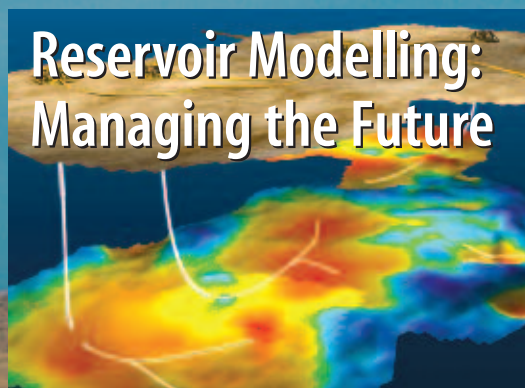




*Cretaceous Park:  
Producing oil and gas below the scenery*

## Kurdistan: First Exploration Well Hits Oil



**ExPROFILE**



Hank Hamilton

# SEARCHING FOR EXPLORATION DATA?

BLACKBEARD	D	J	J	H	J	Q	T	R	D	M	D	Q	G	U	Y
BUZZARD	X	I	N	T	E	R	P	R	E	T	A	T	I	O	N
DATA	Z	I	V	D	O	Z	X	O	J	P	T	O	H	F	H
HYDROCARBONS	H	W	T	H	U	N	D	E	R	H	O	R	S	E	E
INTERPRETATION	B	U	D	V	E	B	M	O	Y	A	V	K	F	T	Q
PETROLEUM	L	X	B	A	T	G	S	U	D	R	A	Z	Z	U	B
PROSPECTS	A	D	P	H	T	P	B	B	R	S	M	U	A	Q	X
SEISMIC	C	T	R	U	E	A	N	W	D	Z	E	P	X	T	V
THUNDER HORSE	K	G	M	C	J	E	S	E	I	S	M	I	C	I	H
WELL LOGS	B	B	T	D	A	V	V	L	X	U	P	C	E	U	N
	E	S	T	Z	M	U	E	L	O	R	T	E	P	U	K
	A	V	R	F	S	U	X	L	X	Y	C	R	E	T	B
	R	K	G	H	Y	D	R	O	C	A	R	B	O	N	S
	D	K	Q	E	U	M	B	G	N	D	U	I	A	M	J
	G	S	B	Q	H	N	A	S	E	F	S	O	X	P	N

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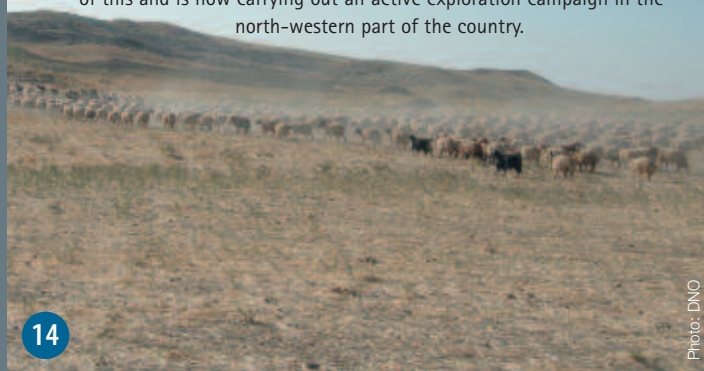
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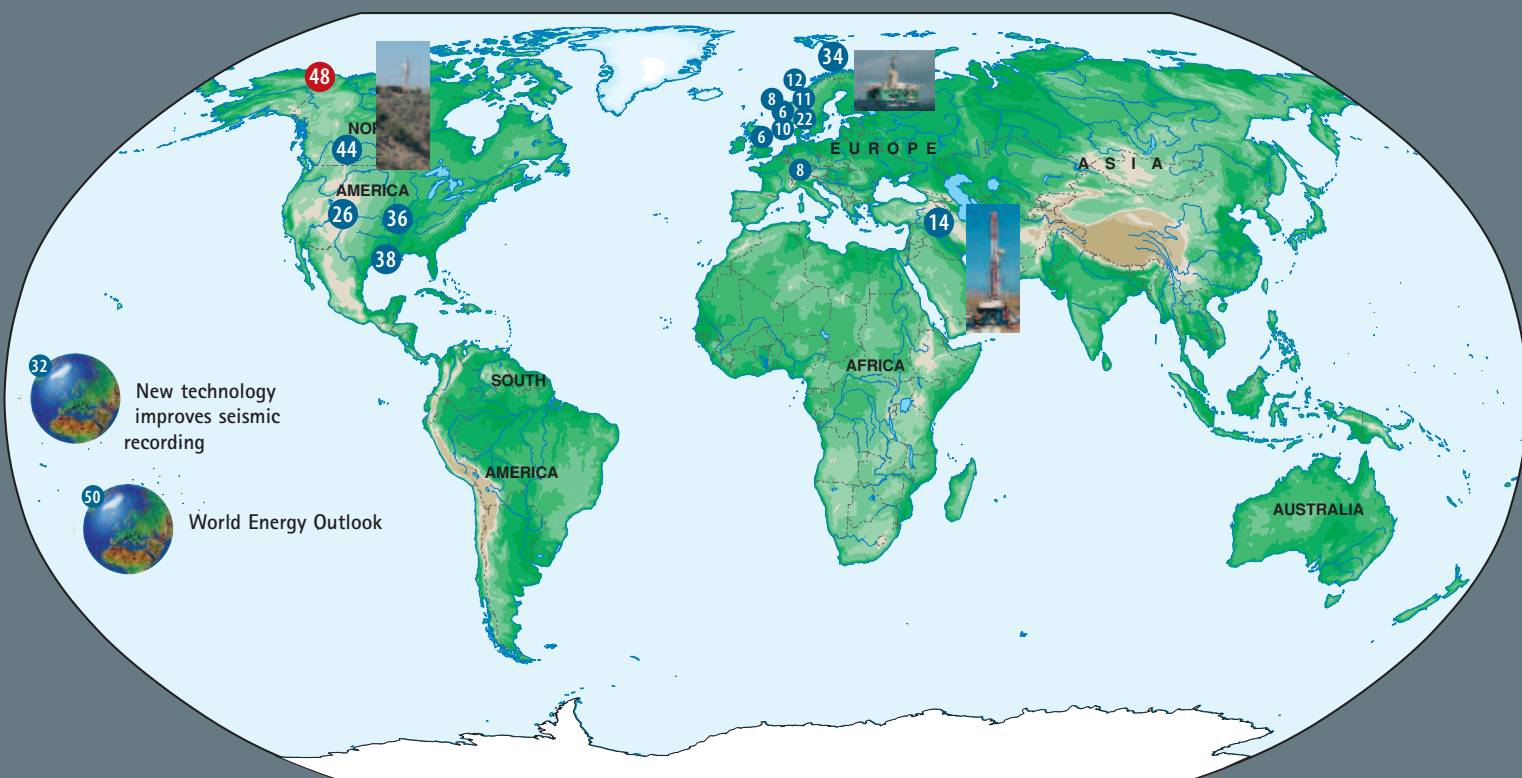
The four million Kurds have recently enjoyed complete autonomy in the region of Iraqi Kurdistan and established an independent state. For the first time in their long history, they are successfully negotiating for control over new oil discoveries in their own terrain. Norwegian independent DNO is taking advantage of this and is now carrying out an active exploration campaign in the north-western part of the country.



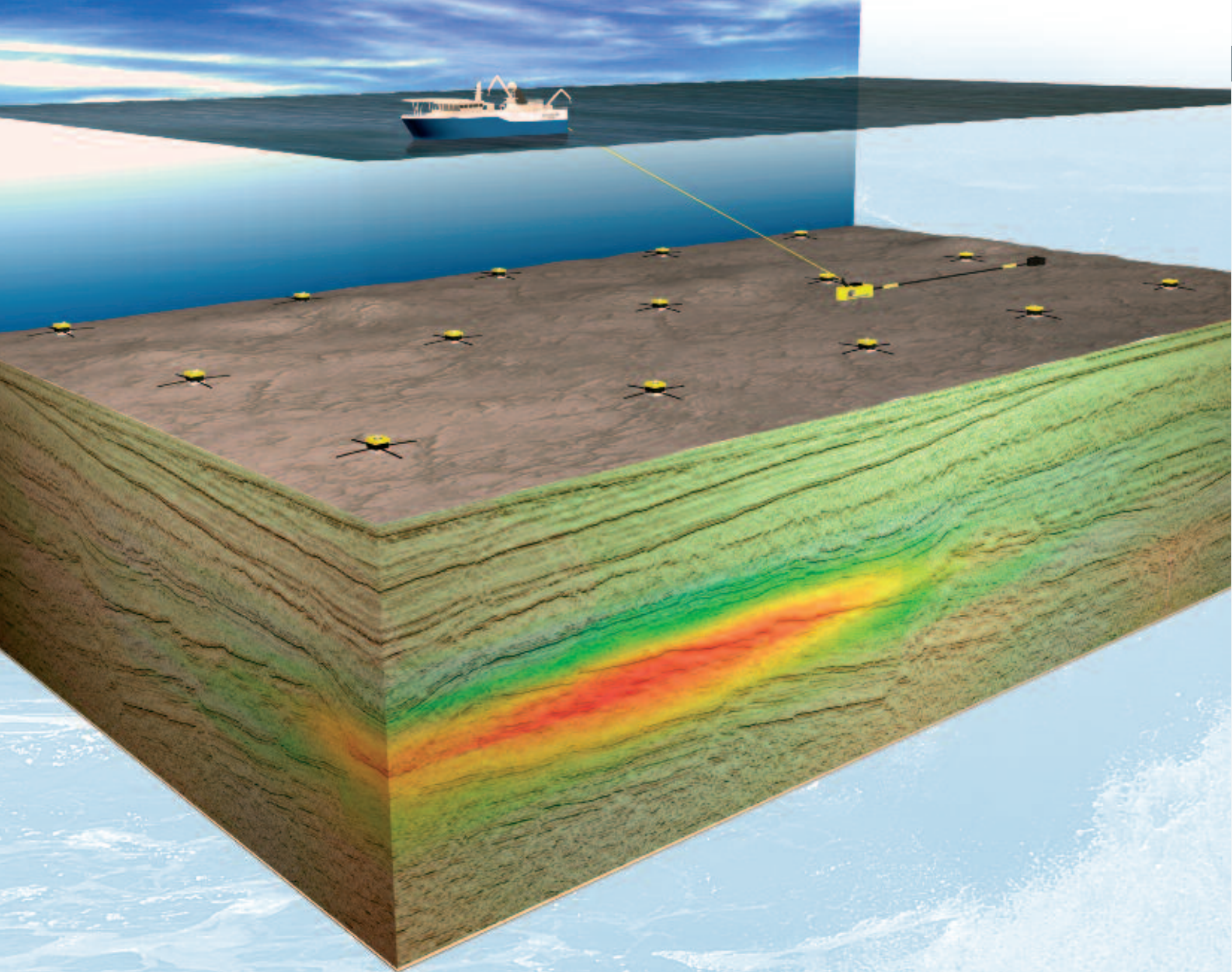
Oil is flowing to the surface in numerous seeps, nearby world class fields have been producing for decades, and now a small independent oil company may have hit a giant in oil rich Kurdistan.



New software claims to revolutionise history-matching by reducing manpower requirements and assessing the uncertainty of reservoir simulation models in a quantitative manner. In this way Dag Terje Rian, President of Scandpower Petroleum Technology, believes the software will better reflect how oil and gas fields behave during production.







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## Incredibly Cheap

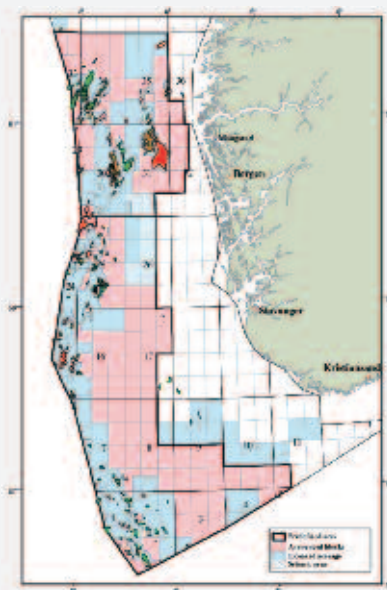
A total of 45 production licenses were just recently awarded in mature areas on the Norwegian continental shelf. The companies have been offered participating interests in 73 blocks or parts of blocks, and 26 companies – including a few of the supermajors – have in this way expanded their acreage portfolio in the North Sea and on the Halten Terrace in the Norwegian Sea (see also related story on page 12).

The Norwegian authorities say they are pleased with the interest. The many offers demonstrate that mature areas on the Norwegian shelf are very attractive internationally, and that there are still plenty of opportunities offshore Norway despite few discoveries the past few years. The result is more extensive exploration activity, something which is necessary in order to make sure that the resources are exploited in the best possible way, according to the Minister of Petroleum and Energy Odd Roger Enoksen.

The APA-system (**A**wards in **P**redefined **A**reas) was introduced in 2003, with the purpose of encouraging more efficient exploration of the mature regions. Companies receiving APA acreage must commit to a faster exploration of the acreage than has been or is normal in Norway's traditional licensing rounds. They also have less time to assess whether they want to drill or develop possible finds than has been usual. Acreage must be relinquished if it is not to be developed.

The awards are all in mature areas, i.e. within geological provinces with a proven petroleum system characterised by many discoveries and several producing fields. The geological, technical and political risks are all small. Also, it is noteworthy that the work commitment on all but two licenses does not include the drilling of an exploration well.

Companies wanting to get access to low risk acreage should look upon the APA-system as an excellent opportunity to both improve their acreage situation and increase their oil and gas reserves. Compared with many other offers – inside as well as outside Norway – the APA system offer incredibly cheap opportunities.



Halfdan Carstens  
Editor in Chief



Photo: DNO

## Finding oil in Iraq

Middle East and Iraqi oil reserves are said to play an increasingly important role in the coming years and decades. The reason is huge reserves, as reported independently by several institutions and experts, and the general belief that there are also vast amounts of undiscovered oil in the ground.

The BP Statistical Review of World Energy is using a reserve figure of 115 billion barrels of oil at the end of 2004 for Iraq. Five years ago, the US Geological Survey estimated the undiscovered resources to be 45 billion barrels in their World Petroleum Assessment (GEO ExPro No. 1, 2004). Other geologists and institutions are far more optimistic and want to multiply that number several times.

Within this context it is quite exciting that the small and independent Norwegian oil company DNO is carrying out an exploration campaign in Kurdistan, not far away from the supergiant Kirkuk oil field discovered in 1927 and which has been producing more than 70 years.

DNO has performed geological studies, acquired seismic data, and the first well is now being drilled in a well-known and prolific petroleum province (the Zagros Low Folded Zone) that stretches from Iran through Iraq. With numerous oil seeps on the ground within the license area, the operator has reason to be very optimistic. For good reason, it seems. The operator struck oil after drilling only 350 m. See cover story starting on page 14.

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## Focusing on 3D Modelling



Jan Egil Fivelstad, Managing Director of Blueback Reservoir, offers his services to oil companies regardless of what kind of 3D modelling software they are using.

"Our intention is to do a lot more than just project work. We want to transfer knowledge to the oil companies, thereby enabling their own staff to do high quality 3D modelling and

to enhance their understanding of the reservoirs," says founder Erik Wulff-Pedersen in the newly established consulting company Blueback Reservoir AS, an independent company serving the petroleum industry with reservoir geoscience consulting services.

"Our vision is simply to increase the reservoir characterization know-how of our customers, and to work with them to maximize the value of their 3D geological models," he says.

The company was founded last year by a group of highly experienced people, with a long history of both software development and consultancy services within the 3D geological modeling domain. The team has set their sights on making the technology that the reservoir geologists and engineers are using more accessible.

"We deliver three kinds of services, 'advanced', 'standard' and 'basic', in addition to long term placement of consultants within customer organizations. 'Advanced' services include looking at the entire workflow within a company and maximizing their reservoir performance. We analyze how the companies work and recommend improvements. By 'standard' we mean project work and training, while 'basic' includes data loading and quality control," explains Jan Egil Fivelstad, Managing Director of Blueback Reservoir. To achieve this he has a group of highly skilled consultants available to perform services on a worldwide basis.

"In the future we expect that there will be a great need for geophysicists, geologists and reservoir engineers with expertise in 3D modelling. What we see today is a lot of new applications with a great variety of functionality and versatility. What companies lack, however, is skilled staff that can take full advantage of the technology and integrated solutions for the whole *seismic-to-simulation workflow*. Many companies have already invested in this technology, but not all are taking full advantage of it," says Wulff-Pedersen. "This is why we are trying to carve a niche in a growing and exciting market," he concludes.

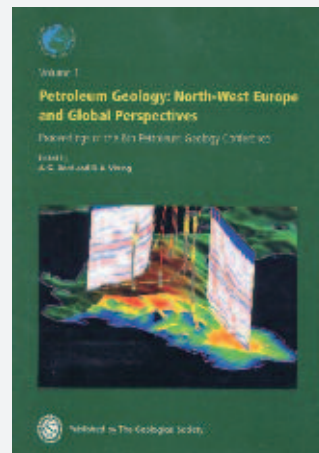
## Very Informative – and Very Impressive!

Two years have past since the sixth in a series of petroleum geology conferences concerning Northwest European exploration and production (October 2003). The proceedings have just arrived and in the same format as previous proceedings.

The proceedings from the conference come in two volumes, and together comprise more than 1650 pages. It's colossal in weight, it's colossal in content and it's colossal in knowledge. It is an impossible task to do a proper review by reading all the articles (although it is tempting). Instead, it suffices to say that geoscientists with an interest in the petroleum geology of the North Atlantic realm are sure to find plenty of reading and excellent illustrations.

There are nine main chapters: The Global Resource Content, Exploration Histories and Future Potential, Better Recovery through Better Characterization, Gas Renaissance, Atlantic Margins: New Insights, Regional Synthesis and Large-Scale Tectonics, Deep-water Plays and Reservoirs, Understanding Petroleum Systems, Unlocking the Future with Innovative Geophysics and 3D Visions. "The 3D Visions session was a first for a major geoscience conference," write Tony Doré and Bernie Vining in the Foreword.

