface slicks detected by satellite and from the air, of which 90% turned out to be actively bubbling seeps.

Fertile minds then turned to how technology might promote this sort of direct hydrocarbon detection onshore: here we need to add the additional concept of *microseeps*, the notion that in addition to *macroseeps*, there is a more pervasive background of seepage resulting from one or all of several different vertical migration mechanisms. The 'sine qua non' here is that some of this background seepage is derived from hydrocarbons escaping from reservoirs.

A couple of technologies can be highlighted. The first uses satellite-based remote sensing to search for 'anomalies' in soil geochemistry or vegetation that are the results of alteration caused by microseepage. The second uses a novel sampling device, laid out in extensive grid pattern on the ground (or on the water) and directly collecting hydrocarbons over a period of a few weeks: the offshore version of this device was reviewed in *GEO ExPro*, Vol. 7, No. 5.

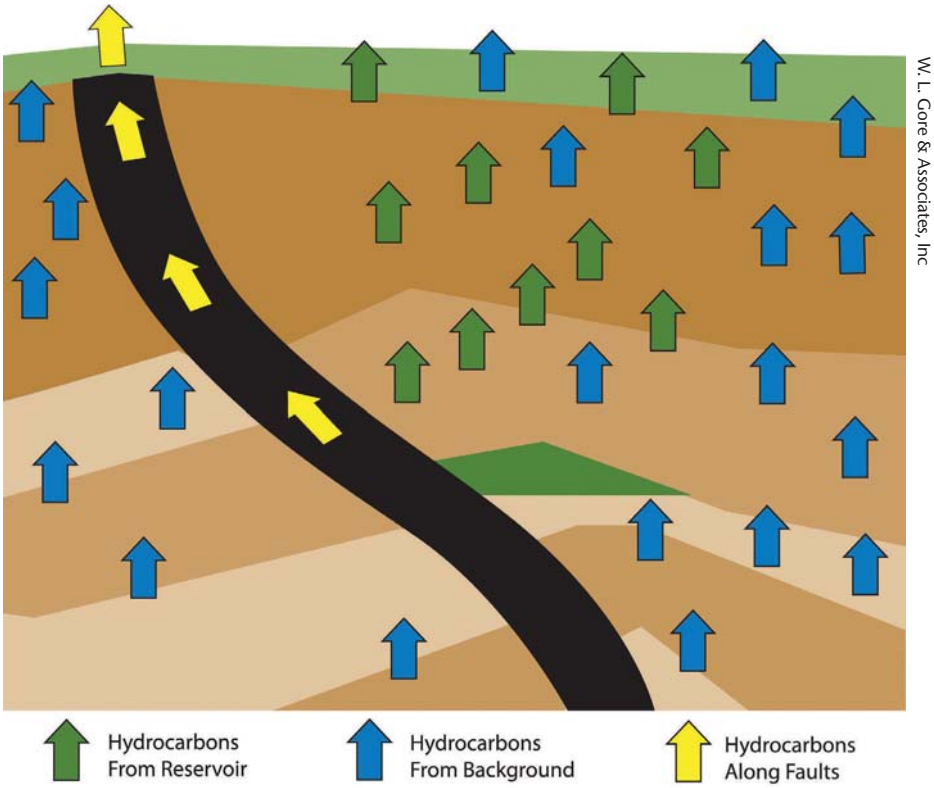
Both types of data can then be analysed to show anomalies that pop out from the background, the inference being that these indicate where the microseepage derives from previously reservoired hydrocarbons. Many examples have been shown where these anomalies are located above known petroleum accumulations.

Once again, the key to these approaches becoming useful direct hydrocarbon detection methods is geochemical proof that what is being seen is, or is the result of, mature hydrocarbons escaping from a reservoir. Technology moves on, of course, but I do seem to remember that back in the early 1990s (in contrast to their offshore experience) BP was unable to so ground-truth any of the onshore anomalies they saw around the world.

Full Tensor Gravity Gradiometry

One of the more important breakthroughs of the last few years has been the coming of age of airborne gravity via Full Tensor Gravity Gradiometry (FTG). Put simply, two extremely sensitive gravimeters, one above the other, record all 9 tensor components of the earth's gravitational field. In comparison with conventional gravimetry, the twin gravimeters allow much of the 'in-flight' noise to be removed and this 'full tensor' approach allows the source of anomalies to be located relatively precisely in the 3D sub-surface (see *GEO ExPro* Vol 8, No. 1).

Thus, reasonably precise, reconnaissance ▶



W. L. Gore & Associates, Inc

Macroseepage, detectable in visible amounts, where the pathway follows discontinuities and the seep may be offset from the source and reservoir, in comparison to microseepage, where hydrocarbons are detectable in analytical amounts, and the pathway is nearly vertical, overlying the source or reservoir.

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phase, 3D images of the sub-surface can be generated. FTG becomes an especially powerful tool when integrated with other geophysical technologies, for example with modest amounts of 2D seismic or perhaps magnetics, especially when 'depth to basement' is a key deliverable. Obviously this can be used anywhere as a relatively inexpensive early stage exploration tool but it should prove particularly useful in remote or hostile onshore areas; the jungles of Gabon and the Congo would be examples.

Onshore Seismic Miles Behind

However, seismic technology is the main, some would say the only, means of interrogating the sub-surface in sufficient detail to allow insightful geological prediction and the precise location of wells. So I am going to state quite baldly that onshore exploration technology is miles behind offshore. Why is this?

The availability of regional or 'exploration' 3D has been the main driver of exploration success in deep water. Huge swathes of multi-client 3D, covering, for example, 5,000 km^2 blocks offshore Angola, are available at prices as low as US $3,000/km^2, are turned around exceedingly rapidly, and are interpreted at great speed. The technology drivers have been highly efficient and effective acquisition systems based on vessels capable of towing many streamers and multiple guns, together with simultaneous processing,to some extent on-board, but mainly via satellite transmission. This is aided by powerful interpretation workstations, capable of dealing with these vast surveys and delivering both time and attribute-based interpretations. What is more, very complex geological problems, for example at great depth or beneath salt or basalt, can now be tackled, for example by multi-azimuth, wide-azimuth and wide-angle recording.

As an 'old codger' I would simply point out that this is an incredible transformation from the days of 'postage stamp' size surveys in the North Sea that took two years to go from design to delivery of a final product, and when interpretation on paper invariably meant that possibly only 1 line in 10 was fully interpreted!

Integration is Key

Thus, modern 3D lies at the heart of modern offshore exploration, integrating stratigraphy, sedimentology, facies prediction, rock physics, hydrocarbon phase prediction on the regional and prospect scales, and then providing a 'surgical' tool for choosing exploration well locations.

It is a fact that such integration is much rarer onshore; 3D seismic plays a much lesser role.

Recently I heard talk of exploration in the Llanos foreland of Colombia where 'everybody now explores with 3D seismic', leading to success rates as high as 75% – pretty remarkable in an onshore environment. The terrain is this area is moderately undulating 'cow country' so relatively straightforward for acquiring 3D – and yet the cost per square kilometre is roughly an order of magnitude – ten times – that of offshore multi-client 3D…so we are talking US $25-30,000/km^2. Step back into the Llanos fold belt itself, and the cost is more like US $100, 000/km^2.

Why so? Why these differences? How can we pay so much!

My contention is that onshore seismic has simply not yet seen the acquisition technology breakthrough that transformed offshore 3D over 15 years ago. What this means is that, in turn, onshore exploration itself remains untransformed. As my old friend Ian Jack has pointed out many times, supported by Bob Heath of iSeis, (both at recent *Finding Petroleum* events), the absolute key is the slow pace and man-power intensive nature of using cables, and that the first breakthrough we seek is the advent of lightweight, long-life, wireless systems.