There are nine main chapters, opening with The Global Resource Content and following on to look at Exploration Histories and Future Potential, Better Recovery through Better Characterization and Gas Renaissance. Next are chapters on Atlantic Margins: New Insights, Regional Synthesis and Large-Scale Tectonics,



Petroleum Geology: North-West Europe and Global Perspectives  
Proceedings of the 6th Petroleum Geology Conference  
Edited by A.G. Doré and B.A. Vining  
Published by The Geological Society, 2005

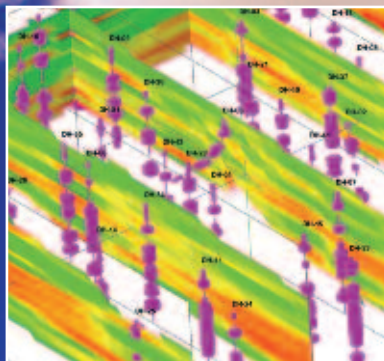
Deep-water Plays and Reservoirs, Understanding Petroleum Systems and Unlocking the Future with Innovative Geophysics, before the proceedings finish with a chapter on 3D visions. "The 3D Visions session was a first for a major geoscience conference," write Tony Doré and Bernie Vining in the Foreword.

In addition to all that, there is a DVD enclosed that features 28 QuickTime movies including, for example 3D visualization of sandstone intrusions in the Lower Eocene of the Outer Moray Firth (GEO ExPro, no. 5-6, 2005), 35 core displays and also a PDF file for the entire proceedings volumes. The DVD provides links from the main text to movies from the 3D Visions section, and to core display and associated posters.

All in all, a very informative and impressive publication!



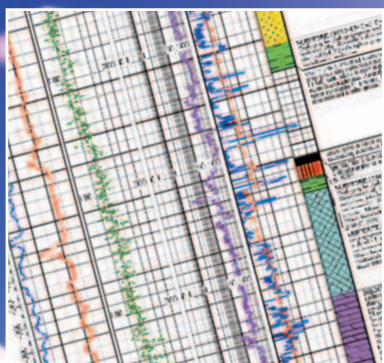
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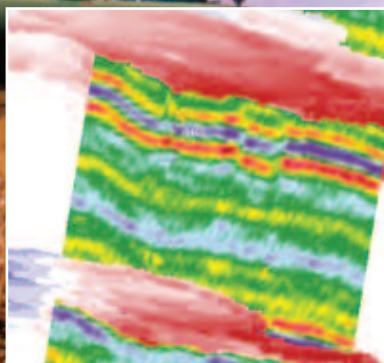
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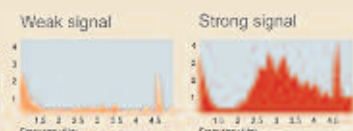
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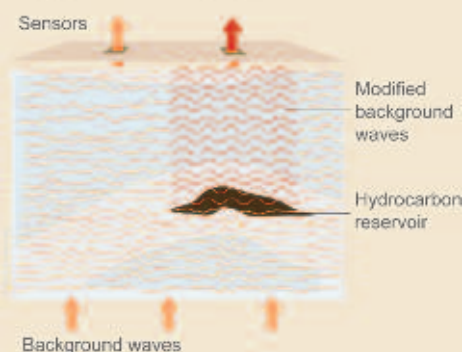


# Using Earthquakes to Find Oil

Hydro has recently invested in a Swiss company developing new geophysical technologies to determine whether promising geological formations contain oil or gas.



© Spectraseis



High sensitivity instruments are used to record low frequency seismic data at the surface. The instruments pick up waves generated by natural activity in the earth's crust over 1-2 hours. Seismic waves that have passed through hydrocarbon layers exhibit characteristic anomalies which can be isolated from seismic background noise and artificial noise sources, such as production equipment. By identifying these spectral signatures and comparing results from near-by areas, high probability hydrocarbon-bearing zones can be identified.

Zurich-based Spectraseis Technologie AG provides surveys and data processing services using ultra-sensitive spectrometers and proprietary software to generate maps showing probable distributions of hydrocarbon deposits in a survey area, based on the analysis of passive, low frequency seismic data. Hydro is the sole industrial owner in Spectraseis Technologie AG.

Spectraseis' technology, dubbed "Hydrocarbon Microtremor Analysis" or HyMAS, works in almost the same way as when a doctor uses a stethoscope to monitor a patient's heart. By positioning sensors in the ground, signals can be received from the earth's interior. The data gathered is then sent to Spectraseis for analysis.

By listening to the signals emitted, a chart can be drawn up that reveals the probability

of discovering hydrocarbons in an area. In this way it is possible to assess - without drilling - whether promising geological formations may contain oil or gas.

"The method increases the probability of discovery and helps improve exploration efficiency by reducing costs and the time it takes to find oil and gas," says Arne Frøiland, Technology Ventures' investment manager in Norsk Hydro.



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Finding oil and gas by measuring microtremors.

Some of the main contributors to the ant-tracking success, from left: Stein Inge Pedersen, Randy Pepper, Øystein Amundrud, Trygve Randen, Hilde Borgås and Gastón Bejarano.



Photo: Schlumberger

## And the Winner is...

The annual World Oil awards are often referred to as the "Oscars of the oil industry." This year, technology developed in Stavanger, Norway, won the "Best Exploration Technology award", writes Lianne Qvale, North Sea Contact for Schlumberger.

Schlumberger won the prize for a tool, nicknamed "ant-tracking" (GEO ExPro Vol. 1, No. 2), that allows geoscientists to approach fault interpretation on a fault system level. The interpreter's ability to differentiate and manipulate fault systems, rather than individual faults, represents a new paradigm in structural interpretation. The Petrel\* workflow tools Automated Structural Interpretation module uses a new data conditioning process combined with an advanced computing algorithm.

Automating fault interpretation dramatically accelerates the process of reservoir characterisation. Instead of spending days or months trying to interpret faults on a conventional workstation, a whole fault structure can be understood within a few hours.

The ant-tracking module was developed from an idea hatched in the Schlumberger Stavanger Research Centre (SSR) in 2000. Research engineers built a prototype that was validated with client data and continually refined over a two-year period.

In 2002 Schlumberger acquired Petrel workflow tools. The company quickly saw that Petrel was the perfect platform for the module. It was therefore reworked to fit the Petrel mind-

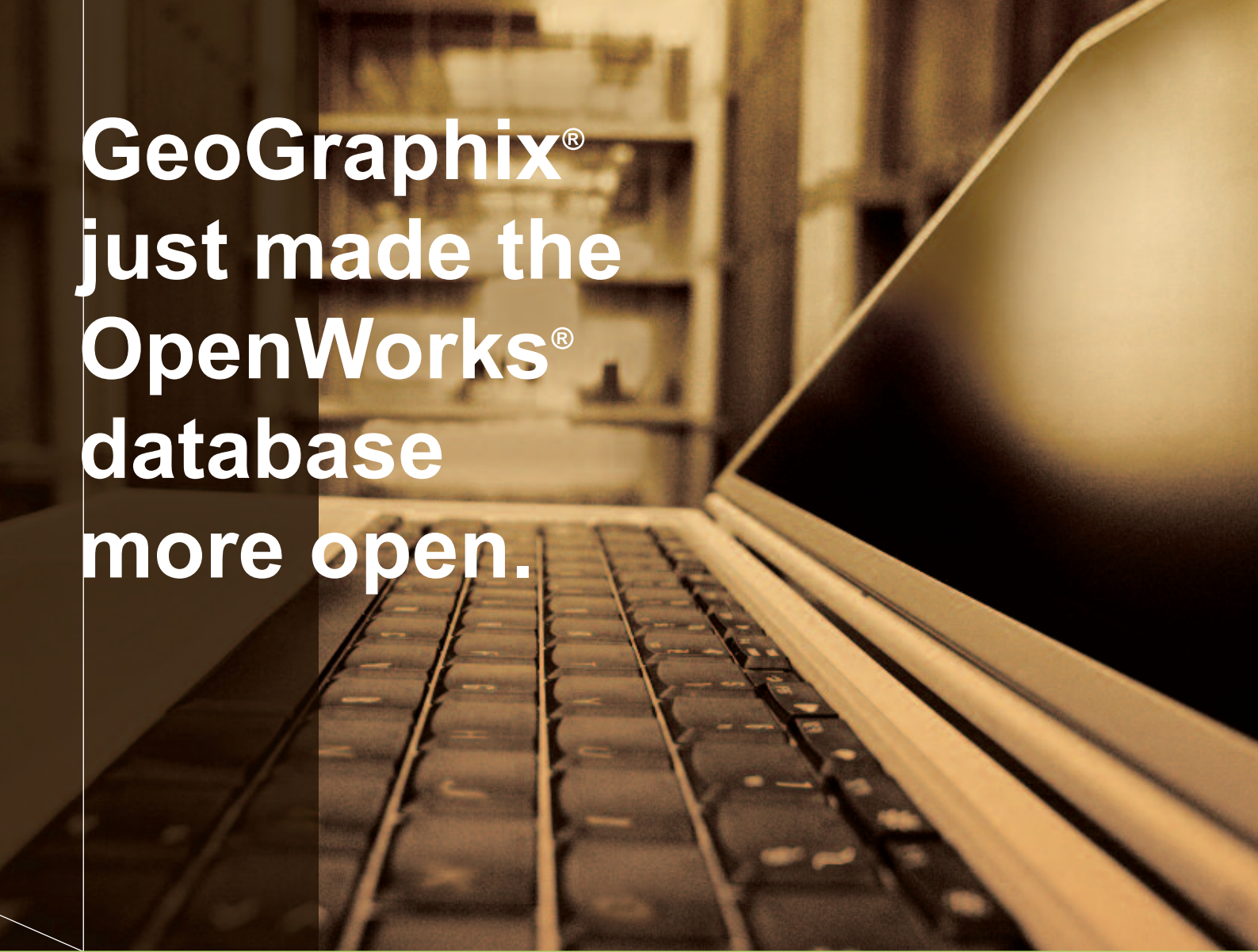
set, and that's what makes it different. It's part of an integrated workflow.

Lars Sønneland, director of SSR, emphasises that the success is the result of teamwork. However, two of his people in particular deserve honourable mention.

"Stein Inge Pedersen, research software engineer, was working on a system to automatically extract faults from 3D seismic. It was his idea to use the analogy of programmed biological agents to track fault surfaces," explains Lars. He smiles at the analogy of myriads of virtual ants deployed in a seismic volume continuously searching for discontinuities or faults. These so-called ants lay tracks of electronic pheromones as they move. Intelligent search algorithms use these pheromones to automatically extract fault surfaces, and 3D visualisation produces an image with superior delineation of faults.

"Hilde Borgås, geostatistician, also played an important role," continues Lars. "When you have a fault, which is really a formation that has been broken, you need to be able to quantify it. Using a new novel method, Hilde's work allowed us to measure how much the formation was displaced along the fault surface."





# GeoGraphix<sup>®</sup> just made the OpenWorks<sup>®</sup> database more open.

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# Smallest ever?



Chestnut is located due north of Forties and next to Britannia.

Venture Production plc, the Aberdeen based UK independent oil and gas production company, has announced that the UK Department of Trade and Industry has given its approval for the development of the Chestnut oil field, located in the Central North Sea. Venture specialises in developing fields that bigger companies consider too small to be worth investing in.

Discovered in 1986, the Chestnut field is said to be one of the smallest fields ever developed in the North Sea. Estimated total recoverable reserves for the field amount to between six and nine million barrels. First production from the field scheduled for the second half of 2007, according to a press release from Venture Production plc.

"We are delighted to receive government approval to develop the Chestnut Field. With recoverable reserves of less than 10 million barrels, this will be one of the smallest stand-alone oil field developments yet in the North Sea," Mike Wagstaff, Chief Executive of Venture said.

## Giving Time Back to Geoscientists

*Over the last few years, Landmark's OpenWorks® database has become a key tool for oilfield data management. Designed on Open Systems standards, a single project database can be shared by a number of team members, from seismic interpreters to drilling engineers, using a wide variety of proprietary and third-party UNIX-based applications.*

GeoGraphix, along with other Windows-based vendors, have developed links that would move data to and from the OpenWorks database, but this had very little impact on the overall amount of time spent managing data in the PC space. In fact, this "linking" approach was actually adding complexity in the way of significant data duplication.

Like Landmark, GeoGraphix, a brand of the Halliburton Digital and Consulting Solutions Division, decided to directly address this problem. As Brad Bechtold, director of GeoGraphix, explains, "With the improved capabilities of GeoGraphix's geological and geophysical suite of applications called Discovery® and more than 8,000 OpenWorks database users worldwide, we were continually asked by our clients if we could make the Windows-based Discovery suite reside directly on the OpenWorks database, allowing users access to both the database and the functionality of their Windows interpretive tools.

"We set up a consultation with our customers, and discovered that geoscientists and IT professionals had to maintain multiple copies of data in OpenWorks and Windows-based databases. This was not delivering the level of integration needed, and was having a serious impact on our customers' ability to increase their productivity," Bechtold said. "In fact, geologists, geophysicists and IT professionals estimated that they were spending up to 70 percent of their time moving and synchronizing information between multiple

platforms, applications and projects because they lacked a common integration environment to facilitate collaboration."

Two years later, after more than 100 man-years of application development between GeoGraphix and the OpenWorks development team, "Discovery on OpenWorks" was born in October 2005. First tested through a customer advisory board with members based in Canada, the U.S. and Latin America, this system has been designed and approved by the actual market for which it was intended.

Geoscientists can now choose the right applications between GeoGraphix and Landmark to support their interpretation or decision processes without complicating the project environment. GeoGraphix expects the product will reduce the time its clients spend in

nonproductive tasks, such as data replication, by 300 percent.

Not only do the geoscientists benefit from this innovation, but, for the IT professional, there is a 2 to 4 times reduction in data storage, plus the advantages of reduced complexity and greater data security. Management sees the cost benefits of increased productivity and better control on corporate knowledge.

As Commercialization Manager Vince Molliconi points out, "OpenWorks users worldwide have been asking for easy data access with the ability to choose the right tool for the job, regardless of platform and without having to keep copying data. The Discovery on OpenWorks solution achieves this for them. With this innovative system, we are giving back time to the geoscientists!"

Jane Whaley

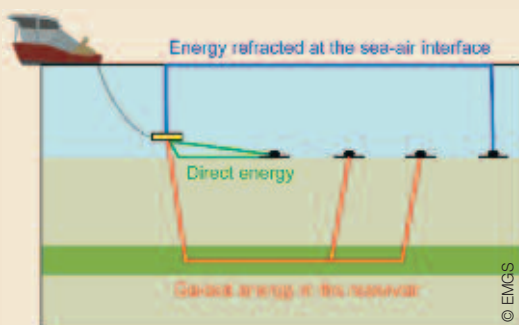


The launch of Discovery® on Open Works® at the SEG Conference in Houston in November 2005 generated a lot of interest, as can be seen from the crowds gathered at this press event



# Shell and emgs will Collaborate

**Shell and Electromagnetic Geoservices AS (emgs) have signed an agreement to collaborate on expanding the capabilities of emgs' proprietary marine electromagnetic surveying technique known as seabed logging.**




Shell has had success with the seabed logging (GEO ExPro No. 1/2004, GEO ExPro No. 5-6/2005) in a variety of geological settings in various basins around the world. The company believes that the enhanced capabilities that will be achieved through the agreement will support its position as a leading exploration company.

Under the terms of the agreement, emgs will receive funding for conducting research, testing concepts and developing software. Shell backing will secure access to emgs' software resources and computers, and the participation from the emgs organisation and the key individuals needed to achieve common objectives. In addition, Shell will fund exclusive seabed logging surveys.

The research efforts will focus on enhancing operating efficiency and expanding the applications of seabed logging. Both parties expect to gain competitive advantage from the collaboration. emgs will accelerate its development programme and improve understanding of the requirements of one of its biggest customers. Shell will benefit from emgs' technical support and will, for an agreed period, receive exclusive rights to the advances in seabed logging that are developed together with emgs.

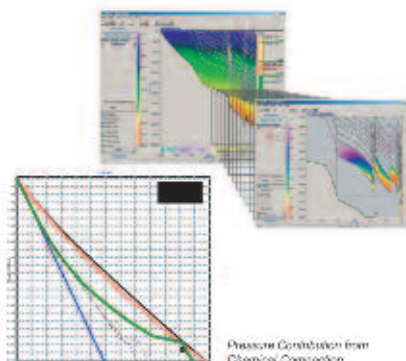
"Shell uses seabed logging to reduce exploration risks and deliver a greater number of successful wells in less time. We recognise that the full capability of 3D



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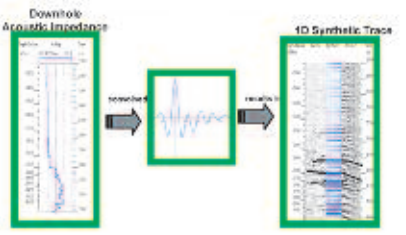
- Advanced heat flow (radiogenic and stretching), maturation and expulsion analysis
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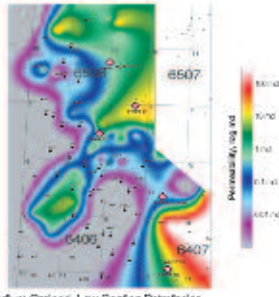
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**Exemplar** predicts reservoir quality away from the borehole by modelling sandstone porosity and permeability with sophisticated compaction and cementation algorithms. The package interfaces directly with Fobos Pro and output data types include burial history, petrography, petrophysics and thin section point-count data.

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imaging and the inversion of seabed logging data over various frequency bandwidths are very important to this and look forward to working with emgs to develop this capability," says Dirk Smit, Shell Exploration Technology Manager.

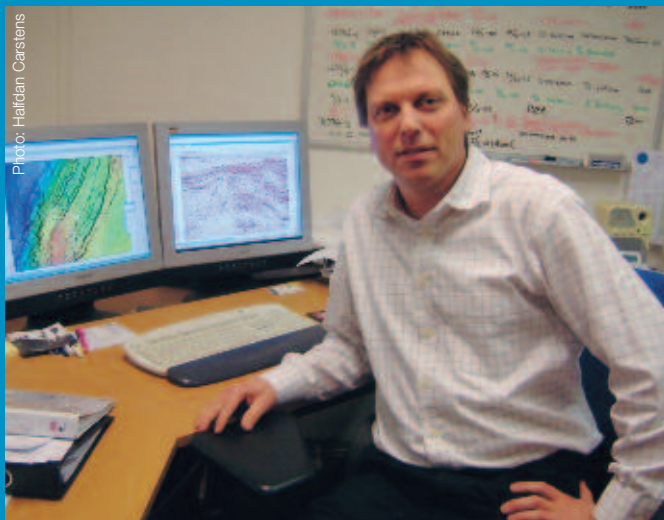
Christian Bukovics, Exploration Manager for the Northwest European Atlantic Margin area in Shell adds "The Norwegian Sea is an example of a geologically complex area where a further refinement of the seabed logging method is critically important to enable its successful application, in turn

leading to better exploration outcomes."