I am fully aware that it would be unreasonable to expect onshore 3D seismic prices to drop to the level of offshore multi-client data, largely because onshore seismic crews have to contend with a variety of terrains and topographies and that significant numbers of people will inevitably be involved in deploying onshore seismic equipment. A better message than a simplistic 'cheaper please!' is that the cost of onshore 3D needs to be at the point where shooting it extensively – so it can be used for regional and prospect work – fits neatly into the 'gradually focussing your onshore exploration' approach.

Many onshore areas have not seen recent exploration using modern technologies, in particular a suite of technologies that can be *integrated* both to understand geological setting and to choose well locations with precision.

These technologies all exist: the key to unlock the whole will be a step change in our ability to obtain onshore 3D seismic. ■

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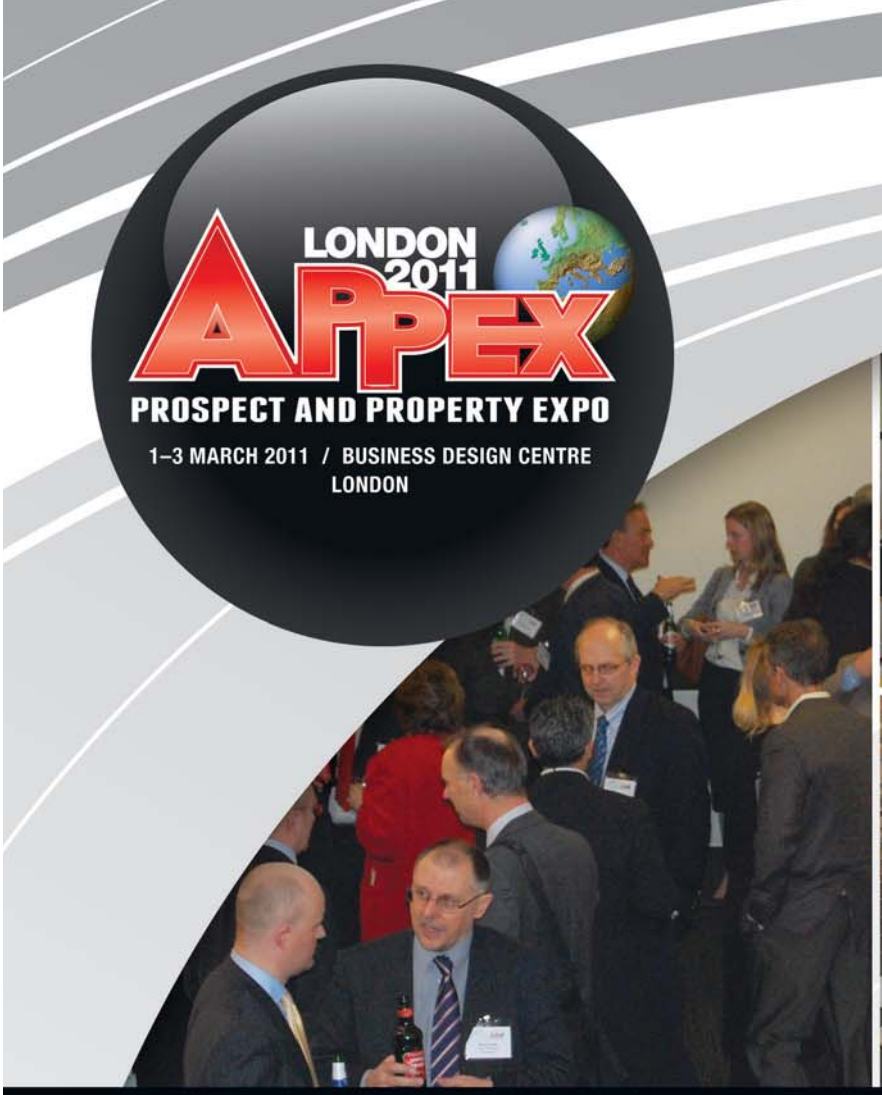

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The Earth's Oldest Fossils

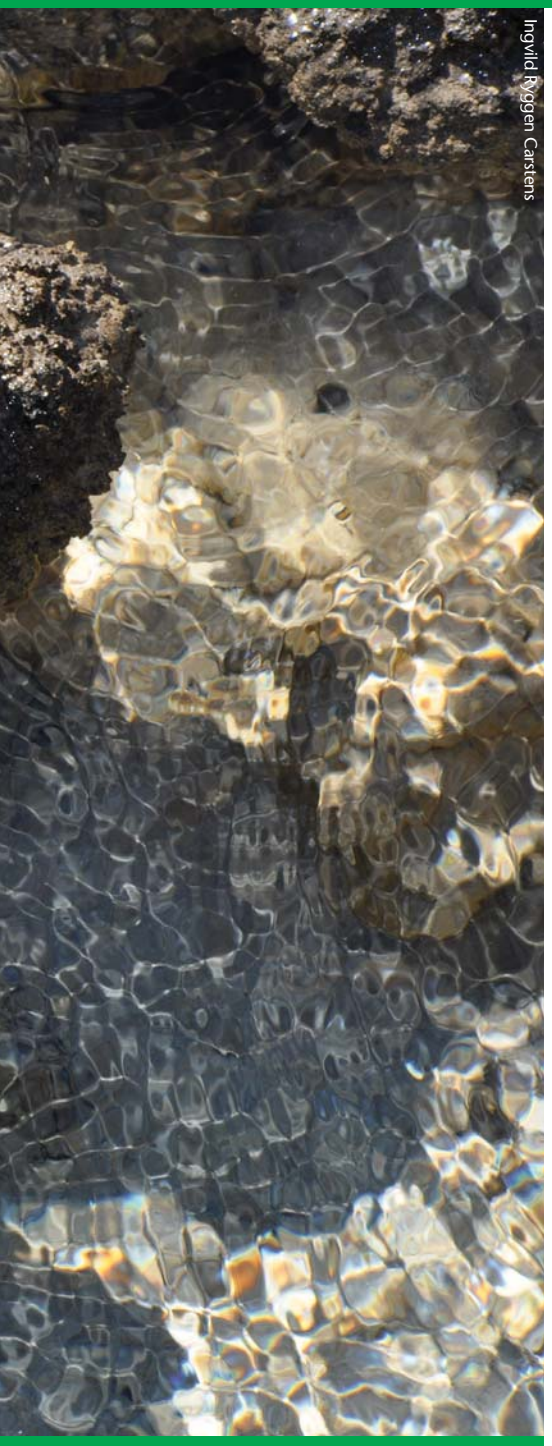
On a splendid white beach in Shark Bay, Western Australia, I finally found the world's oldest fossils. They are commonly referred to as living rock, and they have ruled the earth for approximately 3.5 billion years, and continue to live today. No other form of life has survived so long.

INGVILD RYGGEN CARSTENS

Since I first read about stromatolites in Gabrielle Walker's book *Snowball Earth*, I have felt a deep desire and pull to one day go and see for myself this ancient and incredible life form at Shark Bay in Western Australia. Their life story and survival have the ability to give any geologist – or geo 'geek' – a feeling of awe and amazement. Is it not incredible that they are still around, this organism that spawned complex life?

It is just before 7am in the morning, and I pull off the main road to Shark Bay and head down a gravel road towards Hamelin Pool. It is still dark outside, but soon the sun will be rising and I want to be there early, to catch the first rays as they strike the primeval living algae I have come all this way to see.

The ground is covered in dew after a cool night – it is the end of May, and the depth of winter is approaching. I grab my jacket and my camera and as I leave the car park and start walking towards these ancient living creatures, I literally feel like I am stepping back through time.


Ingvild Ryggen Carstens

The water is tranquil and there is no one down here this early in the morning. Some birds are singing in the treetops as the sun's first rays strike the bay. I walk along the shore and stare and stare down the beach. A carpet of stromatolites cover the entire inside of the bay – the sight is mesmerizing.

Living Rock

Stromatolites are often described as the Earth's oldest fossils, the earliest proof we have of life's emergence on Earth. For billions of years the stromatolites ruled the world. They appear in the fossil record in the Precambrian, long before the development of complex life, and for years they puzzled geologists.