Terje Eidesmo, President and Chief Executive Officer of emgs, is also enthusiastic about the collaboration: "Shell is widely recognised as one of the most technologically innovative companies in the energy industry. At emgs, we are all delighted that Shell has chosen to work exclusively with us on enhancing electromagnetic surveying technology. By signing this agreement with Shell, we are further consolidating our position as the market leader in marine electromagnetic surveying."

# Introducing Seabed Logging

For the first time seabed logging has been introduced as a work commitment on the Norwegian Continental Shelf. Altogether six licenses require either acquisition or modelling of electromagnetic data.



Per Gustav Granholm, Exploration Manager in DNO, is an eager proponent of using seabed logging in screening prospects.

Just before year end 26 companies were awarded participating interests in 45 production licences in the North Sea and on the Halten Terrace in the Norwegian Sea. This proves that there is still considerable interest in exploring mature parts of the Norwegian continental shelf, as pointed out by Mr. Odd Roger Enoksen, Minister of Petroleum and Energy. And the reason is quite obvious, as the oil companies get access to cheap acreage within low risk geological provinces that have many play models and prospects yet to be tested.

The work commitments vary, from "no work commitment" to the drilling of a "firm well". For the first time, however, the work commitments

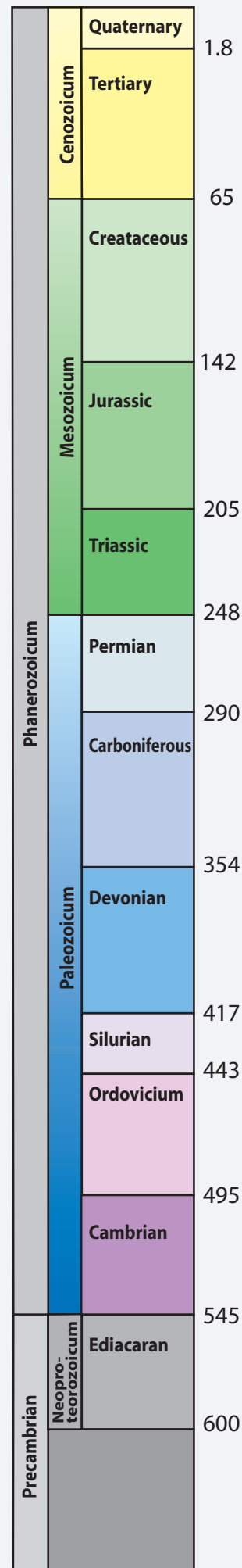
include acquisition of electromagnetic data (seabed logging (SBL)). In four licenses acquisition of electromagnetic data will be the first thing to do, and in another two licenses modelling of seabed logging will be done, and possible acquisition of em-data carried out, as part of the geological evaluation, before making a decision on what to do next (i.e. "drill or drop").

The small independent company DNO has entered into three licenses involving seabed logging, one in the North Sea and two in the Norwegian Sea. "This is a method that we have started to use when risking and ranking our project portfolio," says Per Gustav Granholm, Exploration

Manager in DNO. "Bearing in mind that it is very difficult to access a drilling rig these days, we have to make sure that we are drilling the best prospects first. We are therefore doing our best to rank the prospects based on current technology. And it turns out that with seabed logging it is possible to single out structures with hydrocarbons from structures filled with water, given the right geological conditions," Granholm adds.

Granholm is of the opinion that seabed logging has great potential as an exploration tool, and he is eager to develop the method further. This includes modelling, acquisition, processing, interpretation and presentation of results. He is also aware of the limitations and pitfalls that apply. "Currently there are several limitation to the method, such as water depth, depth to the reservoir and thickness of the reservoir, but we firmly believe that they will be overcome in the long run. Actually, we see improvements from one month to the next. Seabed logging thus has the potential to be an integrated part of the seismic interpretation and prospect evaluation," Granholm says.

Four other operators, Dong, Hydro, Pertra and Talisman, have also decided to use seabed logging as part of their work commitment.







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# Targeting Giants in Kurdistan





Most of the Kurdistan region is part of the foothills of the Zagros with an undulating landscape and a few sporadic mountaintops. Geologically, Iraq can be divided into five main geological provinces: a) the stable Arabian platform, b) the Mesopotamian Foreland Basin, c) the Zagros Low Folded Zone, d) the Zagros High Folded Zone, and e) the Zagros thrust Zone. The Oil discoveries are mostly in the Zagros Low Folded Zone and the Mesopotamian Basin. DNO is carrying out their operations in the Zagros Low Folded Zone northwest of Kirkuk and close to the border with Syria and Turkey. Some of the larger fields have been highlighted (green: oil; red: gas).



Great Wall Drilling Company (GWDC) rig #9 mobilized from China and commenced drilling operation on the well Tawke #1, the first well to be drilled by DNO in Kurdistan. This is a new rig fitted with a top-drive drilling system and capable of drilling to 5,000 meters depth. GWDC is also providing most of the well services for DNO, including mud-logging, electric logging, cementing, coring and testing. In December of 2004 DNO established a local office and an organization in the city of Erbil situated a few hours drive from the Tawke #1 well. An expatriate management team for the Kurdistan operations has been established in Dubai, which today can be reached with a non-stop flight from Erbil. Dubai has got the infrastructure and service providers to serve the entire Middle East region including Iraq.

**Oil is flowing to the surface in several seeps within the license area, and nearby giant fields have been producing for decades. The well Tawke # 1 is certainly being drilled in a proven petroleum province, and the first well by a foreign company in Kurdistan is now testing a huge structure delineated by modern seismic data.**

*Halfdan Carstens*

**L**ate November the Tawke #1 well was spudded in the prolific Zagros Fold Belt of northern Iraq with DNO ASA (DNO) as the operator. It is estimated to take 60 days to drill the well that is targeting three different reservoir zones in the Tertiary and the Cretaceous, down to a depth of 3,000 meters.

"The structure is huge and has great potential for significant commercial discoveries," says Magne Normann, Project Director for DNO in Iraq. He adds that the first well will have to be drilled before oil quantities can be announced, but it is not uncommon that billion barrels fields in Iraq have been placed on production. This first exploration structure to be drilled is relatively close to existing pipeline infrastructure exporting crude oil from Iraq through Turkey to the Mediterranean coast.

Needless to say, not only the operator, but the entire petroleum upstream sector, is excited about this first well being drilled by a foreign company in the autonomous Kurdish region of Iraq, following the collapse of the Iraqi regime in 2003.

Tawke # 1 well, located northeast of the river Tigris, is the first well being drilled under the existing Production Sharing Agreements (PSA) that covers some 4,000 km<sup>2</sup>. The small and independent oil company DNO signed the PSA agreements with the Kurdistan Regional Government (KRG) in June 2004. DNO has a 40% interest in the licenses. The initial drilling campaign includes three wells, but DNO is already planning a further four exploration wells in the agreement areas. "Additional appraisal drilling is highly likely, and DNO is already negotiating terms for a second drilling rig to be mobilized to Kurdistan," Normann says.

DNO is already present in the Middle East and is producing approximately 17,000 barrels per day from three fields in Yemen. The company also has an active exploration campaign going on in Yemen (GEO ExPro No. 3, 2004), where prospects with both Cretaceous sandstones and Precambrian crystalline rocks are being tested.



Magne Normann is Project Director for all of DNO's activities in Iraq and has an international background as a petroleum engineer. He has held senior positions for oil companies as well as drilling contractors in several countries including Norway, USA, UK, Singapore and Yemen. In the background we see a satellite map of the area where the operations in Kurdistan is taking place.

### **Iraqi oil production**

"We consider northern Iraq as the most promising geological province in the world for the next 20 years," says Magne Normann. It is easy to agree with him, as almost 200 billion barrels of oil equivalent is already proven in the Zagros Fold Belt (Iran and Iraq combined).

According to the BP Statistical Review of World Energy 2005, the Iraqi oil production averaged 2 million barrels of oil per day in 2004. As can be seen from the graph (page 17), however, the oil production has had a turbulent history the last 25 years.

Since 1969 it was rising continuously, reaching a record level of almost 3.5 million barrels per day in 1979. Major drops in crude oil production accompanied both the 10-year long war with Iran and the 1991 Gulf War. Output dropped from almost 3.5 million barrels per day in 1979 to 900,000 barrels daily in 1981, following the onset of the war with Iran, and from 2.9 million barrels per day in 1989 to 300,000 bar-

rels daily in 1991, following the embargo on Iraqi oil exports. In September 1991, the UN proposed a plan to allow Iraq to raise revenue for humanitarian purchases and war reparations by exporting limited quantities of oil.

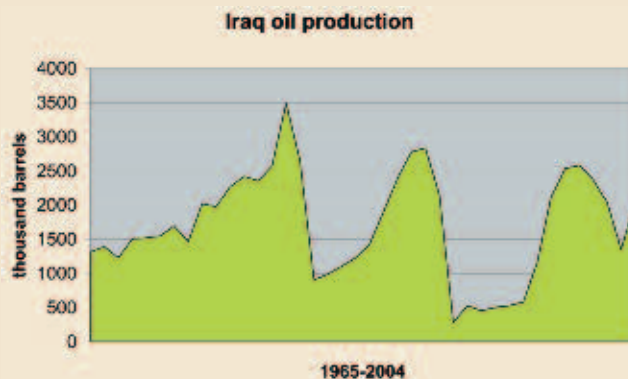
For most of the 1990s, the US-imposed trade embargo reduced Iraqi access to oil industry technology, supplies, and investments. Some four years ago it was indicated that of Iraq's 73 oil fields, only 24 were actually in production.

Iraq's target is reportedly 6 million barrels of oil per day. With reservoirs possibly being damaged because of lack of reservoir management attention through several decades, this is going to be a tough case. New discoveries will certainly help to meet the ambitious target.

"We estimate that it will take approximately 18-24 months from project sanction to bring a discovery in northern Iraq into production, if we hit commercial quantities of oil," says Normann.



The Iraq oil production has a complicated story since 1965, reflecting political turmoil. Source: BP Statistical Review of World Energy 2005



## Oil seeps everywhere

"The first hydrocarbon exploration license in the area was operated by Iraq Petroleum Company (IPC) who had a large concession area east of the Tigris River (mostly Kurdistan) back in the early 1920's and onwards. Until the IPC exploration concession ceased in 1960/61, there is little documentation indicating that the DNO acreage was properly evaluated at that time. Only field geology in the highly folded zones to the north is documented. Since the early 60's, little or no hydrocarbon exploration has taken place in the area," says Nils Bang, Project Geologist with DNO.

Nils has spent several months for DNO doing the necessary mapping and sampling in order to analyze the outcropping formations that the company will hit while drilling. "It's a beautiful country to do geo-

logical fieldwork in," he says.

Some seismic of fair to bad quality had already been acquired in the area before DNO entered the scene, but there was an urgent need for more data to define 4D-closures that made drillable prospects. Altogether, 440 km of 2D seismic were acquired across selected areas of the Dohuk and Erbil PSAs agreement areas; the PSAs are named after the cities with the same name.

"Before the seismic campaign, however, we did a lot of regional geological studies to get a better grip on the prospectivity. Some data was located in Iraq, but most of it was located outside, and it became apparent that we had to search wide to establish a reasonable database. We have also been doing geological mapping within the license area," Bang explains.

"This part of Iraq belongs to the Zagros



Photo: DNO

Mertz 18 vibrators were used to acquire 2D seismic in Kurdistan. They all belong to DNO but were operated by Terra Seis International of Canada.

## Iraq – A lake of oil

According to the BP Statistical Review of World Energy 2005, Iraq has oil reserves of 115 billion barrels and gas reserves of 3,17 trillion m<sup>3</sup> (135 oil equivalents altogether). Iraq is thus only trailing behind Saudi Arabia and Iran with respect to conventional oil reserves. If we include heavy oil, however, the Canadian oil sands reserves ranks higher than both Iraq and Iran, and possibly also higher than Saudi Arabia (GEO ExPro No. 5/6, 2005).

Estimates of Iraq's potential oil reserves, i.e. undiscovered oil resources, are very speculative, as the country as a whole should be considered underexplored. Another factor adding to the uncertainty is the lack of knowledge about the petroleum systems that stems from the minimal amount of geological studies carried out during the last decades.

"Of all the uncertainties in assessing world oil resources, one of the greatest is the future of Iraq," says Thomas Albrandt who was in charge of the USGS World Petroleum Assessment 2000 (GEO ExPro No. 1, 2004).

Nevertheless, it is widely believed that Iraq may soon prove oil reserves in the order of 200 billion barrels, close to a 100% increase. Iraq will then rank as no. 2 in the world with respect to oil reserves. Others are of the opinion that the Iraqi reserves eventually will be proved to be 300 billion barrels.

"Iraq contains whole petroleum systems: world-class source rocks, overlain by excellent reservoirs and terrific evaporite seals," says Albrandt (Geotimes, 2002). Their assessment of Iraq is, however, not as optimistic as that of many other unofficial sources. The USGS mean estimate for undiscovered resources in Iraq is 45 million barrels of oil and 21 billion barrels of oil equivalents of gas.



Photo: DNO

## Kurdistan

The Kurds are an Iranic people inhabiting a mountainous area of Southwest Asia that includes parts of Iraq, Turkey, and Iran as well as smaller sections of Syria, Armenia and Lebanon. Ranging anywhere from 25 to 27 million people, the Kurds comprise one of the largest ethnic groups without their own country in the world.

The Iraqi Kurdistan, also called Southern Kurdistan, is a large area situated in northern and northeastern parts of Iraq, including Erbil (Hewlêr), one of the largest cities in Iraq, and the capitol of the Kurdistan Regional Government. The Kurdish Autonomous Region is a political entity established in 1970 following the agreement of an Autonomy Accord between the government of Iraq and leaders of the Iraqi Kurdish community.

For over a century, many Kurds have campaigned and fought for the right to 'self-determination' in an autonomous homeland known as "Kurdistan". The governments of those countries with sizable Kurdish populations are actively opposed to the possibility of a Kurdish state, believing such a development would require them to give up parts of their own national territories.



The city of Dihok is the centre of the Dihok Governorate. Kurdistan region cover three governorates and those are Dihok, Erbil, and Sulemanian.

Photo: DNO

Fold Belt that strikes southeast-northwest through both Iran and Iraq. Numerous oil fields have been discovered in both countries, and a sizeable discovery was recently announced by Norsk Hydro operating in Iran close to the border with Iraq."

"The DNO PSA agreement area contains a number of structures of different magnitude. Not all of them are, however, considered highly prospective. Some of the structures are uplifted and breached during the Pliocene and Pleistocene folding and uplift," Bang says.

The experienced geologist, who can add several years working in the Zagros Fold Belt for another company on his CV before joining DNO, do like the geological obser-

vations he has made. "There are several nice structures with good oil seeps in many places, which is a good reason to be optimistic about this area," he says.

Nils Bang points out that the reservoirs may be problematic, often with very variable matrix porosity and complex fracturing. "One of the biggest challenges is to develop a high reservoir understanding so that the recovery of oil from each structure can be increased from the very low 10-15% which is so common in the area," he says.

Provided that DNO makes a discovery, there appears to be a lot more work in the pipeline for reservoir geologists with experience in carbonate rocks!

### Completed in four months

Having made the decision to acquire seismic data with the plan to continue with drilling, the initial task was to establish a secure environment for all personnel involved. "We first hired a risk management company with good understanding and experience from similar activities in Iraq. Considerable efforts were made to have a security plan implemented, which would provide protection and security for all personnel involved in our operations. We worked closely with the Kurdistan Regional Government (KRG) on this issue, and KRG is providing all security guards for the operations. There is no doubt that we have an excellent security team in place," says Normann.





One of several oil seepages discovered during geological fieldwork. These tar beds, covering more than 1 km<sup>2</sup>, are close to the area where the 1st exploration well is being drilled. Jurassic marine shales and carbonates are the major sources of hydrocarbons produced in the Zagros Fold Belt.

"Our first international contractor mobilizing to Kurdistan was Terra Seis International (TSI) of Canada. At the time of bidding this work, there were many concerns raised by the contractors. Those were ranging from political concerns; i.e. contractors being blacklisted for future work in Iraq, to concerns related to the security of expatriate personnel. It was a must to involve the international contractors as much as possible in preparing and implementing security plans. It initially turned out that very few contractors were interested in this opportunity. This has now changed," says Normann.

"TSI is offering geophysical services to many oil companies operating in challenging geographic, economic and political lands. Their specific focus is to work in tropical, transitional or mountainous terrains."

The seismic acquisition execution model for DNO was somewhat different than normal. TSI brought the core expatriate crew to Kurdistan, predominantly supervisors, whilst the rest of the crew was recruited locally by DNO. Instead of using dynamite source, it was decided to use vibro-source technique. As TSI did not own any vibrators at that time, DNO procured five second hand vibrator units with the assistance of TSI which were tested and

upgraded in Canada before being mobilized to Kurdistan via Turkey. "This was hard work for all parties involved. Working outdoors in 50 °C in the middle of the summer is hard for anybody. TSI did a professional job," concludes Normann.

The seismic acquisition survey took four months to complete, starting May 17th and ending September 20th. The data was transferred via the Internet and processed continuously by the company PSS-Geo in Oslo, Norway.

"Interpreting the data was done whilst it was recorded, and prospects were defined from late summer through to October when we had ranked all the prospects we were able to define," says Bang.

### Need for training

"The Iraqis have lost one generation of petroleum geoscientists because decades of unrest," says Normann. "This is really sad because Iraq was once a centre of excellence within the petroleum sector in the Middle East. There are still a lot of highly skilled personnel, but they would typically be 60+ years today and there are very few in the country to replace the older generation. Extensive training of the younger generations is an absolute must, and DNO is heavily involved in providing special

## Kirkuk – and thereafter

Drilling for oil and gas dates back to the dawn of the 20th century. In 1902 the very first exploration well was spudded in the Zagros Basin in northeast Iraq. However, it took another 20 years before the first small discovery was made in 1923.

Iraq's dramatic entry into the oil era, however, began in 1927 when the first well on the structure Kirkuk – Baba Gurgur # 1 – struck oil under high pressure and suffered a severe blowout. Close to 1 million barrels of oil was wasted before the well was controlled. Kirkuk, named after the town with the same name, has later proved to be a supergiant oil field (for definition, see page 50) with original reserves of 17 billion barrels, approximately one fifth of the original reserves in Ghawar (Saudi Arabia), the world's largest oil field.