Laminar structures formed of large colonies of cyanobacteria, stromatolites thrive in calm, warm, saline waters, and today we only find them in hypersaline lakes and protected marine bays and lagoons. This hostile environment keeps predators at bay and provides a safe haven for the stromatolites to develop. They form through the process of trapping, binding and cementing sedimentary materials with calcium carbonate produced by the cyanobacteria, which look like sticky slime. Slowly, as sediments and other material are trapped, layers are built up, growing between only 0.5 and 1 mm per year.

Cyanobacteria, or blue-green algae, are prokaryotes, which is a primitive organism without a cellular nucleus. The cyanobacteria receive their energy through the process of photosynthesis, converting carbon dioxide and water into organic compounds, like sugar and oxygen. During the billions of years that the stromatolites dominated the Earth, they slowly changed the composition of the Earth's atmosphere into an oxidizing atmosphere. This process is believed to have laid the groundwork for the emergence of complex life during the Cambrian explosion.

The stromatolite population peaked in numbers and diversity about 1.25 billion years ago, but by the time of the Cambrian explosion their numbers had been reduced to a fifth of this. It is widely believed that the reason for their decline was that the stromatolites became the number one source of energy for more complexly evolved life forms.

Stromatolites are extremely fragile and vulnerable to external forces. As a result, we only find them at a handful of places throughout the world today – so why here at Hamelin Pool?

Hamelin Pool Marine Nature Reserve

Hamelin Pool Marine Nature Reserve covers an area of 1,270 km^2. The unique conditions here mean that it is one of a handful of places in the world where stromatolites still thrive, and is the location where we find the largest and most diverse population of stromatolites today.

The hypersaline waters of Hamelin Pool makes life uninhabitable to other marine life and the shallow waters protect the fragile stromatolites from strong currents and violent seas. The water is twice as salty as the water found in the open ocean, and the reason for this is the Faure Sill, a sandbank that has formed over thou- ▶

MAKING HISTORY ACCESSIBLE

Hamelin Pool Telegraph Station was built back in 1884. It became an important communication and transportation center because of its strategic location between Perth and Roebourne, and remained an important hub until the arrival of newer, more sophisticated technology in the 1950s.

The area around Hamelin Pool was the home to large sheep farms, and cotton was an important export. Hamelin Pool thus served as a transportation hub for ships delivering cargo and transporting wool to Perth. Neighboring sheep stations all delivered their wool to Hamelin Pool, from where it was taken out to the waiting ships on carts right trough the stromatolite field. You can still see the wheel tracks these carts made in the stromatolite mats in Hamelin Pool.

From the old telegraph station at Hamelin Pool, a 1.4 kilometre walking trail has been developed. The path winds its way through an old quarry site and past other historical interest points on its way down to the beach and the goal of our journey – the stromatolites. Since the stromatolites are so fragile and slow growing, a walkway has been built so we can walk among these ancient fossils and admire their beauty.

Signs have been placed along the Boolagoorda Walk. These convey information about the history and origin of the stromatolites in Hamelin Pool in a fun and instructive way. The creative illustrations and the style of the storytelling are very suitable for children of all ages, and do an excellent job of making geology accessible to the masses.

There are three basic types of stromatolites. Sub-tidal stromatolite columns that are always submerged in water take the shape of cones and domes, while inter-tidal stromatolites usually grow in stratiform or branching shapes, like mushrooms or anvils. They are exposed above water during low tide. Stromatolites also grow as mats in inter-tidal environments. Both sub-tidal and inter-tidal stromatolites are found in Hamelin Pool.

sands of years through the trapping of sediment and organic materials by sea grass. It inhibits the flow of tidal water between Hamelin Pool and the rest of the bay, creating the hypersaline conditions in Hamelin Pool.

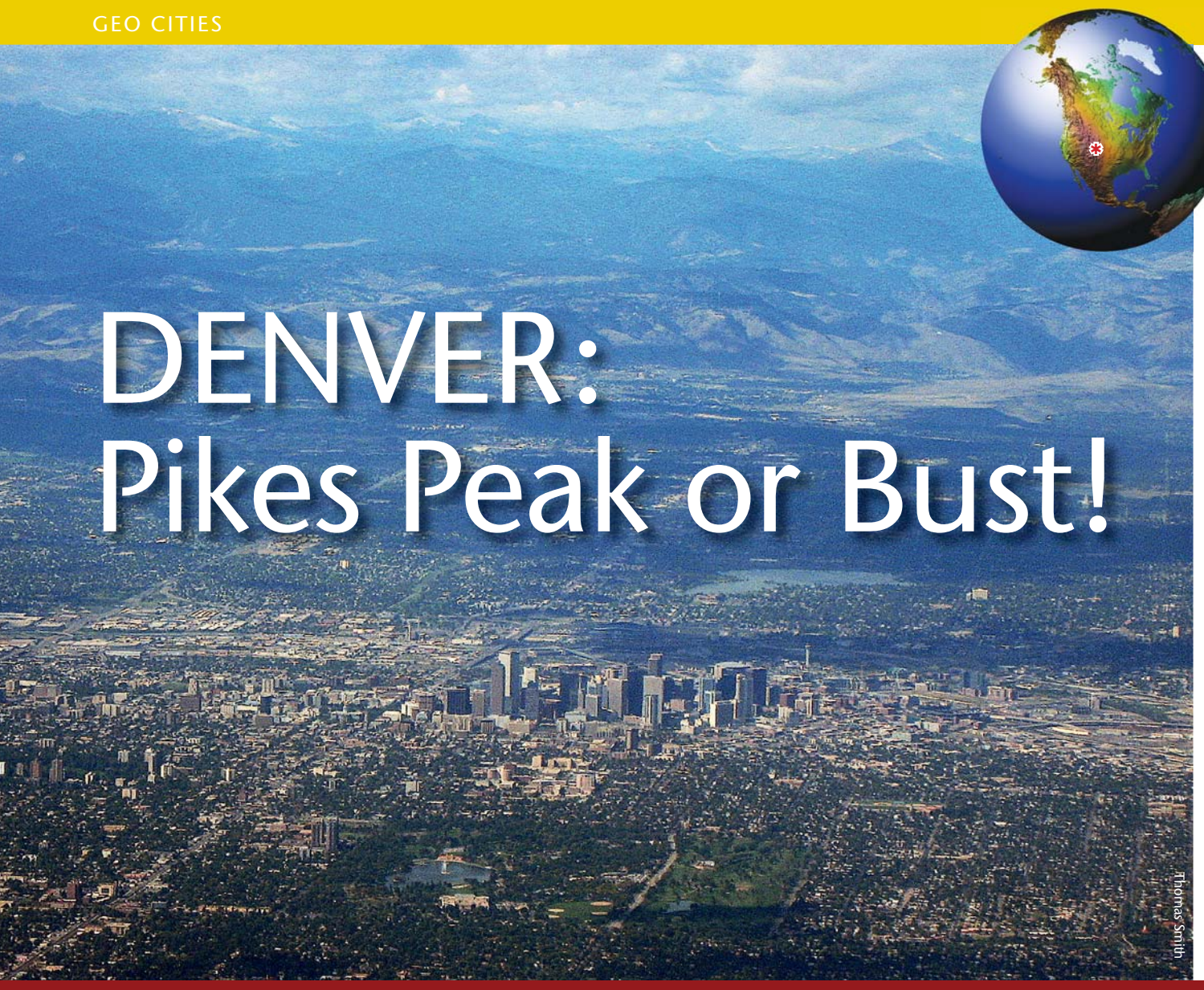
Geologist Philip Playford discovered the stromatolites at Hamelin Pool in 1956. They were the first documented living examples of the structures which had been found fossilized in very old rock from all over the world. Stromatolites were believed to be extinct, wiped out by the competition from more complex life forms. These fossils had puzzled geologists for decades and there had been much disagreement between researchers whether the stromatolites were remnants of living organisms. The discovery of the living stromatolites solved this enigma.