Kirkuk is a large, narrow anticline, stretching some 150-200 km, striking northwest-southeast with three domal accumulations and with a 610m oil column. The principal reservoir is a reefal late Eocene to Oligocene (Tertiary) limestone. Oil is also found in younger limestones and older Cretaceous reservoirs. The overlying salt and anhydrite beds have formed a slightly imperfect seal that has allowed oil and gas seeps in localized areas. Certain gas seepages have long been known as "Eternal Fires". The source rock is thought to be Cretaceous dolomites and limestones.

The city of Kirkuk, 370 km north of Baghdad, with close to 1 million inhabitants, is now the centre of the northern Iraqi petroleum industry.

As of today a total of 75 major oil and gas fields have been discovered in Iraq. Nine of them are considered supergiants (including Kirkuk, Rumalia South, Rumalia North, Majnoon) and 22 giants, according to Mohammad Al-Gailani (Geotimes, 2003).



Kurdish flag from a nearby village. The Kurdish flag has three horizontal bands with a golden emblem at the center. The sun emblem has a religious and cultural history among the Kurds, stretching into antiquity.



The Prime Minister of the Kurdistan Region, HE Netchirvan Barzani, performing the formal opening of the commencement of the 1st exploration well, Tawke-1, being drilled in Kurdistan, Iraq. Magne Normann has the overall responsibility of all activities related to Iraq.

courses and on-the-job training at Middle East and European training centers.

There is a great need for geologists, geophysicists, reservoir engineers and petroleum engineers to fill in for the older generations," he says and adds further, "It is our duty to support an educational program for the young students that are going to build this country in the years to come. We have signed a Memory of Understanding with the Ministry of Oil in Baghdad which focuses on training as well as providing university education at Master of Science degree level for initially six students".

## From high to low risk

Both Iraq and Kurdistan have come a long way since the fall of Saddam Hussein. "We firmly believe that progress will be made towards stability in the country," Normann says.

"While the political risk may have seemed sky-high at the time of signing the Production Sharing Agreements in June 2004 with the Kurdistan Region Government (KRG), this risk has been more or less removed with the introduction of the new Constitution in October 2005, giving the Kurds rights to 'new' oil discoveries within their region," he adds.

"Kurdistan has a unique position under the new Constitution to explore and develop 'new' oil under their own control, and DNO was the first international oil company in more than two decades to perform

seismic and drilling in Iraq. The high discovery potential of mega size oil fields makes an interesting future for our stakeholders. Both KRG's and DNO's combined efforts is a move towards an interesting future", concludes Magne Normann, Project Director for DNO in Iraq.

## Making a discovery

The first well within DNO's PSA's located in the Kurdish area of Northern Iraq, Tawke # 1, has already encountered movable oil at the top of the first prospective reservoir interval.

Tawke # 1 had by late December reached the first prospective reservoir interval at approximately 350 meters. While drilling into the top of the reservoir section the well took influx of oil under pressure. The oil was circulated out and flared off in a controlled manner. Samples of the oil were taken confirming an API gravity of approximately 24 API. This API grade corresponds to oil produced from other fields at similar reservoir level in Northern Iraq.

The forward plan is to continue drilling the full reservoir section, which could be up to 800 meters thick according to the prognosis. Thereafter wireline logging will be undertaken to evaluate the reservoir with respect to reservoir characteristics and movable oil content, DNO said in a press release.

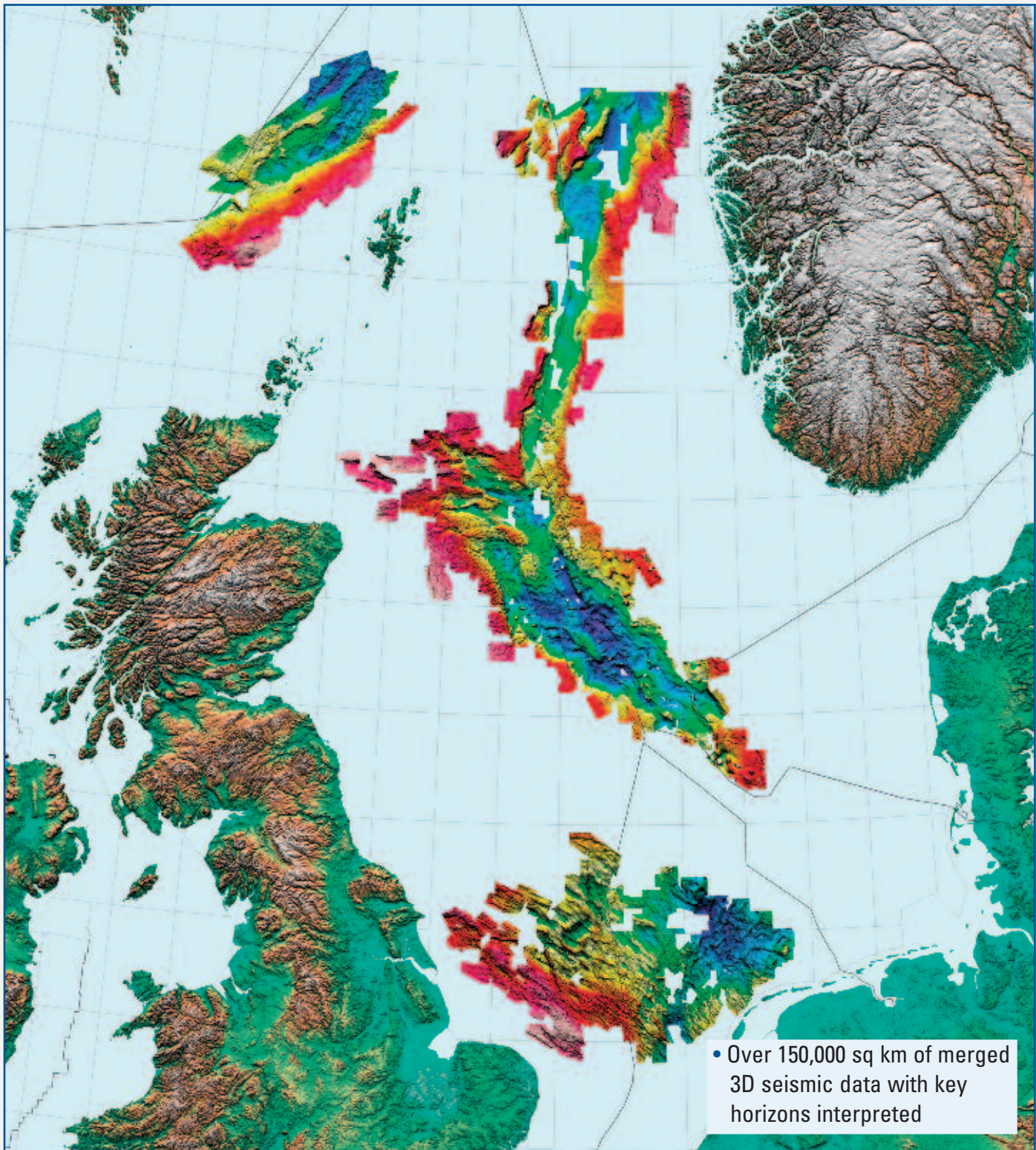


One of several oil seepages in an area close to the 1st well being drilled. The local population has for generations used oil from these oil seepages for domestic needs.



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# Managing the future

History-matching of reservoir simulation models, meaning adjusting and optimising the simulation model based on observed production data, has been a complex and time consuming task for the industry for years.

*Halldan Carstens*

New software claims to revolutionise history-matching by reducing manpower requirements and assessing the uncertainty of reservoir simulation models in a quantitative manner. In this way the developers believe the software will better reflect how the real world behaves when producing oil and gas.

## Maximizing reserves

The company is growing, and it's growing fast.

Dag Terje Rian, President of Scandpower Petroleum Technology, is very pleased with the past and current year's achievements. He feels ready to conquer new markets with the company's innovative technology that promises to dramatically reduce the time required to history-match complex reservoir simulation models. Moreover, he promises to minimise the time it takes to estimate the likely range of uncertainties in predicted future production.

"With our new software MEPO®, which is designed to support the process of history-matching of reservoir simulation models, we are reducing manpower requirements



Photo: Halldan Carstens

John Olaf Rømme (left) and Dag Terje Rian, Vice President and President of Scandpower Petroleum Technology, respectively.

as well as the uncertainties when doing reservoir simulation. The software helps to identify solutions which produce, not just the best possible match, but a number of acceptable matches for better predicting the range of future production" Rian says.

"Ultimately, the oil companies will produce more oil and gas and maximize their reserves, which is why they have been willing to invest hundreds of thousands of dollars in new software," he adds.

## More time for analysis

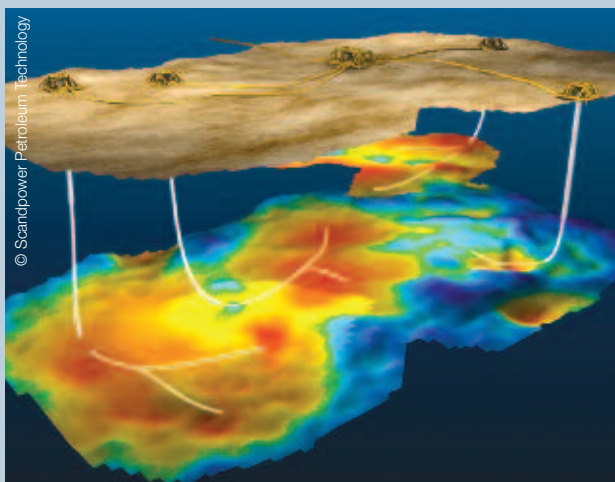
Oil companies spend significant resources on creating models for reservoir simulations.

However, as the turnaround time for creating and updating reservoir models has been significantly reduced, the reservoir engineer still has to validate the models through history matching and uncertainty assessment, before generating production forecasts, and this has always been an elaborate and time consuming task.

"The industry has been lacking efficient tools for assisted history-matching and analysis; furthermore, the resource requirement for reservoir optimization is of such a magnitude that industry has tended to rely on a limited number, or single, reservoir profile," Rian says.

"The new tool will enable the reservoir engineers to focus their energy on qualitative analysis rather than quantitative calculations," he adds.

There has been a need for this product for a long time, but it is only with the introduction of powerful computers that it has been possible to do the necessary calculations within an acceptable time frame.



Reservoir model with gas (red) above oil (green) and water (blue).



## How it works

The idea behind the new technology is to model past production, thereby being able to predict the future production of an oil or gas field.

"It is as simple as that, but it is no easy task to carry out. Powerful computers are needed, and during the process of doing countless calculations, experienced reservoir engineers are needed for supervision. To get a result for a given field may actually take a couple of weeks," explains Rian.

Despite this, it is still a major improvement from how it was achieved previously, and how it is still done by a lot of oil companies that have not yet invested in this modern and efficient technology.

Dag Terje Rian draws a cube on the white-board. "This is the static reservoir model with all the inherent uncertainties. The grid in itself may be erroneous, and within each cell parameters like porosity and permeability may also be incorrect," he explains.

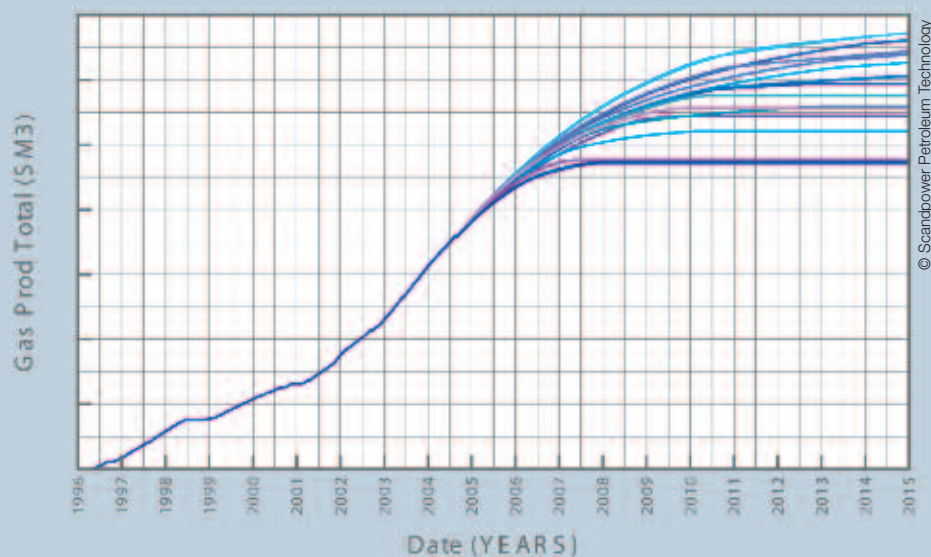
"The numbers within each cell are exported to the dynamic simulation model. If the input values are incorrect the simulation will naturally also be wrong. Without any production history to compare with before production start-up, the reservoir engineers are at this stage left with their own predictions for future production."

"After having produced the field for some time, however, the reservoir engineer will have a historic production to compare with the model he started out with. If there is a good fit, he may continue to simulate the production of the field in the same way as he has done so far. However, if there is a mismatch, the reason may be found in the static or the dynamic modelling parameters, meaning that it is necessary to change them. With a large number of unknowns that may include porosity, permeability and fault barriers, this is a very difficult stage," Rian explains.

Using MEPO, the static model may be changed. Specific data in a given cell, permeability, for example, may be altered.

"Only by trial and error is it possible to match a number of production profiles based on varying the input parameters. The user may, however, influence the process. His knowledge of the reservoir parameters, static as well as dynamic, is essential to define a range of parameter values that need to be optimized. There is no way to do this in an automatic manner."

"This is an interactive process," Rian emphasizes.



History matching defines a process to find a set of model parameters that minimise the difference between simulated and observed reservoir data. This example from the Statoil operated Gungne North Sea gas condensate reservoir demonstrates the uncertainty in cumulative gas production when forecasting using a set of alternative history matched models on.

## Gaining ground

Having established production profiles, decisions must be made based on questions like: Where to drill the next well? Which wells need to be closed? Which wells should be recompleted? Where will the water come? The ultimate goal is, of course, to maximize production and optimize the reserves.

The task of the reservoir engineer is to look into the future. Using MEPO, it may be possible to manage the future by selecting a particular scenario for future production that is more likely than others.

A number of the major oil companies have already adopted the new software. One of the first significant achievements was realized when successfully applying MEPO® to Chevron's Captain Field located in the UK sector of the North Sea, where eight acceptable matches were found using fundamentally different parameter combinations, quantifying uncertainties for new infill wells.

"MEPO® provided us with a time and cost-efficient tool to better understand the impact of the dynamic uncertainties on the reservoir model and history matches. It successfully assisted us in improving the quality of our production forecasting," says Gert de Jonge, of Chevron UK.

"Based on the response we have got so far we believe this solution could save the oil companies significant time and costs compared to conventional methods and

other applications." It appears the oil companies are of the same opinion. "There are clear indications that the product is succeeding and winning recognition by the month," says Dag Terje Rian.

## SPT

Scandpower Petroleum Technology (SPT) develops and sells software and related consulting services to the oil and gas industry. The main business area is software for dynamic modelling of multiphase flow (OLGA®), where the company has a leading position worldwide. The technology has been developed through many years by Norwegian research institutions and the oil industry. MEPO® is a new software tool developed over five years and introduced to the market in 2004. SPT has 140 employees, with head office in Oslo and regional offices in Dubai, Hamburg, Houston, London, Mexico City, Milan, Moscow and Perth. The company has had considerable growth during the last few years, from a turnover of USD 5 million in 1999 to more than USD 25 million in 2005.

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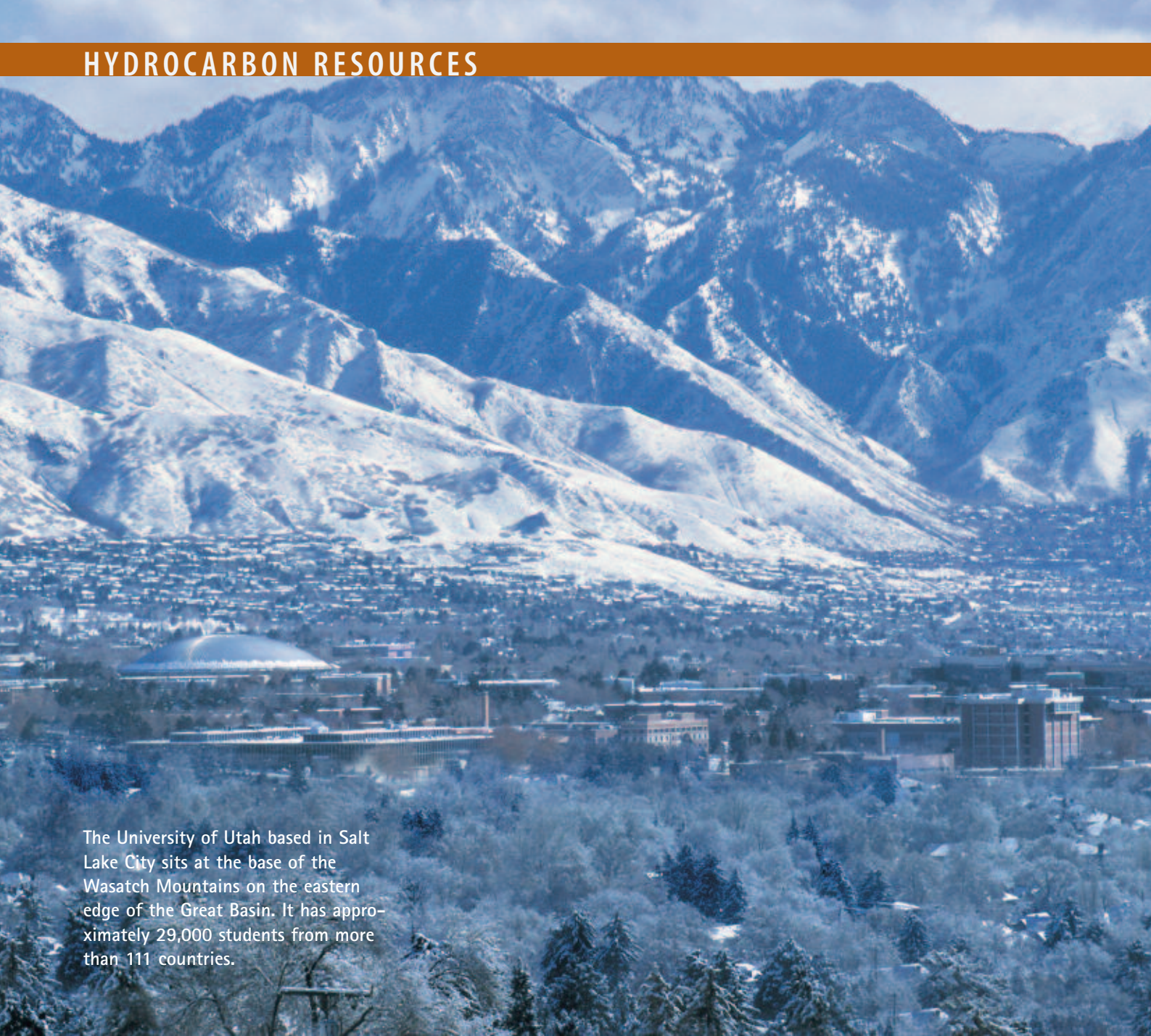
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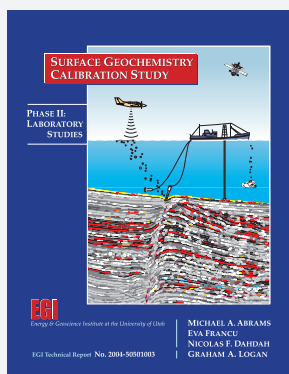


The University of Utah based in Salt Lake City sits at the base of the Wasatch Mountains on the eastern edge of the Great Basin. It has approximately 29,000 students from more than 111 countries.

# Storming the Ivory Tower

The oil shock of 1973 transformed the global energy picture. As lines of automobiles snaked down the street awaiting their turn at the pumps, the realization dawned that plentiful, cheap energy was not something to be taken for granted. Many governments and leaders in the petroleum industry began asking scientific questions about fossil energy and alternative energy sources. And it is to this environment that the Energy & Geoscience Institute (EGI) at the University of Utah traces its roots.

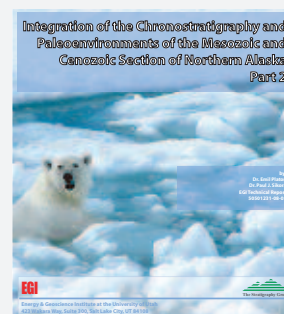




Multi-phased study to improve surface geochemistry calibration. Phase 1 evaluated and identified current best practices. Phase 2 developed innovative new methods to sample and analyze surface geochemical samples, and the on-going Phase 3 is testing these new approaches in the field.



This study continues EGI's 15-year record of working the Caspian region from north to south. This phased study collected, analyzed, and interpreted new geochemical and chronostratigraphic data for the Central Caspian region.



An integrated high-resolution chronostratigraphic and paleoenvironmental framework for the Mesozoic and Cenozoic of northern Alaska.



*Raymond Levey, Energy & Geoscience Institute (EGI) at the University of Utah*

The Energy & Geoscience Institute (EGI) at the University of Utah has now for a decade served as center for dedicated research in the energy sector. Located in Salt Lake City in the University of Utah Research Park, EGI is a not-for-profit research organization that has conducted multi-disciplinary projects on behalf of industry and government for more than 30 years.

EGI was created in 1996 through the merger of the University of Utah Research Institute, an organization focused on geothermal energy, and the fossil energy group from the University of South Carolina's Earth Sciences and Resources Institute.

The merger of these two internationally known research organizations propelled the University of Utah to the forefront of applied geological and engineering research focused on the energy sector. The Institute serves as a cost-shared research laboratory to the petroleum industry and governments, and has conducted more than \$200 million of energy research.

A university-based institute like EGI is the ideal place to conduct such research, since today's complex scientific and technological problems are often too broad to be solved by a single researcher working in isolation. Instead EGI creates an environment where multi-disciplinary research can flourish. Involving students in this dynamic environment exposes them to a team-based problem-solving process that closely reflects the approaches used in today's corporations.

## Building relationships with industry

Traditionally there has been skepticism within the petroleum industry of the value of university research. Too often the image was of academics sitting in their ivory towers unwilling to tackle the problems facing industry. This is a caricature, of course, that does not accurately reflect reality. But, like most caricatures, it contains a kernel of truth.

The foremost requirement for success in meeting industry's research needs is delivering information, approaches, knowledge, and technologies that are directly applicable to their problems. The foundation for doing so is communication and relationships developed between the institute



EGI has conducted more than 480 projects in 62 countries over the past 3 decades.

and industry. This strategy has enabled EGI to develop the largest upstream energy industry supported research program at any university in the world—its Corporate Associate program.

Currently 50 companies from 19 countries support EGI research through an annual membership. Together these companies represent the most active international exploration companies in the world, with a combined market capitalization of more than \$1 trillion. As a Corporate Associate they have direct access to EGI's research, information and data, and scientific expertise.

By building personal relationships with petroleum explorationists, EGI's scientific staff learns what industry's challenges are. As a result, both the Director and the senior scientific staff work hard to develop extensive personal networks within each

## Changing scope

The history of research has been varied. During the 1960s and 1970s research was synonymous with large, well-respected corporate laboratories, including Bell Labs, General Electric, Dow, DuPont, and Esso/Exxon. These labs were multi-disciplinary with broad research portfolios. They fostered innovation and made significant contributions to scientific knowledge, both fundamental and applied. In addition, they provided lucrative, secure employment for class after class of science graduates.

In the 1980s and 1990s the situation changed. For better or worse, corporate emphasis shifted to near-term performance, preferring to outsource everything that didn't contribute to short-term profitability. The result was corporate downsizing and cutbacks that led many companies to dismantle their large research organizations.

In order to centralize decision-making and performance responsibility, many corporations adopted a business unit model. This reinforced the trend away from scientific research, as business units instead sought specific solutions to their immediate problems. In fact, in some cases corporations completely lost the ability to fund research that could not be directly tied to a business unit.

But while corporations were reluctant to devote the necessary resources, the need for such research remained strong. This need created opportunity for the university research community, and resulted in the formation of numerous centers and institutes dedicated to advancing the scientific and technological state of the art.

### EGI CORPORATE ASSOCIATE PROGRAM

Amerada Hess	Norsk Hydro
Anadarko	Occidental
Apache	Oil India
BHP Billiton	Oil Search
BP	OMV
BPC Ltd.	Paladin Resources
CEPSA	Petrobras
Chevron	PetroCanada
ConocoPhillips	Petronas-Carigali
Devon	Pioneer
El Paso	Premier Oil
EnCana	Reliance Energy
ENI-AGIP	RepsolYPF
Frontera	ROC Oil
Gaz de France	RWE Dea
Hardman Resources	Samson
Kerr McGee	Shell
LUKOIL	Sipetrol
Lundin Group	Spinnaker
Maersk Oil	Statoil
Marathon	Talisman
Nation's Energy	Total
Newfield	Vintage
Nexen	Wintershall
Noble Energy	Woodside





EGL is within a half-day drive of 5 national parks, which provide an excellent natural laboratory for geological research and field trips.

company at both the managerial and technical levels. They then develop approaches to solve these problems. Having established relationships with the explorationist on the front-line of his or her company's activities in a particular region or discipline creates a feed-back loop that involves them in the design of a solution, and incre-

ases the likelihood of a breakthrough.

The Institute also receives strategic advice from their Advisory Board, comprised of senior executives from the international energy industry and the University of Utah. The current Chairman of the **Advisory Board** is Steven Bell, President of BHP Billiton's global petroleum exploration and

new business development. He is flanked by Vice Chairman Robert Ryan, General Manager of worldwide exploration at Chevron, and Executive Secretary Kenneth Crouch, Executive Vice President at Kerr-McGee. The Advisory Board meets twice annually to advise EGL on strategic developments in the global energy scene. The resulting dialog is unique and valuable, and enables EGL to remain at the forefront of worldwide energy issues and tackling the challenges faced by industry.

### The need for global reach

The energy industry in general and the petroleum industry in particular are international in scope. EGL's Corporate Associates are from 19 countries with exploration interests across the globe. As a result, over the past 6 years I have personally visited and negotiated cooperative research relationships with industry and government in Europe, South America, Africa, and Asia. Developing and maintaining the contacts with the research sponsors and partners that are essential to EGL's success have led them to develop a strategic alliance with Imperial College London, and maintain offices in Houston, Calgary, and Sydney.

The foundation for much of EGL's global research is alliances and partnerships with local organizations in countries where they are active. These groups range from governmental research organizations, such as the Geological Institute of Azerbaijan and Geoscience Australia, to academia like Universidade Federal Fluminense in Brazil or Moscow State University. They have a wealth of knowledge and experience beneficial to industry, and involving them in EGL projects provides opportunity to demonstrate this expertise.

The international and cross-cultural aspect of EGL's research activities requires scientific staff with similar diversity. EGL's personnel are from 14 countries and col-

## Best in class

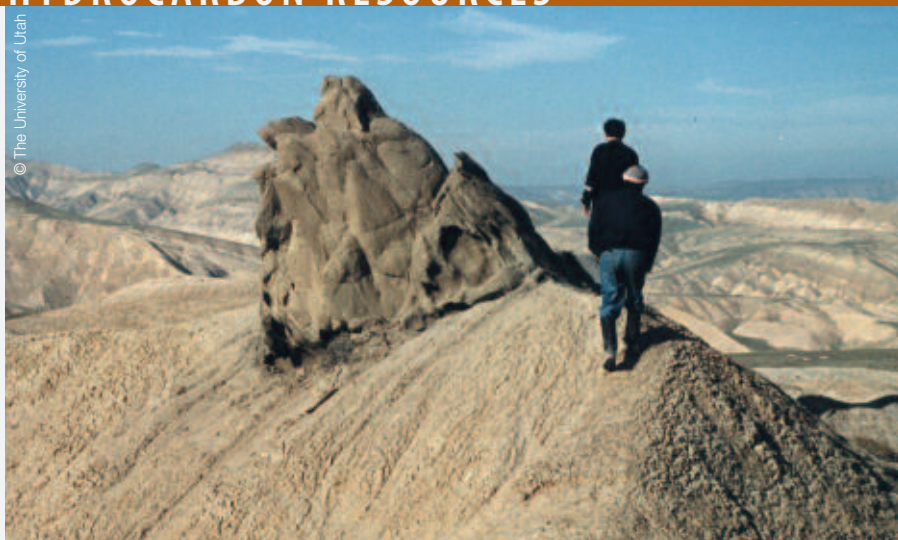
An example of developing best-in-class research programs is EGL's Surface Geochemical Calibration study. Michael Abrams, a 19-year Exxon veteran, joined EGL in 2000 as manager of the petroleum geochemistry group. Based on his global experience evaluating geochemical surveys he had always wanted to evaluate the successes and failures of surveys after drilling a prospect. The idea was to evaluate current methodo-

logies and determine their efficacy for finding hydrocarbons.

With the support of 15 companies, he designed a multi-year research project to do such an evaluation. Involving many of the supporting companies' experienced and top-notch geochemists in the analysis and interpretation, EGL evaluated 20 basins around the world.

The basins represented a cross-section of

basin types and tectonic styles, including those with active and passive seeps, as well as onshore and offshore measurements. The results were a series of calibrations and methods to reduce the risk of misinterpretation. Subsequent phases of the project designed new methods to improve the results of surface geochemical surveys and test them in the field.



EGI scientists have been working cooperatively with colleagues from the Geology Institute of Azerbaijan since 1991. Here they are inspecting a mud volcano.

lectively speak more than 18 languages. They have worked on all seven continents and in more than 60 countries. Many EGI scientists also have significant industry experience, having worked for Exxon, Shell, Amoco, Unocal, and JNOC.

## The business of applied research

Notwithstanding the success that EGI has enjoyed, getting industry funds to support applied research remains a highly competitive venture. The way to compete successfully is by choosing several disciplines as core areas, and then working diligently to create broad and deep expertise in these areas. This requires a constant search for the best and brightest scientists and technical staff, and not everyone who was successful in either academia or industry has what it takes to succeed in this environment. It requires entrepreneurial flair to see and communicate the application of scientific knowledge to industry problems.

In looking for new trends, strategies, or areas where EGI can expand its expertise, much time is spent benchmarking other institutes and for-profit research corporations. My objective is to find ways to enhance EGI's existing core strengths, add new value to EGI's Corporate Associates, and identify the problems that individual companies cannot tackle alone.

Sometimes developing or expanding core strengths does not happen through organic growth, but rather by acquisition. An excellent example occurred in 1999 when BP donated to EGI the Global Composite Standard Database, which had been

developed by Amoco over nearly 40 years. The database consists of detailed micropaleontologic and other time-scale data to provide detailed chronostratigraphic control, spanning Cambrian to present, in over 100 basins. It provides EGI with a tool to develop high-resolution chronostratigraphic frameworks in important oil-bearing provinces, such as the Gulf of Mexico, West Africa, and the North Sea. It also builds EGI's ability to conduct paleo-climatic and paleo-oceanographic studies.

EGI continues to expand and improve this global database. It has great potential to improve understanding of the world's petroleum basins, as well as earth's history. In fact, it has potential to improve understanding of global temperature fluctuations through time as defined by changes in global biota. As such it could contribute positively to the ongoing debate on global climate change.

## Science for energy

The common theme in our projects is taking cutting-edge science and applying it to industry problems. The world has changed since EGI got its start in 1973 in a high-energy price environment, but those high prices have returned. Then as now EGI is unafraid to storm the ivory tower and

## From Utah to Landmark

Bridging academia and industry to lead such an organization requires a blend of academic rigor and entrepreneurial savvy. Director Raymond Levey possesses those qualities. He was appointed Director in 1999, after serving as Deputy Director since 1997. His background includes a decade at Shell Oil where he was involved in petroleum exploration, development, and research. He also spent 7 years at the University of Texas at Austin where he served as Associate Director for Fossil Energy at the Bureau of Economic Geology before coming to the University of Utah. He earned his Ph.D. in geology at the University of South Carolina.

A university-based institute needs not only visionary leadership in the director's chair, but also within the university administration. The University of Utah excels here. There is both a societal and University expectation that its intellectual capital

will be an economic engine that benefits the State and the world through innovation and scientific advances. Their record doing so is impressive, ranging from the first human implant of an artificial heart and advances in genetic research to computer technology and visualization techniques. Many world-renowned high-tech corporations were either founded or are presently led by University of Utah faculty and alumni, including Landmark Graphics Corporation, Silicon Graphics,

Netscape, Adobe, Novell, TerraTek, and Pixar.



Raymond Levey, Director of EGI, exhibiting at a recent conference, showing EGI's global research efforts.

tackle real-world problems with real-world impact. From the Arctic to Borneo, from petroleum to geothermal, from basic to applied research, they do it by building personal relationships and forging alliances.

And as a result, EGI is the place where the international petroleum and geothermal industries come for the science to find energy.





Seminar; **Biennial Geophysical Seminar –**  
*“Closing the gap in reserves replacement*

Time: **20<sup>th</sup> – 22<sup>nd</sup> March 2006**  
Place: **Radisson SAS Caledonien Hotel,**  
**Kristiansand, Norway**

Organizer: **Norwegian Petroleum Society (NPF)**  
P.O.Box 573, Sentrum  
N-0105 OSLO, Norway  
Phone: 0047 – 22 43 29 69

Further information and registration can be  
obtained/done from [www.npf.no/](http://www.npf.no/),  
[http://www.npf.no/course.php?id=23&time=23&w\\_lang=en](http://www.npf.no/course.php?id=23&time=23&w_lang=en)  
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*Numerical Rocks AS has a leading-edge technology that combines computer generated rock models (virtual rocks) with numerical simulations to determine a variety of reservoir rock properties. The technology is based on 8 years of successful research at Statoil ASA, and is now brought to the market by Statoil Innovation. The company develops software, conducts technical services and research as well as consulting related to the e-Core technology. Numerical Rocks AS is based in Trondheim, Norway.*

Numerical Rocks is building up the organisation and is looking for the following key personnel:

## **Reservoir technology, petrophysics and pore physics 3 vacant positions**

Detailed job description is available at [www.numericalrocks.com](http://www.numericalrocks.com).  
For more information, please contact Technical Director Pål-Eric Øren at  
[peoe@numericalrocks.com](mailto:peoe@numericalrocks.com), +47 99 20 29 93

Please send your applications and CV to [info@numericalrocks.com](mailto:info@numericalrocks.com) before  
31st January 2006.

# Improving Seismic Quality

The advent of the individually steerable streamer has led to the development of WesternGeco's 'Over/Under' seismic recording technique, resulting in a dramatic improvement in seismic quality and the ability to visualise sub-salt and sub-basalt.

Jane Whaley

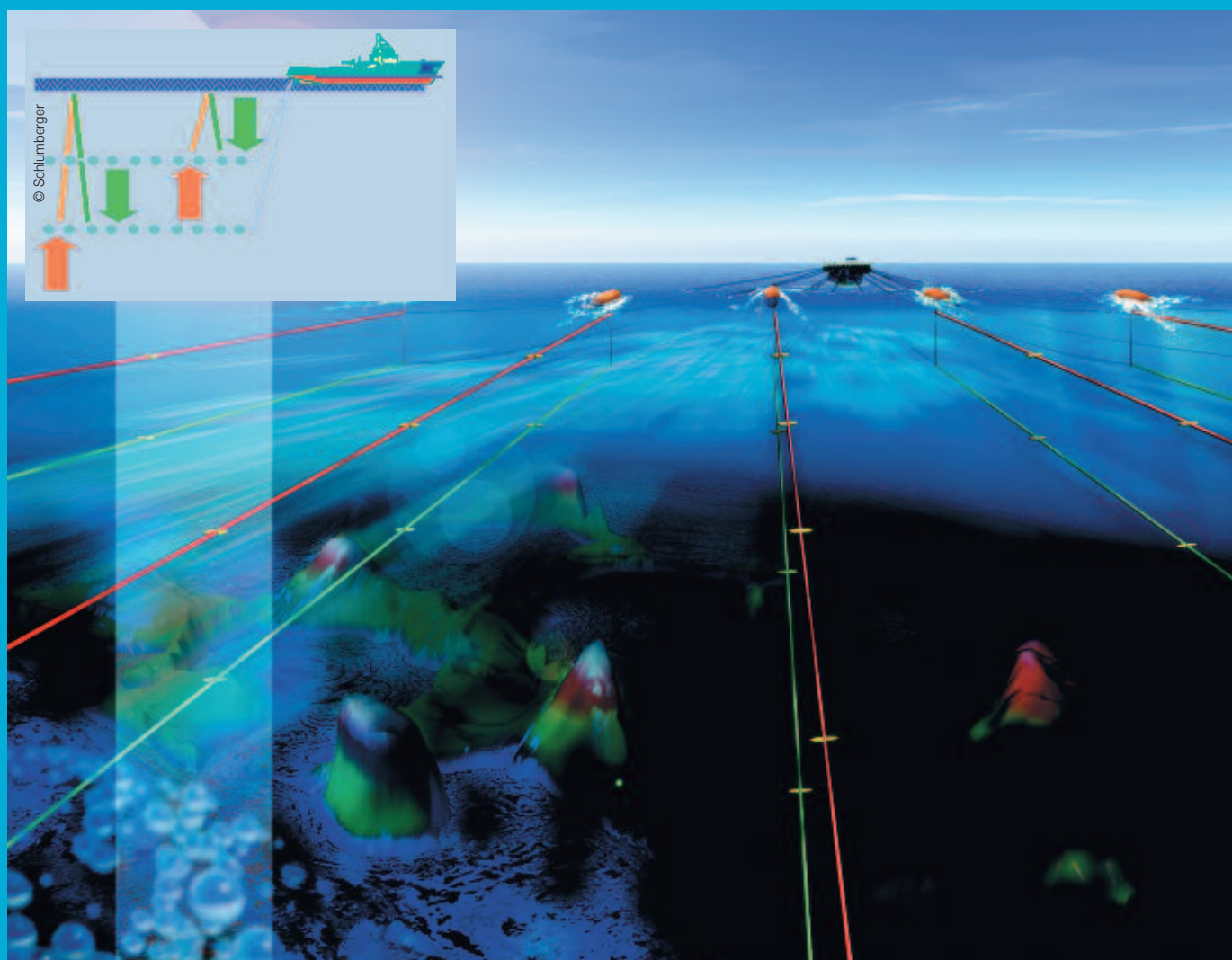
With many of the world's basins now explored, the search for new hydrocarbons is becoming dependent on improvements in seismic data quality. One of the new acquisition techniques is WesternGeco's Over/Under technology, which involves the towing of multiple streamers at different depths, in order to broaden band-

width and improve signal to noise ratio.