The Magic of Hamelin Pool

During the last 6,000 years, shells have been deposited along the shore of Hamelin Pool and Lharidon Bight. These are remains of another salt-tolerant life-form, the Chardiid Cockle, a brown mollusk living in tiny, bivalve shells, which is more abundant in Shark Bay than anywhere else in the world, as it has been allowed to thrive in this environment without predators.

The shells have accumulated on the sea floor and are continuously washed ashore. When it rains, calcium carbonates within the shells dissolve, and, when dried, form crystals that cement the shells together to form a soft limestone called coquina. For years, the limestone was quarried and used as building material in several buildings throughout Shark Bay. On a visit to Hamelin Pool, you can still see the old quarries when you are walking down towards the stromatolites. The quarry is no longer in continuous operation. However, limestone is still quarried when the existing coquina limestone buildings need maintenance.

The sun is shining brightly now, and I think I have seen all there is to see. I dwell a little longer on the walkway, admiring this amazing life form that spawned complex life. A few people have found their way down the trail and onto the walkway now. It is time for me to go, and let others experience the magic of Hamelin Pool. Reluctantly I begin to make my way back to the car. But I am taking a piece of the magic with me – the feeling of having stepped back through time and been allowed to see a little bit of what the world looked like, millions of years ago. ■



DENVER: Pikes Peak or Bust!

JANE WHALEY

With the superb backdrop of the Rocky Mountains, the 'mile high' city of Denver has one of the most attractive locations of any oil town.

Although Denver is now well known as a center of the oil industry, it owes its origins to a quite different mineral – gold. In 1858 a small group of miners crossed the great plains of the Colorado Territory and found small quantities of the precious metal at the confluence of the South Platte River and Cherry Creek, near the center of present day Denver. Word got out of the first significant gold discovery in the Rocky Mountain region, and before long, over 100,000 people had flocked to the region to seek their fortunes. The mountains, including the towering Pikes Peak, 100 km south-west of Denver, acted as a signpost to the gold fields and a symbol of encouragement to flagging newcomers crossing the plains, leading to the expression 'Pike's Peak or Bust!'

Gold, Silver and Oil

The initial finds were not large, but the town established itself as a trading center for the area as the gold prospectors searched the Rocky Mountain foothills. Fortunes were made by people staking out plots of land and selling it on to new-comers. One of these entrepreneurs was a General William H. Larimer, who laid out the plans for a city which he named after the Kansas Territorial governor James Denver. This did not afford Larimer the political favour he had hoped – by the time the city was called after him, Denver was no longer in office!

When gold was discovered deeper in the Rocky Mountains, it looked as though the city might die, like the 500 or so ghost towns now deserted in Colorado, as the miners left to chase the latest elusive dream. But many eventually returned to the town, which grew steadily from less than 5,000 in 1870 to over 100,000 by 1890. This growth was partially fuelled by a silver boom, which finally crumpled with the financial collapse in 1893. However, by then the railroad was passing through Denver, so its future as a major trading post at the foot of the Rockies was assured.

Finally, oil was discovered in 1901 in

Boulder, on the edge of the Rockies about 40km to the north-west of Denver. It was the first of many finds in the Denver Basin, allowing the city to take its place as one of the major oil metropolises in the world. And not just oil: the Wattenberg Field, which covers an area of about 6,500 km^2, was found in the 1970s just north of the city. It is one of the largest natural gas fields in the US and is thought to hold over 5 Tcf of recoverable gas.

City of Culture

Growing as it has out of a mining background, there has always been plenty to do in Denver. Gaming houses, theaters, music halls and drinking saloons, not forgetting well frequented 'houses of ill repute' soon appeared as the town grow, all ready to prize the hard-earned gold and silver from the relaxing miners. But by the beginning of the twentieth century, Denver was fast achieving respectability, and became an elegant city with fountains, beautiful houses, tree-lined streets and over 200 parks. Now with a population of over 600,000, it is the the largest city for many miles, and for more than 125 years it has been the cultural, shopping and entertainment capital of this vast region.

Denver is renowned as a major cultural center, rich in art and music. The original Denver Theater was built in 1864, followed by many other theaters, concert halls and opera houses. The city now has the nation's second largest performing arts center, the Denver Performing Arts Complex, which can accommodate over 9,000 people. There are also many galleries and museums, including the seven story Denver Art Museum. There is a thriving classical music scene, but the city is also well known for more modern culture: Denver was a gathering point for poets of the "beat generation." Neal Cassady was raised in Denver, and a portion of Jack Kerouac's beat masterpiece, *On the Road,* takes place in the city. And the Red Rocks open air amphitheatre to the west of Denver hosted the Beatles in 1964, as well as many other famous groups, festivals and events.

A Great Place to Live

Lying just 557 km (346 miles) west of the exact center of the United States, Denver has a semi arid, continental climate, which can be very unpredictable, due to the expanse of the High Plains stretching to the east and the Rocky Mountains rising in the west. The climate can show great extremes, with locals claiming they can have all four seasons in one day. Waking up to heavy snow and then going home from work in shirtsleeves is not unknown, while temperatures of over 33°C (90°F) are common in summer. It is, however, a very pleasant place to live, with over 300 days of sunshine a year, and the altitude means the air, even in the center of the city, always feels fresh and clean.


Jane Whaley

The 15th step of the state capitol building is exactly 5,280 feet – one mile – high.

But for many people, as well as enjoying the cultural life of the city, or watching sport at one of the huge stadiums, one of the best things about Denver is the mountains outside. With only a short drive of less than 25 km (15 miles) you can be in the 'foothills', a gentle series of peaks ranging from 2,130 to 3,350m (7,000 to 11,000 ft) high. Rising behind them is the Continental Divide, the line of over 4,000m high peaks which marks the watershed separating rivers that drain to the Pacific from those that flow eastwards. This vast area is riddled with trails and paths of very degrees of difficulty for day trippers, hikers, mountain bikers and horseriders, and in the winter, of course, skiing and snowboarding are easily accessible from Denver. Not to mention the fast flowing rivers, ideal for canoeing, kayaking and white water rafting, as well as for admiring the geology and surrounding mountains as you shoot the rapids.

And in case you think this all sounds far too healthy, hale and hearty – Denver brews more beer than any other American city!

JANE WHALEY/THOMAS SMITH

USA: Idaho's First Gas Find

Idaho, a state famous for its potatoes, had 156 consecutive dry oil and gas exploration wells drilled since 1903 – until gas was found in the Western Idaho Basin in 2010. Operator, Bridge Resources Corporation and its partner, Paramax Resources Ltd. drilled five exploratory wells between March and May of 2010, with three confirmed discoveries. They found the gas by exploring two separate project areas about 60 km north-west of the state capitol of Boise. A total of 11 wells have been drilled and Paramax has reported six successfully drilled and cased gas wells.

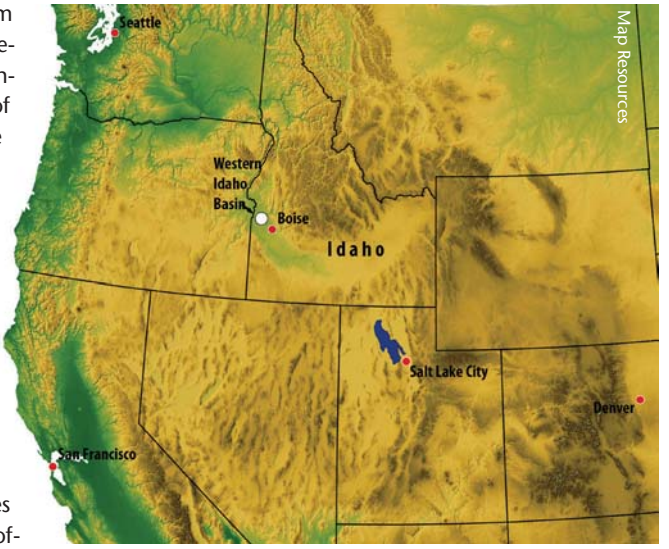
The gas-bearing sands have been located at depths from 490m to 1,400m. The operator completed a four well drilling program late in 2010 in the **Hamilton** project area with 71.8 Bcf gas reserves. Lying just north of the Hamilton area, the **Willow** project is slightly smaller in area but is reported to contain about the same amount of gas reserves.