Tunde Laniyan is Product Champion of WesternGeco's Over/Under project, which is masterminded from the WesternGeco Technology Centre in Oslo. Originally hailing from Nigeria, Tunde is an Electrical Engineer who worked for WesternGeco in Nigeria, Mexico, the UK and the US before moving to Norway in 2005 to champion this important project.

## Vertically aligned streamers

"The theory for Over/Under seismic acquisition has been around for a long time, probably since the early '80s," Tunde explains. "We knew that if we could tow two 'layers' of streamer exactly on top of each other, measuring the same wavefield, we could perform decomposition of the up- and down-going wavefields to combine the datasets. This technique enables us



The Over/Under technique requires an array with both vertical and horizontal streamers recording the same wavefield, with a horizontal displacement of less than +/- 5 m



to remove the 'ghost-notches' that always modulate the seismic frequency spectrum, allowing us to extend the bandwidth at both ends of the scale." In addition, Over/Under allows the streamer to be towed at greater depth, away from the interference of the surface waves, which significantly improves the signal-to-noise ratio.

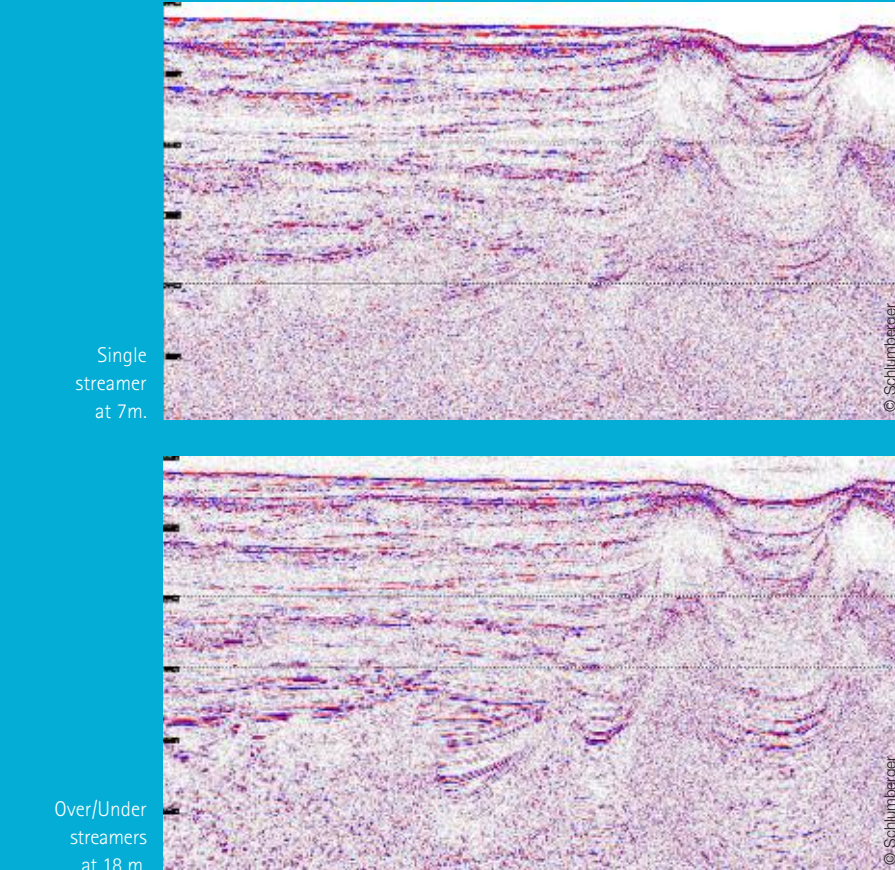
However, the accuracy essential for this technique to be successful, requiring a horizontal displacement of less than 5m, meant that it could not be effectively developed until the advent of the individually steerable seismic receiver and source. The development of WesternGeco's Q-Marine, which uses a fully-braced acoustic network to position each hydrophone, allowed the theoretical concept of Over/Under acquisition to become a reality.

"We started research into the application of Q-Technology to multiple level towing back in 2002," says Tunde. "We consider that we are the only company with the technology to do this, with steerable single sensor streamers. There had been a steady take up of Q-Technology by clients, so we knew the industry were ready for this. We carried out the first practical tests early in 2004 and have already undertaken commercial projects using it."

## New deep targets imaged

The enhanced bandwidth allows for more sophisticated processing and imaging techniques and advanced multiple attenuation methods. Tunde points out that with this technology "clients can tell if they're dealing with sandstone or shale, oil or gas. They can confidently identify thin structures and stratigraphic traps, giving them the ability to recognise hydrocarbon bearing sand layers less than 15m thick. One of the most important applications of this new technique is for sub-salt and sub-basalt imaging, particularly at depth. For example, we have recently successfully performed Over/Under surveys imaging the sub-basalt horizons in the Northeast Atlantic."

"This technology is also ideal for 4D surveys, especially for reservoir management," Tunde adds. With each streamer accurately positioned at greater depth and with favourable currents, we can safely control close passes by rigs, and, importantly, obtain very good repeatability between surveys. The enhanced imagery resulting from Over/Under acquisition gives us a very clear picture of changes in the reser-



Seismic examples from (Gulf of Mexico) showing the difference in quality of record obtained using single and over/under streamers. The benefit of the broader bandwidth and quieter towing regime gained through using over/under streamers is clearly seen in the sub-salt imaging in the second record.

voir."

"Client feedback has been very positive. We have used the technology in the Gulf of Mexico, West Africa and West of the Shetlands, all areas where penetration through layers of salt and basalt to illuminate deep targets are key challenges. With

Over/Under technology it is possible to tune the seismic frequencies for optimal solutions to these challenges. We are potentially opening up new areas and plays worldwide."



Tunde Laniyan is an Electrical Engineer from Nigeria who worked for WesternGeco in Nigeria, Mexico, the UK and the US before moving with his family to Norway in 2005 to manage the Over/Under project

Photo: Jane Whaley

# A Breakthrough for the Barents Sea

After more than 60 wells in the Barents Sea, a significant oil discovery has now been confirmed by the drilling of a third well on a segmented structure.

*Halfdan Carstens*

Eni, with partners Statoil and DNO, have now confirmed that a major discovery has been made in the Barents Sea when drilling well 7122/7-3 in the eastern part of the Hammerfest Basin. In a recent press release, the Norwegian Petroleum Directorate (NPD) says that hydrocarbons were hit in three different zones, all of Triassic age.

According to unofficial sources, it may turn out to be the biggest oil field discovered offshore Norway for many years. Even more important, following 25 years of exploration, it is the very first major oil discovery in the Norwegian part of the Barents Sea. This find may eventually also trigger oil production from the nearby Snøhvit field, which will soon start producing gas.

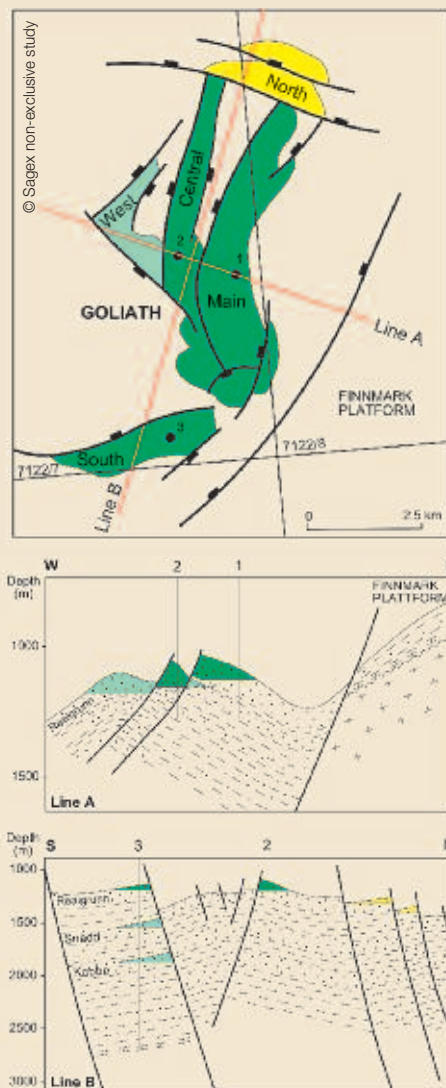
In November, it became known that oil had been hit in Upper Triassic sandstones of the Realgrunnen Group, the same as the previous Goliath accumulations. A few weeks later the semi-submersible Erik Raude also hit oil in the deeper Snadd and Kobbe formations of Upper and Middle Triassic age, respectively.

The upper section of the borehole was thus considered an appraisal well on the Goliath field, which, as is also the case with Snøhvit, consists of several segments of which two had already been proven to be oil bearing. The lower section of the well is to be considered a true wildcat, as the two previous wells on the field did not test deeper Mesozoic or Palaeozoic rocks.

Goliath, discovered in 2000, has 43 million barrels of proven oil, according to official figures from NPD. The main reservoir of the new segment is likely to double that estimate. Further, the deeper pools that now apparently are proved may double or triple the total volume.

The well was drilled into Permian carbonates without finding any hydrocarbons.

"The deep discovery is very encouraging for further exploration in the Norwegian Barents Sea. It proves both a seal that can retain hydrocarbons and the presence of a pre-Jurassic oil source rock, which have been major risk factors for exploration in



Goliath consists of several segments, of which three have been tested by the drillbit. In the southern segment, a deeper pool is proven by the third well as illustrated in the lower x-section. Finding oil in Middle Triassic sandstones has important implications for future exploration.

this area," says Torbjørn Throndsen, chief geologist on petroleum systems with Sagex. "The Goliath accumulations have so far been seen as charged by long distance migration by spill of oil legs from the major gas fields of the Snøhvit complex. This is not a likely mechanism for the deep accumulations, pointing to the Permo-Triassic basin development in order to explain the petro-

## "Global significance"

"Developing the Barents Sea as a new oil and gas province will be of global importance," says chief executive of Statoil Helge Lund, when attending the annual conference of the Confederation of Norwegian Enterprise (NHO) in January. "According to the International Energy Agency (IEA) world energy demand will rise by about 50 per cent before 2030," he said.

"More than 80 per cent of this increase will have to be met by fossil fuels. The oil and gas resources in the Barents Sea could play an important role in securing the USA's and Europe's energy supplies for a long time to come. I believe that it is also of great national importance that we participate actively in developing the Barents Sea's oil and gas resources, in both Norwegian and Russian sectors."

"We would be able to set technological as well as environmental standards. We need to use solutions which ensure coexistence between the fishing industry and the petroleum business, he added."

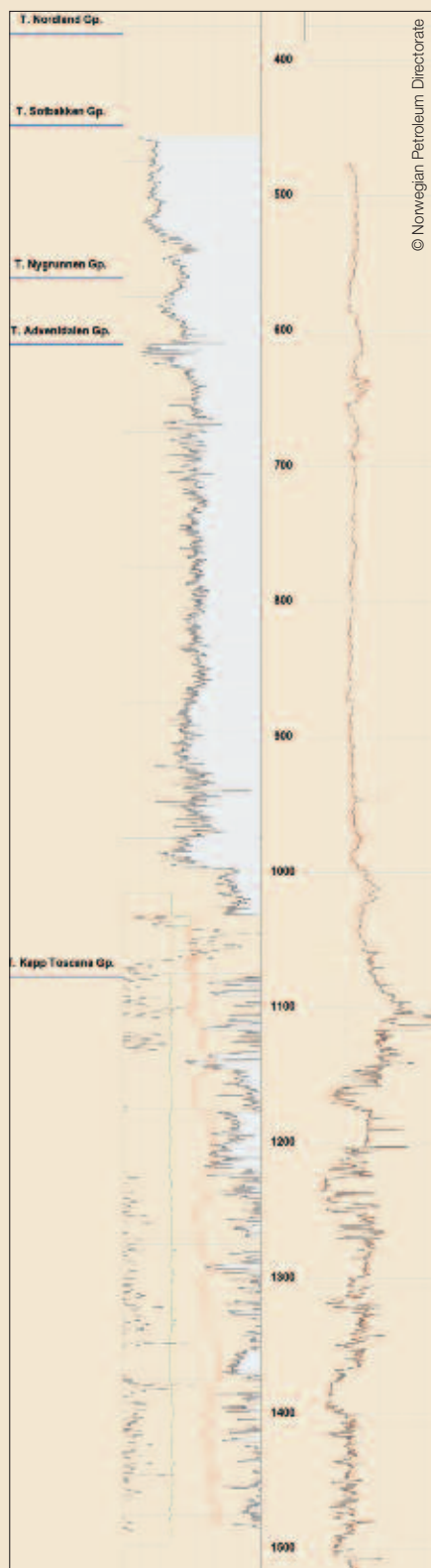
Mr Lund stressed that the Statoil-operated Snøhvit development is creating much activity and optimism in Hammerfest and western Finnmark county. Roughly 13,000 people have so far been involved in work at the Hammerfest LNG plant for gas liquefaction at Melkøya.

"Statoil has been a pioneer in the Barents Sea and we want to play a central role in the further development of the far north and the northerly parts of the Norwegian Sea," said Mr Lund. "We hope that the government will arrange for a high level of activity in the time ahead."

leum population," Throndsen says.

"The discovery in the deeper formations is seen as highly positive, because it proves a previously unconfirmed petroleum potential in this part of the Hammerfest basin. The discovery might be of great significance for future exploration of adjacent areas of the Barents Sea," NPD said in their press release.





The discovery well on Goliath encountered oil in the Jurassic between 1102 m and 1146 m and later produced 680m<sup>3</sup> oil/day (4300 bopd) during a drill stem test. The Goliath field is a faulted structural closure in the crestal part of a major northeast-southwest trending roll-over anticline situated in the southeastern part of the Hammerfest Basin.



Eirik Raude was used to drill well 7122/7-3. In 343 m of water the well reached a total depth of 2701 m below sea level. The well was extensively logged and cored, but was not tested. Another well is planned on this structure this year.

## Snøhvit ("Snow White")

Goliath is located to the southeast of the giant Snøhvit field where gas was first discovered in 1981. The field primarily contains gas with smaller quantities of oil and condensate. Recoverable reserves in Snøhvit amount to 161 billion Sm<sup>3</sup> (1 billion barrels of oil equivalents) of gas and 5 million tonnes of NGL. The field also contains approximately 50 million barrels of technically recoverable oil in a 14-16 meter thick oil zone. The operator Statoil has yet to make a decision to produce this oil leg.



Snøhvit is the first field development in the Barents Sea. Without surface installations, the Snøhvit project involves bringing huge volumes of natural gas to land for liquefaction and export from the world's northernmost liquefied natural gas (LNG) facility. The processing plant is on Melkøya island outside Hammerfest in northern Norway. LNG will be shipped by special carriers to markets in Europe and the USA when deliveries start in 2007.

# How do you Build an Oil Company from Scratch?

Lyndon West, founder of international service company IEDS, has changed track and set up a new company, Index Oil and Gas Ltd (Index), aimed at the US gas industry. We talk to him about his experiences in this new field.

*Jane Whaley*

Lyndon was one of the founders of Integrated Exploration and Development Services Ltd (IEDS), an international data, information and scouting company, created in 1987. This proved to be a very successful venture, growing to an annual revenue of almost £5 million by 1998, when it was purchased by the American organisation IHS. Lyndon stayed with them for a few years, helping to develop the amalgamated company, before moving on to pastures new in 2003.

## Low Cost, Low Risk Strategy

And very different pastures they were! With his business partners, all of whom have many years experience in the oil industry, Lyndon created Index in order to enter the US exploration and production market.

"We set up Index with different fundamental principles from many other start-up oil and gas companies," Lyndon explains. "Because we concentrate on low cost/low risk and rapid cash-flow build-up, we are looking at smaller reserves in the early stages of our development. Many new start-up companies are looking for high capital growth, which gives high potential but, obviously, brings with it higher risk."

"We were looking for an area where we could develop a reserve and production base with quick cycle times, in order to build cash-flow. In our initial phase we wanted to create a business in an area with low commercial or political risk and with an excellent and accessible transport infrastructure. All this pointed to the gas market in the US, where there is increasing demand, declining supplies and there are



Lyndon West, Managing Director of Index Oil and Gas Ltd., is happy running his US gas exploration company from his rural Gloucestershire home.

many opportunities for independent exploration companies, in a relatively low cost environment. Gas prices have been consistently good and the net payback to producers is high. We pay a lease bonus to the landowner, both royalties of 15 to 25% and production taxes of approximately 7%, so 70-75% after tax goes to the operator, which after Opex and Capex (operating and capital expenditure) delivers a good return."

## Successful Kansas Wells

After raising initial capital, Index entered the US market by buying a 5% stake in the Kansas 1 well in Seward county, south-west Kansas. This lies in an established petro-

leum province and produces from the Lower Ordovician Arbuckle Formation, which consists of karstic dolomite reservoirs with an average of 27 feet net pay. Oil is found in both structural and combination structural/stratigraphic traps, with uplift and erosion during late Mississippian to early Pennsylvanian time resulting in enhanced porosity. The oil is probably sourced by long-distance migration of hydrocarbons from the Anadarko Basin, as source rocks in the province are thought to be thermally immature for oil generation. Seal is provided by overlying Pennsylvanian limestones and shales.

This has proved a very successful venture for Index, generating a regular income



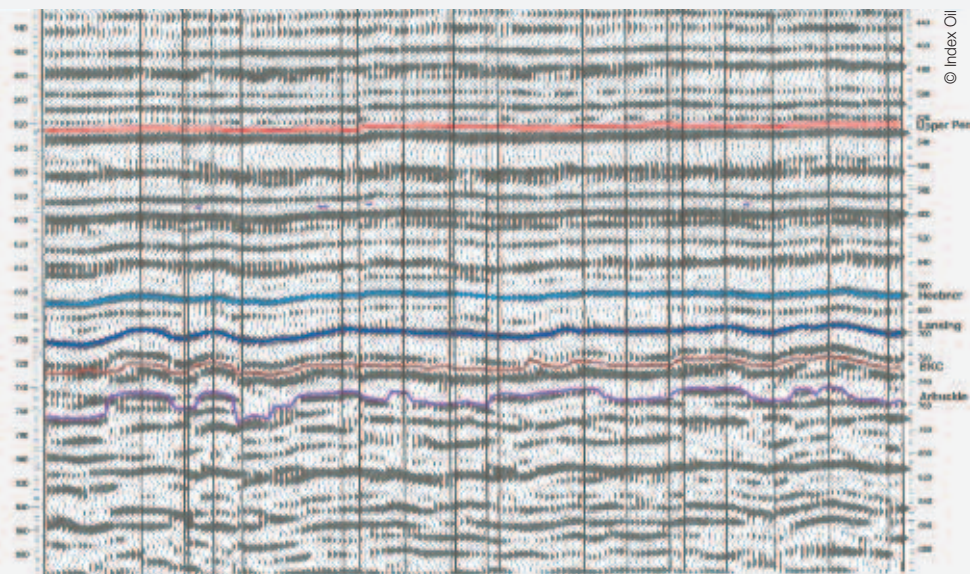
and with up to 20 years of reserves. Lyndon continues the story: "In 2004 we participated in several 3D seismic surveys in the same area, identifying a number of undrilled structures and, with the operator, we have now drilled another 9 wells. In fact, this area has an impressive 90% commercial success rate with the drill bit, with 14 completed wells from 15 drilled and 13 currently on production within our project area."

"That was the first phase of our plan for Index, with the aim of establishing production and, most importantly, credibility in the industry. Our second phase, scheduled for 2005 – 2007, involves spreading ourselves further, so we now have up to 12% interest in four wells in Louisiana and South Texas. We are still in a low cost environment, but have increased our equity – and our risk. We aim to raise \$5 million in order to increase our reserves to 6 – 8 Bcfg (1 – 1.33 million boe), with production of 3.5 Mcfg/d (583 boe) by investing this capital".

### Strategic Alliances are Key

One of the key features of Index Oil is their ability to build excellent strategic alliances with important partner companies. "This has been vital to our success," says Lyndon. "Building good relationships is so important, but you need to be happy with your partners and understand what they want from the relationship as well. In fact, we probably met 20 or 30 potential partners before we finally settled with Security Energy, our partner in Kansas. In Texas and Louisiana we are working with established onshore operator Crawford Energy. Building these types of relationships gives us continued access to off-market opportunities."

Assuming Phase 2 is successful, by 2007



Seismic example from Index Oil's Kansas acreage. The purple line shows the top of the Lower Ordovician Arbuckle formation, the main reservoir target, showing typical karstic features.

Index hopes to move to Phase 3, where the plan is to identify and enter projects at an earlier stage, taking higher equity, with associated higher risk. In this manner Index plans to greatly increase the reserves and production base, while continuing to generate cash. "At the moment we are staying in the US, but eventually it is possible that we may move outside North America to achieve the larger reserves we will be looking for," Lyndon adds.

### Interesting Challenge!

So how has Lyndon found the experience of building a new oil company in the US? "It's been an interesting challenge," laughs Lyndon. "It is extremely competitive to get into deals and you have to be sure that any potential partner understands the business. Sometime you come across

investors who fancy moving into the industry but don't understand the risk." Lyndon, who is proud of his Welsh origins and accent, and is still based in the UK, has not found any problems or prejudice when dealing with the Texan oil men and "good ol' boys".

Index are now at a very key moment in their development and have plans to take the company to market in the near future. Flotation should allow Index the capital they need to realise their plans. "Our strategy is not to go for huge investment at this point but to manage dilution for shareholders and provide continued growth. Working in the US is serving our plans very well, and the future is looking good, as the US needs all the gas we can find."

## GEO EXPRO 2006

**GEO ExPro** - Geoscience & Technology Explained – is a reader friendly magazine for geoscientists, petroleum engineers and decision makers containing features, interviews, news and short notes.

Our magazine is building on the success of the Norwegian GEO, edited by Halfdan Carstens who received the 2004 AAPG journalism award.

### Main events 2006

- No. 1 North American Prospects Expo (NAPE) in Houston, 2-3 February  
APPEX in London, 6-9 March
- No. 2 AAPG 2006 Annual Convention in Houston, 9-12 April
- No. 3 EAGE 68th Conference & Exhibition in Vienna, 12 – 15 June
- No. 4/5 SPE Annual Meeting in San Antonio, 24-27 September  
SEG 76th Annual Meeting in New Orleans, 1-6 October
- No. 6 Petex in London, 21 – 23 November



# Rock and Roll and all that ... Seismic!

Photo: Ingvid Ryggren Carstens





## Hank Hamilton is doing a job he loves, helping steadily grow the successful seismic company, TGS-NOPEC. And he still has time for the occasional outing as bass player with the TGS rock and roll band!

Jane Whaley

**"T**GS always had, and still has, a very different philosophy from most seismic companies, with a distinct business model," Hank explains. "In effect, TGS is primarily a marketing organisation, close to its customers, and generating ideas through them. It does not own or operate vessels and, until recently, did not undertake much in-house processing or interpretation, preferring to subcontract these tasks and thereby lower risk."

Having worked in the seismic industry for a number of years, Hank admired this TGS business model, so he was very happy when he was invited to join the company as Chief Executive Officer in 1995.

"Instead of running vessels," he continues, "TGS concentrates on generating project ideas with clients, then contracting the most suitable vessel for data acquisition, while ensuring that the seismic obtained is of the highest possible quality. We achieve this by employing highly skilled quality control personnel and as a result we have acquired a reputation as a very high end provider, first in 2D and now in 3D as well."

With Hank in charge, TGS has maintained this effective business model and still works closely with clients, with a certain number of them 'signing up' to each project before commencement, which also helps spread the risk.

### Technological knowledge and business sense combined

Hank was brought up in the beautiful town of Charlotte, North Carolina and on graduation in 1981 was employed by Shell in New Orleans as an interpreter. "Large oil companies used to perform all exploration functions in-house, including owning their own seismic boats and undertaking all processing – very different from now!" Hank explains. He worked on advanced data processing, "pre-stack depth migration – very advanced for those days."

Although he enjoyed the technical work, Hank had a strong interest in the business side of the industry and after taking two years of MBA coursework at Tulane University he moved to GECO in

Houston, working first in technical marketing and sales and then as Manager of the multi-client business unit in the Gulf of Mexico. As Hank points out, "in these roles you have to have a good knowledge of the technology, and I still find it incredibly interesting, but I found I like the 'score card!'"

### Blossoming of 3D seismic

In 1991 Hank moved with his young family to Stavanger as GECO Manager of Marine Acquisition for Europe, Africa and the Middle East. When he arrived in Norway, GECO were operating a fleet of six 3D seismic vessels, but his arrival coincided with the blossoming of the 3D industry, as oil companies realised the value of the new technology. "It was very exciting," Hank remembers. "We built or commissioned a number of new 3D seismic boats and at the same time GECO purchased seismic companies Prakla and SSL. By the time I left Norway after two years, we were operating 18 vessels in that region."

Hank enjoyed living in Norway. "We loved the lifestyle. It is very friendly and family orientated." He adds "I wasn't so keen on the long, dark, cold winters – but the summers were wonderful!"

In 1993 Hank Hamilton returned to Houston, in charge of all GECO product lines for North and South America. "At about that time we realised that although GECO's core market was contract work, the Gulf of Mexico was ideal for the multi-client, speculative survey market, which TGS was dealing with, so we linked with them for projects of this nature." This led inevitably to his move to TGS, which was then quite a small company, with only 80 employees.

### Offering the complete package

TGS had traditionally concentrated on the Gulf of Mexico and Africa, while a rival seismic company, Nopec, had a similar multi-client seismic business centred on the North Sea. In 1998 TGS and Nopec merged, making TGS a public company, as Nopec had floated on the Norwegian stock exchange a few months earlier.

1998 was the memorable year when oil prices dropped to \$10 a barrel, but TGS-

NOPEC continued to thrive. As Hank puts it "the low oil price effectively played into our hands. There was an overcapacity of seismic vessels all over the world and prices consequently dropped dramatically. As we don't own boats, this didn't hurt us, but instead we started aggressively putting our profits into seismic acquisition. Our products have a long shelf life of up to 10 years, so the more data we acquire in the down cycles, the more future profits we see in the up cycles."

In 2002 TGS-NOPEC expanded into the field of well logs with the acquisition of A2D. "It had the same business model as TGS," explains Hank. "A2D take simple analogue well data, scan and digitise it and then sell the digital data on a multi-client basis. With the addition of A2D, we can offer a far more complete package; not just seismic, but well data with, for example, synthetics, AVO packages, interpreted regional studies. Maybe at a later date we will be able to add in core descriptions, paleontological studies and similar well-based information. This can be packaged together and delivered to the client in a format which can be read directly into a work station."

TGS did not have a large-scale in-house 3D processing capacity until June 2004, when it purchased NuTec Energy, a company specialising in high end data processing and pre-stack depth migration imaging. Hank explains "We had used NuTec on a contract basis and were impressed by the technology. Buying the company gives us the capacity to successfully reprocess and rejuvenate older data."

### Innovations for the future

Hank has plenty of ideas for maintaining TGS in the forefront of the business. "The technology is constantly evolving. The best recent innovations have all involved imaging deeper targets – advances such as longer offsets and improved processing algorithms. Through NuTec we are undertaking research into seismic imaging and are building up a 'top notch' research department."

"There are many excellent new techniques and developments that have been introduced in the last couple of years,

which we need to follow in order to keep ourselves ahead. I think there is a lot of potential in 4C (4 component geophysics) although the industry has yet to accept it fully". Hank explains the concept of 4C. "Traditional seismic records only the pressure or P-wave emitted by a sonic source, ignoring the shear (S-wave) component, which does not travel through water. However, by placing gimballed geophones on the seafloor, we can measure not only in the horizontal in-line and cross-line components of the S-wave, but also the vertical component, as well as the traditional P-wave. At the moment oil companies think that it is an expensive and specialised process, but the results can help us to see areas obscured by gas, and tell us about subsurface lithology and fluid movement. These developments gradually become accepted, in much the way that AVO analysis has now become an established tool for the analysis of vp/vs and fluid detection."

The use of digital sensors is another development which Hank feels will drive the industry forward. "Conventional sensors are analogue and signals from discrete sensors are summed prior to the results being digitised in modules within the cable. Digital sensors are now being introduced, leading to an explosion in the volume of data available. This allows the use of more advanced processing algorithms for intelligent noise cancellation."

## Moving into frontier areas

The multi-client business model means that TGS tend to work in areas with favourable terms for the industry, as a number of clients need to be interested in order to make a survey viable. "We like to work in this way because pre-funding through clients both validates the initial idea and reduces the financial risk," Hank explains. "The world's major offshore oil and gas basins have been good to us for a long time and are now mature areas, but the industry believes that there is still plenty more to be found there, so we expect to be returning to these places with the new tools."

Recently, however, TGS has been working in new areas such as Sakhalin and the Barents Sea. "These areas have interesting geology," he says "but with a seasonal working regime and a difficult production environment, our work there is a long term investment. East Africa is another area where we have begun to find increasing



Photo: Jane Whaley

Hank Hamilton performing with the TGS band "The Attenuators" during the SEG Conference in November 2005.

interest. It's a very frontier area where little work has been done. We have acquired a number of coarse grid 2D surveys there, and plan to go back and resurvey selected areas in denser 2D and finally 3D where there is enough industry interest.

## The company oil companies think of first

Hank is positive about the future of the seismic industry. "The oil companies are starting to spend more money, and we have had a good uptake for our surveys in these frontier areas." He adds that the amalgamation of seismic companies which occurred a few years ago was good for the industry. "We had an unhealthy industry then, with too many players. Now that we have only 5 or 6 major companies the business is more organised, although it is interesting to see the arrival of a number of new companies on the seismic scene. However, our business model using multi-client projects has allowed us to generate superior returns and we are confident we can weather any potential future downturn in the industry."

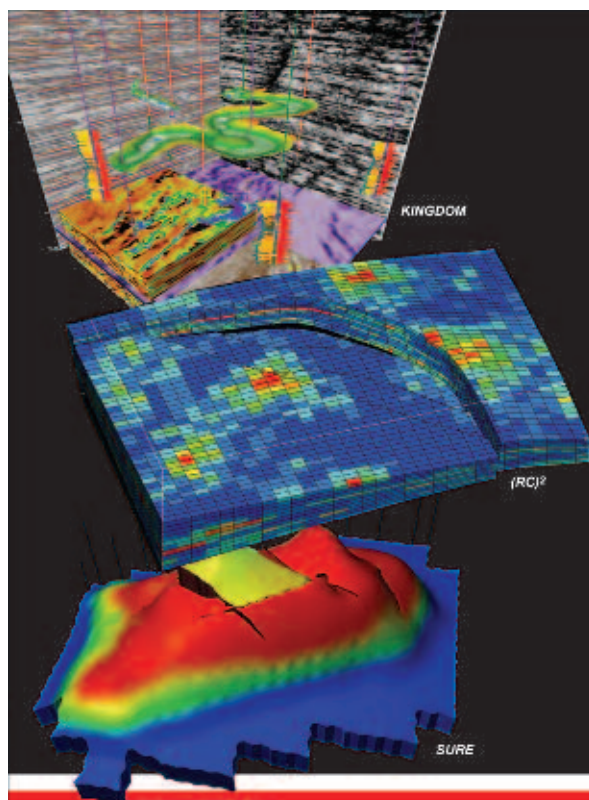
As would be expected with such a high profile job and the associated travel to TGS

worldwide offices, Hank does not find himself with very much free time. He does, however, enjoy a round of golf whenever he has the chance, playing off a very respectable handicap of 6. He also gets together with 3 other guys from TGS, playing bass in their aptly named group 'The Attenuators'. They have been playing together for about 3 years and perform classic rock and roll and blues, frequently entertaining the attendees at TGS parties. Hank is characteristically modest about his music. "The other guys are really good musicians, and they are so patient with me. I've learnt a lot from them and they are always prepared to take the time to explain to me the best way to play each piece."

Hank admits that he cannot imagine doing anything other than his present job. "This is what I like doing best," he says. "I have a wonderful team and supportive board of directors, who understand the business model and company vision. It's quite a simple model, so we haven't got the problem of multiple groups vying for resources – we are all pulling in the same direction."

"We intend to grow steadily with one simple ambition: to be the company that oil companies think of first!"





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# Cretaceous Park

Glacial meltwater and subaerial erosion after the ice age has sculptured a badlands landscape within Upper Cretaceous clastic sedimentary rocks. Abundant dinosaur fossil bones and skeletons have been exposed making the Dinosaur Provincial Park in Canada the richest dinosaur locality in the world.





The gently rolling prairie grasslands cease abruptly, plunging the visitor into a world of hoodoos, pinnacles, deep ravines and flat-topped, steep-sided hills (buttes). The Red Deer River has been eroding into the Cretaceous sedimentary rocks since the end of the last ice age. The badlands landscape the river is creating, with deeply eroded rocks, little vegetation and a wilderness of slopes, scarps and narrow, twisting valleys, stretches from the border to Saskatchewan and all the way up to Edmonton. Sandstones, siltstones and shales containing complete dinosaur skeletons belong to the 80 m thick Dinosaur Park Formation, overlying the Oldman Formation which only yields fragments of fossil bones. On top of the Oldman Formation are the dark marine shales of the Bearpaw Formation, witnessing a transgression in Late Cretaceous times.



A trip to Dinosaur Provincial Park is a 75 million-year foray back in time. This region was then a subtropical paradise, featuring lush vegetation similar to the coastal plains of the southeastern United States today, populated by turtles, crocodiles and sharks. Here, on the shores of an inland sea that, at times, extended from the Arctic Ocean to the Gulf of Mexico, dinosaurs once hunted and mated. This is also where they ultimately met their demise, leaving an amazingly rich fossil and bone record for paleontologists, geologists and ordinary tourists to discover. The park lies only two hours east of Calgary and is thus easily accessible by car. Two hours north of the park you reach Drumheller, which hosts the outstanding Royal Tyrrell Museum of Paleontology (<http://www.tyrrellmuseum.com/>), with numerous exhibits that illustrate geological evolution throughout the Phanerozoic eon (Cambrian through Quaternary, compare page 12). Hundreds of thousands of visitors each year spend a day or two in this small town situated within the valley carved by the Red Deer River.



Photo: Halidan Carstens

In the Late Cretaceous, the landscape in what is now known as Alberta was very different. The climate was subtropical, and the low swampy country was home to a variety of animals, including 30 species of dinosaurs. The conditions were also perfect for the preservation of their bones as fossils. Today, after a century of excavations, more than 150 complete dinosaur skeletons have been discovered, as well as numerous scattered concentrations of bones called "bone beds". Visitors can find the "bone beds" without the skills of an experienced paleontologist. Visitors are, however, only allowed in designated areas.



Halfdan Carstens

In the Western Canadian Sedimentary Basin due east of Calgary (GEO ExPro 2/3, 2005), within a unique geological setting caused by rivers eroding into soft sandstones, creating a badlands landscape, huge amounts of dinosaur fossils are found in Upper Cretaceous rocks. For petroleum geoscientists concerned with the environment, it is interesting to learn that the park lies above producing oil and gas fields.