The two companies have leased about 445 km^2 consisting of both state and private lands. The development areas cover 145 km^2. More seismic including a 3-D survey and drilling to include exploration of other prospects has been indicated in company press releases.

The state has been caught a little by surprise and officials are scrambling to update regulations. The Idaho Oil and Gas Conservation Commission, headed by Governor Otter, met in February to discuss needed changes. "The oil and gas business in Idaho has been dormant for over 20 years," says Erik Wilson, Minerals Program Manager for the Idaho Department of Lands. "Consequently, we have out of date regulations. We are working on new regulations, however budget cuts to the Department and lack of institutional knowledge are making it difficult to deal with the situation."

The gas discoveries are close to an existing gas pipeline that is currently operating below capacity. The companies are working with state officials to meet all regulatory requirements and are hoping for commercial production early in 2011.

Idaho's first commercial gas finds are located 60 km north-east of Boise in the lower Snake River plain.



INDIA: Asia's First Shale Gas Discovery

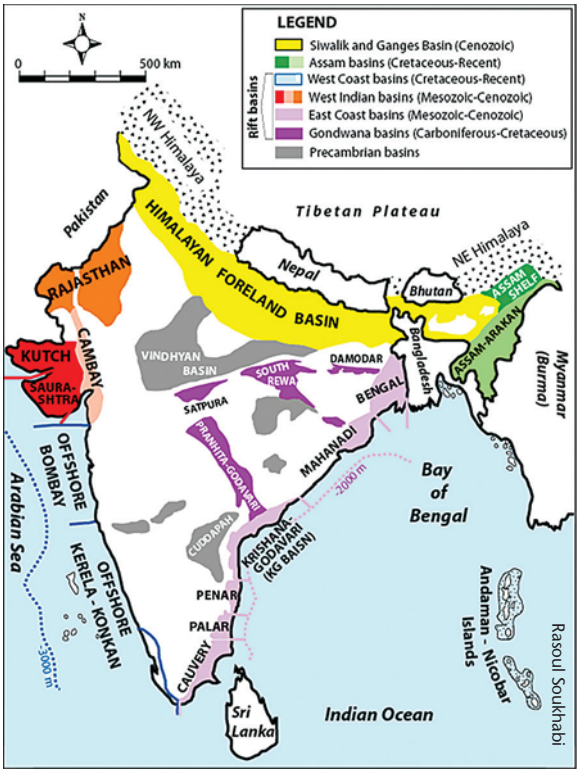
A major breakthough in Asian exploration was made in January, 2011, when Indian national oil company ONGC made the first discovery of shale gas in Asia with its **RNSG-1** well near Durgapur in West Bengal in the Damador Basin, about 150 km north-west of Kolkota. The gas was found in the main target, the Barren Measure Shale, at a depth of around 1,700m, and ONGC will test a number of zones before publishing the results.

Studies undertaken by ONGC institutions suggest that there are promising shale formations in many other well explored basins, including the Cambay, Krishna Godavari, Assam-Arakan and Cauvery basins. Estimates of the amount of shale gas to be found in India vary widely, from 500 Tcf to 2,000 Tcf, but since research into shale bedrocks in India is still in its infancy, these figures are open to debate.

RNSG-1, which was spudded on 26 September 2010, is part of a pilot program which will involve the drilling of a further three wells in the Damodar Basin. This area was chosen for the first well as it is considered to have significant potential because of the shallow depth of the shale formation and the abundance of water for possible future fraccing activities. The R & D project will continue with two further wells in the Raniganj sub-basin in West Bengal, and two wells in North Karanpura sub-basin in Jharkhand, also in north-east India.

In light of its expertise in shale gas drilling in the US, Schlumberger were awarded the contract to carry out the drilling and assessment of the first wells.

Main sedimentary basins of India. Initial shale gas exploration is concentrated in the north-east.



GHANA: Two More Discoveries

The new discovery off Ghana is only a few kilometres from the giant Jubilee field, which was discovered in July 2007 and began producing oil through the FPSO Kwame Nkrumah in December last year.

Another major discovery has been made in the prolific West Cape Three Points Block offshore Ghana, home of the giant Jubilee field. On February 10 it was announced that the **Teak-1** well, which lies about 50 km from the coast in 868m of water, had discovered approximately 73m of oil, gas and condensate in a number of horizons, potentially opening a new exploration play fairway in the Mid-to-Lower Campanian interval in the Tano Basin. In the shallower Campanian-aged reservoirs, the well found 6m of oil pay in the upper zone and 33m of gas lying over 15m of good quality 40° API oil in the lower zone. The deeper Turonian reservoirs were found to have 14m of gas-condensate pay in two separate zones, with 5m of oil at a deeper level. At the Campanian level, the hydrocarbons are believed to be in an up-dip combination structural and stratigraphic trap, potentially 50 km^2, while the older reservoirs contain stratigraphic traps.

Teak-1 is about 10 km north and updip of the Jubilee oil field and 4.6 km north-east of the successful Mahogany-2. The well was designed to evaluate multiple objectives and test alternative trapping mechanisms, and was suspended pending further field appraisal.

Partners in Teak are Kosmos Energy and Anadarko Petroleum Corp. with 30.875% each, Tullow Oil with 22.896%, and EO Group and Sabre Oil & Gas with 3.5% and 1.85 respectively, with a 10% share carried for Ghana National Petroleum Corp.

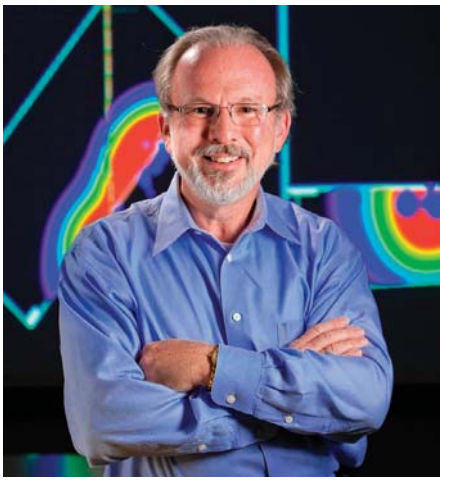
And there was further joy for the consortia drilling in Ghana less than a month after the Teak discovery, when the **Enyenra-2A** well in the Deepwater Tano licence, about 25 km west of Jubilee, was reported to have encountered good quality oil in excellent sandstone reservoirs. The discovery is significant as pressure data proves that the oil is in communication with the Owo-1 well, confirming that the **Owo** oil discovery, now renamed Enyenra, is a major light oil field.

Enyenra-2A intersected 21m of net oil pay in the Upper Channel and 11m of net oil pay in the Lower Channel, and also tested a deeper Turonian fan where five metres of gas-condensate bearing sandstones were intersected.

Tullow Oil, with nearly 50% stake, is the operator of the block.

Tracking Advances in Geophysics

With the U.S. having an increasing need to become more energy independent, we asked **Peter Duncan, President of MicroSeismic, Inc.** how new seismic technologies, and microseismic in particular, will provide the greatest impact on the oil and gas industry.



Peter Duncan founded MicroSeismic, Inc., a seismic imaging firm that pioneered the use of microseismic monitoring to listen natural, low-energy seismic noise emitted from a reservoir during hydraulic fracturing stimulation.

You have been involved in geophysical technology for more than 30 years. What have been the major developments in that time?

Many geophysics advances have been tied to improvements in computing technology and data storage. For example, the ability to measure and record seismic events from many channels in the field allowed for significant advances in 3D seismic, giving geophysicists the ability to record the full 3D wavefront.

Advances in amplitude variation with offset AVO and bright-spot technology have allowed geophysicists to better detect fluids and differentiate between hydrocarbons and water.

The next big development was probably 4D seismic, which allowed the geophysicist to track the location and movement of hydrocarbons in the reservoir over time, aiding production efficiency.

In the last few years, microseismic has gained ground as an important technique. I liken microseismic monitoring to putting a stethoscope on the chest of the reservoir, making direct measurements of fluid movement and other dynamics and interpreting what these observations mean for long-term productivity.

Which promising developments proved unsuccessful or disappointing?

4D seismic does not work well in many carbonate reservoirs. Signal-to-noise limitations prevent us from observing changes to the bulk elastic or reflective properties of some source rocks, making the differentiation between hydrocarbon and water in the reservoir difficult.

Multi-component seismic acquisition has probably been the most disappointing. We have not seen many cases where multi-component data delivered sufficient value to overcome its acquisition costs, or enough value to drive further development.

How has passive seismic contributed?

Over the past decade, the most successful passive seismic technique has been microseismic monitoring, which deploys geophones to detect the naturally occurring seismic events that occur in the reservoir as a result of stress changes. The largest microseismic monitoring application by far has been during hydraulic fracturing activities, initially to determine *where* and *when* the rock fractured during stimulation and later to understand *how* the it fractured, which tells you something about the stress field in the reservoir and provides fundamental insight into how the reservoir might produce.

Other important, though smaller, applications for microseismic include monitoring cyclic steam injection processes in heavy oil production and checking the integrity of underground salt domes that store hydrocarbons and chemicals.

In what ways do you see the seismic industry developing?

I think that as shale plays keep developing, there will be many applications for conventional seismic acquisition techniques to characterize them. We are beginning to appreciate just how variable these plays are.

On the passive seismic side, I see microseismic monitoring developing to make long-term reservoir observations well into the productive life of a reservoir, helping to improve production efficiency. I also think that permanently installed microseismic monitoring will augment other measurements, including active seismic and downhole pressure and temperature monitoring. The integration of these measurements will be key to further developing the digital oil field concept, which aims to turn fields into fully monitored processes that can be tweaked in real time to optimize production.

New technologies often come out of academic institutions. Do oil and gas companies offer enough support?

I think the oil and gas industry has always been very well connected to, and supportive of, academic research. In the past 20 years, we've seen oil companies shrink their own research laboratory capacity, mainly because of the challenges of developing fundamental research into cost-effective, deployable technologies. They realized that it would be easier to outsource technology development to small, entrepreneurial firms or academic institutions that were driven to produce results in the field. I think that in the geophysical arena, oil companies are spending more money today than in the past, both with academic institutions and the entrepreneurial world. The service companies have continued to do their own R&D spending, as well as support universities and entrepreneurial start-ups.

In 2008, as an SEG/AAPG Distinguished Lecturer, you spoke at 45 venues around the world. How was that experience?

It was tremendous. Roughly half of my lectures were at universities all over the world. The number of smart students who are getting into geology and geophysics around the world was surprising, but very exciting. The student lectures were full of bright and energetic young people who asked great questions, even though in many cases, English was not their first language. This experience gave me a lot of faith in the ongoing health and prosperity of our industry.

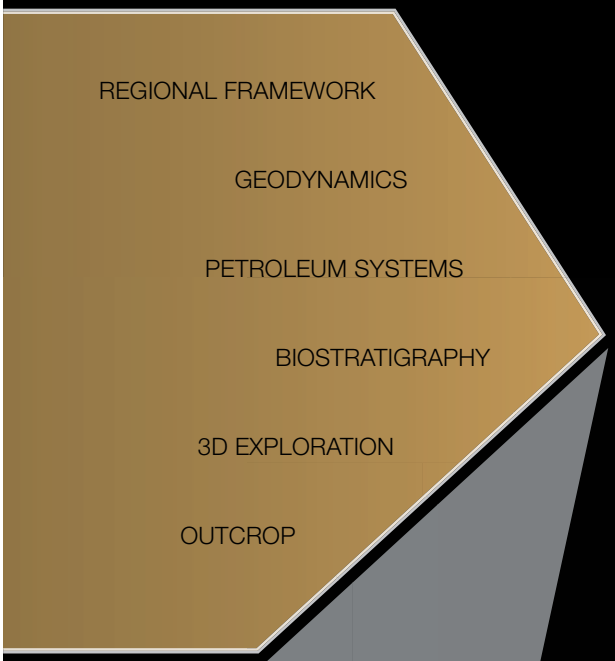
How do you manage to keep abreast of scientific developments while working at a senior management level?

I tend to focus on the specific niche of our technology area, and as we are fundamentally involved in driving this technology area, it is not too difficult to stay current.

Additional sources of information include reading technical papers and attending conferences in our very narrow field, and receiving day-to-day feedback from our technical people. When I attend the large conventions, I go to the plenary sessions, which cover a broad sweep of technology trends and developments. These sessions provide the highlights, and I can then dig deeper on my own.

TED MOON

a limited view can only get you so far...



Exploration geoscience: get the complete picture

It's no longer enough to understand just one particular area in isolation to carry out successful oil and gas exploration. The future of exploration requires a broader geological view and improved knowledge of global analogues, to make your interpretations more accurate. This is where the **Neftex Earth Model** can help.

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Australian Shale Gas

An Emerging Industry Gains Momentum

Australian shale gas exploration and exploitation may be in its infancy but it has certainly gathered pace over the last twelve months. Three shale gas exploration wells have been drilled and a number of companies have reported strategies and plans that incorporate Australian shale gas exploration and development.

Primarily, shale gas potential is being evaluated in the Perth and Canning Basins in Western Australia and the Cooper Basin in South Australia. All these locations have existing infrastructure and domestic markets for gas, making any developments economically viable even with the potential increases in drilling costs such projects are facing.

North Perth Basin

In November 2010 AWE Ltd announced it had identified a very large potential gas resource in the Carynginia Shale in its Perth Basin shale gas acreage, reporting that it may hold 13 to 20 Tcf gross gas in place. It had embarked on the assessment of the shale gas potential of the North Perth Basin in March 2010 with the drilling of Woodada Deep 1. The Carynginia formation was the primary objective, with the shallower Kockatea Shale providing a secondary target. The interbedded shale and tight sandstones of the Irwin River Coal Measure were identified as a tertiary target and serve as the source rock for the producing Woodada conventional gas field.

Initial core analysis from Woodada Deep 1 suggested the Carynginia Shale had characteristics (depth, thickness and mechanical properties) comparable to some producing shale units in the USA. AWE reported that evaluation of the middle interval of the Carynginia Shale showed it contained dry gas, predominantly methane and small quantities of ethane, liquefied petroleum gas and carbon dioxide.

Canning Basin

Buru Energy and New Standard Energy have identified significant shale gas potential within the Canning Basin, with the latter reporting independent regional estimates of 40 to 480 Tcfg in place. The Ordovician Goldwyer Shales and the Lower Carboniferous Laurel Shales have been recognised as the primary targets for shale gas exploration in the Canning Basin.

Buru Energy is undertaking extensive re-evaluation of the Canning Basin for unconventional resources. Along with the Mitsubishi Corporation, Buru Energy is fracturing and testing the Laurel Shale in the re-entered Yulleroo 2 well in EP 391 with the aim of determining the potential for commercial development. It also plans to drill a well to further test the shale gas potential in the Yulleroo Province during 2011. NSE is planning to re-enter the Lawford 1 well in EP 417 in 2011 to assess the Laurel Shales prospectivity, as the original well was suspended above this section. NSE is also looking to farm-out interests in its acreage prior to drilling the Goldwyer Shale later in 2011.

Cooper Basin

Beach Energy has reported that the Nappamerri Trough could have potential shale gas resources of 200 Tcf in place. An early Permian shale sequence comprising the Roseneath, Epsilon and Murteree shales is the primary target. This sequence has a consistent thickness across the Nappamerri Trough and has characteristics conducive to the commercial development of shale gas.