The Dinosaur Provincial Park in Alberta, Canada, with its famous assemblage of dinosaurian fossils, badlands landscape and cottonwood trees, has been a UNESCO World Heritage Site since 1979. With this designation, it is within the ranks of other globally significant areas such as the Grand Canyon (GEO ExPro No. 2, 2004) and the Norwegian Fjordlands (GEO ExPro No. 4, 2005).

The park is situated within the badlands, named so by early French explorers who were thought to be the first to refer to 'les mauvaises terres a traverser,' which, in Eng-

Before entering the park, on top of the grassland, visitors can have the benefit of informative signs explaining everything about the park. The signs are located on the grasslands, a flat to gently rolling plain with a few major hills; characterized by cold winters, warm summers, high winds and low precipitation. Dinosaur Provincial Park is located in the warmest and driest sub-region in Alberta, with a few permanent streams that have exposed Cretaceous shales and sandstones, creating the extensive badlands that visitors can see below the prairie.



The Royal Tyrrell Museum of Palaeontology is one of the world's largest palaeontological museums and is one of Alberta's main tourist attractions. The museum is named after Joseph B. Tyrrell who stumbled across a huge *Albertosaurus* skull in the badlands along the Red River more than 100 years ago. Drumheller thereafter became a Mecca for paleontologists, not only Canadians, but from all over the world. The museum was opened in 1985 and offers a world class exhibit hall with more than 35 complete dinosaur skeletons and a Cretaceous Garden containing the plants dinosaurs ate millions of years ago. The museum is also a center for excavations in the park.

lish, means "bad lands which are hard to cross." Badlands occur at several locations in southern Alberta and are found principally along the steep sides of major valleys, especially the Red Deer River Valley, where they extend more or less continuously for about 300 km.

## The story behind the scenery

In Late Cretaceous times, a shallow, subtropical sea covered the interior of North America. The Park lies close to the former shoreline and was an environment of moist deltas with thriving swamps. The rocks that we observe along the Red Deer

Valley tell the story of the ancient sea's fluctuating water levels and the changing position of the shoreline. These rock layers have been divided into three units, each representing different ages and depositional environments.

The oldest and lowermost exposed unit, approximately 30 m thick, is named the **Oldman Formation**. It consists of pale yellow sandstones and siltstone deposited about 77 million years ago. The park was a low-lying flood plain across which rivers and streams wove their way eastwards to the sea. The climate was hot and dry and frequent flash floods carried sediments



Byron Waight, conservation officer of the Dinosaur Provincial Park, is himself a geologist and spends the summer season in the park with the objective of pursuing a career specializing in resource protection and public safety. In winter he works in Kimberlite Exploration for various agencies.



## Living in harmony

The only development pressure affecting Dinosaur Provincial Park is ongoing development of natural gas. Producing hydrocarbons from sedimentary rocks below the park does not, however, appear to harm the environment.



Photo: Halidan Carstens

All wells are drilled outside the boundary of the World Heritage Site. Well heads are kept low and painted neutral colors to minimize visual impacts. No roads are built to the well sites. Access is by dirt trails across grazing lands, thus minimizing new public access to Dinosaur Provincial Park World Heritage Site boundaries. There are no direct impacts on fossil resources in the Dinosaur Provincial Park World Heritage Site.



Exploration and production wells are drilled on the prairie grasslands next to the canyon. As evident, the well is inclined to reach a target directly below the badlands. Stringent environmental standards within the park require oil and gas companies to distance their activities at least 150 m from the edge of the valley and to return the land to its original state before leaving the site.



Photo: Halidan Carstens

Great rivers that flowed through this area some 75 million years ago left the sand and mud deposits that make up the valley walls and hills of modern-day Dinosaur Provincial Park. At the end of the last ice age, about 15,000 years ago, water from the melting ice carved the valley through which the Red Deer River now flows. Today, water from prairie creeks and run-off continues to sculpt the layers of these badlands, the largest in Canada. As a result, new fossils appear every year, making fossil hunting an exiting experience for the few palaeontologists who are allowed to explore the valley on their own.

and broken dinosaur bones into the area.

The **Dinosaur Park Formation**, 80 m thick, consists of red sandstones, siltstones, shales and thin layers of coal. Meandering rivers and estuaries deposited these sediments as the sea level rose and the shoreline of the inland sea advanced westwards. Dinosaurs flourished in the subtropical climate, and the complete skeletons collected in the park come from these rocks. More than 30 different species of dinosaurs have been found.

The **Bearpaw Formation**, only 10 m thick, consists of dark brown and black marine sediments, which were deposited only two million years later as the sea made its final advance over Alberta. These rocks contain abundant marine fossils, but no dinosaur fossils.

There is a huge gap in the sedimentary record, as the rocks above the Bearpaw Formation are glacial deposits that came into place during the last ice age. This absence of rocks – representing a hiatus of

some 74 million years – is the result of mountain building as the Rocky Mountains came into existence during the Tertiary. Periods of stability with deposition of fluvial deposits on the plains alternated with periods of uplift which produced rapid erosion of both the mountains and the plains. Huge quantities of Cretaceous rocks were consequently washed away and deposited on the plains.

The badlands began to form around 15,000 years ago as the glaciers, advancing from the Hudson Bay to the east, melted, and the scouring action of the glaciers exposed the soft, easily eroded rocks. Glacial meltwater cut them deeply, creating step-sided channels. In present times a strongly seasonal climate, with intense summer rains and prolonged winter frost, enhances the effectiveness of erosion. Weathered material is stripped at a faster rate than soils can form or plants establish, so that runoffs cut deeply incised rills and channels.

## Oil and gas

The creation of much of Alberta's oil and gas began about 400 million years ago, in

the Devonian Period, when the ancient Pacific ocean flooded Alberta.

Reefs flourished in these shallow warm waters, and when they died their skeletons remained, and the next generation of reefs started to build on top of the dead remains. In this way, as thousands and millions of years passed, the reefs grew and stood up like underwater "skyscrapers" that later formed traps for oil and gas.

These carbonate Devonian rocks underlie the prairies and outcrop both against the Canadian Shield to the north and in the Rocky Mountains to the west. When water levels were high, the reefs were drowned in mud mixed with dead plants. These argillaceous rocks with abundant organic matter were exposed to heat as they were buried and started generating oil and gas.

Important pools of natural gas were also formed less than 100 million years ago in the Cretaceous. They accumulated closer to the surface in sandstones, remnants of ancient beaches.

Some of the oil and gas fields lie direct below the Red Deer River and the park itself. Drilling rigs and production wells are therefore frequently seen in this area. With the strict enforcement of environmental standards it has been proved that a national park can coexist with petroleum activity.

## The ultimate experience

The next time you are in Calgary, make sure you set aside a couple of extra days for sightseeing, one day for Dinosaur Provincial Park, and one day for Royal Tyrrell Museum of Paleontology. In the park you will find more dinosaur bones than you would ever dream of, and in the museum you will meet both skeletons and replicas of these fascinating animals that are now extinct. Moreover, it is a journey through geological time featuring the spectacular history and diversity of life on Earth.

For geologists, geophysicists and reservoir engineers interested in our geological past, a visit to the Canadian badlands must be the ultimate experience when it comes to dinosaurs and museums.



Photo: Haldan Carstens

Dinosaur Provincial Park contains numerous landforms produced by erosion. The most familiar ones are hoodoos. A hoodoo is a pillar of sediment carved by wind and water erosion. Because the underlying rock is more susceptible to the forces of nature, it erodes more quickly than the surface rock (also known as the cap stone). This process creates the unusual landscape known as the badlands.



Photo: Haldan Carstens

The Royal Tyrrell Museum in Drumheller, north of the park, has excellent exhibits and offers a tour through geological time, with galleries and feature exhibitions that celebrate the spectacular history and diversity of life on Earth, as well as honoring the paleontologists who bring the stories to life. The dinosaur on display is an ornithomimid, or "bird-mimic", probably belonging to the genera Ornithomimus ("bird-mimic") or Struthiomimus ("ostrich-mimic"), according to R. Fred Hammer, Heritage Appreciation Program Supervisor of the Dinosaur Provincial Park-World Heritage Site. It is currently at the Royal Tyrrell Museum in Drumheller, but was apparently originally on display from the late 1960s until 1984 at the Provincial Museum of Alberta in Edmonton, and then moved to Drumheller in preparation for the museums opening in 1985.



Photo: Haldan Carstens

While Cottonwood and willow trees share the moist riverbanks with saskatoon, rose and buffalo-berry bushes, cacti, greasewood and many species of sage survive in the hot and dry badlands. Here we see a Prickly Pear Cactus. Prairie grasses dominate the landscape above the valley rim.



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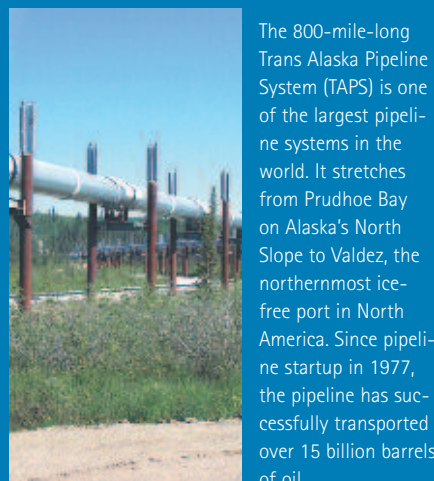
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# Huge volumes left in the ground

The coastal plain of the Arctic National Wildlife Refuge in Alaska is not likely to be exploited for hydrocarbons in the near future. Nevertheless, this geological province is referred to as the "nation's single greatest onshore prospect for oil".



The coastal plain ("1002 area") of the Arctic National Wildlife Refuge in Alaska, bounded to the south by the Brooks Range, is by USGS believed to contain billions of barrels of oil. The 1998 USGS petroleum assessment concluded that up to 16 billion barrels remain unexploited.



The 800-mile-long Trans Alaska Pipeline System (TAPS) is one of the largest pipeline systems in the world. It stretches from Prudhoe Bay on Alaska's North Slope to Valdez, the northernmost ice-free port in North America. Since pipeline startup in 1977, the pipeline has successfully transported over 15 billion barrels of oil.



The question of whether or not to allow drilling in the Arctic National Wildlife Refuge (ANWR) has been an unresolved political topic for more than 25 years. In 1980, President Jimmy Carter and the Congress set aside an area on the coastal plain for potential exploration and development: the 1002 area. They did so because of initial indications of the area's hydrocarbon potential. Opponents of petroleum exploration in the ANWR 1002 area celebrated a victory at the end of 2005 when the US Senate blocked an attempt to initiate drilling this year.

The Arctic National Wildlife Refuge, located just east of the giant Prudhoe Bay oil field, was established in 1980 to preserve unique wildlife, wilderness and recreational values. The refuge is said "to support a greater variety of plant and animal life than any other protected area in the circumpolar arctic". The future of the coastal plain (referred to as the "1002 area") was, however, left in limbo because of the area's potentially enormous oil and gas resources and its importance as a wildlife habitat. Congressional authorization is now required before drilling may proceed in this area.

The coastal plain, covering approximately 6000 km<sup>2</sup> (the equivalent of a North Sea quadrant, 30 UK blocks or 12 Norwegian blocks), stretches southward from the coast to the foothills of the Brooks Range. This area of rolling hills, small lakes, and braided

rivers is dominated by tundra vegetation consisting of low shrubs, sedges, and mosses.

In 1998, the US Geological Survey (USGS) re-examined the geology of the ANWR 1002 area and prepared a comprehensive petroleum resource assessment that involved 3 years study by 40 USGS scientists.

The total quantity of technically recoverable oil within the entire assessment area (including the offshore within the 3-mile boundary) was estimated to 10.3 billion barrels (mean value), with 30% located in the offshore basin. The study also indicated that at least 5.7 billion (95% probability) and possibly **as much as 16.0 billion (5% probability) barrels of oil** exists in ANWR.

Altogether almost 40 oil fields have been discovered in Alaska's "North Slope" to date. Recoverable reserves are probably close to 20 billion barrels of oil and 8 billion barrels of gas (o.e.). The Prudhoe Bay oil field, situated on the coastal plain less than 100 km from the western boundary of ANWR, was soon recognized as the largest oil field in the United States when discovered in 1968. Initial recoverable reserves have been estimated to more than 13 billion barrels of oil. The most prolific reservoirs occur within sandstones and conglomerates of the Permian-Triassic section, with deltaic sandstones of the Sadlerochit Group being the principal productive unit.



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# World Energy Outlook

IEA projects growth in Middle East and North Africa oil and natural gas sectors through 2030.

## CONVERSION FACTORS

### Crude oil

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

### Natural gas

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

### Energy

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

### Numbers

Million = 1 x 10<sup>6</sup>  
Billion = 1 x 10<sup>9</sup>  
Trillion = 1 x 10<sup>12</sup>

### Supergiant field

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

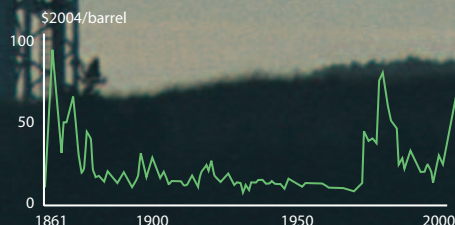
### Giant field

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

### Major field

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

## Historic oil price



"The importance of the Middle East and North Africa (MENA) to global oil and gas markets cannot be underestimated. These countries have vast resources, but these resources must be further developed. Investment should not be delayed," said Mr. William C. Ramsay, Deputy Executive Director of the Paris-based International Energy Agency, as he presented findings from the World Energy Outlook 2005: Middle East and North Africa Insights.

"World energy demand is projected to increase by over 50% between now and 2030. World energy resources are adequate to meet this demand, but huge investments will be needed to bring these resources to consumers. Oil and gas imports from the Middle East and North Africa will rise, creating greater dependence for large importers like China and India," the report says.

**Energy-related CO<sub>2</sub> emissions will consequently also climb by 2030. They will be 52% higher than today.** "These projected trends have important implications and lead to a future that is not sustainable – from an energy-security or environmental perspective. We must change these outcomes and get the planet onto a sustainable energy path," added Mr. Ramsay.

World Energy Outlook 2005 focuses on the energy prospects in the Middle East and North Africa to 2030, covering in detail developments in Algeria, Egypt, Iran, Iraq, Kuwait, Libya, Qatar, Saudi Arabia and the United Arab Emirates.

In the MENA region, surging populations, economic growth and heavy energy subsidies drive domestic energy demand. Primary energy demand more than doubles by 2030. At the same time, MENA oil production will increase by 75% by 2030 and natural gas

production will treble, allowing more gas exports. **The region's share in global oil production will increase from 35% today to 44% in 2030.**

The oil and gas resources of the Middle East and North Africa (MENA) will therefore be critical to meeting the world's growing appetite for energy. The greater part of the world's remaining reserves lie in that region. They are relatively under-exploited and are sufficient to meet rising global demand for the next quarter century and beyond.

But there is considerable uncertainty about the pace at which investment in the region's upstream industry will occur, how quickly production capacity will expand and, given rising domestic energy needs, how much of the expected increase in supply will be available for export. The implications for both MENA producers and consuming countries are profound.

**Oil production (including natural gas liquids) is projected to rise from 29 million bopd in 2004 to 33 million bopd in 2010 and to 50 million bopd by 2030.** In some countries, this may require opening up the upstream sector to foreign investment. The contribution of giant oilfields to total production will drop sharply, from 75% today to 40% in 2030, as mature giant fields decline and new developments focus more on smaller fields.

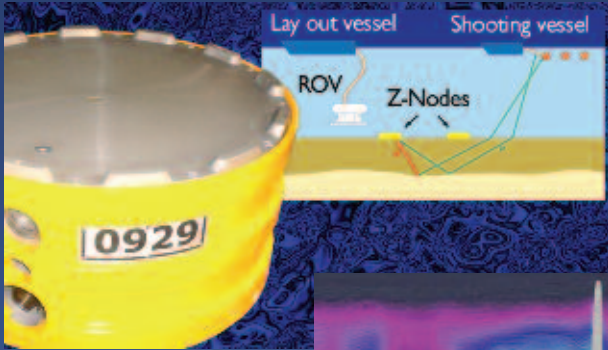
Saudi Arabia, which has the largest proven reserves of oil in the world, will remain by far the largest supplier. Its output will rise from 10.4 million bopd in 2004 to 11.9 million bopd in 2010 and just over 18 million bopd in 2025. In some countries, including Iraq, increased production will hinge on large-scale foreign investment, the report says.



More oil and gas have to be found in places like this in order to meet the world's energy demands the next 25 years.



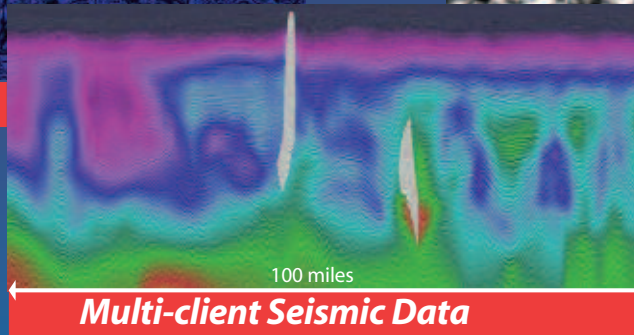
# Just who *is* Fairfield?



## Acquisition

### Z3000 Node System

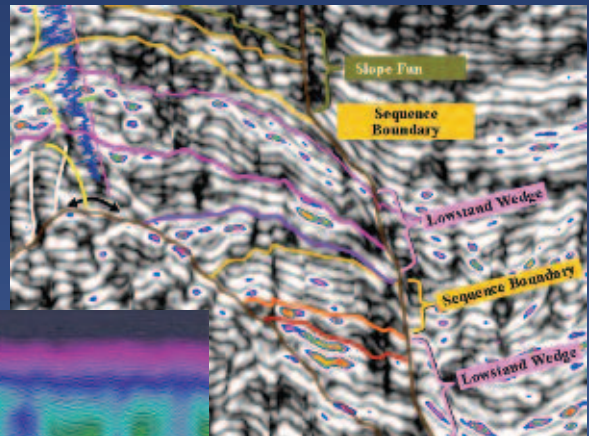
The latest and most advanced seismic system of its kind – the Z3000 Node System acquires data to 3000 meters of water depth.



## Multi-client Seismic Data

### Prestack Depth Migration

This 100-mile crossline is an extraction from Fairfield's multi-client database. The color velocity overlay demonstrates the complexity of the geology and the need for prestack depth migration.



## Processing

### SPICE

Seismic data processing by experienced professionals is available world-wide. Fairfield's new SPICE technology shows critical structural and stratigraphic detail extracted from the seismic wavelet.

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



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