Beach Energy drilled two shale gas exploration wells in PEL 218. Encounter 1 was spudded in October 2010 and intersected nearly 400m of shale within the Roseneath, Epsilon and Murteree sequence, thicker than expected. Five cores taken from this well are being evaluated to provide estimates of gas in place figures and assist in the design of future fracture stimulation programmes.

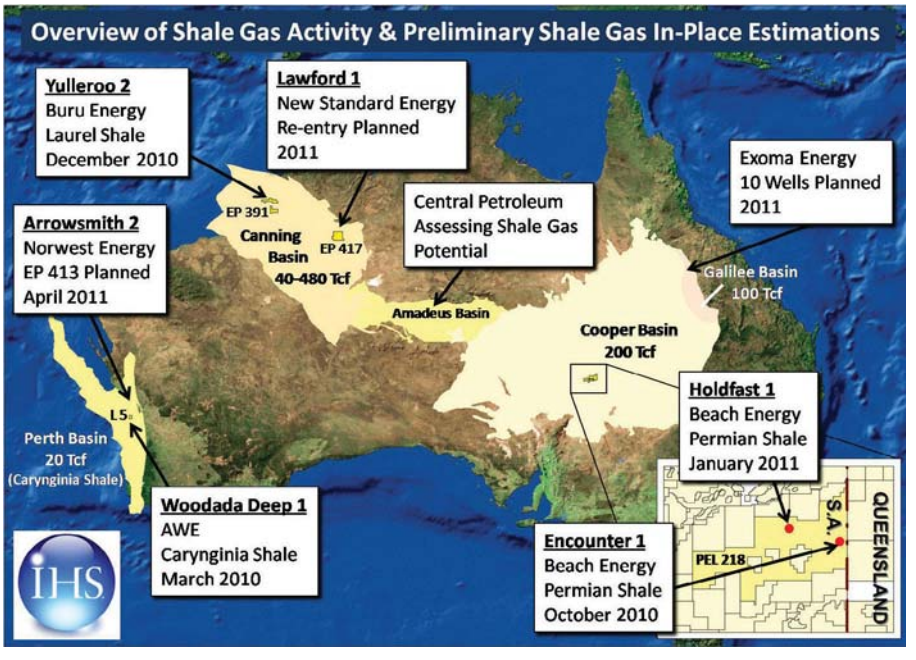
The Holdfast 1 well was spudded in January 2011 and if successful will be fracture stimulated along with Encounter 1 in April 2011. Beach reported that as a result of the increased thickness of the target section in Encounter 1, an eight stage fracture stimulation programme is planned, similar to the multi-fracture techniques used in the USA.

The Future

As the exploitation of shale gas in Australia gains momentum a number of companies have identified potential within other Australian basins with drilling planned for 2011. Central Petroleum has carried out an assessment of unconventional resources in its Amadeus Basin permit, focusing on the Lower Larapinta Group sediments. Central reported that the findings of a consultancy report were promising, although a significant amount of further seismic, drilling and testing is required to confirm resource estimates.

In the Galilee Basin, Exoma Energy has reported gas in-place estimates of 100 Tcf within the Toolebuc Shale, and plans to drill 10 shale gas wells during 2011, after agreeing a deal with strategic farm-in partner CNOOC. Similarly, Western Gas and Power Ltd has identified shale gas potential in its North Perth Basin DR11 permit and Norwest Energy and AWE plan to drill Arrowsmith 2 in EP413 in April 2011. Norwest Energy recently agreed a deal with Indian Government explorer Bharat PetroResources Ltd, who will acquire 50% of Norwest's interest in Perth Basin permit EP 413, providing US$ 10 million in exploration and drilling funds to evaluate the shale gas potential.

PAUL WEBBER, IHS



CONVERSION FACTORS

Crude oil
1 m^3 = 6.29 barrels
1 barrel = 0.159 m^3
1 tonne = 7.49 barrels

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

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

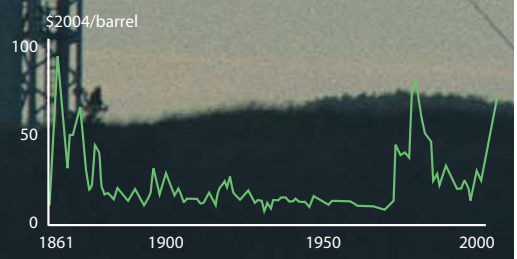
Numbers
Million = 1 x 10^6
Billion = 1 x 10^9
Trillion = 1 x 10^{12}

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

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

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

Historic oil price



The Energy Outlook

Demand for energy is bound to increase taking into account an ever increasing population seeking better welfare. Meaning that fossil fuels will continue to be in demand.

"Demand for energy is tied to the human desire for a better life." So it is. The question is how much energy – and what kind – are we going to use in the next 20 years. ExxonMobil has one answer; this year's *The Outlook for Energy: A view to 2030*, from which this quote came, offers their perspectives on our needs.

To put it briefly, ExxonMobil forecasts the global demand for energy in 2030 to be about 35 percent higher than it was in 2005. The reason for this increase is population growth and expanding economies.

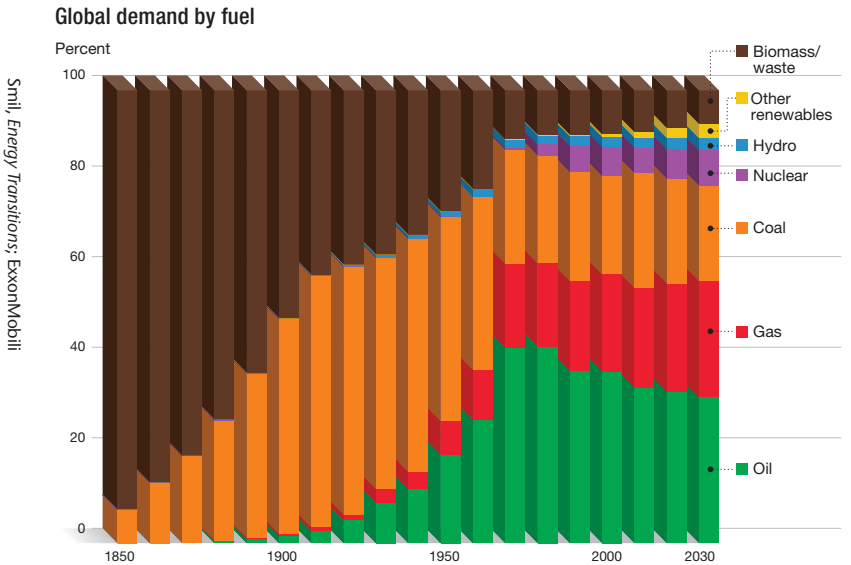
While OECD energy demand will be essentially unchanged, due to increased energy efficiency, non-OECD countries – China in the lead – will be responsible for a dramatic climb in energy demand, as a "desire for a better life" within the huge population grows. As a result China and India will average annual GDP growth of 6 percent in the next 20 years. And don't forget, by 2030 the world's population will reach nearly 8 billion, with 85% (i.e. almost 7 billion) residing in non-OECD countries.

In order to meet this substantial increase in demand, ExxonMobil believes that we will have to continue to expand the use of *all* available energy sources. However, there will be a shift in trends as natural gas will overtake the role of coal as the second largest global energy source, even if coal continues to predominate as a fuel for power generation in non-OECD countries.

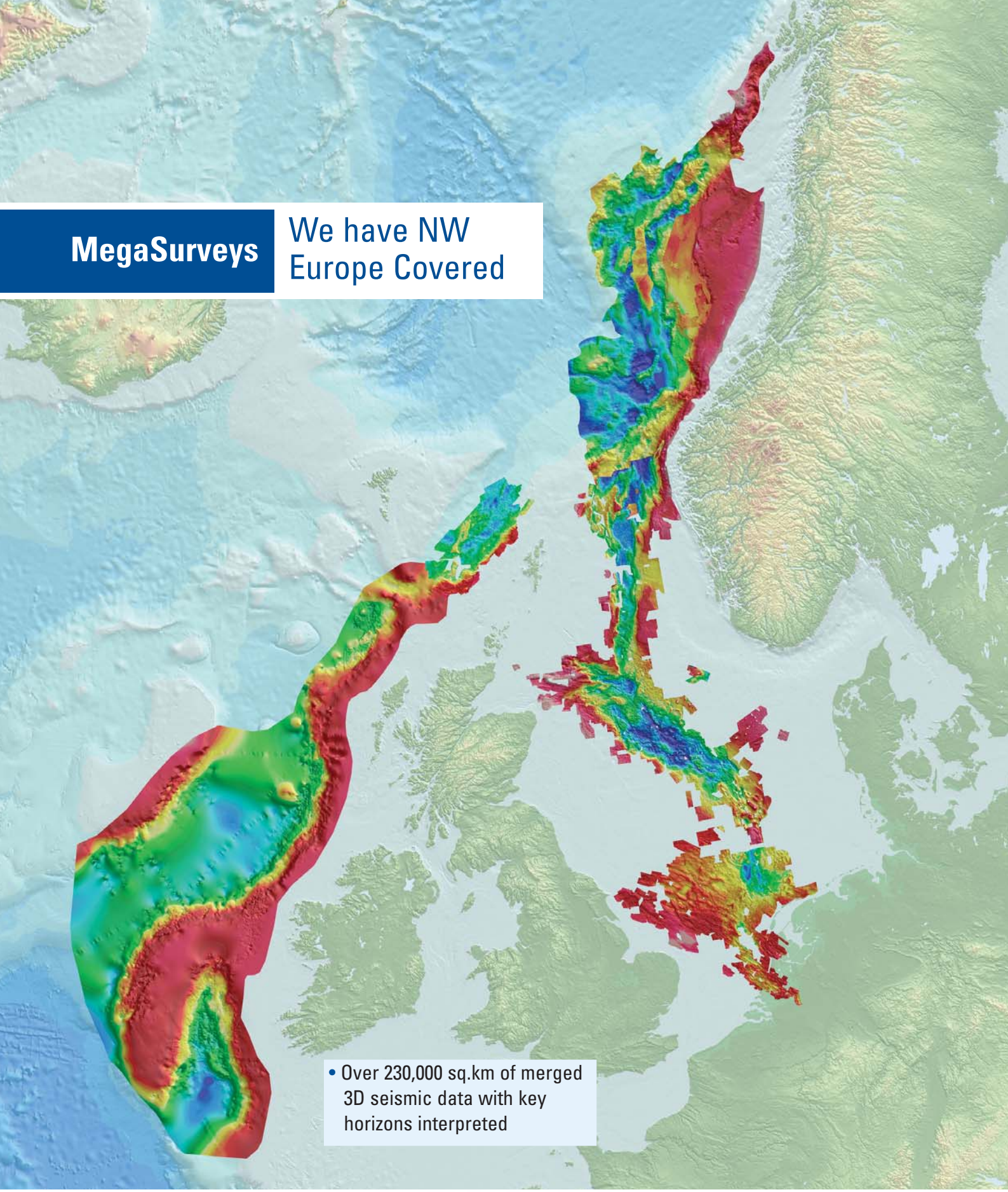
It is therefore necessary to make it clear that the production and use of liquid oil will increase in absolute numbers. While the output is now roughly 85 million barrels per day, it will be around 110 million barrels a day as of 2010, according to the ExxonMobil *Outlook*. Where will it all come from? That of course, remains to be seen, but one source is deep water.

In recent years, more than 14,000 wells have been drilled in water depths of 2,500 feet (i.e. ca. 800m) or more, according to ExxonMobil (the company has itself drilled more than 250 deep wells), and global deepwater production has more than tripled since 2000 to approximately 5 million barrels a day. By 2015 it could possibly rise to as much as 10 million barrels a day, the supermajor's report says. That certainly takes care of a good portion of the demand. As for the next 15 years, the report says nothing.

HALFDAN CARSTENS



Historical use of energy from 1860 up to 2010 and forecasted to 2030. Note that fossil fuels will predominate the next 20 years, as they have done since the dawn of the 20th century, while the use of renewables will still be minimal, percentagewise.



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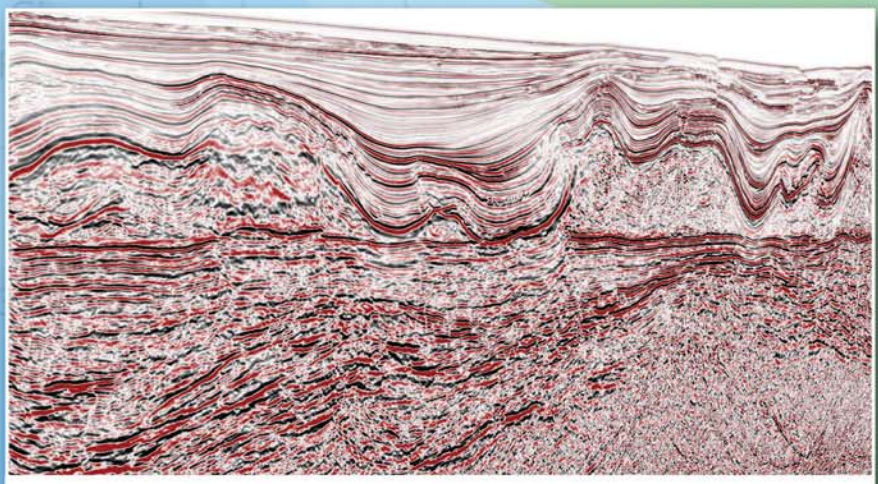
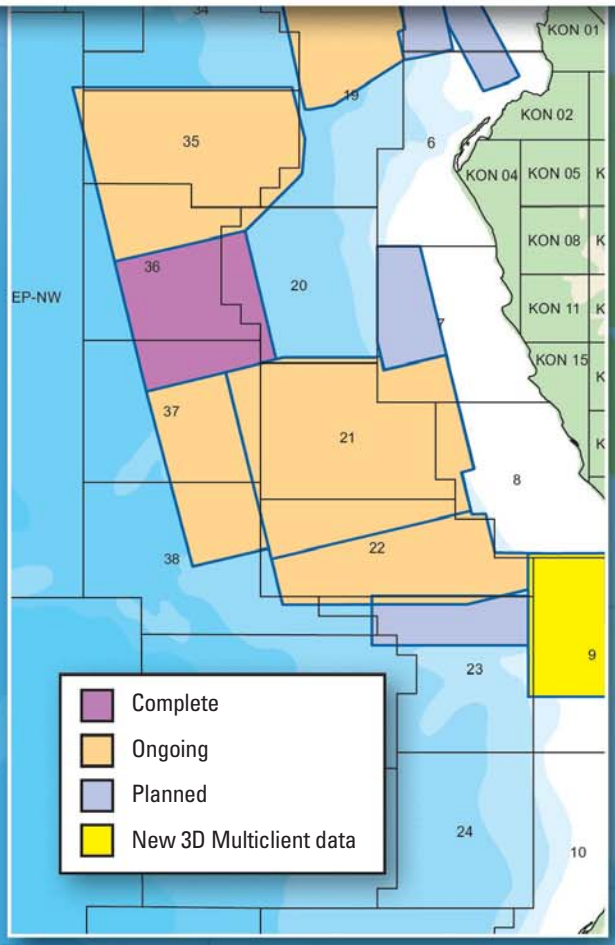


Anisotropic TTI Gaussian Beam PreSDM
(maximum frequency 40Hz)–using final velocity model



Multiclient Services

New 3D multiclient acquisition, and a huge reprocessing project in the Kwanza basin (focusing on presalt imaging) are underway. Highlights from this multiclient project include:

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

Final products will be available in phases from Q3 2010.

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